

RTI Report No. 6448-018/004/01F

April 27, 1999

**Corrective Action Plan for the Northwest Site Area
General Electric - Wilmington, NC**

Prepared for:

General Electric Company
Wilmington, North Carolina

Prepared by:

Jeff W. Reynolds, P.G., P.HG.
Michael I. Lowry
Andrew D. Stahl, P.G., C.P.G.
LeaAnne J. Meschke
Caroline J.B. Anderson, Ph.D.
Scott A. Guthrie
Carolyn C. Keith
Jerry T. Conrad
Jennifer M. Lloyd

Geosciences Department
Center for Environmental Measurements and Quality Assurance

April 27, 1999

**Corrective Action Plan for the Northwest Site Area
General Electric - Wilmington, North Carolina**

Responsible Party: General Electric Company
Post Office Box 760
Wilmington, North Carolina 28402

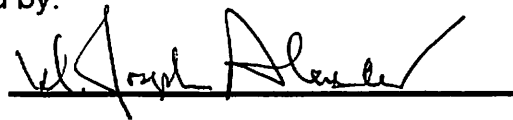
Contact: Herbert R. Strickler, Manager
Site Environment, Health and Safety
(910)675-5721

Prepared by: Research Triangle Institute
Geosciences Department
PO Box 12194
Research Triangle Park, NC 27709
(919)541-8758

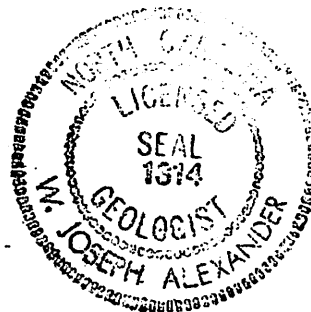
Reviewed by:



Jeff W. Reynolds, P.G., P.H.G.
Project Hydrogeologist and Manager,
Hydrogeologic Assessments Program
Licensed NC Geologist No. 1075
AIH Professional Hydrogeologist No. 1467



W. Joseph Alexander, P.G.
Manager, Geosciences Department
Licensed NC Geologist No. 1314



DIVISION OF ENVIRONMENTAL MANAGEMENT
Certification for the Submittal of a Corrective Action Plan
Under 15A NCAC 2L .0106(l)

Responsible Party: General Electric Company
Address: Post Office Box 760
City: Wilmington **State:** NC **Zip Code:** 28402

Site Name: General Electric Company
Address: 3901 Castle Hayne Road
City: Wilmington **County:** New Hanover **Zip Code:** 28401

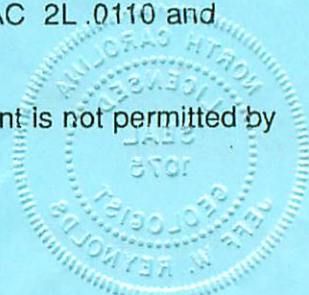
Groundwater Section Incident Number: N/A

I, Jeff W. Reynolds, a Professional Engineer Licensed Geologist (circle one) for Research Triangle Institute (firm or company of employment), do hereby certify that the information indicated below is enclosed as part of the required Corrective Action Plan (CAP) and that to the best of my knowledge the data, site assessments, engineering plans and other associated materials are correct and accurate.









(Each item must be initialed by hand by the certifying licensed professional).

1. JWR A listing of the names and addresses of those individuals required to be notified to meet the notification requirements of 15A NCAC 2L .0114 (b) are enclosed. Copies of letters and certified mail receipts are also enclosed. A copy of the newspaper notice and the title of the newspaper(s) where it was published must be included, if applicable.
2. JWR A Professional Engineer or Licensed Geologist has prepared, reviewed, and certified all applicable parts of the CAP in accordance with 15A NCAC 2L .0103(e).
3. JWR A site assessment is attached or on file with the appropriate Regional Office which provides the information required by 15A NCAC 2L .0106(g).
4. JWR A description of the proposed corrective action and supporting justification is enclosed.
5. JWR A schedule for the implementation of the CAP is enclosed.
6. JWR A monitoring plan is enclosed which has the capacity to evaluate the effectiveness of the remedial activity and the movement of the contaminant plume, and which meets the requirements of 15A NCAC 2L .0110 and .0106(l).
7. JWR The activity which resulted in the contamination incident is not permitted by the State as defined in 15A NCAC 2L .0106(e).

(OVER)



In addition, the undersigned also certifies that to the best of my knowledge and professional judgement and in accordance with the requirements of 15A NCAC 2L .0106(I), the following determinations have been made and are documented in the CAP:

8.  all sources of contamination and free product have been removed or controlled in accordance with 15A NCAC .0106(f) and (I).
(See guidance document).
9.  the contaminants have the capacity to degrade and attenuate under the site-specific conditions.
10.  the time and direction of contaminant travel can be predicted with reasonable certainty.
11.  the migration of the contaminant will not result in any violation of the standards specified in 15A NCAC 2L .0202 at any existing or foreseeable receptor.
12.  the contaminants have not and will not migrate onto adjacent properties, or adjacent properties are served by public water supplies which cannot be influenced by contaminants migrating off-site, or adjacent landowners have consented in writing to a request allowing the contaminant upon their property.
13.  groundwater discharge of the contaminant plume to surface waters will not result in a violation of 15A NCAC 2B .0200.
14.  the area of the contaminant plume has not been identified by a state or local government use planning process for resource development.
15.  all necessary access agreements needed to monitor groundwater quality have been or can be obtained.

(Please Affix Seal and Signature)

NOTE: Any modifications made to this form may result in the return of your submittal.



Table of Contents

List of Acronyms and Abbreviations	vii
Executive Summary	viii
Acknowledgments	xiii
1.0 Introduction	1
1.1 Background Information	1
1.1.1 Former NW-CaF ₂ Storage Area	2
1.1.2 Former Lubricants Area	3
1.2 Purpose of Corrective Action Plan	4
1.3 Document Framework	4
2.0 Summary of Assessment Activities Completed	6
2.1 Groundwater Flow	6
2.2 Extent of Contamination	7
2.2.1 Inorganic Constituents	7
2.2.2 Volatile Organic Compounds	9
3.0 Summary of Corrective Actions Completed	10
3.1 Former NW-CaF ₂ Storage Area	10
3.2 Former Lubricants Area	11
4.0 Potential Receptors	12
4.1 Structures	12
4.2 Adjacent Properties	12
4.3 Groundwater Resources	13
4.4 Surface Water, Drainage Ditches, and Surface Impoundments	13
4.5 Environmentally Sensitive Areas	14
4.5.1 Findings of Recent Sampling Activities - Swampy Area	14
4.5.2 Derivation of Surface-Water Standards	15
4.5.2.1 Human-Health Standards	16
4.5.2.2 Ecological-Based Standards	16
4.5.3 Comparison of Results to Applicable Standards and Benchmarks	17

5.0 Evaluation of Potential Corrective Actions	19
5.1 Objectives	19
5.2 Evaluation of Remedial Alternatives	19
5.2.1 Pump-and-Treat	19
5.2.2 Air Sparging with Soil-Vapor Extraction	20
5.2.3 Monitored Natural Attenuation	21
5.2.3.1 NC DENR Policy on Monitored Natural Attenuation	21
5.2.3.2 EPA Policy on Monitored Natural Attenuation	21
6.0 Technical Evaluation of Monitored Natural Attenuation	23
6.1 Volatile Organic Compounds	23
6.1.1 Factors and Mechanisms Influencing Natural Attenuation	23
6.1.2 Site-Specific Factors	25
6.1.2.1 Source Depletion and Presence of Degradation Products	25
6.1.2.2 Measurements of Natural-Attenuation Parameters in Groundwater	26
6.1.2.3 Presence of a Downgradient Hydraulic Boundary	29
6.1.2.4 Presence of a Downgradient Geochemical Boundary	29
6.1.2.5 Measured and Predicted Contaminant Migration Patterns	29
6.1.2.6 Absence of Human and Ecological Risk	33
6.2 Uranium	33
6.2.1 Factors and Mechanisms Influencing Natural Attenuation	34
6.2.2 Site-Specific Factors	35
6.2.2.1 Removal of the Source	35
6.2.2.2 Measured and Predicted Contaminant Migration Patterns	35
6.2.2.3 Presence of a Downgradient Geochemical and Hydraulic Boundary	38
6.2.2.4 Absence of Human and Ecological Risk	39
6.3 Fluoride	39
6.3.1 Factors and Mechanisms Influencing Natural Attenuation	39
6.3.2 Site-Specific Factors	39
6.3.2.1 Removal of Source	40
6.3.2.2 Measured and Predicted Contaminant Migration Patterns	40
6.3.2.3 Presence of a Downgradient Hydraulic Boundary	41
6.3.2.4 Absence of Human and Ecological Risk	41

7.0 Monitoring Plan	42
7.1 Field Sampling Plan	43
7.2 Quality Assurance Project Plan	43
7.3 Contingency Plan	44
8.0 Schedule and Reporting	45
9.0 References	46

Appendices

A	Copies of Notification Letters for CAP Submittal
B	Pneumatic Slug-Testing Activities - Northwest Site Area
C	Summary of Groundwater Analyses - Northwest Site Area
D	Correspondence Between GE and NC DENR Regarding Evaluation of Uranium in Groundwater - Northwest Site Area
E	Adjacent Property Owner Consent Letter
F	New Hanover County Local Water-Supply Plans
G	Groundwater Flow and Contaminant Fate and Transport Modeling Information
H	Groundwater and Surface Water Field Sampling Plan for Monitored Natural Attenuation Corrective Action for Northwest Site Area
I	Quality Assurance Project Plan for Northwest Site Area

List of Figures

1-1	Location of General Electric Plant Site - Wilmington, NC
1-2	Locations of Former NW-Calcium Fluoride Storage Area and Former Lubricants Area - Northwest Site Area
2-1	Locations of Sampling and Monitoring Points in the Northwest Site Area
2-2	Generalized Configuration of Potentiometric Surface - Northwest Site Peninsula Area
2-3	Configuration of Potentiometric Surface - Northwest Site Area
2-4	Conceptual Model of Hydrogeologic Framework in Northwest Site Area
2-5	Horizontal Extent of Fluoride In Groundwater - Northwest Site Area
2-6	Vertical Extent of Fluoride in Groundwater - Former NW-CaF ₂ Storage Area

List of Figures (continued)

- 2-7 Horizontal Extent of Uranium Exhibiting Non-Natural Isotopic Ratios in Shallow Groundwater - Northwest Site Area
- 2-8 Horizontal Extent of Uranium Exhibiting Non-Natural Isotopic Ratios in Deeper Groundwater - Northwest Site Area
- 2-9 Vertical Extent of Uranium Exhibiting Non-Natural Isotopic Ratios in Groundwater - Former NW-CaF₂ Storage Area
- 2-10 Horizontal Extent of TCE in Groundwater - Northwest Site Area
- 2-11 Horizontal Extent of cis-1,2-DCE in Groundwater - Northwest Site Area
- 2-12 Horizontal Extent of Vinyl Chloride in Groundwater - Northwest Site Area
- 2-13 Vertical Extent of TCE in Groundwater - Northwest Site Area
- 2-14 Vertical Extent of cis-1,2-DCE in Groundwater - Northwest Site Area
- 2-15 Vertical Extent of Vinyl Chloride in Groundwater - Northwest Site Area
- 4-1 Surface-Water Features in the Northwest Site Area
- 4-2 Comparison of Predicted cis-1,2-DCE Concentrations in Swamp Standing Water to Ecological Benchmarks - 0 to 35 Years From Present
- 4-3 Comparison of Predicted TCE Concentrations in Swamp Standing Water to Ecological Benchmarks - 0 to 60 Years From Present
- 6-1 Reductive Dehalogenation of Chlorinated Ethenes
- 6-2 VOC Trends for Groundwater Samples from Well OB-5
- 6-3 Dissolved Oxygen in Groundwater - Northwest Site Area
- 6-4 Ferrous Iron in Groundwater - Northwest Site Area
- 6-5 Groundwater Oxidation-Reduction Potential - Northwest Site Area
- 6-6 Distribution of Methane in Groundwater - Northwest Site Area
- 6-7 Distribution of Ethene in Groundwater - Northwest Site Area
- 6-8 Vertical Cross Section Showing Simulated Groundwater Flow Pathlines and Equipotential Head Contours - Northwest Site Area
- 6-9 Comparison of Measured and Simulated cis-1,2-DCE Groundwater Plumes - Current Conditions
- 6-10 Predicted Distribution of cis-1,2-DCE (>70 µg/L) in Groundwater - 0 to 5 Years From Present - Northwest Site Area
- 6-11 Predicted Distribution of cis-1,2-DCE (>70 µg/L) in Groundwater - 15 to 30 Years From Present - Northwest Site Area
- 6-12 Predicted cis-1,2-DCE Concentrations in the Swampy Area - 0 to 35 Years From Present
- 6-13 Maximum Predicted Surface Concentrations of cis-1,2-DCE in Swampy Area With and Without Natural Attenuation
- 6-14 Predicted Distribution of TCE (>2.8 µg/L) in Groundwater - 0 to 5 Years From Present - Northwest Site Area

List of Figures (continued)

- 6-15 Predicted Distribution of TCE ($>2.8 \mu\text{g/L}$) in Groundwater - 15 to 50 Years From Present - Northwest Site Area
- 6-16 Predicted TCE Concentrations in the Swampy Area - 0 to 50 Years From Present
- 6-17 Maximum Predicted Surface Concentrations of TCE in Swampy Area With and Without Natural Attenuation
- 6-18 Predicted Distribution of Vinyl Chloride ($>0.5 \mu\text{g/L}$) in Groundwater - 0 to 5 Years From Present - Northwest Site Area
- 6-19 Predicted Distribution of Vinyl Chloride ($>0.5 \mu\text{g/L}$) in Groundwater - 10 to 20 Years From Present - Northwest Site Area
- 6-20 Trends for Total Uranium in CAF-A Series Wells - Former NW-Calcium Fluoride Storage Area
- 6-21 Modeled Distribution of $^{235}\text{Uranium}$ ($>0.00015 \text{ mg/L}$) in Groundwater Without and With Natural Attenuation - 30-Year Source Duration
- 6-22 Predicted Distribution of $^{235}\text{Uranium}$ ($>0.00015 \text{ mg/L}$) in Groundwater - 0 to 50 Years From Present - Northwest Site Area
- 6-23 Predicted Distribution of $^{235}\text{Uranium}$ ($>0.00015 \text{ mg/L}$) in Groundwater - 100 to 250 Years From Present - Northwest Site Area
- 6-24 Modeled Distribution of Fluoride ($>2 \text{ mg/L}$) in Groundwater Without and With Natural Attenuation - 30-Year Source Duration
- 6-25 Predicted Distribution of Fluoride ($>2 \text{ mg/L}$) in Groundwater - 0 to 5 Years From Present - Northwest Site Area
- 6-26 Predicted Distribution of Fluoride ($>2 \text{ mg/L}$) in Groundwater - 10 to 20 Years From Present - Northwest Site Area
- 7-1 Contingency Plan Flow Chart - Northwest Site Area Corrective Action

List of Tables

- 2-1 Summary of Assessment Activities - Northwest Site Area
- 4-1a Summary of Inorganic Analyses From SWS-Series Sampling Points
- 4-1b Summary of VOC Analyses From SWS-Series Sampling Points
- 4-1c Summary of VOC Analyses From Standing-Water Sample (Surface Water)
- 4-2 Published Benchmark Concentrations for Potential Ecological Receptors
- 4-3 Comparison of VOC Concentrations in Swamp-Water Samples to Proposed Environmental Benchmarks
- 5-1 NC DENR Conditions for Approval of a Natural-Attenuation CAP
- 5-2 EPA Considerations for Evaluating a MNA Corrective-Action Approach
- 6-1 Summary of Natural-Attenuation Parameters Measured in January 1999 - Northwest Site Area

List of Tables (continued)

- 6-2 Quantitative Screening of Anaerobic Degradation Evidence in Northwest Site Area
- 6-3 Summary of VOC Transport Parameters
- 6-4 Predicted Maximum ²³⁵U and Estimated Total Uranium Concentrations in Groundwater - Northwest Site Area
- 6-5 Estimated Distribution Coefficient for Uranium in Swampy Area North of Former NW-CaF₂ Storage Area

List of Acronyms and Abbreviations

BCF	bioconcentration factor
CaF ₂	calcium fluoride
CAP	Corrective Action Plan
CSA	Comprehensive Site Assessment
DCE	dichloroethylene
DENR	Department of Environment and Natural Resources
DO	dissolved oxygen
DT	dietary intake
EPA	Environmental Protection Agency
EVS	Environmental Visualization System
FCR	fish consumption rate
f _{oc}	fraction organic carbon
FSP	Field Sampling Plan
GE	General Electric Company
GMGV	groundwater monitoring guideline value
K _d	distribution coefficient
K _{oc}	organic carbon partitioning coefficient
K _{ow}	octanol-water partitioning coefficient
mg/L	milligrams per liter
MNA	monitored natural attenuation
mV	millivolts
msl	mean sea level
NAF	natural attenuation factor
NCAC	North Carolina Administrative Code
NFS	Nuclear Fuels Services, Inc.
NRC	Nuclear Regulatory Commission
NW-CaF ₂	northwest calcium fluoride
ORP	oxidation-reduction potential
pCi/g	picocuries per gram (radiologic activity in solids)
pCi/L	picocuries per liter (radiologic activity in liquids)
PQL	practical quantitation limit
QAPP	Quality Assurance Project Plan
QC	quality control
²²⁶ Ra	radon-226 isotope
RfD	reference dose
RTI	Research Triangle Institute
SVE	soil-vapor extraction
TCE	trichloroethylene
TOC	total organic carbon
U	uranium
^x U	uranium isotope, where x = atomic weight (e.g., ²³⁸ U)
VOCs	volatile organic compounds
WQS	water-quality standard

Executive Summary

Organic and inorganic materials have been identified in groundwater in a remote section of General Electric's Wilmington, North Carolina, facility. As part of a multi-year project in this area of the site, General Electric removed the source of inorganic constituents in groundwater and the source of volatile organic compounds in groundwater is no longer a threat to groundwater quality. Assessment of the hydrogeologic framework, the horizontal and vertical extent of contamination, and properties affecting the fate and transport of the constituents in groundwater has been completed. The assessment information was summarized in a Comprehensive Site Assessment report submitted to the Wilmington Regional Office of the NC Department of Environment and Natural Resources in late 1998. There are no human drinking-water receptors downgradient of the former source areas and development of the area is not expected. The groundwater contamination will continue to attenuate via natural processes and is not predicted to pose significant human or ecological risks. Evaluation of existing geochemical and hydrogeologic data and the results of fate and transport modeling of the groundwater contamination indicate that monitored natural attenuation is the appropriate corrective action for this area. Monitoring of groundwater quality in the area will continue and periodic updates of monitoring results will be provided to the appropriate regulatory agencies.

The Research Triangle Institute (RTI) has prepared this Corrective Action Plan (CAP) to identify and describe an appropriate remedy for groundwater contamination identified in a remote northwest area of the General Electric (GE) site in Wilmington, North Carolina.

Assessment and monitoring activities, including offsite assessment, have been performed in the area. A *Comprehensive Site Assessment for the Northwest Site Area* (CSA) summarizing the assessment and monitoring activities in the area has been developed and submitted to the NC Department of Environment and Natural Resources (DENR). This CAP includes updated results of assessment and monitoring activities completed after submittal of the CSA report.

Contamination Sources

Contamination in the remote northwest site area of the GE facility is attributed to material storage practices typical of the late 1960s when the site was developed. The storage of calcium fluoride (CaF_2) material (containing low levels of uranium) in unlined trenches in a controlled-access, 1-acre parcel has resulted in contamination of shallow groundwater by low levels of fluoride and uranium exhibiting non-naturally occurring isotopic ratios.

Consultation with long-term and retired employees revealed that intermittent disposal of lubricants and coolants from tube reducers, apparently contaminated with small quantities of trichloroethylene (TCE), occurred in an

approximately 1-acre parcel adjacent to the former NW-CaF₂ storage area (referred to as the former lubricants area). Consequently, TCE is present in groundwater in the area above the NC groundwater standard. Cis-1,2-dichloroethylene (DCE) and vinyl chloride, both of which are degradation products of TCE, are also present above NC groundwater standards, suggesting that degradation of the parent material (TCE) is underway. The volume of solvent in the discarded lubricants is unknown; however, evidence of separate-phase volatile organic compounds (VOCs) has not been observed. VOC concentrations in soil at the former lubricants area are below NC's risk-based soil remediation goals and are not expected to result in continuing groundwater contamination.

Groundwater Flow

The two former source areas are positioned on the eastern flank of a relic sand dune that forms a topographically prominent sandy peninsula that is surrounded by low-lying swampy areas. In the study area, groundwater flows from the upland recharge area of the peninsula and discharges into the surrounding swampy area. The average groundwater velocity is estimated to be on the order of 0.1 to 0.15 ft/day in the upland area but much lower in the downgradient swampy area, which serves as both a geochemical and hydraulic boundary to contamination.

Extent of Contamination

As described in the CSA, the horizontal and vertical extent of contaminated soil and groundwater have been characterized. The extent of fluoride in groundwater is mapped to be just beyond the GE property line and limited to the relatively shallow portion of the aquifer. Similarly, uranium exhibiting non-natural isotopic ratios is mapped to be just beyond the GE

property line (approximately 50 feet) and limited to the relatively shallow portion of the aquifer.

Because natural uranium is ubiquitous in the environment, there is not a numeric NC groundwater standard for total uranium. However, substances that are not naturally occurring (such as uranium exhibiting non-natural isotopic ratios) are not permitted by the State in groundwater above laboratory practical quantitation limits. As isotopic abundances cannot be reliably quantified when the total uranium concentration is less than 0.002 mg/L (with the analytical method used for this project), only samples with total uranium concentrations greater than this assessment threshold concentration are analyzed for isotopic abundance. The extent of uranium exhibiting non-natural isotopic ratios above the instrument practical quantitation limit has been characterized. This approach for evaluating the extent of uranium in groundwater has been accepted by the NC DENR, Groundwater Section, in a memorandum to GE dated October 16, 1998.

Groundwater contamination by VOCs is more widespread than fluoride and uranium, extending off of the GE site and into a swampy area north of the former source area. The vertical extent of VOCs in groundwater has also been delineated and is deeper than the inorganic groundwater contaminants.

Corrective Actions Completed

In accordance with GE's nuclear-fuel manufacturing license and a plan approved by the Nuclear Regulatory Commission (NRC), the CaF₂ material and affected soil were excavated and moved by GE's material recovery contractor to GE's secure onsite warehouse as an interim control measure until

feasible methods for recovering uranium from the CaF_2 are evaluated. Intermediate soil (soil exhibiting activity levels between the minimum release criterion and the lower limit for onsite storage) also was excavated and transported offsite for disposal. A total of approximately 10,000 tons of CaF_2 and associated soil have been excavated from the former NW- CaF_2 storage area. Secondary follow-up soil sampling revealed total uranium levels below the NRC release limit. No additional removal is expected to be necessary in this area, and final compliance sampling and analysis will be completed in 1999.

Corrective action for soil in the former lubricants area is not considered necessary. The area of highest likely VOC contamination in the former lubricants area was identified using a passive soil-vapor survey, geophysical surveys, and two exploratory borings. Shallow soil contamination was found to be minor in both borings. None of the soil samples exhibited concentrations exceeding applicable NC soil remediation goals and separate-phase waste materials were not observed. If greater VOC soil concentrations were once present in the source area, they evidently have degraded and/or were flushed out of the soil over time.

Potential Receptors

The area downgradient of and potentially affected by the northwest site area groundwater contamination is remote and undeveloped. There are no structures (i.e., utility vaults, basements) in the vicinity of the northwest site area that could intercept the contamination. A small stream originates at the northeast corner of the former NW- CaF_2 storage area parking and staging area. This stream intercepts shallow groundwater and winds through the swampy area north of the northwest site area to Prince George Creek. Neither inorganic nor

organic contaminants have been identified in samples collected from various locations in the stream.

None of the potentially affected area downgradient of the northwest site area is inhabited and, according to the adjacent property owner, development of the area is not planned. Some of the potentially affected area is located on GE property, and the remainder is off-site and used as part of a hunting preserve. Groundwater is not currently withdrawn from the area for any purpose. Therefore, the impacted groundwater poses no human risk via the drinking-water pathway. According to local officials and the available Wilmington-area local water-supply plans, groundwater in this area is not expected to be used as a future public-water resource.

The owner of the adjacent property has been informed of the groundwater contamination and has indicated to GE a desire to have the adjacent property continue to serve as a hunting preserve. Permission has been granted by the adjacent property owner allowing contaminated groundwater to migrate onto her property as the proposed corrective action is implemented.

The swampy area downgradient of the northwest site area is assumed to be a wetland. As wetlands are considered to be waters of the State, shallow standing water present in the swampy area is classified as and regulated under rules pertaining to surface water. Although contamination has not been detected in the samples of surface water collected from the small stream in the area, sporadic levels of VOCs (primarily cis-1,2-DCE and TCE) have been detected in shallow groundwater in a localized area within

the swampy area. In addition, low levels of VOCs were detected in a standing-water sample collected from the swampy area.

Potential ecological risks posed by the VOCs discharging into the swampy area were evaluated by comparing measured and predicted levels of VOCs in shallow groundwater to published benchmark concentrations (levels observed to have low or no adverse effects on general ecological receptors). The measured and predicted concentrations do not exceed published ecological benchmarks or applicable surface-water standards established for the groundwater contaminants.

Proposed Corrective Action Approach

Any corrective action implemented in the northwest site area must have the following primary objectives:

- ▶ Ensure protection of human health and the environment,
- ▶ Address both the organic and inorganic materials identified in northwest site area groundwater,
- ▶ Minimize impacts or other disturbances to the adjacent property, and
- ▶ Prevent creation of additional waste products through the remediation process and avoid the risks to human health and the environment associated with handling such waste.

Only groundwater remediation technologies were evaluated in this CAP because (1) the source of inorganic contaminants has been removed, (2) soil contamination by VOCs has not been detected above levels posing a continuing threat to groundwater, and (3) evidence of free-phase contaminants has not been found at the site. Based on the US

Environmental Protection Agency's (EPA's) factors supporting implementation of monitored natural attenuation (MNA), NC regulations regarding implementation of natural attenuation corrective action plans, and available site information, MNA is considered to be the most viable remedial approach for the groundwater contamination identified in the northwest site area as described in the following section.

Information Supporting Natural Attenuation

MNA has been accepted by EPA as a potentially appropriate corrective action for groundwater contaminated by each of the contaminants present in groundwater in the northwest site area. Several factors support use of natural attenuation to address groundwater contaminated by the organic and inorganic substances in the northwest site area, including:

- ▶ Depletion of VOCs in the former source-area soils to below cleanup levels,
- ▶ Presence of VOC degradation products,
- ▶ Presence and distribution of conditions in groundwater that are conducive to degradation of VOCs,
- ▶ Removal of the source of inorganic contaminants (fluoride and uranium),
- ▶ Presence of a downgradient hydraulic and geochemical boundary (i.e., the swampy area),
- ▶ Measured and predicted (modeled) contaminant migration patterns, and
- ▶ Minimal human and ecological risk.

Monitoring

A site-specific Field Sampling Plan (FSP) and a Quality Assurance Project Plan (QAPP) have been prepared to implement the monitoring of natural attenuation at the site. 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, quality control (QC) sampling, and field documentation. A monitoring network fulfilling NC regulatory requirements is in place, both on the GE property and on the adjacent property. Consent allowing access to the adjacent property for monitoring purposes has been given.

The media to be monitored include groundwater, surface water (streams), swamp pore water, and swamp standing water. Monitoring of these waters enables evaluation of contaminant fate and transport and verification that downgradient receptors (such as surface-water bodies) are not being impacted.

Sampling locations have been established at key points along the migration pathway, including:

- ▶ Groundwater near the contaminant source (or former source area),
- ▶ Groundwater at various depths within the aquifer,
- ▶ Shallow groundwater (swamp pore water) where it discharges to swampy-area sediment,
- ▶ Standing water in the swampy area, and
- ▶ Surface water in streams that flow throughout the swampy area.

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 plumes are not expanding in size.

Schedule and Reporting

The routine monitoring described in the FSP will initiate in the first quarter of 1999. It is expected that the monitoring will continue until the contamination levels fall below the appropriate levels (i.e., NC groundwater standards or other appropriate criteria).

Initially, groundwater samples will be collected quarterly for the inorganic and organic contaminants of concern from wells monitoring the contaminant plumes. In addition, samples of swamp standing water will be collected annually. Samples of surface water will be collected annually for the contaminants of concern, and groundwater samples will be analyzed annually for parameters indicating continued natural attenuation of the contaminant plumes. The sampling schedule may be modified, depending on the findings of the sampling activities.

Results of monitoring activities in the northwest site area will be provided to DENR in the form of periodic reports. The reports will include, at a minimum, a description of the field activities and results of monitoring activities, including data-validation information.

The progress of the MNA approach, including discussions of changes in contaminant concentration over time, plume migration, recommended changes to the monitoring program, and other pertinent information, will be included as appropriate in the periodic reports or during periodic update meetings that GE may schedule with appropriate divisions of DENR. Contingency activities are planned for implementation in the event of unexpected monitoring results.

Acknowledgments

This document was prepared by staff in RTI's Geosciences Department in the Center for Environmental Measurements and Quality Assurance. The primary document author and project leader is Jeff Reynolds. Technical and modeling support on Section 6.0 and Appendices B and G was provided by Michael Lowry. Additional technical review was provided by Joe Alexander. Technical review and preparation of the project Field Sampling Plan and Quality Assurance Project Plan (Appendices H and I) were provided by Andrew Stahl and Caroline Anderson, with assistance from Scott Guthrie and Carolyn Keith. The lead field geologist for this project is Carolyn Keith; field support was provided by Jim Rabon, Steve O'Brien, and Matt O'Brien. LeaAnne Meschke and Aimee Harmon provided technical information on ecotoxicology and environmental benchmarks (Section 4.0). Caroline Anderson provided geochemical and quality assurance support. LeaAnne Meschke and Jerry Conrad prepared maps for the document and 3-D graphics were prepared by Michael Lowry. Jenny Lloyd and LeaAnne Meschke developed the project database and provided data management support (Appendix C).

1.0 Introduction

The Research Triangle Institute (RTI) has prepared this Corrective Action Plan (CAP) to identify and describe an appropriate remedy for groundwater contamination in a remote northwest area of the General Electric (GE) site in Wilmington, North Carolina. This CAP has been prepared in general accordance with guidelines designated by the North Carolina Department of Environment and Natural Resources (DENR) (DENR, 1998) and is in accordance with regulations specified in Title 15A of the North Carolina Administrative Code (T15A NCAC) Subchapter 2L Section .0106. The following sections provide background information for the portion of the GE site affected by this CAP, the purpose of this CAP, and the document framework.

1.1 Background Information

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 facility encompasses over 1,600 acres and extends westward from US Highway 117 to the Northeast Cape Fear River (Figure 1-1). There are currently two principal manufacturing activities conducted at the GE-Wilmington site: nuclear fuel and components, and aircraft engine parts.

Groundwater contamination by volatile organic compounds (VOCs) and inorganic constituents has been identified in a remote northwest area of the GE-Wilmington site. This contamination is associated with historical material storage and handling activities typical of the late 1960s when the GE site was developed. Assessment and monitoring activities, including offsite assessment, have been performed in the area. A *Comprehensive Site Assessment for the Northwest Site Area* (CSA) (RTI Report No. 6448-018/003/01F) (RTI, 1998), summarizing the assessment activities conducted in the area has been developed and submitted to NC DENR. Updated results of monitoring activities completed after submittal of the CSA are provided in this document.

Contamination in the northwest site area is attributed to two adjacent primary source areas: (1) the former northwest calcium fluoride (NW-CaF₂) storage area and (2) a former lubricants area. These former source areas are presented in Figure 1-2 and are described in the following subsections.

1.1.1 Former NW-CaF₂ Storage Area. Historically, GE's original manufacturing process for low-enriched uranium resulted in the production of a fluoride waste stream containing primarily ammonium fluoride and low levels of uranium. In this process, nearly all of the uranium in the fluoride waste is recovered for reuse and ammonia is recovered by steam stripping after pH stabilization with lime. The resulting solid material is referred to as CaF₂ and contains low levels of uranium (GE, 1989). The CaF₂ material has a chalky-white appearance and can be powdery or in larger, more solidified fragments.

The CaF₂ material was placed in storage facilities onsite in compliance with its nuclear-fuel manufacturing license and applicable regulations at that time. One of these storage facilities was located in a remote northwest region of the GE site and is referred to as the former NW-CaF₂ storage area (Figure 1-2). Approximately 70,000 cubic feet of CaF₂ was placed in seven shallow, unlined trenches in a fenced 1-acre area from the late 1960s to the mid-1970s. The CaF₂ material was present at thicknesses ranging from less than 1 foot to over 7 feet (D'Appolonia, 1977). Over the years, the former NW-CaF₂ storage area became heavily vegetated, and the exact delineation of the storage trenches became less well defined.

In 1994, GE decided voluntarily to move the CaF₂ material from the former NW-CaF₂ storage area for future recovery of uranium under the conditions of their license and with approval from the Nuclear Regulatory Commission (NRC). A survey-and-release plan was developed by Nuclear Fuels Services, Inc. (NFS), GE's material recovery contractor, and the plan was reviewed and approved by the NRC. Under the recovery plan, free release¹ of the area would be granted if the area exhibited an average activity of less than

¹Reference to free release of the former NW-CaF₂ storage area indicates that the area meets NRC criteria for unrestricted release from regulatory control (i.e., GE's fuel manufacturing license). Neither deed restrictions nor other institutional controls will be required after free release of the area by NRC.

30 picocuries² per gram (pCi/g) in the remaining soils, lowering dose levels for the area to near background levels. The CaF₂ and contaminated contact material (soils) with activities exceeding 200 pCi/g were to be excavated and transported by truck to a secure warehouse on GE's property as an interim control measure until feasible methods for recovering uranium from the CaF₂ are evaluated. Intermediate soils (exhibiting activities between 23 and 200 pCi/g) were to be packaged and transported via truck to an offsite disposal facility in Pinewood, South Carolina.

Prior to initiating the recovery effort, GE requested that RTI conduct a hydrogeologic and water-quality investigation to characterize groundwater conditions before, during, and after the excavation process. Assessment activities were initiated in 1995, and fluoride was detected in groundwater above the allowable level (2.0 mg/L) specified in T15A NCAC 2L .0200 (referred to herein as the NC groundwater standards). Uranium exhibiting non-natural isotopic ratios above the method practical quantitation limit (PQL) was also identified in groundwater. The NC DENR was notified of the planned recovery activities and initial findings, and has been provided with regular updates of the site activities and groundwater quality during the material recovery and area assessment activities.

1.1.2 Former Lubricants Area. In 1991, VOCs were identified in groundwater at the GE plant site. Consultation with long-term and retired employees revealed that intermittent disposal of lubricants and coolants from tube reducers, apparently contaminated with small quantities of trichloroethylene (TCE), occurred in this remote area of the site³ (Figure 1-2). Consequently, a sample of groundwater was collected from an observation well in the northwest site area adjacent to the former NW-CaF₂ storage area (well OB-5) in early 1993. The sample from this well contained VOCs, primarily cis-1,2-dichloroethylene (DCE, a degradation product of TCE) and low levels of trans-1,2-DCE and 1,1-DCE (also degradation products of TCE). Evidence of 1,1-dichloroethane at levels significantly lower than the NC groundwater standard was also detected. Detection of these VOCs resulted

²A curie is a unit quantifying the radioactive decay (number of disintegrations per second) of an isotope. One curie equals 10¹² picocuries, and one picocurie equals 0.037 disintegrations per second.

³The volume of material released is uncertain; however, investigations have revealed that VOC concentrations in soil at the former lubricants area are below levels expected to impact groundwater quality and also are below the risk-based soil remediation goals described in DENR, 1997. Consequently, there is not a continuing source of VOCs to groundwater from this area.

in the inclusion of this area in a site-wide CAP for organic compounds in groundwater (RTI, 1994).

NC DENR was notified during a meeting on April 6, 1995, that in order to prevent delays in the uranium recovery efforts for the former NW-CaF₂ storage area, assessment of the organic compounds in groundwater would be postponed until after the CaF₂ recovery efforts were complete. Assessment activities for the organic compounds have since been performed at the former lubricants area and are summarized in a CSA developed for the northwest site area (RTI, 1998).

1.2 Purpose of Corrective Action Plan

The purpose of this CAP is to identify and describe an appropriate remedy for groundwater contamination identified in a remote northwest portion of the GE-Wilmington site in accordance with T15A NCAC 2L .0106. The contamination identified in the area is associated with former material and disposal activities typical of the late 1960s when the site was developed.

1.3 Document Framework

This CAP has been prepared in general accordance with guidelines designated by NC DENR (1998). Although the organizational structure for this document may differ slightly from that presented in the guidance, the elements required for approval of the CAP are present. Information pertaining to projected costs of the proposed remedial approach described in this CAP is not included.

This document also includes the requirements for a natural attenuation CAP specified in T15A NCAC 2L .0106(I) as designated on the *Certification for the Submittal of a Corrective Action Plan* (DENR Form GW-100(I)) and is in substantial agreement with guidelines presented in the T15A NCAC 2L Implementation Guidance for Section .0100 (DENR, 1995).

As required by T15A NCAC 2L .0114, copies of the CSA and this CAP, along with copies of the required notification letter, have been provided to the adjacent property owner and the appropriate local officials as follows:

Adjacent Property Owner

Mrs. Katharine Sledge
P.O. Box 523
253 N. Powell Blvd.
Whiteville, NC 28472

Local Officials

Mr. Allen O'Neal
New Hanover County Manager
320 Chestnut Street, Room 502
Wilmington, NC 28401

Ms. Diane Harvell, Supervisor
New Hanover Environmental Health Division
2029 S 17th Street
Wilmington, NC 28401

Copies of the notification letters are provided in Appendix A. GE representatives met personally with the adjacent property owner on April 8, 1999. Notification letters were provided personally to the local officials listed above during a meeting at the Wilmington Regional Office of DENR; follow-up copies will be provided via certified mail. Upon approval of this CAP, the individuals listed above will be notified as appropriate within 30 days of receiving such approval.

2.0 Summary of Assessment Activities Completed

Characterization of soil and groundwater contamination and hydrogeologic features on and off the GE site has been performed as shown in Figure 2-1. A chronological summary of assessment activities, including updates and references to associated documents presented to DENR, is presented in Table 2-1. NC DENR (through the Division of Water Quality - Groundwater Section and the Division of Radiation Protection) has been provided with periodic updates of the assessment activities performed in the northwest site area and related findings. A CSA was developed to summarize the results of assessment activities completed in this area of the site (RTI, 1998). This CSA was submitted to the Wilmington Regional Office of DENR on December 15, 1998. The results of assessment activities completed after submittal of the CSA, as well as updated monitoring results, are included in this CAP.

2.1 Groundwater Flow

The two former source areas are positioned on the eastern flank of a relic sand dune that forms a topographically prominent sandy peninsula that is surrounded on three sides by low-lying swampy areas (Figure 1-2). In the northwest site area, the subsurface is composed primarily of undifferentiated sands down to approximately 30 feet. There are no continuous and extensive clay layers or distinct confining units in the northwest site area. A rocky zone is present below this layer, containing a mixture of semi-consolidated sandstone and unconsolidated fine sand. Some voids have been encountered in this formation.

In the study area, groundwater flows from the upland recharge area of the peninsula and discharges into the surrounding swampy area. Large and local-scale groundwater contour maps of the area are provided in Figures 2-2 and 2-3, respectively. A generally east-west trending groundwater divide bisects the peninsula just south of the former lubricants area. Groundwater in the area of the former NW-CaF₂ storage area and the former lubricants area flows toward the north, discharging strongly into the swampy area as evidenced by the large vertical upward hydraulic gradient. A vertical upward gradient of 0.146 has been measured between monitoring points SWS-8 and OSW-1A. In fact, the static water level

is above the land surface in well OSW-1A. In contrast to the upland areas, the horizontal hydraulic gradient in the swampy area is much lower and estimated to be on the order of 0.0007, considering the measured groundwater elevation is about 4 feet above mean sea level (msl) at the boundary of the swampy area and is expected to be about 1 foot above msl at Prince George Creek, located 4,500 feet north of the swampy area boundary. This swampy area serves as both a geochemical and hydraulic boundary to contamination as described in Section 6.0. A conceptual site model for the northwest site area is provided in Figure 2-4.

Additional slug testing was recently performed in the northwest site area to confirm permeability estimations presented in the CSA and to evaluate the permeability of the sediments in the lower rocky zone of the aquifer. The additional testing included performance of pneumatic slug tests on selected wells in the northwest site area. Details of the additional testing activities are provided in Appendix B. The additional hydraulic testing indicated slightly lower permeability estimations than those described in the CSA. The average linear groundwater velocity is expected to be slightly lower than that presented in the CSA. The average linear groundwater velocity is estimated to be on the order of 0.1 to 0.15 ft/day in the upland area and (based on the significantly lower hydraulic gradient) much lower in the swampy area.

2.2 Extent of Contamination

The horizontal and vertical extent of contaminated soil and groundwater has been characterized through the use of exploratory borings, swamp-water sampling points, soil-vapor sampling points, and monitoring wells (Figure 2-1). A compilation of analytical results for the groundwater and swamp-water sampling points in the northwest site area is provided in Appendix C. A summary of the contamination identified and the extent of contamination is provided in the following sections.

2.2.1 Inorganic Constituents. Inorganic constituents identified above NC groundwater standards include fluoride and uranium exhibiting non-natural isotopic ratios, both of which originated from the former NW-CaF₂ storage area. The highest levels of fluoride measured in groundwater during routine monitoring of the northwest site area have occurred in well CAF-8B. The highest level measured was 12.8 mg/L in February 1998. The most recent concentration of fluoride measured in this well is 10.2 mg/L (November 1998).

Natural uranium (U) 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 (such as that present in the CaF_2 material) has higher percentages of ^{234}U and ^{235}U . Percent enrichment of uranium in an environmental sample is calculated by dividing the concentration of ^{234}U and ^{235}U 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 material previously stored in the NW- CaF_2 storage area at the GE site is approximately 2.2 percent by weight. The presence of uranium at enriched levels (above the naturally occurring abundance of 0.72 percent ^{235}U) can be used as a reliable indication of contamination originating from the former NW- CaF_2 storage area and is the basis of including uranium in this CAP. The isotopic signature of the uranium manufactured at the GE-Wilmington facility approximately matches the average isotopic signature of uranium in groundwater collected from the downgradient onsite monitoring wells in the area. It should be noted that although naturally occurring uranium typically has long-lived progeny nuclides (such as ^{226}Ra) associated with it, the chemical processing of the uranium performed at the GE facility effectively separates the progeny radionuclides (Potter, 1998).

There is not a numeric NC groundwater standard for total uranium. However, substances that are not naturally occurring (such as uranium exhibiting non-natural isotopic ratios) are not permitted in groundwater above the method practical quantitation limit (PQL) and are addressed in this CAP. As isotopic abundances cannot be reliably quantified when the total uranium concentration is less than 0.002 mg/L (with the analytical method used for this project); only samples with total uranium concentrations greater than this assessment threshold concentration are analyzed for isotopic abundance. For the northwest site area assessment, the extent of contamination by uranium is indicated by the distribution of the isotope ^{235}U at concentrations above the PQL of 0.00015 mg/L. This approach was accepted by the NC DENR, Groundwater Section, in a memorandum to GE dated October 16, 1998. Correspondence between GE and DENR regarding evaluation of uranium in groundwater in the northwest site area is provided in Appendix D.

The highest levels of ^{235}U measured in groundwater during routine monitoring of the northwest site area have occurred in well CAF-6A located directly downgradient of the former NW- CaF_2 storage area. The highest level measured was 0.04578 mg/L in well CAF-6A in March 1996, and the most recent ^{235}U concentration measured in this well was

0.00170 mg/L (November 1998). The highest total uranium concentration and activity in the March 1996 sample from CAF-6A were 2.11802 mg/L and 3,180.72 pCi/L, respectively. The total uranium concentration and activity in the most recent sample (November 1998) were 0.0808 mg/L and 110.7 pCi/L, respectively.

The extent of fluoride in groundwater is inferred to be just beyond the GE property line and limited to the relatively shallow portion of the aquifer (Figure 2-5). Fluoride is present at greater depths in the aquifer than uranium, most likely due to differential sorption of the fluoride onto the aquifer material. The vertical extent of fluoride is provided in Figure 2-6.

The extent of uranium exhibiting non-natural isotopic ratios in groundwater is inferred to be just beyond the GE property line and limited to the relatively shallow portion of the aquifer (Figures 2-7 and 2-8). The vertical extent of uranium exhibiting non-natural isotopic ratios is provided in Figure 2-9.

2.2.2 Volatile Organic Compounds. Groundwater contamination by VOCs extends further offsite than the inorganic constituents, to the fringe of the swampy area north of the source area (Figures 2-10 to 2-12). The highest level of VOCs detected in the area is cis-1,2-DCE at 9,115 µg/L (in a sample from exploratory boring OCB-1, drilled June 1997). The highest concentration of cis-1,2-DCE recently measured in a monitoring well is 740 µg/L in well CAF-17C, located immediately downgradient of the former source area. The horizontal extent of VOC impacts into the swampy area has been delineated in shallow groundwater samples as described in Section 7.5.2 and 7.5.4 of the CSA (RTI, 1998). Cis-1,2-DCE has been detected in shallow swamp-water samples from location SWS-9; clean groundwater has been found in shallow groundwater beyond the leading edge of the plume. There is no evidence of free-phase contamination in the northwest site area.

The vertical extent of VOCs in groundwater has been delineated; VOCs extend deeper than the inorganic constituents and into the rocky section of the aquifer (Figures 2-13 to 2-15). VOC have not been detected above NC groundwater standards at depths greater than 56 feet. Based on the available information, it is unlikely that VOCs have migrated in deeper groundwater beyond the area that has been delineated in the shallow groundwater zone.

3.0 Summary of Corrective Actions Completed

3.1 Former NW-CaF₂ Storage Area

As described in Section 1.1.1, GE decided to voluntarily move the CaF₂ material from the former NW-CaF₂ storage area under the conditions of their license and with approval from the NRC. A survey-and-release plan was developed by NFS, GE's material recovery contractor, and the plan was reviewed and approved by the NRC.

The CaF₂ material and affected soil (exhibiting a total activity of greater than 200 pCi/g) were excavated (to the water table) from the trenches from February to August 1996. The material was loaded into trucks and transported to GE's secure onsite warehouse as an interim control measure until feasible methods for recovering uranium from the CaF₂ are evaluated. Intermediate soil (soil exhibiting activity levels above the minimum release criteria of 30 pCi/g but below the 200 pCi/g limit) was primarily located between the former CaF₂ storage trenches. This intermediate soil was also excavated and transported via truck offsite to a disposal facility in Pinewood, South Carolina. This soil was tested for the potential presence of leachable inorganic and organic contaminants as described in Section 5.5 of the CSA; no leachable constituents (except fluoride) were identified. Approximately 6,000 tons of CaF₂ and associated soil were initially excavated from the former NW-CaF₂ storage area.

After excavation of the CaF₂ and associated soil, NFS collected surface and subsurface soil samples from the excavated pit bottoms and adjacent area for total uranium analysis (as described in Section 5.6 of the CSA [RTI, 1998]) for an initial evaluation of excavation effectiveness. Elevated uranium activity levels (exceeding the release criteria of 30 pCi/g) were detected only in the pit bottom area. An additional approximately 4,000 tons of soil were excavated and secondary follow-up sampling revealed total uranium levels below the NRC release limit. Final compliance sampling and analysis will be completed in 1999.

With this excavation and disposal, source materials associated with the former NW-CaF₂ storage area have been removed. No significant additional removal of soil is expected to be necessary in this area.

3.2 Former Lubricants Area

Soil sampling activities in the former lubricants area are described in Sections 5.8 and 5.9 of the CSA (RTI, 1998). The area of highest likely contamination was identified using a passive soil-vapor survey and geophysical surveys. Exploratory borings were drilled in two locations within the former lubricants area (one in the area of highest measured VOCs soil vapor and one directly downgradient). Shallow (soil) contamination was found to be minor in both borings, suggesting that the contamination is more predominant in the groundwater, and the soil is not likely behaving as a continuing source of groundwater contamination. In addition, none of the soil samples exhibited concentrations exceeding the applicable soil remediation goals listed in the Inactive Sites Program Guidelines for Assessment and Cleanup (DENR, 1997). If greater VOC soil concentrations were once present in the source area, they evidently have degraded and/or flushed out of the soil over time. Therefore, corrective action for soil in the former lubricants area are not considered necessary.

4.0 Potential Receptors

Based on T15A NCAC 2L .0102(19), a receptor is defined as "any human, plant, animal, or structure which is, or has the potential to be, adversely effected by the release or migration of contaminants." The NCAC 2L implementation guidance (DENR, 1995) expands the definition of receptor to include:

- ▶ Properties for which there is a potential for groundwater use, public water is not available, and permission of the adjacent property owner(s) allowing the contamination to migrate onto their land has not been obtained;
- ▶ Drainage ditches and surface impoundments; and
- ▶ Environmentally sensitive areas (including wetlands).

The potential receptors of the contamination documented in the CSA (RTI, 1998) and this document are described in the following sections.

4.1 Structures

The area downgradient and potentially affected by the northwest site area contamination is remote and undeveloped. There are no structures (i.e., utility vaults, basements) in the vicinity of the northwest site area that could be affected by the groundwater contamination.

4.2 Adjacent Properties

The owner of the property adjacent to the northwest site area, Mrs. Katherine Sledge, has indicated to GE the desire for her property to continue its present use as a hunting preserve. Mrs. Sledge has granted permission for the plumes to migrate onto her property as the proposed corrective action is taken. Documentation of this permission, required per T15A NCAC 2L .0106 (1)(5)(B), is provided in Appendix E. As a result, the adjacent property is not considered to be a receptor as defined in the Subchapter 2L implementation guidance (DENR, 1995). Evaluation of the expected migration of the materials of concern in groundwater is provided in Section 6.0.

4.3 Groundwater Resources

As described earlier, none of the potentially affected area downgradient of the northwest site area is inhabited and, according to the adjacent property owner, development of the area is not planned. Some of the potentially affected area is located on GE property and the remainder is offsite and used as part of a hunting preserve. Groundwater is not currently drawn from the potentially affected area for any purpose. The nearest existing groundwater well is a hand pump located over 2,000 feet east of the area. This well is not in use. The location of this well is cross gradient and, therefore, would not intercept groundwater from the former storage area. The minimum distance from the former NW-CaF₂ storage area to the nearest domestic well, conservatively assumed to be the westernmost residence in the Wooden Shoe subdivision, is approximately 7,100 feet east and would not intercept groundwater from the former storage area. Therefore, the impacted groundwater poses no human risk via the drinking-water pathway.

According to the available Wilmington-area local water-supply plans, groundwater in this area is not expected to be used as a future public-water resource. Documentation of the local water-supply plans for New Hanover County water systems is provided in Appendix F. In addition, conversations with the New Hanover County Water and Sewer Department (Jeff Malpass - Engineering Division) revealed that there are currently no plans for additional water-supply wells in the potentially affected area (Sledge property).

4.4 Surface Water, Drainage Ditches, and Surface Impoundments

Surface-water features in the northwest site area are shown in Figure 4-1. A small stream in the northwest site area originates at the northeast corner of the NW-CaF₂ storage area parking and staging area. This stream intercepts shallow groundwater and flows through the swampy area north of the northwest site area to Prince George Creek (located approximately 4,500 feet north of the GE property line). Prince George Creek intersects the Northeast Cape Fear River approximately 8,200 feet north of the GE property line and is classified as a Type C surface-water body by the DENR Water Quality Section (T15A NCAC 2B .0101[c]).

A small water body created after excavation of CaF₂ material is present on the GE property. However, after final compliance sampling has been completed, the former NW-CaF₂ storage area excavation will be filled with clean soil and the area reforested. There are no

surface impoundments in the area that could potentially be receptors of the contaminated groundwater.

Surface-water samples were collected from the small stream originating near the former NW-CaF₂ storage area in 1997 (as described in Section 6.0 of the CSA) and again in January 1999. Neither the inorganic nor organic contaminants of interest were identified in the surface-water samples. Potential impacts on wetland surface-water quality are discussed in Section 4.5.

4.5 Environmentally Sensitive Areas

According to T15A NCAC 2B .0202(64), wetlands are defined as "areas that are inundated or saturated by an accumulation of surface or groundwater at a frequency and duration sufficient to support...a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs and similar areas." Although the swampy area downgradient of the northwest site area has not been delineated, it is assumed that a portion of the potentially-affected swampy area may be classified as a wetland based on observations of field staff (e.g., water inundation, plant species, soils). Contamination has not been detected in the samples of surface water collected from the small stream that flows through the swampy area (Figure 4-1). However, low levels of VOCs have been detected in several samples of shallow groundwater and one sample of standing water (i.e., puddle) in the swampy area. The inorganic contaminant plumes do not extend to the swampy area (i.e., elevated levels of fluoride or uranium exhibiting non-naturally occurring isotopic ratios have not been detected in samples of swamp pore water [groundwater] from the swampy area). Results of groundwater samples collected from the swampy area are presented in Tables 4-1a and 4-1b.

4.5.1 Findings of Recent Sampling Activities - Swampy Area. Sporadic levels of VOCs have been detected in shallow groundwater samples collected from three of the SWS-series sampling points in the swampy area (SWS-1, SWS-8, and SWS-9; Figure 4-1). Results of samples collected from the SWS-series sampling points are summarized in Tables 4-1a and 4-1b, complete VOC results are provided in Appendix C, Part II. TCE above the NC groundwater standard of 2.8 µg/L was detected in one sample from SWS-9 collected in August 1998 (at 30.4 µg/L) but has not been detected in subsequent samples above the PQL. Varying levels of cis-1,2-DCE have been detected in SWS-1, SWS-8, and SWS-9, but levels above the NC groundwater standard of 70 µg/L have been detected only

in SWS-9 in August 1998 and January 1999. The concentration of cis-1,2-DCE was much lower (8.47 µg/L) in the sample collected in November 1998. It should be noted that swamp pore-water samples collected from the SWS-series sampling points are indicative of groundwater (not surface water) conditions at approximately 3 feet below the swampy-area land surface.

Because the swampy area is a groundwater discharge zone, a sample of standing water that accumulated in a shallow depression in the land surface (i.e., puddle) adjacent to SWS-9 was collected and sampled for VOCs on January 29, 1999. VOC concentrations in the standing-water sample were compared to the shallow groundwater (i.e., swamp pore-water from SWS-9) samples to evaluate the attenuation of VOCs as groundwater discharges upward through the swampy-area sediment. The most rapid reductive dechlorination rates, affecting the widest range of chlorinated hydrocarbons, occur in highly reducing conditions, such as sulfate-reducing and methanogenic environments typical of the swampy area (Bouwer, 1994). The results are provided in Table 4-1c. There is evidence of volatilization and attenuation of the cis-1,2-DCE as it moves upward in groundwater through the swampy-area sediments. The concentration cis-1,2-DCE in the standing-water sample (35.1 µg/L) is lower than the swamp pore-water concentrations in SWS-9.

4.5.2 Derivation of Surface-Water Standards. According to T15A NCAC 2B .0208, "the concentration of toxic substances in surface waters will not render waters injurious to aquatic life or wildlife, recreational activities, public health, or impair the waters for any designated uses." Section 2B .0208 also provides procedures for interpreting the narrative standards for toxic substances, including:

- ▶ Human-health based standards (i.e., concentrations will not exceed the level necessary to protect human health through exposure routes of fish, shellfish, and/or water consumption), and
- ▶ Aquatic-life based standards (i.e., concentrations will not result in chronic toxicity).

Derivation of surface-water standards for VOCs applicable to both streams and standing water present in the swampy area based on these two procedures is described in the following sections.

4.5.2.1 Human-Health Standards. Because the surface waters in the streams and wetlands is not used as a drinking-water source, they are classified as Class C surface waters. Consequently, there is no risk to human health posed by the direct ingestion of surface water. Therefore, derivation of a WQS for surface water based on water-consumption is not applicable. Potential exposure via fish-tissue consumption was evaluated according to regulations presented in T15A NCAC 2B .0208. Specific standards are not available for non-carcinogens such as cis-1,2-DCE. However, a chemical-specific standard can be calculated using the following equation presented in T15A NCAC 2B .0208 (a)(2)(A)(i):

$$WQS = (RfD - DT) \times \text{Body Weight} / (FCR \times BCF)$$

where:

- RfD = reference dose (0.01 mg/kg/d, EPA, 1996a),
- DT = estimated non-fish dietary intake (conservative value of 0),
- FCR = fish consumption rate (DENR default of 6.5 gm/person/day), and
- BCF = bioconcentration factor (cis-1,2-DCE does not bioaccumulate; however, a conservative value of 15.26 L/kg-lipid was used based on ORNL, 1996a).

The conservatively calculated human-health based WQS for cis-1,2-DCE is 7,057 µg/L.

For TCE, a specific WQS is provided in T15A NCAC 2B .0208 because of its inclusion with carcinogenic substances. The fish-consumption based Class C surface-water standard for TCE is 92.4 µg/L.

4.5.2.2 Ecological-Based Standards. According to the T15A NCAC 2B .0208 regulations, the concentrations of toxic substances shall not result in chronic toxicity. VOCs are biodegradable in environmental media and tend to reenter the atmosphere relatively quickly through volatilization, are metabolized in many ecological receptors, and do not bioaccumulate or biomagnify. Given the nature of VOC behavior, exposure pathways to ecological receptors are mostly likely to occur through inhalation and ingestion pathways. Organisms at risk of exposures are primarily within the soil and plant communities. The inability of these organisms to remove themselves from contaminated areas increases their risk of potential exposure. Lesser exposures are also possible in mammalian and avian species; however, VOCs are readily metabolized and excreted in these species. Since

these chemicals demonstrate minimal bioconcentration and biomagnification, impacts from transfer of VOCs through food chain mechanisms are not expected to be significant.

Standards for cis-1,2-DCE and TCE in surface water downgradient of the northwest site area are interpreted to equal the chronic aquatic community benchmark concentrations (590 µg/L and 47 µg/L, respectively). Table 4-2 presents the proposed benchmark concentrations for several potential ecological receptors. These concentrations are based on published data (ORNL, 1996a) and, because of conservative assumptions and uncertainty factors, are typically lower than the lowest levels of toxicity developed for each chemical. Chronic benchmarks for aquatic community organisms were selected because of their relatively lower benchmark concentrations, as compared to other potential receptors.

4.5.3 Comparison of Results to Applicable Standards and Benchmarks. Potential ecological risks posed by the VOCs present in the swampy area were evaluated by comparing measured and predicted levels to:

- ▶ published acute and chronic ecotoxicological benchmark concentrations (levels observed to have low or no adverse effects on general ecological receptors), and
- ▶ human-health based WQs calculated in Section 4.5.2.1.

The comparisons of the concentrations of cis-1,2-DCE and TCE measured in the swamp pore-water (groundwater) sample from SWS-9 and the adjacent standing-water (surface-water) sample to acute and chronic benchmark concentrations are provided in Table 4-3. Low levels of VOCs were detected in the swamp pore-water and standing-water samples. However, the measured and predicted levels of the VOCs of concern in shallow swamp pore-water samples are not expected to exceed the lowest benchmarks presented in Table 4-3 (and therefore applicable surface-water standards). Comparisons of predicted cis-1,2-DCE and TCE levels expected in the swamp standing-water samples (according to the calibrated fate and transport modeling described in Section 6.1.2.5) to ecological benchmarks/surface-water standards are provided in Figures 4-2 and 4-3, respectively. Based on available information, these benchmark concentrations are also protective of other organisms potentially present in the swampy area including piscivorous (fish-eating) mammals and terrestrial plants (Table 4-3).

Potential impacts to the soil invertebrate community were also evaluated by comparing the maximum predicted shallow soil (sorbed) concentrations of TCE to the published benchmark for the soil invertebrate community. Using the maximum predicted concentration of TCE in swamp pore water (shallow groundwater) in the swampy area (approximately 30 µg/L), a maximum soil concentration was calculated based on the following equation:

$$C_{\text{soil}} = C_{\text{water}} \times K_d$$

where:

- C_{soil} = Maximum predicted TCE concentration in soil (mg/kg),
- C_{water} = Maximum predicted TCE concentration in shallow groundwater in swampy area (mg/L) - based on modeling results presented in Section 6.1.2.5,
- K_d = Distribution coefficient, 51.5 L/kg, based on $K_d = K_{oc} \times f_{oc}$,
- K_{oc} = Organic carbon partitioning coefficient (166, from EPA, 1996b),
- f_{oc} = fraction organic carbon (0.31, mean of soil samples collected from swampy area [RTI, 1998]).

Based on the equation above, the maximum predicted soil TCE concentration is approximately 1.54 mg/kg. This is significantly lower than the soil community benchmark of 79 mg/kg and the terrestrial plant benchmark of 14 mg/kg as presented in Table 4-3.

In summary, there are no expected unacceptable risks to potential ecological receptors in the swampy area downgradient of the former source area.

5.0 Evaluation of Potential Corrective Actions

5.1 Objectives

The purpose of this CAP is to identify and describe an appropriate remedy for groundwater contamination in a remote northwest portion of the GE-Wilmington site resulting from storage and disposal practices typical of the late 1960s when the GE site was developed. Any corrective action implemented in the northwest site area must have the following primary objectives:

- ▶ Ensure protection of human health and the environment,
- ▶ Address both the organic and inorganic materials identified in northwest site area groundwater,
- ▶ Minimize impacts or other disturbances to the adjacent property, and
- ▶ Prevent creation of additional waste products through the remediation process and avoid the risks to human health and the environment associated with handling such waste.

5.2 Evaluation of Remedial Alternatives

Only groundwater remediation technologies are appropriate for this CAP because: (1) the source of inorganic contaminants (i.e., CaF_2 and contaminated soil) has been removed, (2) soil contamination by VOCs has not been detected above relevant cleanup standards, and (3) evidence of free-phase contaminants has not been found at the site. The following sections present brief descriptions of the most common potential remedial technologies and their applicability at the site. The technologies considered below are listed in the DENR guidance as the most current conventional methods available (DENR, 1998).

5.2.1 Pump-and-Treat. Pump-and-treat involves the extraction of groundwater to recover contamination and restrict its migration within a known area. Pump-and-treat is an effective technology for controlling plume migration, but its effectiveness at removing contaminants from groundwater to below regulatory standards is questionable (particularly for organic contaminants and uranium due to their sorption to the aquifer matrix). In addition, implementation can involve significant disruption to the adjacent property use and/or appearance.

The VOC plume in the northwest site area extends to the swampy area north of the former source area. Therefore, it would be necessary to install recovery wells within or very near this wetland area. Pumping from shallow recovery wells would likely result in wetland dewatering and associated degradation. Groundwater pumping could be feasible in the upland area to address the less-extensive uranium and fluoride plumes; however, effective recovery of groundwater containing uranium would be problematic. In addition, the uranium recovered from the pumping would be primarily naturally occurring.

Due to the potential for negatively impacting the swampy area adjacent to the site, the high costs of this approach weighed against the low potential risks posed by the contamination, and problems associated with treatment and handling of the recovered materials, pump-and-treat (including pump-and-treat with reinjection of treated groundwater) is not considered appropriate or feasible for this project.

5.2.2 Air Sparging with Soil-Vapor Extraction. Air sparging consists of injecting compressed air into groundwater and saturated soil to encourage volatilization of VOCs into the vapor phase. The volatilized components are transported to the unsaturated zone, where they typically are recovered into a soil-vapor extraction (SVE) system. Air sparging also can stimulate the biodegradation of constituents by increasing the oxygen content of the groundwater.

At the site, there are some effectiveness limitations with air sparging. Air sparging would not be effective for the inorganic impacts (uranium and fluoride) at the site, because these constituents are not volatile. In fact, oxidizing conditions could increase uranium mobility in the aquifer. In addition, the unsaturated zone is very thin in some areas. For example, in the swampy area, the water table is essentially at the soil surface. A vapor extraction system to recover volatilized compounds could not be installed in this area.

Due to the effectiveness and limitations of air sparging/SVE at the site, this technology is not considered applicable or feasible for this project.

5.2.3 Monitored Natural Attenuation. Natural processes in the environment can reduce the mass, toxicity, volume, concentration, and/or mobility of contaminants in soil or groundwater. These processes, including biodegradation, dispersion, dilution, sorption, volatilization, and chemical or biological stabilization, transformation or destruction of contaminants, are collectively referred to as natural attenuation (EPA, 1997). The

processes listed above are inclusive of the mechanisms described in the DENR definition of natural remediation (T15A NCAC 2L .0102[14]). While human intervention is not involved in the actual remediation process, fate and transport monitoring of the contamination is key; hence, the US Environmental Protection Agency (EPA) has defined this approach as monitored natural attenuation (MNA). NC DENR and EPA conditions and guidance for application of MNA at contaminated sites are described in the following sections.

5.2.3.1 NC DENR Policy on Monitored Natural Attenuation. Per T15A NCAC 2L .0106(i), when reviewing any CAP for approval, DENR must consider:

- ▶ the extent of any violations,
- ▶ extent of any threat to human health or safety,
- ▶ extent of damage or potential adverse impact to the environment,
- ▶ technology available to accomplish restoration,
- ▶ the potential for degradation of the contaminants in the environment,
- ▶ the time and costs estimated to achieve groundwater quality restoration, and
- ▶ the public and economic benefits to be derived from groundwater quality restoration.

DENR provides a mechanism for approving a natural attenuation CAP in T15A NCAC 2L .0106(i). Under the provisions of this rule, MNA is applicable for contamination resulting from a non-permitted activity and if the site does not require any ongoing active groundwater remediation (DENR, 1995). These conditions apply to the northwest site area.

A summary of NC DENR conditions and requirements for a MNA CAP and their applicability to this northwest site area CAP is provided in Table 5-1. Satisfaction of requirements presented in the table, as well as other administrative requirements (regarding notifications, professional certifications, submittal of the CSA, schedule, and monitoring plans), must be certified by a licensed geologist or professional engineer on the *Certification for the Submittal of a Corrective Action Plan* (DENR Form GW-100[1]). The completed certification for this CAP is provided at the beginning of this document.

5.2.3.2 EPA Policy on Monitored Natural Attenuation. The EPA has provided guidance regarding factors to be considered when determining whether sites are appropriate for the MNA approach (EPA, 1997). These considerations and their applicability to the northwest

site area MNA CAP are summarized in Table 5-2. Based on EPA's factors supporting implementation of MNA and regulations presented in T15A NCAC Section 2L, MNA is considered to be the most viable remedial approach for the groundwater contamination identified in the northwest site area. In addition, the MNA remedial approach is consistent with the objectives defined in Section 5.1. Site-specific technical information supporting this approach is provided in Section 6.0.

6.0 Technical Evaluation of Monitored Natural Attenuation

As discussed in Section 5.0, MNA is considered to be the most viable remedial alternative for the northwest site area. Materials of interest in the groundwater include VOCs (TCE and its degradation products cis-1,2-DCE and vinyl chloride), uranium exhibiting non-natural isotopic ratios (delineated by the distribution of the isotope ^{235}U), and fluoride. A summary of properties affecting the fate and subsurface transport of the materials of interest are described below as well as in Section 4.0 of the CSA (RTI, 1998).

Technical issues affecting the natural attenuation of each of these constituents are presented below. For each of the materials of interest, the mechanisms for natural attenuation are described (e.g, sorption, biodegradation, dispersion). In addition, factors or conditions that influence natural attenuation are discussed with respect to site-specific observations and measurements, and results of groundwater flow and fate and transport modeling are also presented.

6.1 Volatile Organic Compounds

Evaluation of the mechanisms affecting the natural attenuation of VOCs in the subsurface is evolving rapidly, and the natural attenuation of chlorinated solvents such as TCE has been documented at several sites. One recent technical discussion of the natural attenuation of VOCs is EPA Office of Research and Development's *Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Ground Water* (EPA, 1998a). The mechanisms for biodegradation of chlorinated hydrocarbons (such as TCE) presented in that document are summarized below.

6.1.1 Factors and Mechanisms Influencing Natural Attenuation. Biodegradation is typically the most important destructive process affecting VOCs. In fact, numerous laboratory and field studies have demonstrated that a variety of chlorinated solvents can be biodegraded (EPA, 1998a). Chlorinated organic compounds are typically biodegraded naturally via three potential pathways:

- ▶ use of the contaminant as an electron acceptor (reductive dechlorination, also known as reductive dehalogenation),
- ▶ use of the contaminant as an electron donor, or
- ▶ by cometabolism (destruction by biologically-produced enzymes to no benefit or use by the microorganisms).

The most predominant and effective biodegradation mechanism for chlorinated solvents is reductive dechlorination, an anaerobic biodegradation pathway where the chemical is used as the electron acceptor. Therefore, biodegradation of chlorinated compounds will typically be an electron-donor-limited process and a source of organic carbon to serve as the substrate or the electron donor is required for reductive dechlorination. This process is illustrated in Figure 6-1. The most rapid reductive dechlorination rates, affecting the widest range of chlorinated hydrocarbons, occur in highly reducing conditions, such as sulfate-reducing and methanogenic environments (Bouwer, 1994). During reductive dechlorination of TCE, all three DCE isomers (i.e., cis-1,2-DCE, trans-1,2-DCE, and 1,1-DCE) can be produced, but cis-1,2-DCE is the most common (Bouwer, 1994), and the predominance of cis-1,2-DCE is evident in the northwest site area. Since vinyl chloride is the least oxidized of the chlorinated hydrocarbons, it is less susceptible to reductive dechlorination, and it biodegrades the slowest through this biodegradation pathway. However, vinyl chloride can degrade readily as the primary substrate in biologically mediated oxidation-reduction reactions (McCarty and Semprini, 1994). For example, vinyl chloride will rapidly biodegrade in aerobic conditions, with oxygen serving as the electron acceptor and vinyl chloride acting as the substrate or electron donor.

EPA (1998a) describes three types of plume behaviors, depending on the amount of solvent present, the amount of biologically available carbon in the aquifer, the distribution and concentration of natural electron acceptors, and the types of electron acceptors being used. Type 1 plumes occur where the primary substrate is anthropogenic organic carbon, driving reductive chlorination and resulting in rapid and extensive degradation of the more highly chlorinated solvents. Type 2 plumes are characterized by high concentrations of available native organic carbon. Reductive dechlorination may occur in a Type 2 plume, but possibly at slower rates, depending on the amount of organic carbon available. Type 3 plumes are characterized by inadequate organic carbon (native or anthropogenic). In this scenario, reductive dechlorination will not occur, but vinyl chloride is easily oxidized. A

chlorinated solvent plume can exhibit all three types of behavior in different portions of the plume (EPA, 1998a).

It should be noted that in addition to the biodegradation mechanisms described above, VOCs are also naturally attenuated through the processes of dispersion and, to some degree, sorption. These mechanisms are more important in Type 3 plumes as described above.

6.1.2 Site-Specific Factors. There are several factors in the northwest site area that support use of MNA to address the groundwater contamination by VOCs:

- ▶ depletion of VOCs in the former source-area soils to below cleanup levels,
- ▶ presence of degradation products in groundwater indicating groundwater is naturally attenuating,
- ▶ values for natural-attenuation indicator parameters in groundwater (e.g., dissolved oxygen, oxidation-reduction potential [ORP], and ferrous iron),
- ▶ presence of a downgradient hydraulic and geochemical boundary (i.e., the swampy area),
- ▶ measured and predicted contaminant migration patterns, and
- ▶ absence of human and ecological risk.

These factors are described in the following sections.

6.1.2.1 Source Depletion and Presence of Degradation Products. As described in Section 3.2, soil borings in the former lubricants area did not identify soil VOC concentrations at levels resulting in continuing contribution to groundwater contamination or above risk-based cleanup levels (DENR, 1997). In addition, there is evidence of TCE degradation in the area as TCE is not present in two wells immediately downgradient of the former lubricants area (CAF-17C and OB-5); further, relatively elevated levels of the TCE biodegradation daughter product cis-1,2-DCE have been measured in samples from these wells, along with the presence of vinyl chloride. Based on this and historical information, it is believed that in the former lubricants area, the lubricant substrate (animal fat), along with natural organic carbon, provide a source of organic carbon (electron donor) necessary to facilitate biodegradation of the VOCs at the source area. This interpretation is also

supported by the values for natural-attenuation parameters measured in groundwater in the northwest site area, as described in the following subsection.

Groundwater samples have been collected from well OB-5 for VOC analysis since 1993. TCE has not been detected above PQLs in any of the samples from this well and cis-1,2-DCE concentrations have declined steadily (Figure 6-2). There have been sporadic detections of vinyl chloride in samples from this well (typically at approximately 7 µg/L). The absence (below the typical PQL level of 0.5 µg/L) of TCE, the predominance of cis-1,2-DCE, and the decreasing concentrations of degradation products suggests that the area of the plume directly downgradient of the source is exhibiting Type 1 (reductive dechlorination) plume behavior as defined in Section 6.1.1.

6.1.2.2 Measurements of Natural-Attenuation Parameters in Groundwater. The biodegradation of chlorinated hydrocarbons brings about changes in the groundwater chemistry in the affected area. The intent of monitoring these changes in groundwater is to demonstrate that conditions are conducive for reductive dehalogenation.

Aerobic bacterial respiration requires dissolved oxygen (DO). After depletion of the DO, electron acceptors are used in the following order of preference, as available, and as conditions become more reducing: nitrate, iron(III), sulfate, and then carbon dioxide (methanogenesis) (EPA, 1998a). Natural attenuation of chlorinated solvents can often be documented by measuring the occurrence and distribution of these parameters in groundwater. The key parameters of interest include DO, ferrous iron (II), and oxidation-reduction potential (ORP). These parameters, along with other parameters such as pH, temperature, sulfate, chloride, total organic carbon (TOC), and alkalinity, were measured in November 1998 and January 1999 to aid in evaluation of groundwater conditions with respect to natural attenuation. In addition to the inorganic parameters discussed above, the distribution of methane, ethane, and ethene are important when evaluating the degradation of chlorinated ethenes. A summary of the results of these natural-attenuation parameters collected and measured in January 1999 is provided in Table 6-1. The importance of some of these key parameters (EPA, 1998a), as well as their presence and/or distribution in groundwater in the northwest site area, is described below.

Dissolved Oxygen. Anaerobic bacteria cannot function (and therefore reductive dechlorination will not occur) when the groundwater DO

concentration is greater than approximately 0.5 mg/L. The distribution of DO in the northwest site area is shown in Figure 6-3. The distribution of low DO levels (below 1.0 mg/L) is well correlated with the extent of the TCE and cis-1,2-DCE plumes, indicating that conditions are conducive for reductive dehalogenation in this area.

Iron (II). Ferrous iron (II) is the by-product of the reduction of ferric iron (III). Ferric iron may be used as an electron acceptor in anaerobic environments and may be used as an electron acceptor during degradation of organic carbon and vinyl chloride (EPA, 1998a). Therefore, ferric iron should be depleted in areas of active anaerobic biodegradation. However, the distribution of ferric iron is often difficult to measure, because it typically readily precipitates with other inorganic compounds in groundwater. The accumulation of the by-product of ferric iron reduction (i.e., ferrous iron) is thus useful in delineating potential areas of reductive dechlorination. Reductive dechlorination is more predominant in areas exhibiting higher ferrous iron levels. The distribution of ferrous iron in the northwest site area groundwater is shown in Figure 6-4. The highest ferrous iron levels (over 4.0 mg/L) are found just downgradient of the former lubricants area, and the extent of elevated (over 1.0 mg/L) ferrous iron corresponds well with the extent of the TCE and cis-1,2-DCE plumes.

Oxidation-Reduction Potential⁴. The ORP of groundwater indicates the relative tendency to accept or transfer electrons. Changes in ORP are typically biologically mediated. ORP measurements of less than -100 millivolts (mV) indicate that the reductive pathway is likely; however, the reductive pathway is possible at ORP measurements less than 50 mV (EPA, 1998a). The distribution of negative groundwater ORP in the northwest site area groundwater is shown in Figure 6-5 and correlates well with the distribution of DO (Figure 6-3) and the extent of the VOC plumes in the northwest site area.

⁴For natural-attenuation screening, ORP is measured against a silver/silver chloride (Ag/AgCl) electrode instead of against a standard hydrogen probe (Eh). An Ag/AgCl electrode was used to measure ORP at the GE site.

Methane. The presence of methane indicates strongly reducing, methanogenic conditions, and its presence above background concentrations is indicative of biodegradation (EPA, 1998a). The distribution of methane in the northwest site area groundwater is shown in Figure 6-6. The distribution indicates substantial methane production in the area of highest VOC contamination and, as expected, in the swampy area north of the former source area. The distribution of methane is not contoured in the swampy area, as significant methane production is expected in the entire swampy area due to the high natural organic-carbon content of the swampy-area sediments. Therefore, contouring of these concentrations would not likely be meaningful. The results support the interpretation that biodegradation is active within the VOC plumes.

Ethene. Ethene is one of the end-point daughter products resulting from the reductive dehalogenation process; thus its presence is indicative that degradation of the parent compound is or has been occurring. The distribution of ethene in groundwater in the northwest site area is shown in Figure 6-7. As expected, ethene levels are highest in the areas of highest contamination and, as a result, indicate that biodegradation of the VOCs is or has been occurring in the northwest site area.

Total Organic Carbon. TOC levels were significantly higher in the wells near the former source area, and the TOC distribution corresponded with the distribution of methane, the VOCs, and ethene. The presence of elevated TOC in the most contaminated areas of the plume indicates that there is a sufficient carbon source to facilitate reductive dechlorination.

In addition to the evaluation of the distribution of the key natural-attenuation parameters addressed above, a quantitative screening evaluation of the potential biodegradation of VOCs (based on EPA, 1998a) was conducted using the results of these and other groundwater parameters in the northwest site area. The results of this quantitative evaluation are presented on Table 6-2. Based on the quantitative screening methodology cited by EPA (EPA, 1998a), there is strong evidence for anaerobic degradation of chlorinated VOCs near the former lubricants area, and there is adequate evidence downgradient from the former source area.

6.1.2.3 Presence of a Downgradient Hydraulic Boundary. As described in Section 3.0 of the CSA (RTI, 1998) and in Section 2.0 of this document, groundwater flows from the upland areas of the sand peninsula in the northwest site area and discharges into the swampy area downgradient of the former source areas. The horizontal hydraulic gradient in the upland area is approximately 0.005, and the vertical gradient in the upland area ranges from 0.005 to 0.03 (downward). The flow regime changes significantly at the interface of the swampy area. Groundwater discharges strongly upward into the swampy area as evidenced by the large vertical upward hydraulic gradient (0.146). In contrast to the upland areas, the horizontal hydraulic gradient in the swampy area is very small and reasonably estimated to be on the order of 0.0007. This hydrogeologic setting essentially serves as a hydraulic boundary, limiting the lateral extent of contaminants that may migrate to the swampy area. A groundwater flow model has been developed for the area (refer to Appendix G for specific information on model development and calibration). Figure 6-8 presents a cross-sectional representation of the simulated groundwater flow regime in the northwest site area and indicates that horizontal groundwater flow in the swampy area is very slow.

6.1.2.4 Presence of a Downgradient Geochemical Boundary. The swampy sediments have an extremely high organic carbon content (average of 31 percent). As a consequence of this very high fraction of organic carbon (f_{oc}), these soils will take up appreciable amounts of organic chemicals through sorption. The measure of the effectiveness of sorption, the distribution coefficient (K_d), increases significantly in the swampy sediments. As the K_d increases, sorption becomes more effective. The f_{oc} of the upland sandy sediments of the northwest site area is on the order of 0.001, while the average f_{oc} of the swampy sediments is much greater (0.31). A summary of the site-specific parameters affecting the migration of VOCs dissolved in groundwater in the northwest site area is presented in Table 6-3.

6.1.2.5 Measured and Predicted Contaminant Migration Patterns. The VOCs cis-1,2-DCE and TCE have migrated to the swampy area, which is approximately 1,200 feet downgradient of the former lubricants Area (Figure 1-2). A degradation product, vinyl chloride, has migrated from the former source area; however this constituent has not been detected in the swampy area. When compared with the migration of fluoride and uranium, these VOCs are more mobile. However, as described in this section, natural-attenuation processes, including dispersion, biodegradation, and sorption, are actively limiting the concentration and extent of these impacts.

Three-dimensional numerical groundwater flow (MODFLOW) and contaminant fate-and-transport (MT3D) models were used to evaluate the VOCs of interest (TCE, cis-1,2 DCE, and vinyl chloride) in the northwest site area. Appendix G provides a detailed description of the model development, calibration, and simulations, including assumptions and input parameters.

Calibration of the VOC models involved comparing the measured cis-1,2-DCE plume with model results after a 30-year time period. This analysis considered cis-1,2-DCE, because this constituent is the most prevalent VOC at the site with the broadest extent. Also, cis-1,2-DCE is continuous from the former source area to the swamp, unlike TCE and vinyl chloride. The comparison between the measured and the modeled plume extents for cis-1,2-DCE is shown in Figure 6-9. For this simulation, the sorption parameters were estimated using hydrophobic theory, which involves estimating the parameter using the measured soil f_{oc} , constituent-specific octanol-water partition coefficients (K_{ow}), and organic carbon distribution coefficients (K_{oc}). The same theory was used in estimating sorption parameters for TCE and vinyl chloride. Table 6-3 summarizes the sorption parameters for each constituent estimated using this method. The favorable match between the observed and simulated distribution of cis-1,2-DCE shown in Figure 6-9 was achieved by varying the dispersivities and the first-order biodegradation rate. The resulting dispersivities were 4, 0.3, and 0.1 feet in the longitudinal, horizontal, and vertical directions, respectively. A typical convention is to set longitudinal dispersivities to be in the range of 1 to 10 percent of the length of the plume. Considering the longitudinal dispersivity is only 0.3 percent of the VOC plume length (approximately 1,200 feet) in the northwest site area, the estimated dispersivities are relatively low and, therefore, conservative in estimating potential future migration patterns. The resulting biodegradation rate of 0.11 year^{-1} (a half-life of 6.3 years) is relatively low. In fact, the average field-scale biodegradation rate compiled by EPA's Office of Research and Development is 1.6 year^{-1} (a half-life of 0.43 year) (EPA, 1998b). Although the modeled biodegradation rate for the site is comparatively low, there is compelling evidence that biodegradation is active at the site, as described in Section 6.1.2.2. Therefore, the modeled biodegradation rate is considered to be conservative in estimating potential future migration patterns. Following the EPA-documented range of biodegradation rates for TCE, cis-1,2-DCE, and vinyl chloride (EPA, 1998b), biodegradation rates for TCE and vinyl chloride were estimated to be close to the rate for cis-1,2-DCE, as indicated in Table 6-3.

Following the calibration procedure described above, predictive simulations evaluated the future migration patterns for each of the VOCs of interest. The setup for these simulations included the measured distribution of the VOCs as initial conditions. The sorption, biodegradation, and dispersion parameters corresponded to the values shown in Table 6-3.

Figures 6-10 and 6-11 show the predicted distribution of cis-1,2-DCE from present conditions (1999) into the future. These (and subsequent) three-dimensional representations of current and predicted contaminant patterns contain a vertical slice through the geologic layers underlying the site, including, in order of increasing depth: the highly organic swamp sediments (dark brown), the upper unconsolidated tan-to-gray sand (medium brown), and the deeper rocky zone (light brown). The vertical cut through the geologic layers in the figures is located along the approximate centerline of the plume, oriented 5 degrees east of plant north. In addition, the measured and/or modeled plumes are shown extending from the geologic slice. An additional vertical slice through the center of each plume shows changes in the concentration within the plume interior. The digital aerial photograph of the area is projected onto the surface elevations, and the former lubricants area (the former source for the VOC impacts) is highlighted in red. The white lines are features (e.g., roads and property boundaries) from the areal base map. The view is oriented approximately towards the west (in plant coordinates) and at an angle downward approximately 22 degrees from horizontal. The concentration distribution in these figures was estimated using a three-dimensional kriging geostatistical method implemented by the Environmental Visualization System (EVS). This method uses the irregularly spaced measured concentrations and estimates the three-dimensional concentration distribution throughout the domain. EVS determines the kriging input parameters, including the reach, the domain extent, the range, and the sill, based on the measured data distribution. Three-dimensional kriging in EVS uses a spherical variogram model and a nugget of zero.

Figures 6-10 and 6-11 show the decline in cis-1,2-DCE concentrations over time, with the 70- $\mu\text{g/L}$ plume dissipating in the aquifer between 5 and 15 years from present. Due to the strong sorption onto the highly organic swamp soils, the cis-1,2-DCE remains in the groundwater in contact with these sediments for a longer time period. However, between 30 and 35 years (not shown), the cis-1,2-DCE concentrations are expected to be attenuated below 70 $\mu\text{g/L}$. Figure 6-12 shows the breakthrough of cis-1,2-DCE concentrations in the swampy area in groundwater at a depth just below the swampy-area land surface and at a depth of approximately 15 feet (in the sand below the swamp sediments). As this figure

indicates, the surficial concentrations are expected to increase to a maximum of about 180 µg/L approximately 11 years after current conditions. A comparison of these curves indicates that the swamp geochemical boundary significantly decreases the maximum surface concentrations relative to the maximum concentrations at depth. However, the cis-1,2-DCE remains in the shallow swamp sediments longer due to the strong sorption to the highly organic swampy-area soils.

Figure 6-13 shows the predicted maximum concentrations of cis-1,2-DCE in the groundwater just below the surface in the swampy area. For a conservative comparison, the maximum concentrations of cis-1,2-DCE with no attenuation are also shown in Figure 6-13. The model setup was identical for the two results shown in Figure 6-13, except that sorption and biodegradation were not activated for the bottom graphic (i.e., no attenuation). The results demonstrate that even with the conservative assumption of no future attenuation, the impacts are confined within a relatively small area, which is within the existing monitoring network.

Figures 6-14 and 6-15 show the predicted distribution of TCE from present conditions into the future. These figures describe the steady decline in TCE concentrations over time, with the 2.8 µg/L plume expected to dissipate in the aquifer between 5 and 10 years from present. Due to its sorption onto the highly organic swamp soils, the TCE remains in groundwater adjacent to these sediments for a longer time period. However, between 50 and 55 years (not shown) the TCE should be attenuated below 2.8 µg/L. Figure 6-16 shows the breakthrough of TCE concentrations in groundwater just below the surface in the swamp. As this figure indicates, the predicted concentrations increase to a maximum of about 10 µg/L approximately 18 years after current conditions. The concentrations at a depth of 15 feet (in the sand below the swamp sediments) are shown for comparison. Comparing these curves indicates that the swamp geochemical boundary decreases the maximum surface concentrations relative to the maximum concentrations at depth. However, the TCE remains in the swamp sediments longer due to its sorption to the highly organic swampy-area soils. Also, TCE remains in these soils longer than cis-1,2-DCE, because TCE sorbs more readily to organic matter than cis-1,2-DCE. Figure 6-17 shows the predicted maximum concentrations of TCE in the groundwater just below the surface in the swamp. For a conservative comparison, the maximum concentrations of TCE with no attenuation are also shown in Figure 6-17. The model setup was identical for the two distributions, except that sorption and biodegradation were not considered in the bottom graphic (i.e., no attenuation).

The results show that even with the conservative assumption of no attenuation from current conditions, the impacts would be confined within a relatively small area within the existing monitoring network in the swampy area.

Figures 6-18 and 6-19 show the predicted distribution of vinyl chloride from present conditions into the future. These figures show the steady decline in vinyl chloride concentrations over time, with the plume exceeding 0.5 µg/L expected to dissipate between 20 and 25 years from present (not shown). Vinyl chloride exceeding the typical analytical PQL of 0.5 µg/L is not predicted to reach the swamp sediments.

6.1.2.6 Absence of Human and Ecological Risk. As described in Section 4.0, there are no domestic users of groundwater in the area downgradient of the former source areas, and there are currently no known plans for future development of water supplies from the area. Therefore, there is no risk to human health via the drinking water pathway. Low levels of cis-1,2-DCE and TCE are predicted to migrate into the shallow groundwater and potentially standing water in a localized portion of the swampy area. However, as described in Section 4.5, the measured and predicted concentrations of these contaminants do not exceed proposed acute or chronic ecological risk benchmarks or surface-water standards for the VOCs of concern. As a result, potential ecological risk posed by the VOCs in groundwater in the northwest site area is considered to be minimal.

6.2 Uranium

MNA has been selected by EPA as a final remedy at several Superfund sites contaminated with organic and inorganic contaminants, including radionuclides (Brady, et al., 1998a). Long-lived radionuclides such as uranium do not degrade destructively, but must instead be converted to a stable form or diluted to levels that pose lower risks to potential receptors. 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 geochemical parameters present in that environment (similar to those described in Section 6.1.2.2). Many metals and radionuclides such as uranium are readily removed from soil solutions and groundwater by sorption to mineral surfaces and/or soil organic matter and by the formation of insoluble solids (precipitation). The potential immobility of these compounds make radionuclides and metals strong candidates for MNA. In addition,

radionuclides strongly sorbed in soils are likely to be flushed by larger volumes of recharge, increasing the potential for dilution over time (Brady and Borns, 1997).

6.2.1 Factors and Mechanisms Influencing Natural Attenuation. Uranium occurs in three oxidation states; U(IV), U(V), and U(VI). In natural waters the U(IV) (uranous) and U(VI) (uranyl) oxidation states predominate. The aqueous geochemistry of dissolved uranium is complex, and the concentration of uranium in groundwater is controlled by multiple, interrelated factors. The redox environment, pH, the types and concentrations of other compounds that complex with uranium, and adsorption are all important factors, as discussed below.

The behavior of the three uranium species of interest (^{234}U , ^{235}U , and ^{238}U) in the subsurface is expected to be similar, and the natural attenuation mechanisms described in the following sections are not expected to differentiate between species.

One important control on the behavior of uranium in groundwater is the redox 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(IV) and its aqueous complexes predominate, whereas, in oxidized groundwater, uranium exists mainly as U(VI) and its complexes. This redox sensitivity leads to differences in the concentration of dissolved uranium in groundwater because U(VI) and its complexes are soluble, whereas U(IV) 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[IV]) generally forms strong carbonate complexes. The carbonate complexes are particularly important because they can increase the solubility of uranium minerals, facilitate oxidation of U(IV), and limit the extent of uranium adsorbed in oxidized waters. Other uranium complexes that 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 iron (III) 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(VI) (Langmuir, 1997). Organic matter is also important in determining the sorptive capacity of soils. The extent to which adsorption of U(VI) occurs depends on the aqueous speciation of uranium, which in turn is a function of the redox conditions, pH, and presence of other species.

6.2.2 Site-Specific Factors. There are several conditions in the northwest site area that advocate use of MNA to address the groundwater contamination by uranium exhibiting non-natural isotopic ratios. These include:

- ▶ removal of the source,
- ▶ measured and predicted contaminant migration patterns indicating the immobility of uranium at the site,
- ▶ presence of a downgradient geochemical and hydraulic boundary (i.e., swampy area), and
- ▶ absence of human and ecological risk.

6.2.2.1 Removal of the Source. As described in Section 3.1, the source of uranium exhibiting non-natural isotopic ratios (i.e., the CaF_2 material) has been removed under the guidance of a plan approved by the NRC. Final compliance sampling for the area has been initiated and the former NW CaF_2 storage area is no longer contributing to groundwater impacts in the area.

6.2.2.2 Measured and Predicted Contaminant Migration Patterns. The migration of uranium from the source area has not been extensive. This pattern is evident when comparing the plume of uranium exhibiting non-natural isotopic ratios (Figures 2-7 and 2-8) with the adjacent VOC plumes (Figures 2-10 through 2-12). The VOCs have migrated to the swampy area, approximately 1,200 feet downgradient from its former source area; however, the uranium has been limited within approximately 200 feet of its former source area. The limited migration of uranium may result from multiple attenuating factors, including sorption, dispersion, and precipitation, as described in Section 6.2.1. This section presents analyses of the past and future migration patterns to better understand the potential for and effectiveness of the natural attenuation of uranium at the site.

Measured trends for total uranium in groundwater downgradient of the former NW-CaF₂ storage area are decreasing (Figure 6-20). As described in the CSA, elevated uranium levels were measured for a brief period in monitoring wells directly downgradient of the source area. Elevated groundwater concentrations may have been present in the past after the water table rose into the bottom of the former storage trenches, which may have intermittently mobilized some of the uranium. However, regardless of the cause, the source of uranium has now been removed (Section 3.1), and therefore similar magnitude concentration spikes are not expected in the future.

Three-dimensional numerical groundwater flow (MODFLOW) and contaminant fate-and-transport (MT3D) models were used to evaluate the ²³⁵U plume in the northwest site area. The model simulates the transport of the ²³⁵U isotope, because ²³⁵U is representative of uranium exhibiting non-natural isotopic ratios. Appendix G provides a detailed description of the model development, calibration, and simulations, including assumptions and input parameters. Descriptions of the setup of the three-dimensional graphics presenting the results of the modeling activities are described in Section 6.1.2.5.

Figure 6-21 illustrates the effectiveness of natural-attenuation processes at limiting the migration of uranium at the site. The model setup for these simulations includes a constant source concentration of 0.07 mg/L (the highest measured ²³⁵U concentration) for 30 years within the CaF₂ storage area. Based on the site operational history and the maximum measured groundwater concentrations, this setup is considered to be representative of conditions at the site for the last 30 years. The difference in the two simulation results shown in Figure 6-21 is that the upper diagram represents the plume configuration that would be present with no attenuation (other than dispersion) limiting the plume migration. The lower diagram shows the extent of the ²³⁵U plume with the additional attenuation mechanism of sorption limiting the plume extent. The plume extent with no attenuation is clearly outside the area where impacts have been measured. In contrast, the plume extent with attenuation provides a good match with the measured plume (for comparison, the currently measured plume is shown in Figure 6-22).

For the simulation with attenuation shown in Figure 6-21, the distribution coefficient, K_d , which controls sorption, was adjusted until the simulated plume extent at 30 years was close to the measured plume extent. The K_d resulting from this analysis was 3.5 L/kg for the sand and the sandstone. This K_d value is actually significantly less than the value of 10 L/kg

estimated using site-specific soil and groundwater data, as described in Section 6.2.2.3. The lower K_d value used in the model predicts less sorption and is, therefore, more conservative. Using the estimated K_d of 3.5 L/kg, a porosity of 0.3, and a bulk density of 1.56 g/cm³, the calculated retardation coefficient for uranium is 19.2. This retardation coefficient indicates that the dissolved uranium will travel approximately 19.2 times slower than the groundwater. In summary, the model results presented in Figure 6-21 show that natural attenuation is active and is limiting the migration of uranium at the site.

As described in Section 6.2.1, uranium transport in the subsurface is complex and is likely subject to multiple, interrelated attenuation mechanisms at the site, including sorption, dispersion, and precipitation reactions. It is uncertain which exact combination of mechanisms is responsible for the attenuation evident in Figure 6-21. However, it is clear that natural attenuation of uranium limits the plume migration. The model attributes most of the attenuation to sorption (except for the attenuation attributed to dispersion). Therefore, sorption in the model is a "lumped parameter" mechanism that may represent multiple attenuation mechanisms simultaneously. This treatment simplifies the complex geochemistry of uranium, which is necessary for practical modeling of the complex reactions. However, because sorption is not a destructive attenuation mechanism (sorption, unlike first-order degradation, does not remove mass from the system), this treatment is conservative. For example, given consistent geochemical conditions, precipitation of uranium may remove the compound permanently from the system. In contrast, sorbed uranium may desorb over time, re-entering the groundwater. Therefore, modeling multiple potential attenuation mechanisms as sorption is a simplification necessary for practical modeling; however, this treatment is also conservative.

Figures 6-22 and 6-23 show the predicted distribution of ²³⁵U from present conditions into the future. The model setup for these model results corresponds to the calibrated model setup shown in Figure 6-21 (transport with attenuation). Figures 6-22 and 6-23 show the steady decline in uranium concentrations over time. After 260 years, the 0.00015 mg/L plume is fully dissipated. The maximum simulated ²³⁵U concentrations over the duration of the fate-and-transport simulations are provided on Table 6-4. The predicted maximum total uranium concentration (based on a percent enrichment of 2.2) is expected to be at the EPA proposed drinking-water standard for uranium (0.02 mg/L, Federal Register, 1991) after 60 years. In addition, a site-specific, risk-based groundwater monitoring guideline value (GMGV) was developed to address the groundwater contamination in this area (Potter,

1998). Development of the GMGV followed the procedures used by EPA to develop proposed National Primary Drinking Water Regulations; Radionuclides; Proposed Rule (Federal Register, 1991). The conservatively derived GMGV for this area of the GE site is 0.045 mg/L. The predicted maximum total uranium concentration in groundwater is expected to fall below this risk-based GMGV in less than 10 years. Although the migration of uranium at the site is slow due to attenuation, the modeling results predict that ^{235}U will attenuate below the PQL of 0.00015 mg/L before reaching the swampy area to the north of the site.

6.2.2.3 Presence of a Downgradient Geochemical and Hydraulic Boundary. As described in Section 6.1.2.3, a hydraulic boundary is formed by the swampy area downgradient of the former source areas. In addition, as shown in Section 6.2.2.1, uranium exhibiting non-natural isotopic ratios (delineated as ^{235}U) is not expected to migrate to the swampy area at concentrations above the method PQL.

Site-specific evidence supporting classification of the downgradient swampy area as a geochemical boundary include the:

- ▶ equilibrium uranium K_d estimates calculated from soil and groundwater samples collected from the swampy area, and
- ▶ low DO and reducing conditions present in the swampy area.

Calculations of uranium K_d were made by comparing swampy-area soil-uranium concentrations to uranium concentrations in soil samples obtained directly adjacent to the soil samples (Table 6-5). The uranium K_d values estimated for the swampy area varied from 73 to 1,591 L/kg and averaged 637 L/kg. This significant increase above the average uranium K_d of 10 L/kg estimated for the upland area sediments supports evidence cited in the literature indicating that uranium is readily attenuated by the wetland sediments through sorption.

The most recent groundwater samples collected from well OSW-1A and seven swamp-water sampling points located in the swampy area indicated lower DO concentrations and ORP than samples collected from the upland wells. The average upland and swampy-area DO concentrations were 2.49 and 1.26 mg/L, respectively. The average upland and swampy-area ORP measurements were 124 and -20 mV, respectively. These measurements

support the interpretation that conditions are conducive to reduction of uranium to its less soluble and more immobile form (i.e., U[IV]).

6.2.2.4 Absence of Human and Ecological Risk. As discussed in Sections 4.0 and 6.1.2.6, there are currently no human receptors of the groundwater in the area (via the drinking-water pathway) and development of the potentially affected area is not anticipated. In addition, as described in Section 6.2.2.2, the maximum predicted total uranium concentrations are expected to fall below the human-health risk-based GMGV of 0.045 mg/L in less than 10 years and uranium exhibiting non-natural isotopic ratios is not expected to migrate to the swampy area based on modeling results. As a result, water discharging into the swampy area is not expected to contain elevated natural or non-natural uranium, and adverse impacts to the wetland area and the associated flora and fauna are not expected.

6.3 Fluoride

This section discusses the effectiveness for the natural attenuation of fluoride in the northwest site area. MNA has been selected as the remedial approach for at least two Superfund sites with fluoride-contaminated groundwater as described in Brady, et al., (1998b).

6.3.1 Factors and Mechanisms Influencing Natural Attenuation. Within typical groundwater pH ranges, fluoride occurs predominantly as the F^- ion. The fate and transport of fluoride in soils also plays a role in controlling its behavior in groundwater. The amount of fluoride sorbed by soils varies with soil type and soil pH (Pickering, 1985). Laboratory leaching studies have shown that many soils retain most (>95 percent) of the added soluble fluoride. However, predominantly sandy soils with little clay, iron, and aluminum may only retain half the added fluoride. Acid soils can uptake more than 10 times the fluoride of alkaline soils, most likely due to the replacement by fluoride of hydroxyl groups in hydrous aluminum oxides present in soils at low pH. Clays can also sorb fluoride in varying amounts dependent on the soil pH with greater uptake at lower (more acidic) pHs. The predominant mechanisms for the attenuation of fluoride levels in groundwater are sorption to the aquifer matrix and dilution.

6.3.2 Site-Specific Factors. There are several conditions in the northwest site area that support use of MNA to address the groundwater contamination by fluoride:

- ▶ removal of source,
- ▶ measured and predicted contaminant migration patterns,
- ▶ presence of a downgradient hydraulic boundary (i.e., swampy area), and
- ▶ absence of human and ecological risk.

6.3.2.1 Removal of Source. As described in Section 3.1, the primary source of fluoride (i.e., CaF_2) has been removed. As a result, additional fluoride will not continue to be contributed to the groundwater from the source material.

6.3.2.2 Measured and Predicted Contaminant Migration Patterns. As shown in Figure 2-5, the migration of fluoride in groundwater has not been extensive considering the CaF_2 material was present in the former storage area for nearly 30 years. This pattern is evident when comparing the plume of fluoride (Figure 2-5) with the adjacent VOC plumes (Figures 2-10 through 2-12). The VOCs have migrated to the swampy area, which is approximately 1,200 feet downgradient from the source area; however, the fluoride has been limited within approximately 250 feet of the source area. The relatively non-extensive nature may result from the apparent minor leaching of the fluoride from the solid CaF_2 material, and sorption to the aquifer matrix. This section presents analyses of the past and future migration patterns to better understand the potential and effectiveness of the natural attenuation of uranium at the site.

Three-dimensional numerical groundwater flow (MODFLOW) and contaminant fate-and-transport (MT3D) models were used to evaluate the fluoride plume in the northwest site area. Appendix G provides a detailed description of the model development, calibration, and simulations, including assumptions and input parameters. Descriptions of the setup of the three-dimensional graphics presenting the results of the modeling activities are described in Section 6.1.2.5.

The modeling results presented in Figure 6-24 indicate the effectiveness of natural attenuation at limiting the migration of fluoride at the site. The model setup for these simulations includes a constant source concentration of 12 mg/L (based on highest levels measured in the area) for 30 years within the CaF_2 storage area. Based on the site operational history and the maximum measured groundwater concentrations, this setup is representative of conditions at the site for the last 30 years. The difference in the two simulation results shown in Figure 6-24 is that the upper graphic represents the plume

configuration that would be present with no attenuation (other than dispersion) limiting the plume migration. The lower graphic shows conditions with the additional attenuation mechanism of sorption limiting the plume extent. The plume extent with no attenuation is clearly well outside the area where impacts have been measured. In contrast, the plume extent with attenuation provides a good match with the measured plume (for comparison, the currently measured plume is shown in the upper graphic in Figure 6-25).

For the simulation with attenuation shown in Figure 6-24, the distribution coefficient, K_d , which controls sorption, was adjusted until the simulated plume extent at 30 years was close to the measured plume extent. The K_d resulting from this analysis was 0.6 L/kg for the sand and the sandstone. Using the estimated K_d of 0.6 L/kg, a porosity of 0.3, and a bulk density of 1.56 g/cm^3 , the calculated retardation coefficient for fluoride is 4.1. This retardation coefficient indicates that the dissolved fluoride will travel approximately 4.1 times slower than the groundwater. In summary, the model results presented in Figure 6-24 show that natural attenuation is active and limits the migration of fluoride at the site.

Figures 6-25 and 6-26 show the predicted distribution of fluoride from present conditions into the future. The model setup for these results corresponds to the calibrated model setup shown in Figure 6-24 (transport with attenuation). Figures 6-25 and 6-26 show the steady decline in fluoride concentrations over time. After 25 years (not shown), the 2.0-mg/L plume is fully dissipated. The results indicate that fluoride fully attenuates below the NC groundwater standard of 2.0 mg/L before reaching the swampy area to the north of the site.

6.3.2.3 Presence of a Downgradient Hydraulic Boundary. Fluoride is not inferred to extend to the swampy area north of the former source area. In addition, as described in Section 6.1.2.3, the swampy area downgradient of the former source area serves as a hydraulic boundary, limiting the extent of fluoride migration in the northwest site area.

6.3.2.4 Absence of Human and Ecological Risk. As discussed in Sections 4.0 and 6.1.2.6, there are currently no human receptors of the groundwater in the area (via the drinking-water pathway) and development of the potentially affected area is not anticipated. In addition, fluoride is not expected to migrate to the swampy area based on modeling results. As a result, water discharging into the swampy area is not expected to contain elevated fluoride, and adverse impacts to the wetland area and the associated flora and fauna are not expected.

7.0 Monitoring Plan

As implied by the name of the proposed corrective action approach, monitoring is the most important component of the MNA. The EPA's directive on monitored natural attenuation (EPA, 1997), describes the expectations for monitoring performed to evaluate the effectiveness of the corrective action. Based on EPA (1997), the monitoring program must accomplish the following:

- ▶ Demonstrate natural attenuation is occurring as expected;
- ▶ Identify toxic transformation products, if applicable;
- ▶ Evaluate whether plume is expanding in size;
- ▶ Confirm finding of no impact to downgradient receptors;
- ▶ Detect new releases of contaminants that could impact effectiveness;
- ▶ Demonstrate efficacy of institutional controls, if applicable;
- ▶ Detect changes in environmental conditions that may reduce the efficacy of the natural-attenuation processes; and
- ▶ Evaluate attainment of cleanup objectives.

In addition to the monitoring guidance addressed above in the EPAs' directive on MNA (EPA, 1997), T15A NCAC .0110 and .0106(l)(7) specifies that a "groundwater monitoring program sufficient to track the degradation and attenuation of contaminants and contaminant by-products within and downgradient of the plume...at least one year's time of travel upgradient of the receptor and no greater than the distance the groundwater...is predicted to travel in five years" must be put in place. A monitoring network fulfilling the requirements of this section is in place, both on the GE property and on the adjacent property as described in the Field Sampling Plan (FSP). Written consent allowing access to the adjacent property for monitoring purposes is provided in Appendix E.

A site-specific FSP and a Quality Assurance Project Plan (QAPP) have been prepared for this project to accomplish the monitoring goals specified above. In addition, a contingency plan to address changes in expected conditions in the northwest site area has been developed. These plans are described in the following sections.

7.1 Field Sampling Plan

The FSP (provided in Appendix H) reiterates the objectives of the sampling program 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 are included and referenced where appropriate.

The media to be monitored include groundwater, surface water (streams), swamp pore water, and swamp standing water. Monitoring of these waters enables evaluation of contaminant fate and transport and verification that downgradient receptors are not being impacted.

The sampling locations in the FSP allow for contaminants to be monitored at critical points along the migration pathway as follows:

- ▶ in groundwater near the contaminant source (or previous source area),
- ▶ in groundwater at various depths within the aquifer,
- ▶ in shallow groundwater (swamp pore water) where it discharges to swampy-area sediment,
- ▶ where the swamp pore water mixes with and becomes swamp standing water, and
- ▶ in surface-water streams that flow throughout the swampy area.

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 plumes are not expanding in size.

Initially, groundwater and swamp pore-water samples will be collected quarterly for the target inorganic and organic constituents. In addition, samples of surface water will be collected annually for the constituents of interest, and groundwater and swamp pore-water samples will be analyzed annually for parameters indicating continued natural attenuation of the contaminant plumes. The sampling schedule may be modified depending on the findings of the sampling activities.

7.2 Quality Assurance Project Plan

The QAPP (Appendix I) 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 MNA corrective action. The QAPP will be the quality-controlling document for activities relating to the collection and analysis of samples which are described in the project FSP and will be used in conjunction with the FSP. The QAPP will help 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 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.

The 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, 1998c).

7.3 Contingency Plan

A plan to address changes in expected conditions during the MNA corrective action has been developed and is presented as a flow chart in Figure 7-1. Generally, if changes in expected conditions arise (such as VOC concentrations in swamp standing water significantly higher than predicted or changes in adjacent property ownership), additional samples or other information will be obtained and potential human and/or ecological risks (immediate or future) will be evaluated. If immediate risks are confirmed (e.g., VOCs in surface water greater than acute toxicity benchmarks - refer to Section 4.5), DENR and the adjacent property owner will be notified and adjustments to the corrective action will be made as appropriate. If the findings do not pose immediate risks, the potential for future risks will be evaluated. If there is a potential for future risks (e.g., prolonged levels above chronic toxicity benchmarks) the sampling frequency may be increased to further evaluate the potential future risks. If the additional data indicate potential future risks, then DENR and the adjacent property owner will be notified and adjustments to the corrective action will be made as appropriate. Otherwise, the initial monitoring frequency will be reinstated and the MNA corrective action will continue.

8.0 Schedule and Reporting

The routine monitoring described in the FSP (Appendix H) will initiate in the first quarter of 1999. It is expected that the monitoring will continue until the contamination levels fall below the pertinent cleanup levels (i.e., NC groundwater standards or other appropriate criteria).

Results of monitoring activities in the northwest site area will be provided to DENR in the form of periodic reports. The reports will include, at a minimum, description of the field activities and results of monitoring activities, including data validation information.

The progress of the MNA approach, including discussions of changes in contaminant concentration over time, plume migration, recommended changes to the monitoring program, and other pertinent information will be included as appropriate in the periodic reports or during periodic update meetings that GE may schedule with appropriate divisions of DENR.

9.0 References

- Bouwer, E.J. 1994. Bioremediation of chlorinated solvents using alternate electron acceptors. In: Norris, et al. *Handbook of Bioremediation*. Lewis Publishers. Boca Raton, Florida.
- Brady, P.V., and D.J. Borns. 1997. *Natural Attenuation of Metals and Radiouclides: Report from a Workshop held by Sandia National Laboratories*. Sandia Report No. SAND97-2727. Albuquerque, New Mexico.
- Brady, P.V., B.P. Spalding, K.M. Krupka, R.D. Waters, P. Zhang, D.J. Borns, and W.D. Brady. 1998a. *Site Screening and Technical Guidance for Monitored Natural Attenuation at DOE Sites*. Draft 5. Sandia National Laboratories.
- Brady, P.V., M.V. Brady, and D.J. Borns. 1998b. *Natural Attenuation: CERCLA, RBCA's, and the Future of Environmental Remediation*. CRC Press LLC. Boca Raton, Florida.
- CCME (Canadian Council of Ministers of the Environment), 1997. *Recommended Canadian Soil Quality Guidelines*. Science Policy and Environmental Quality Branch. Ecosystem Science Directorate, Environment Canada. Ottawa, Ontario.
- D'Appolonia. 1977. *Boring Logs - Calcium Fluoride Sampling Program*. Project No. SE77-136. August 1997.
- DENR. 1995. 15A NCAC 2L Implementation Guidance. Division of Environmental Management.
- DENR. 1997. Inactive Hazardous Sites Program; Guidelines for Assessment and Cleanup. Division of Waste management. Superfund Section. Inactive Hazardous Sites Branch.
- DENR. 1998. *Groundwater Section Guidelines for the Investigation and Remediation of Soil and Groundwater: Vol I - Sources Other Than Petroleum Underground Storage Tanks*. Division of Water Quality, Groundwater Section.

- EPA. 1996a. Drinking Water Regulations and Health Advisories. Office of Water. EPA 822-B-96-002. Washington, DC.
- EPA. 1996b. Soil Screening Guidance: User's Guide. Office of Solid Waste and Emergency Response. Publication 9355.4-23. Washington, DC.
- EPA. 1996c. *Amphibian Toxicity Data for Water Quality Criteria Chemicals*. EPA/600/R-96/124. National Health Environmental Effects Research Laboratory, Corvallis, OR.
- 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.
- EPA. 1998a. *Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Groundwater*. Office of Research and Development. EPA/600/12-98/128. Washington, DC.
- EPA. 1998b. *Seminars - Monitored Natural Attenuation for Ground Water*. Office of Research and Development. Report No. EPA/625/K-98/001. Washington, DC.
- EPA. 1998c. EPA Guidance for Quality Assurance Project Plans, EPA QA/G-5. Office of Research and Development. Washington, DC. EPA
- Federal Register. 1991. *National Primary Drinking Water Regulations; Radionuclides; Proposed Rule*. Federal Register v. 56, No 138. July 18, 1991.
- General Electric (GE). 1989. *Environmental Report - Nuclear Fuels and Components Manufacturing*. NEDO #31664.
- Langmuir, D., 1997. Aqueous geochemistry of uranium. In: *Aqueous Environmental Geochemistry*. Prentice Hall, Inc., 600 pp.
- McCarty, P.L. and L. Semprini. 1994. Groundwater treatment for chlorinated solvents. In: Norris, et al. *Handbook of Bioremediation*. Lewis Publishers. Boca Raton, Florida.

- ORNL (Oak Ridge National Laboratory). 1996a. *Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota: 1996 Revision*. Report No. ES/ER/TM-96/R2. Oak Ridge, TN.
- ORNL (Oak Ridge National Laboratory), 1996b. *Toxicological Benchmarks for Wildlife: 1996 Revision*. Report No. ES/ER/TM-86/R3. Oak Ridge, TN. Prepared for the U.S. Department of Energy.
- Pickering, W. F., 1985. The mobility of soluble fluoride in soils. *Environ. Pollut. (Ser. B)*, 9:281-3-8.
- Potter, T.E., 1998. "Groundwater Monitoring Guideline Value for Uranium - Former Northwest Calcium Fluoride Storage Area", Consultant's Report to General Electric. Washington, D.C.
- RTI. 1994. *Corrective Action Plan for Organic Compounds in Groundwater*. RTI Report No. 5040/006/01F.
- RTI. 1997. *Report of Uranium Partitioning in Soil and Groundwater Beneath the Former NW-Calcium Fluoride Storage Area*. RTI Report No. 6448-013/002/01F.
- RTI. 1998. *Comprehensive Site Assessment Report for the Northwest Site Area*. RTI Report 6448-018/003/01F.

Figures

Figure 1-1
Location of General
Electric Plant Site
Wilmington, NC

EXPLANATION



Study Area Latitude / Longitude:
 North 34° 20' 26.21"
 East 77° 57' 15.04"

Source: USGS Orthophotographic
 Map, Castle Hayne, NC Quadrangle, 1970
 Topographic map
 contour interval = 5 feet



Scale:
 1 inch = 2000 feet
 0 FEET 2000

State of North Carolina

INSET NOT TO SCALE



GE - Wilmington, NC Site

Map Preparation Date: 1/6/99

topo_caf_pos.apr

CAP 1-1



Figure 1-2

Locations of Former NW -
Calcium Fluoride Storage Area
and Former Lubricants Area
Northwest Site Area
GE - Wilmington, NC Site

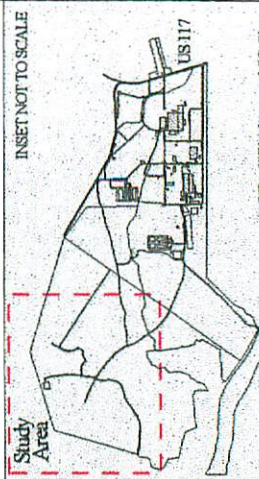
EXPLANATION

- Property line
- - - Unpaved road



Scale:
1 inch = 800 feet
0 FEET 800

Source: USGS Orthophotographic
Map, Castle Hayne, NC Quadrangle, 1970
Topographic map
contour interval = 5 feet



GE - Wilmington, NC Site

Map Preparation Date: 1/699 topo_caf_pot.air CAP 1-2



Figure 2-1

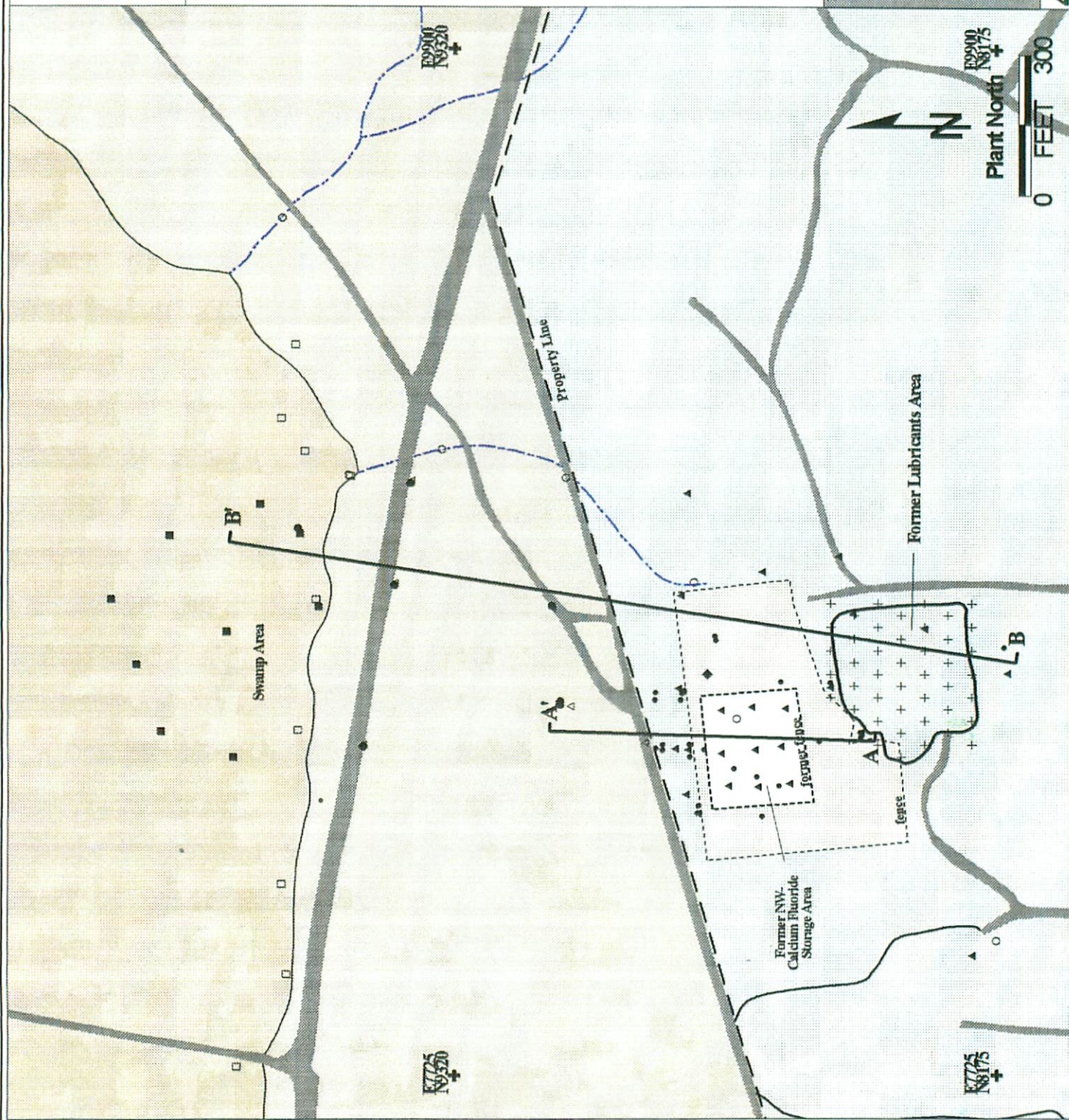
Locations of Sampling and Monitoring Points in the Northwest Site Area

GE - Wilmington, NC Site

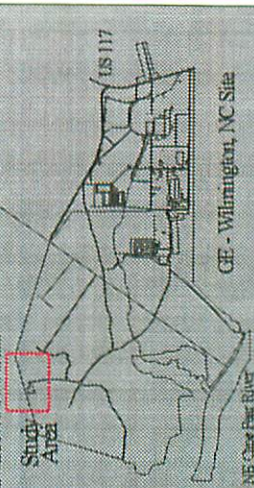
EXPLANATION

- Surface water samples (represents seeps, springs, streams).
- Shallow well point and soil samples.
- △ Offsite exploratory borings.
- OB-series monitoring well (OB-5).
- Onsite monitoring wells.
- ▲ Onsite exploratory borings.
- Swamp-water sampling points.
- Offsite monitoring wells.
- ± Soil vapor sampling points (GORESORBER locations).
- Cross-section orientations.
- Stream location based on field reconnaissance.
- Swampy area.
- Road / trail.

Fenced area (based on Perigon, Inc. drawing no. 7043E95 dated 10/20/95).
Extent of GE property.



INSET NOT TO SCALE



Generalized Configuration of Potentiometric Surface - Northwest Site Peninsula Area

GE - Wilmington, NC Site

EXPLANATION

Potentiometric Surface
(in feet relative to mean sea
level, based on water levels
collected September 28, 1998)



Property line

 Unpaved road

Scale:
1 inch = 800 feet

North

Source: USGS Orthophotographic Map, Castle Hayne, NC Quadrangle, 1970
Topographic map contour interval = 5 feet.
Potentiometric surface contour is variable.

INSET NOT TO SCALE



CE - Wilmington, NC Site

Map Preparation Date: 1/6/99	topo_caf_pot.apr	CAP 2-2
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RTI

RTI

Configuration of Potentiometric Surface - Northwest Site Area

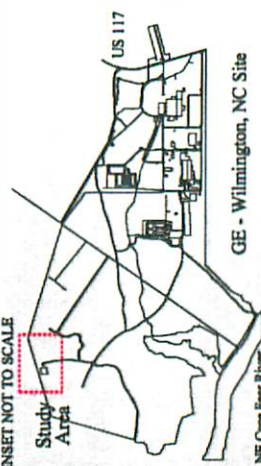
GE - Wilmington, NC Site

EXPLANATION

- | | |
|-----|---|
| ◆ | OB-series monitoring well (OB-5). |
| ● | CAF-series monitoring wells. |
| ▲ | OCW-series monitoring wells. |
| △ | OSW-series monitoring well (OSW-1A). |
| □ | SWS-series swamp-water sampling point. |
| --- | Stream location based on field reconnaissance. |
| — | Line of equal potentiometric surface in feet relative to mean sea level, dashed where inferred. |

Note: Isopleth lines were manually interpolated using water-level measurements collected August 10, 1998. Alternate interpretations are possible. Adjustments were made for some deeper wells in consideration of their greater intake depth. Groundwater elevations shown in parentheses are adjusted elevations derived by multiplying the vertical hydraulic gradient measured in a nearby well pair by the difference in intake depth between the deeper well and the shallower comparison well.

INSET NOT TO SCALE

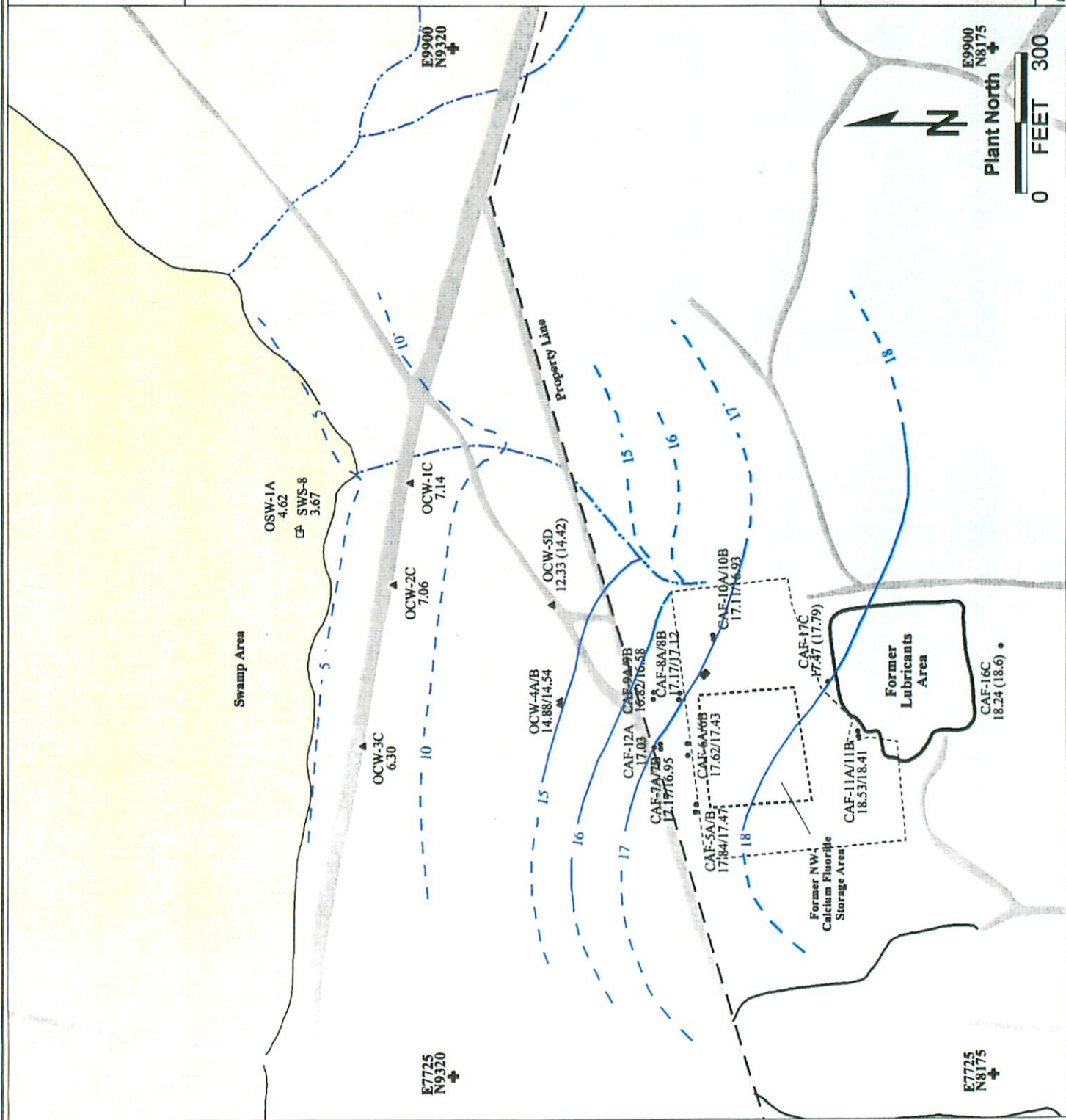


GE - Wilmington, NC Site

Date: 1/6/99

map 1 6 99.apr

CAP 2-3



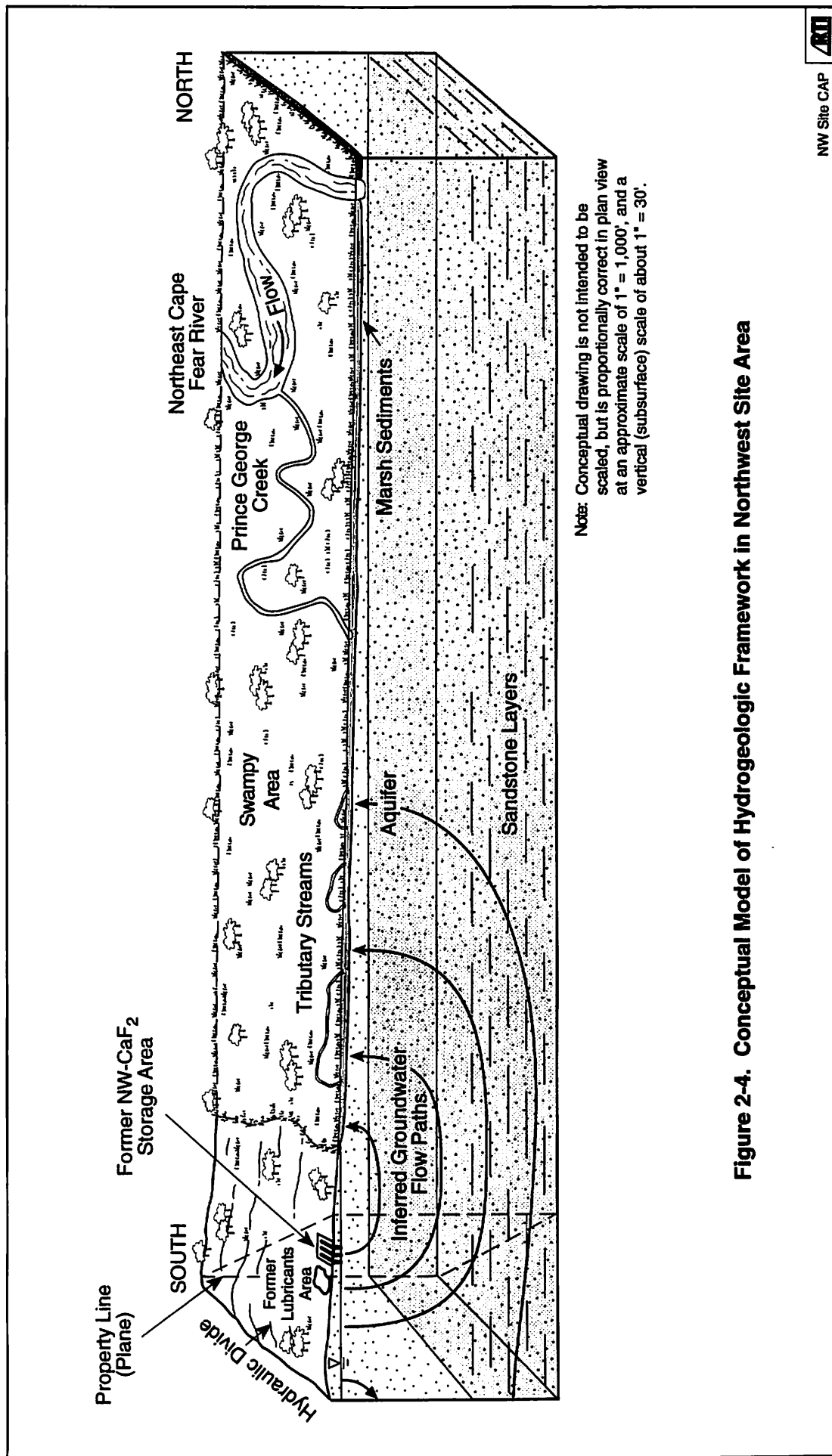


Figure 2-4. Conceptual Model of Hydrogeologic Framework in Northwest Site Area

Figure 2-5

Horizontal Extent of Fluoride in Groundwater - Northwest Site Area

GE - Wilmington, NC Site

EXPLANATION

- ◆ OB-series monitoring well (OB-5).
- CAF-series monitoring wells.
- ▲ Offsite monitoring wells.

Value accompanying each well is the concentration of fluoride measured in unfiltered groundwater collected November 9-11, 1998.

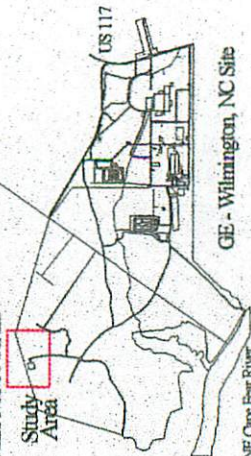
- SWS-series swamp-water sampling point.
- Exploratory borings.

Value accompanying each boring is the maximum fluoride concentration (>2.0 mg/L) detected in boring. Sample depth and boring date shown in parentheses. Samples from borings with maximum fluoride <2.0 mg/L not shown.

- Stream location based on field reconnaissance
- Inferred extent of fluoride greater than or equal to 2.0 mg/L in A-series well horizon.
- Inferred extent of fluoride greater than or equal to 2.0 mg/L in B-series well horizon.

Fluoride extent based on manual interpolation. Alternate interpretations possible. Fluoride analyses by RTI using ion-selective probe.

INSET NOT TO SCALE

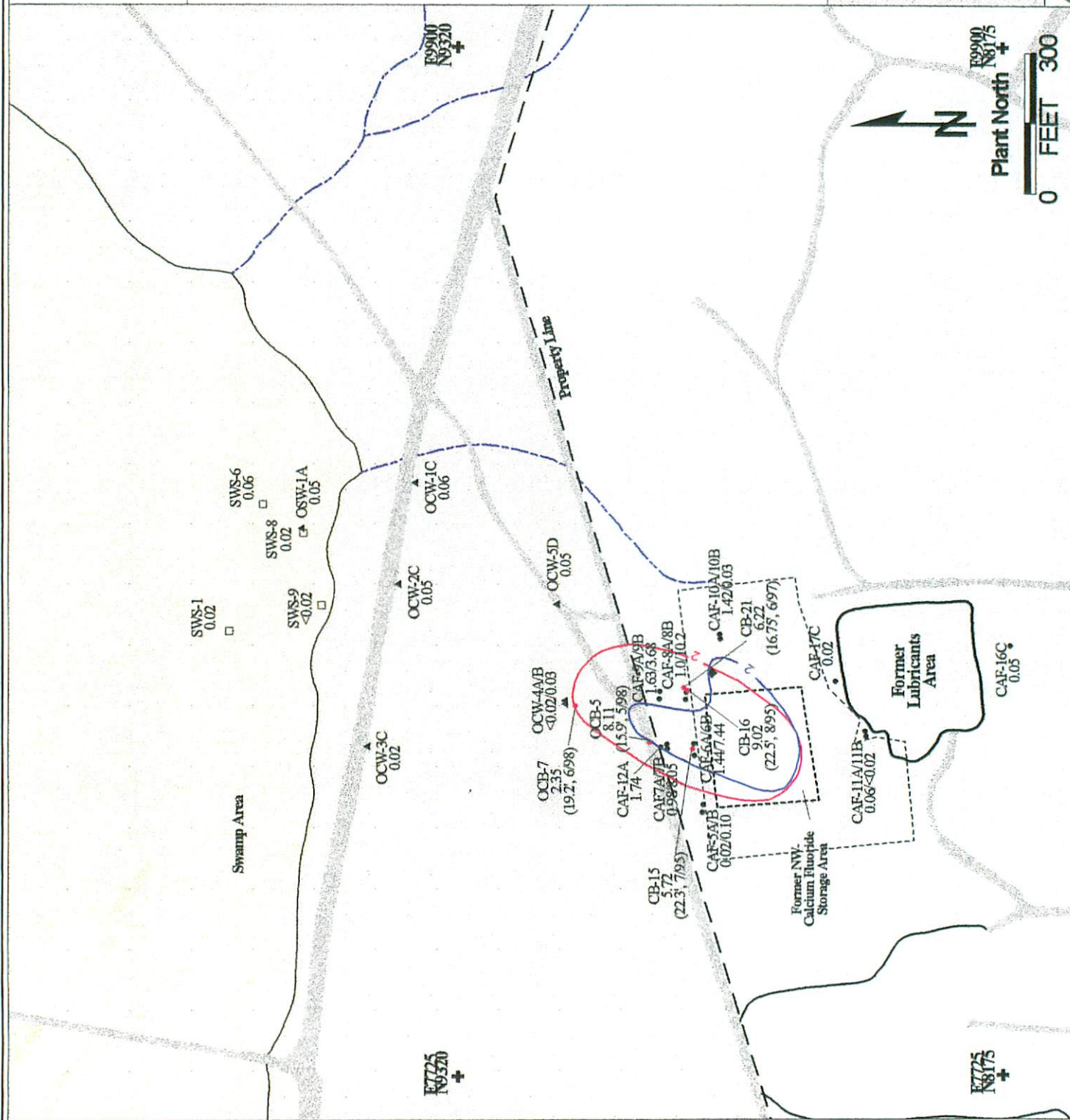


RTI

Date: 2/25/99

map_1_6_99.apr

CAP 2-5



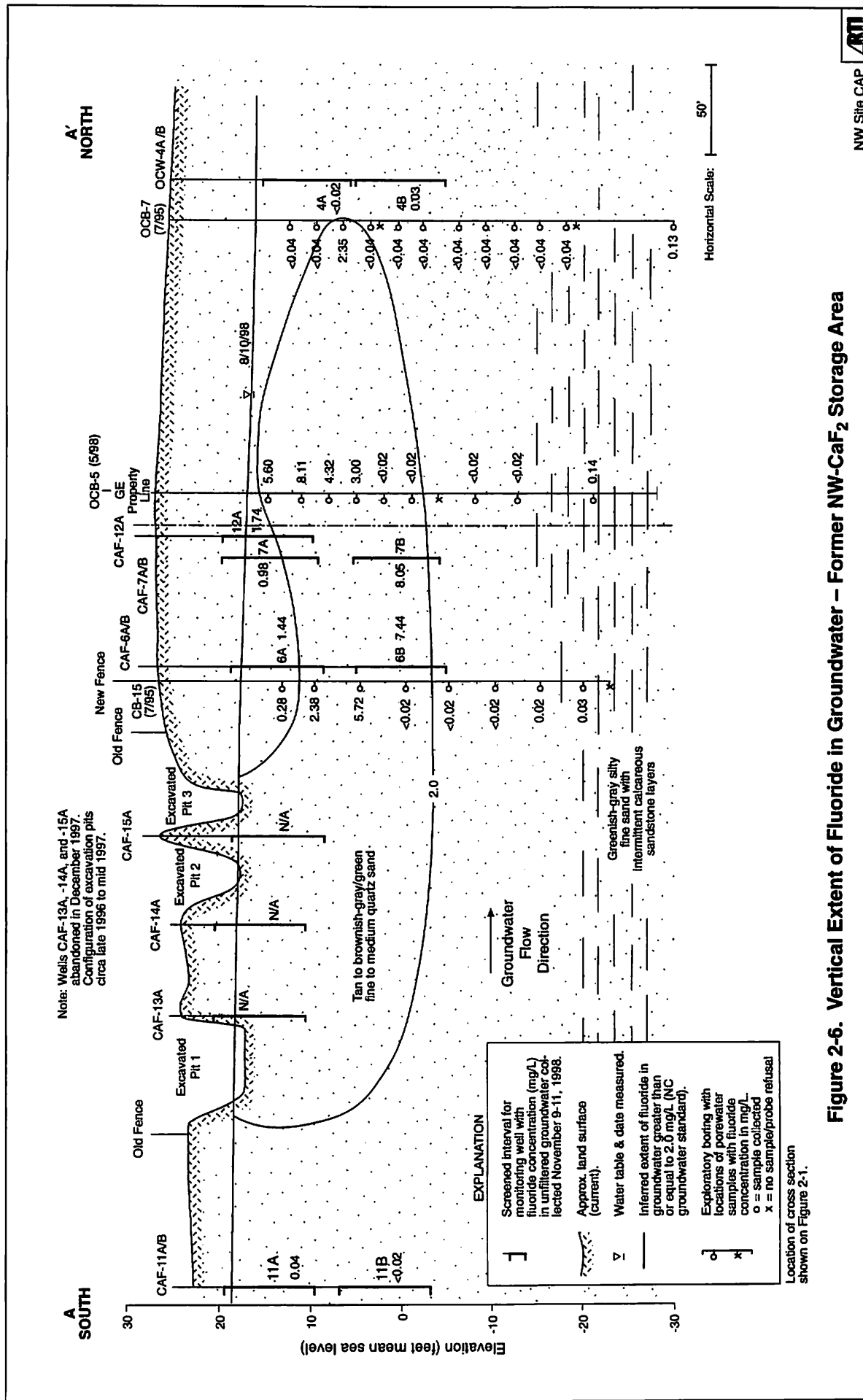


Figure 2-6. Vertical Extent of Fluoride in Groundwater in Groundwater - Former NW-CaF₂ Storage Area

Figure 2-7

Horizontal Extent of Uranium Exhibiting Non-Natural Isotopic Ratios in Shallow* Groundwater - Northwest Site Area

GE - Wilmington, NC Site

EXPLANATION

- ◆ OB-series monitoring well (OB-5),
- CAF-series monitoring wells,
- ▲ Offsite monitoring wells,
- SWS-series swamp-water sampling point.

Value accompanying each shallow well/point is the concentration of total uranium (mg/L) in unfiltered groundwater collected November 9-11, 1998. The concentration of the uranium isotope U-235 (mg/L) is shown in parentheses.**

• Exploratory borings

Value accompanying each boring is the maximum total uranium concentration (mg/L) in the shallower portion of the boring. The U-235 isotope concentration is shown in parentheses. Borings with samples not analyzed for isotopic abundances or with samples containing U-235 below the practical quantitation limit not shown.

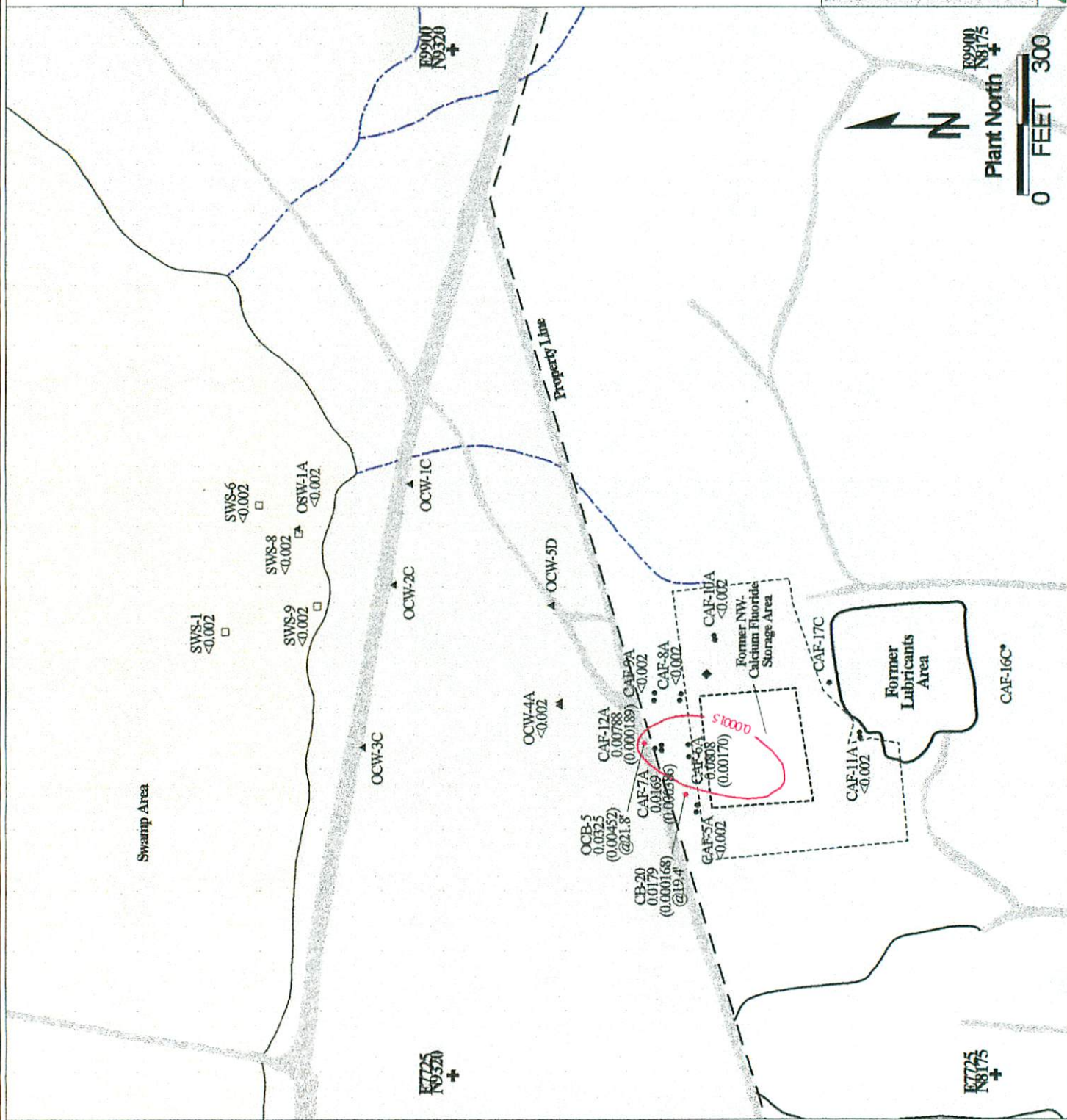
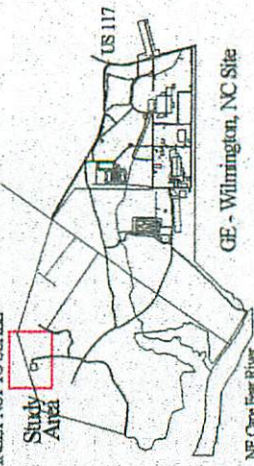
— Stream location based on field reconnaissance.

— Inferred extent of uranium isotope (U-235) in groundwater at or above the isotope practical quantitation limit of 0.00015 mg/L.

*Distribution of uranium shown for shallow groundwater only (A- and SWS-series monitoring wells/points). Extent based on manual interpolation. Alternate interpretations possible.

**Isotopic abundances are reported only when the total uranium concentration is greater than or equal to 0.002 mg/L. Groundwater analyses are performed by R11 using ICP-MS. Total uranium practical quantitation limit = 0.00015 mg/L.

INSET NOT TO SCALE



**Horizontal Extent of Uranium
Exhibiting Non-Natural Isotopic
Ratios in Deeper* Groundwater -
Northwest Site Area**
GE - Wilmington, NC Site

EXPLANATION

- ◆ OB-series monitoring well (OB-5).
- CAF-series monitoring wells.
- ▲ Offsite monitoring wells.

Value accompanying each deeper well is the concentration of total uranium (mg/L) in unfiltered groundwater collected November 9-11, 1998. The concentration of the uranium isotope U-235 (mg/L) is shown in parentheses. **

- **Exploratory borings.**

Value accompanying each boring is the maximum total uranium concentration (mg/L) in the deeper portion of the boring. The U-235 isotope concentration is shown in parentheses. Borings with samples not analyzed for isotopic abundances or with samples containing U-235 below the practical quantitation limit not shown.

Stream location based on field reconnaissance.

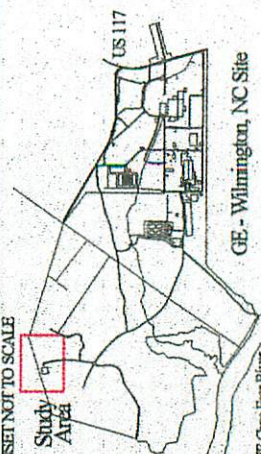
Inferred extent of uranium isotope (U-235) in groundwater at or above the isotope practical quantitation limit of 0.00015 mg/L.

*Distribution of uranium shown for deeper (B-, C- and D-series) monitoring wells only. Extent based on manual interpolation. Alternate interpretations possible.

***Isotopes abundances are reported only when the total uranium concentration is greater than or equal to 0.002 mg/L. Groundwater analyses are performed by RTI using ICP-MS. Total uranium practical quantitation limit = 0.00015 mg/L.



Study Area



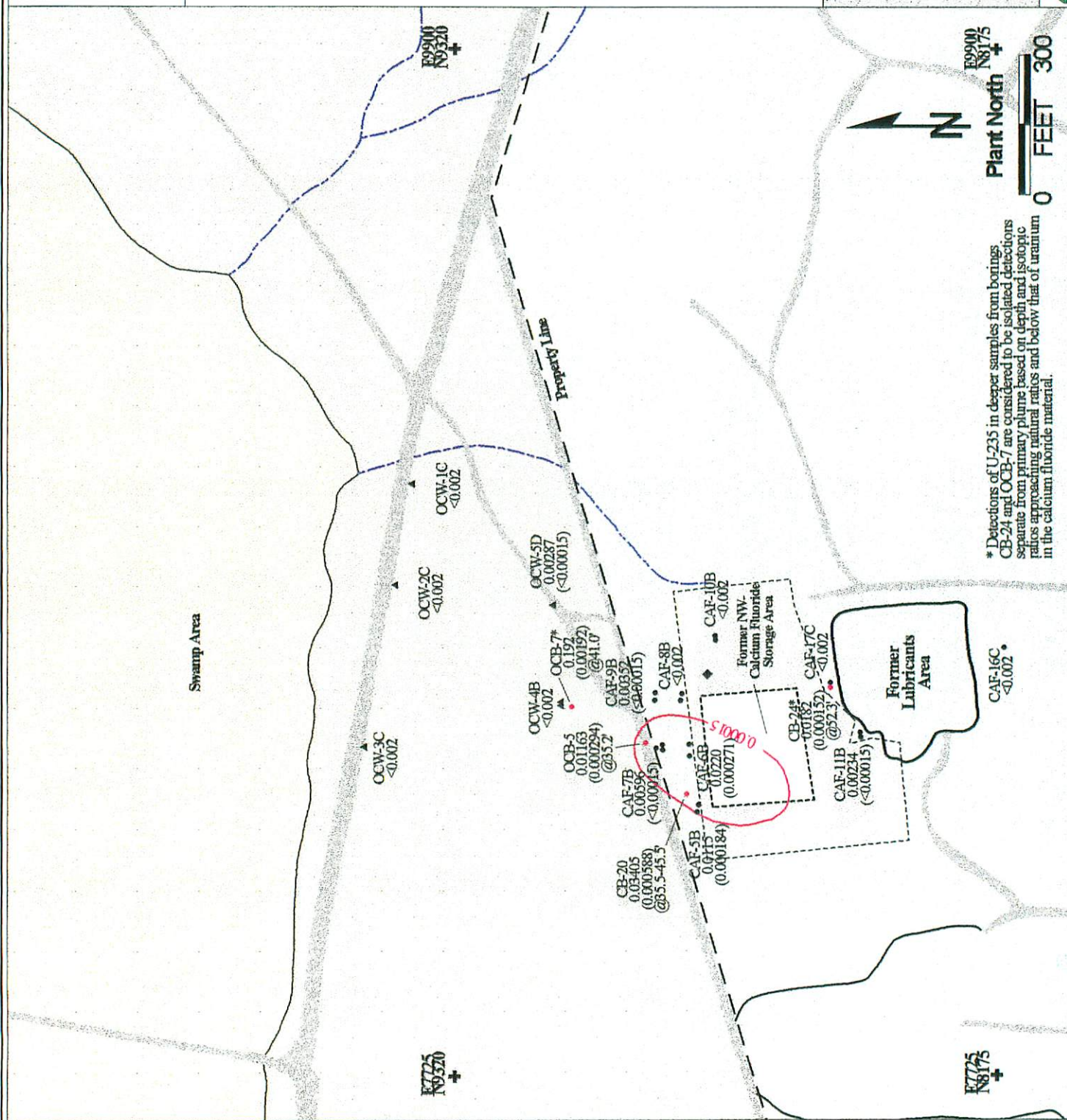
THE CLARK RIVER

RTI

Date: 2/26/99

map 16 99.apr

CAP 2-8



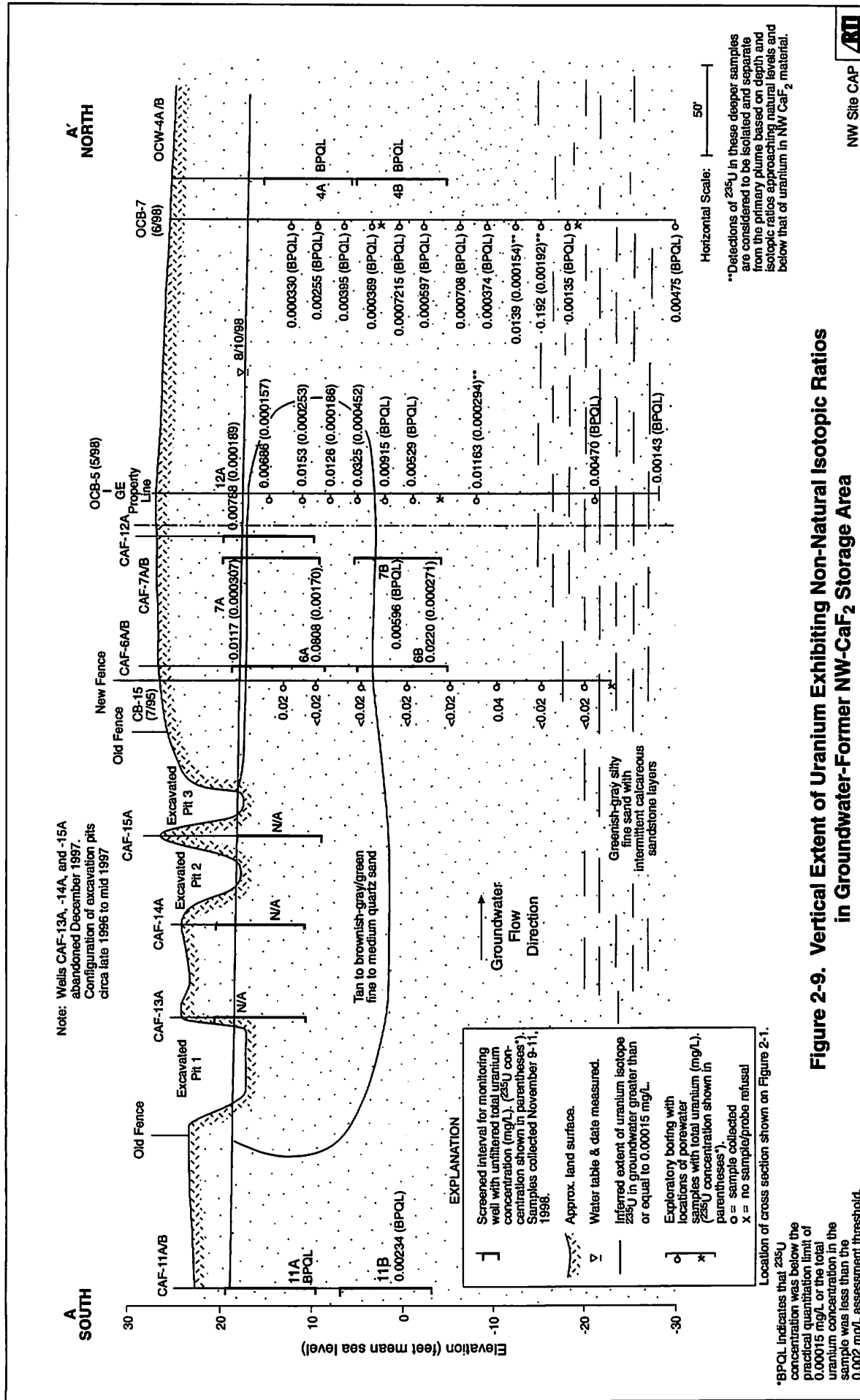


Figure 2-9. Vertical Extent of Uranium Exhibiting Non-Natural Isotopic Ratios in Groundwater-Former NW-CaF₂ Storage Area

Figure 2-10

Horizontal Extent of TCE in Groundwater - Northwest Site Area GE - Wilmington, NC Site

EXPLANATION

- ◆ OB-series monitoring well (OB-5).
- CAF-series monitoring wells.
- ▲ Offsite monitoring wells.

Value accompanying each well is the concentration of TCE (ug/L) in groundwater collected January 11-15, 1999 (except where noted). Value in parentheses is estimated concentration between MDL and PQL.

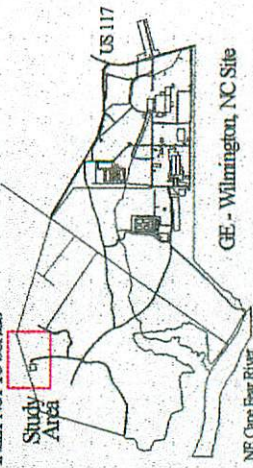
- SWS-series swamp-water sampling point.
- Exploratory borings.

Value accompanying each boring is the maximum concentration of TCE (ug/L) detected in the boring. Sample depth and boring date shown in parentheses. Borings with samples with less than 2.8 ug/L TCE not shown.

- Stream location based on field reconnaissance.
- Inferred extent of TCE in groundwater greater than or equal to 2.8 ug/L (NC groundwater standard).

TCE extent based on manual interpolation. Alternate interpretations possible.
VOC analyses by Oxford Laboratories using Standard Method 6230D.

INSET NOT TO SCALE



map_1_6_99.dwg

Date: 2/25/99

CAP 2-10

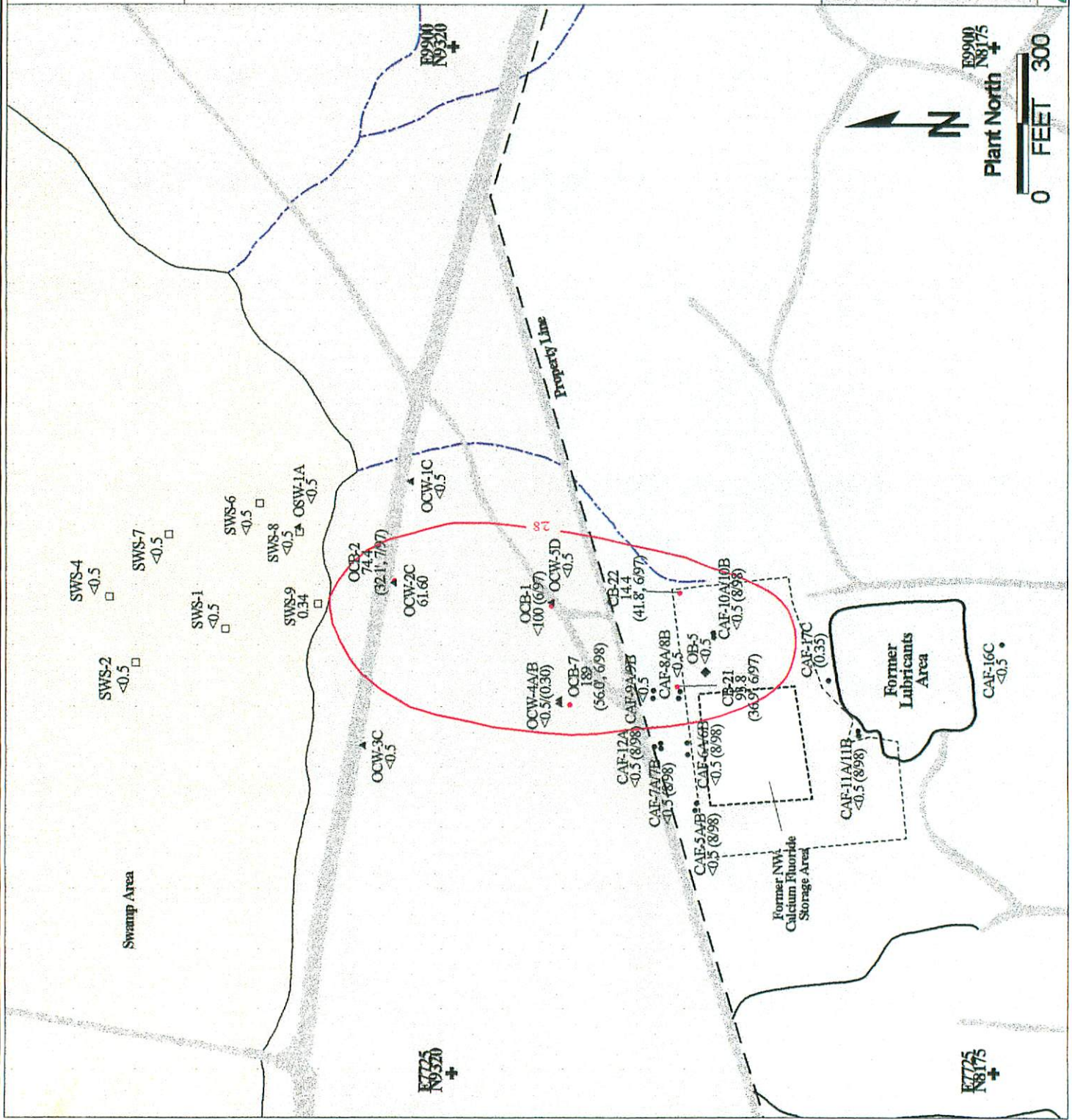


Figure 2-11
Horizontal Extent of cis-1,2-DCE
in Groundwater -
Northwest Site Area
GE - Wilmington, NC Site

EXPLANATION

- ◆ OB-series monitoring well (OB-5).
- CAF-series monitoring wells.
- ▲ Offsite monitoring wells.

Value accompanying each well point is the concentration of cis-1,2-DCE (ug/L) in groundwater collected January 11-15, 1999 (except where noted). Values in parentheses are estimated concentrations between MDL and PQL.

□ SWS-series swamp-water sampling point.

• Exploratory borings.

Value accompanying each boring is the maximum concentration of cis-1,2-DCE (ug/L) detected in the boring. Sample depth and boring date shown in parentheses. Borings with samples with less than 70 ug/L cis-1,2-DCE not shown.

--- Stream location based on field reconnaissance.

— Inferred extent of cis-1,2-DCE in groundwater greater than or equal to 70 ug/L (NC groundwater standard).

Extent based on manual interpolation. Alternate interpretations possible.
VOC analyses by Oxford Laboratories using Standard Method 6230D.

INSET NOT TO SCALE

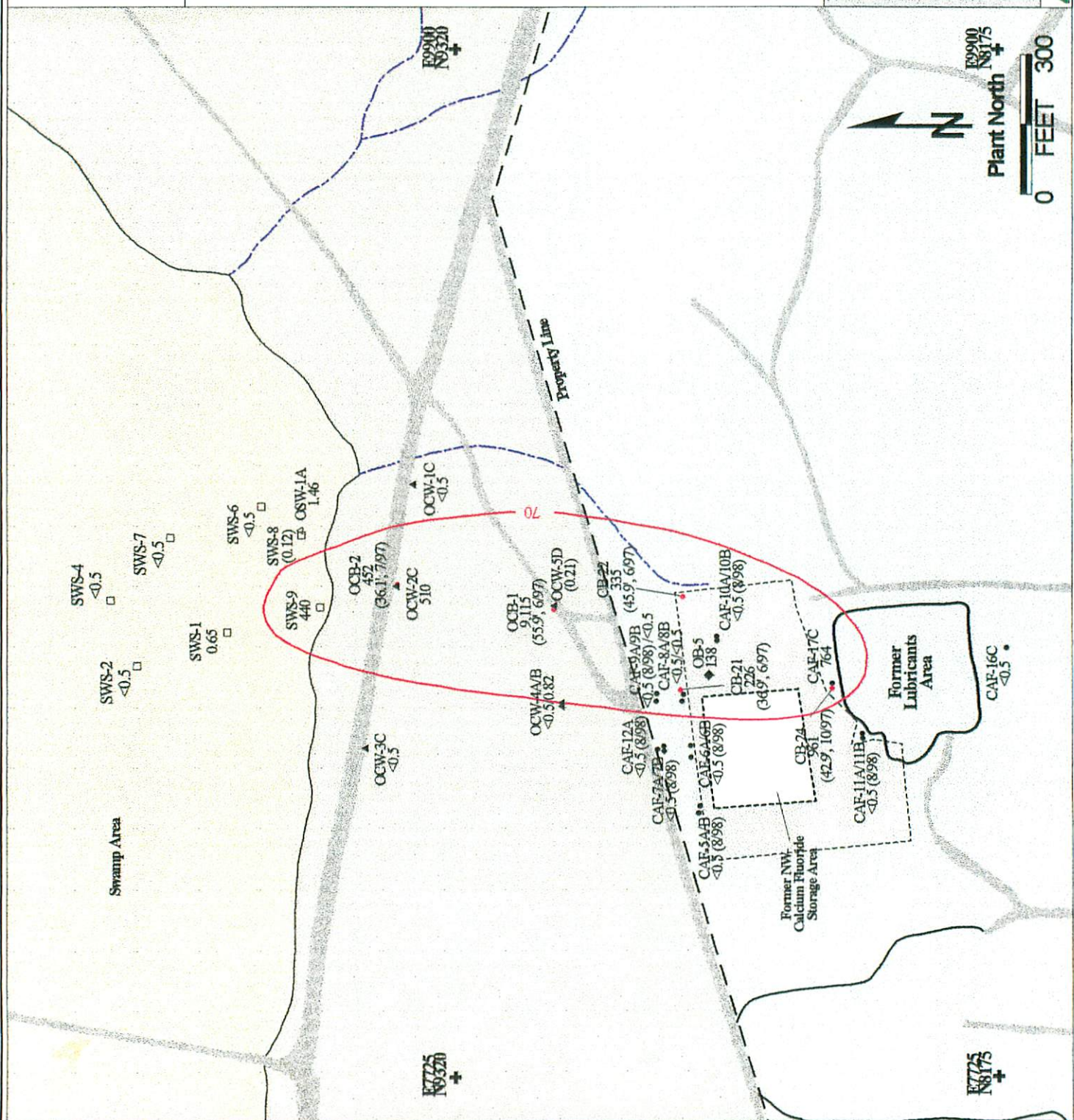
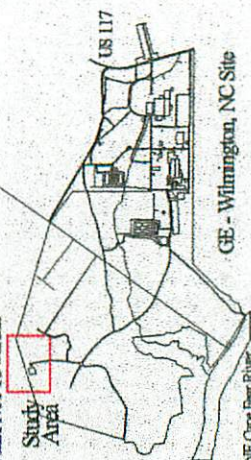


Figure 2-12

EXPLANATION

- ◆ OB-series monitoring well (OB-5).
- CAF-series monitoring wells.
- ▲ Offsite monitoring wells.

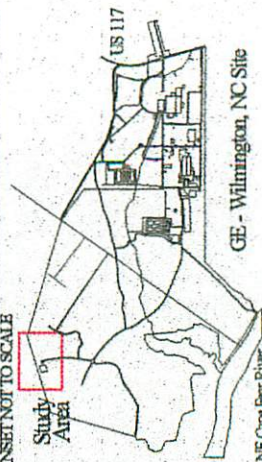
Value accompanying each well is the concentration of vinyl chloride (ug/L) in groundwater collected January 11-15, 1999 (except where noted). Values in parentheses are estimated concentrations between MDL and POL.

- SWS-series swamp-water sampling point.
- Exploratory borings.

Value accompanying each boring is the maximum concentration of vinyl chloride (ug/L) detected in the boring. Sample depth and boring date shown in parentheses. Borings with samples with less than 0.5 ug/L vinyl chloride not shown.

- Stream location based on field reconnaissance.
- Inferred extent of vinyl chloride above practical quantitation limit (0.5 ug/L).

Extent based on manual interpolation. Alternate interpretations possible.
VOC analyses by Oxford Laboratories using Standard Method 6230D.



NE Cape Fear River

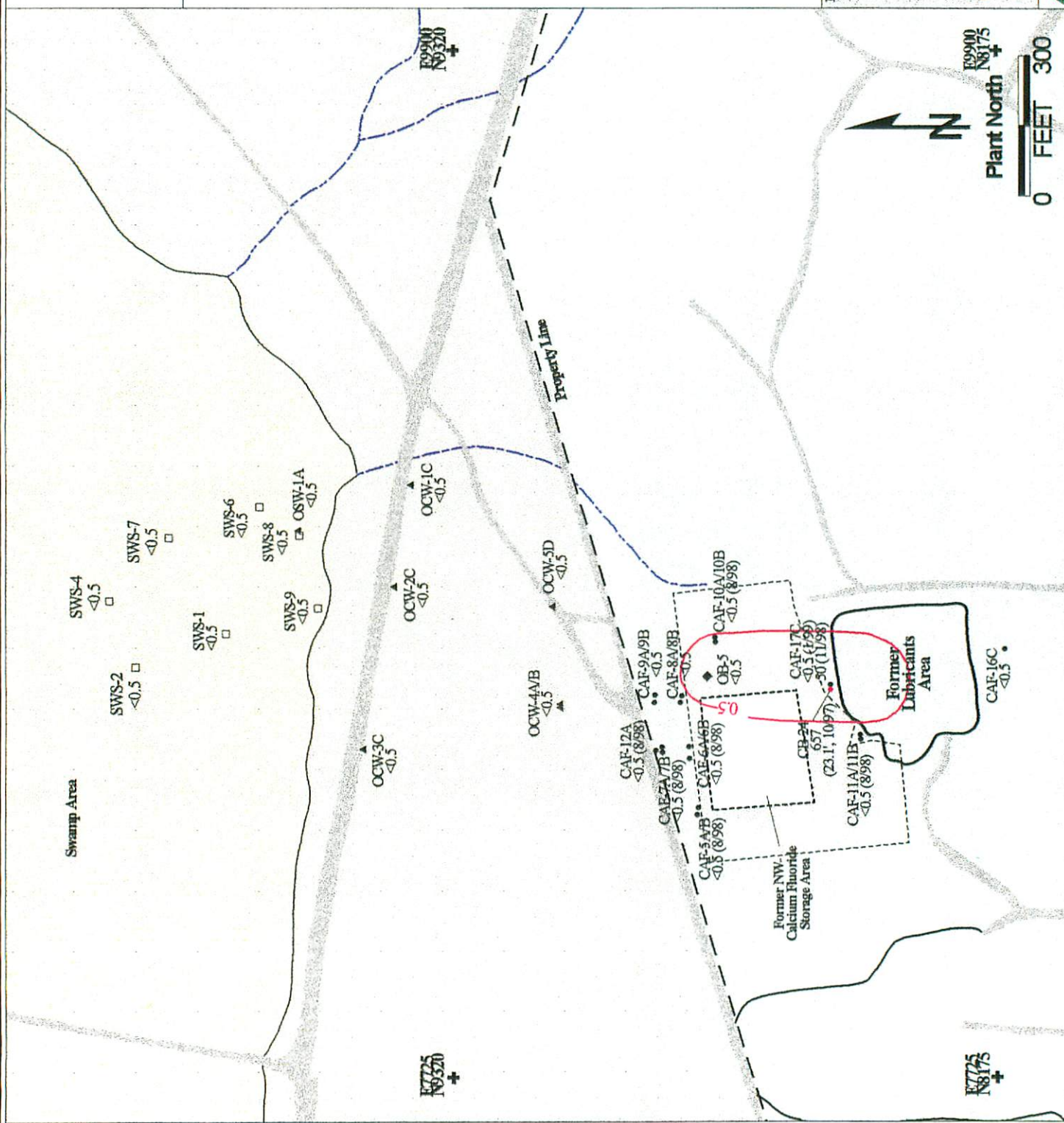
GE - Wilmington, NC Site

ATI

Date: 2/25/99

map 16 99.apr

CAP 2-12



EXPLANATION

Tan to brownish gray-green
fine to medium quartz sand
with intermittent clay and
highly organic sand stringers.
Shaded areas indicate zones of
more distinct gray-tan clay
sediments.

Fine sand with intermittent calcareous sandstone layers, grading to green-gray to green-black glauconitic silty fine sand with depth.

Black to brownish black highly organic peat with intermittent black silt and fine sand.

Position of water table,
measured August 11, 1998.

Screened interval for monitoring wells with TCE concentration ($\mu\text{g/L}$) in groundwater samples collected January 11-14, 1999.

Exploratory boring with
locations of porewater samples
and TCE concentration ($\mu\text{g/L}$).
o = sample collected
x = no sample collected/refusal
of sample probe

inferred extent of TCE in groundwater greater than or equal to 2.8 $\mu\text{g/L}$ (NC groundwater standard).

Land surface

150'

Location of cross-section shown on Figure 2-1.

Note: Estimated concentration between minimum detection limit and practical quantitation limit shown in parentheses.

NW Site CAP

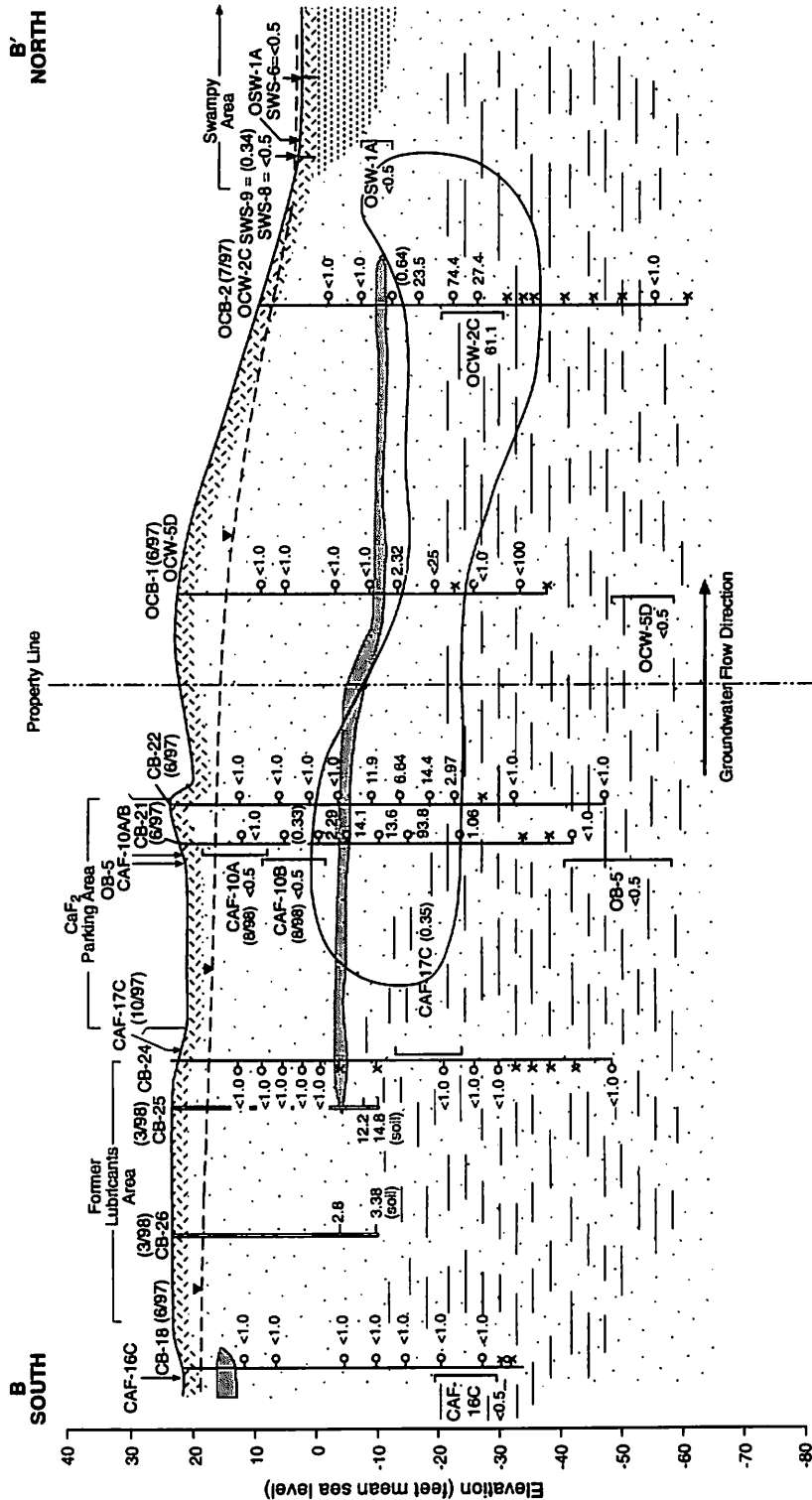


Figure 2-14. Vertical Extent of cis-1,2-DCE in Groundwater – Northwest Site Area

EXPLANATION



Tan to brownish gray-green fine to medium quartz sand with intermittent clayey and highly organic sand stringers. Shaded areas indicate zones of more distinct gray-tan clayey sediments.



Fine sand with intermittent calcareous sandstone layers, grading to green-gray to green-black glauconitic silty fine sand with depth.



Black to brownish black highly organic peat with intermittent black silt and fine sand.



Position of water table, measured August 11, 1988.

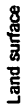


Screened interval for monitoring wells with cis-1,2-DCE concentration (µg/L) in groundwater samples collected January 11-14, 1989.



Exploratory boring with locations of porewater samples and cis-1,2-DCE concentration (µg/L). o = sample collected, x = no sample collected/refusal of sample probe.

Inferred extent of cis-1,2-DCE in groundwater greater than or equal to 70.0 µg/L (NC groundwater standard).



150' Horizontal scale

Location of cross-section shown on Figure 2-1.

Note: Estimated concentrations between minimum detection limit and practical quantitative limit shown in parentheses.

NW Site CAP



B' NORTH

B SOUTH

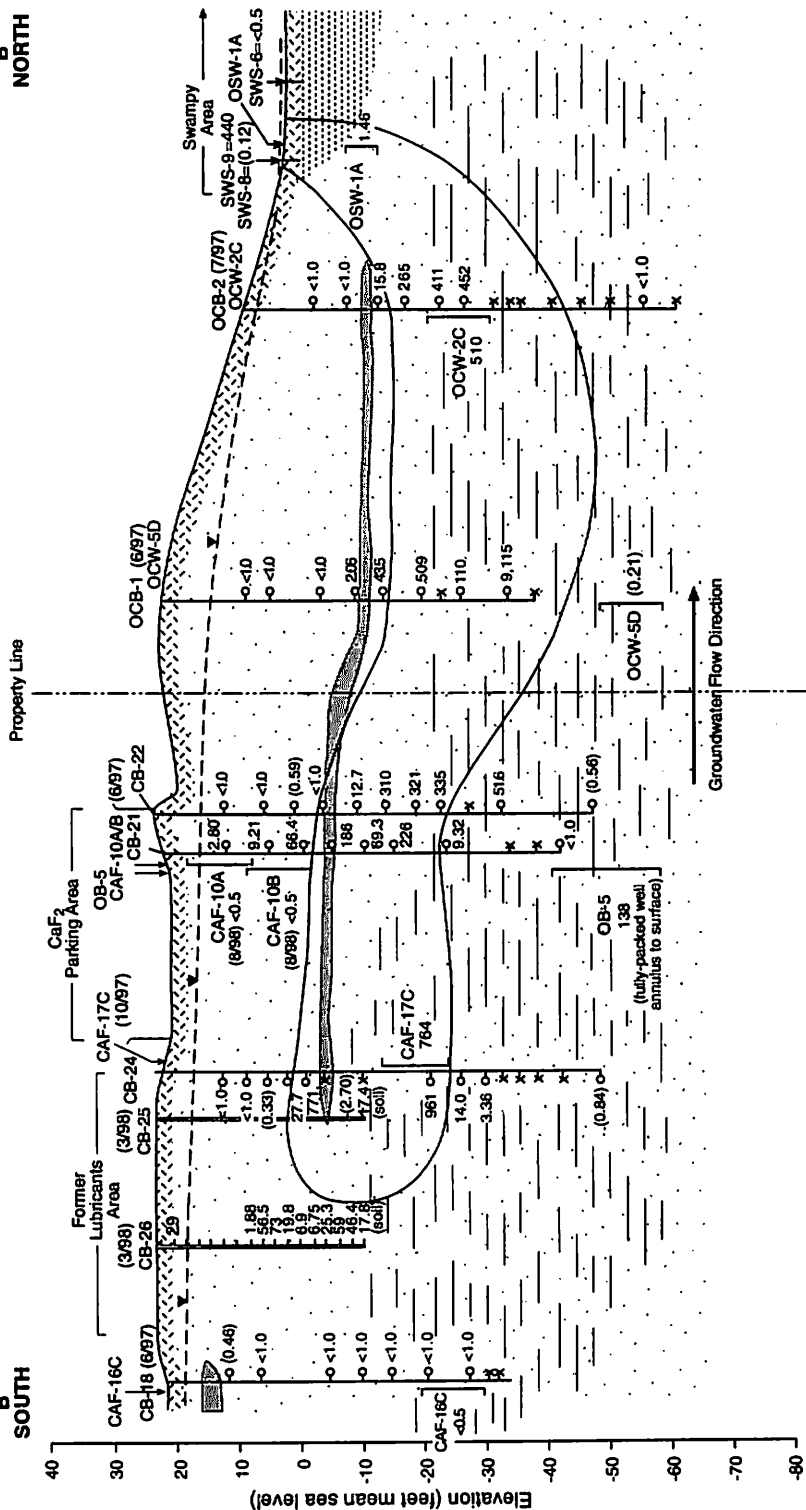
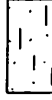


Figure 2-15. Vertical Extent of Vinyl Chloride in Groundwater--Northwest Site Area

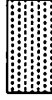
EXPLANATION



Tan to brownish gray-green fine to medium quartz sand with intermittent clayey and highly organic sand stringers. Shaded areas indicate zones of more distinct gray-tan clayey sediments.



Fine sand with intermittent calcareous sandstone layers, grading to green-gray to green-black glauconitic silty fine sand with depth.



Black to brownish black highly organic peat with intermittent black silt and fine sand.



**Position of water table,
measured August 11, 1998.**



Screened interval for monitoring wells with vinyl chloride concentration ($\mu\text{g/L}$) in groundwater samples collected November 9-11, 1998.



**Exploratory boring with
locations of porewater samples.
o = sample collected
x = no sample collected/refusal
of sample probe**



Inferred extent of vinyl chloride detection in groundwater ($\geq 0.5 \mu\text{g/L}$).



Land surface

150' Horizontal scale

Location of cross-section shown on Figure 2-1.

Note: Estimated concentration between minimum detection limit and practical quantitation limit shown in parentheses.

NW Site CAP

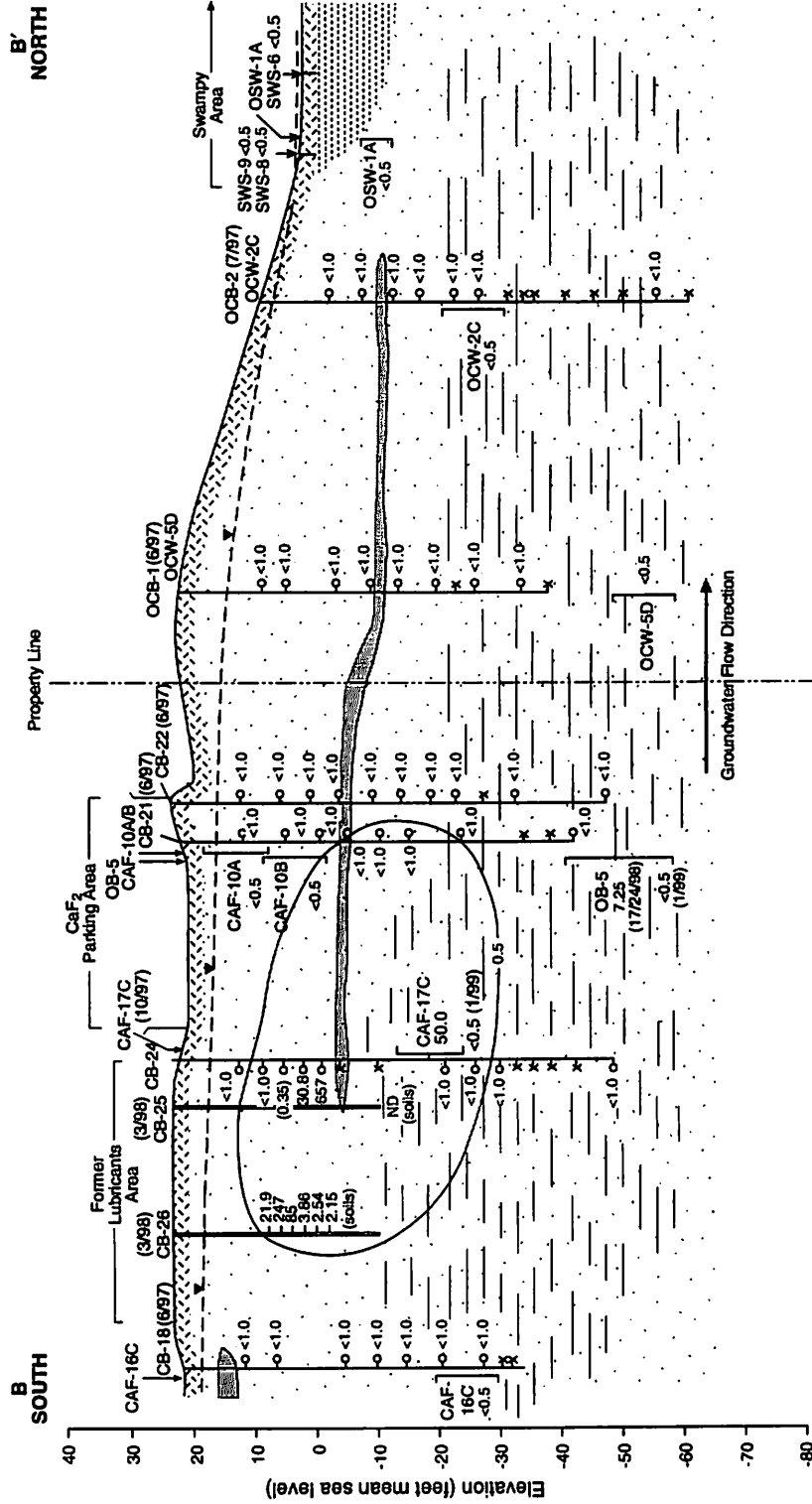


Figure 4-1

Surface-Water Features in Northwest Site Area

GE - Wilmington, NC Site

EXPLANATION

- Stream location (dashed where inferred)
- Location of SWS-series swamp-water sampling points.
- Approximate surface-water sample location (1997 samples - refer to Section 6.0 of CSA [RTI, 1998])
- Approximate surface-water sample location (January 1999)



1 inch = 1500 feet

0 Feet 1500

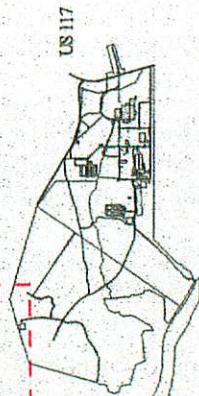
North

Note: Stream locations based on topographic map features and field reconnaissance.

Source: USGS Orthophotographic map, Castle Hayne, NC Quadrangle, 1970. Contour interval = 5 feet.

INSET NOT TO SCALE

Map Area



GE - Wilmington, NC Site



Map Preparation Date: 2/16/98 topo_caf_pot.apr

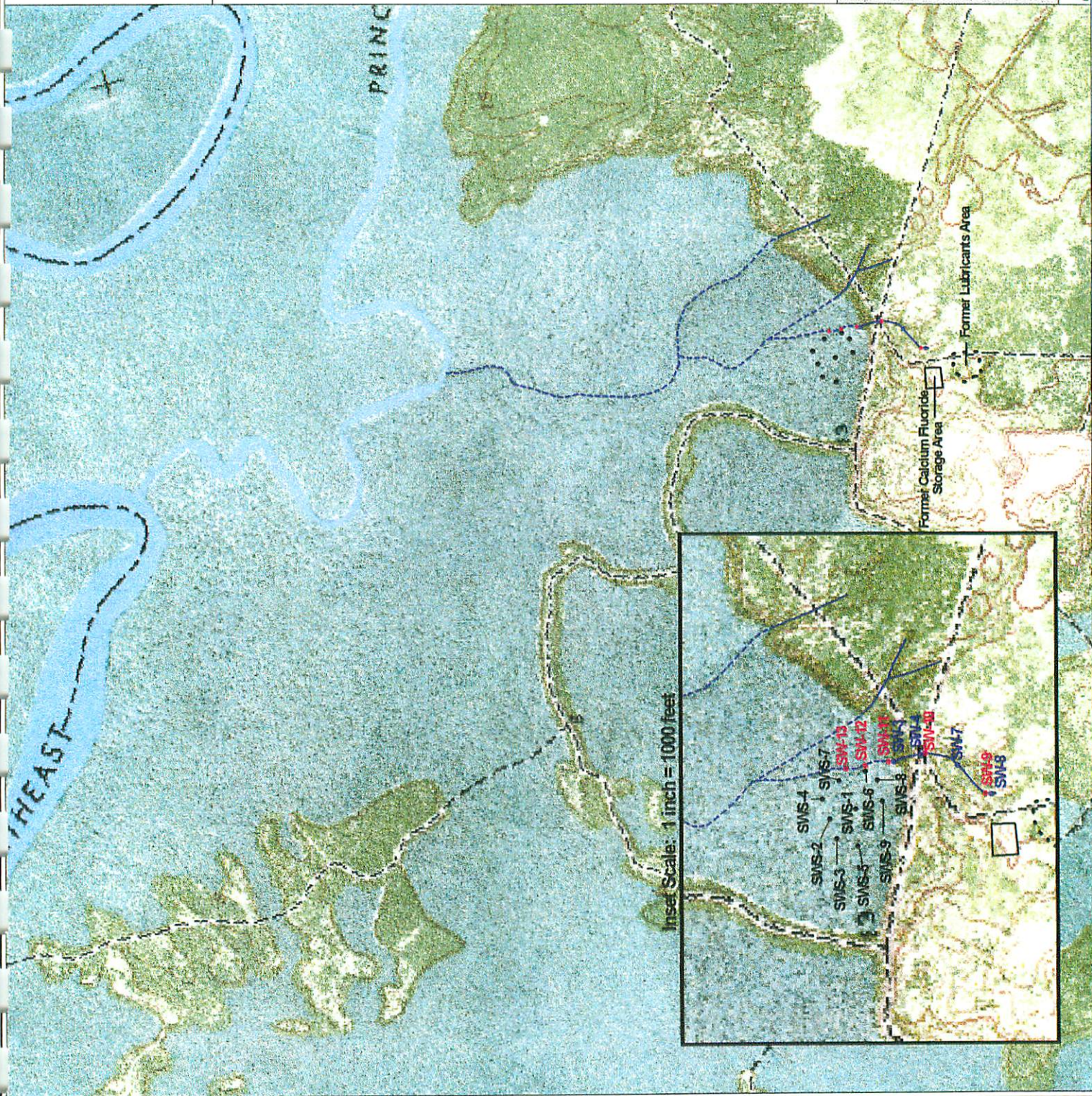
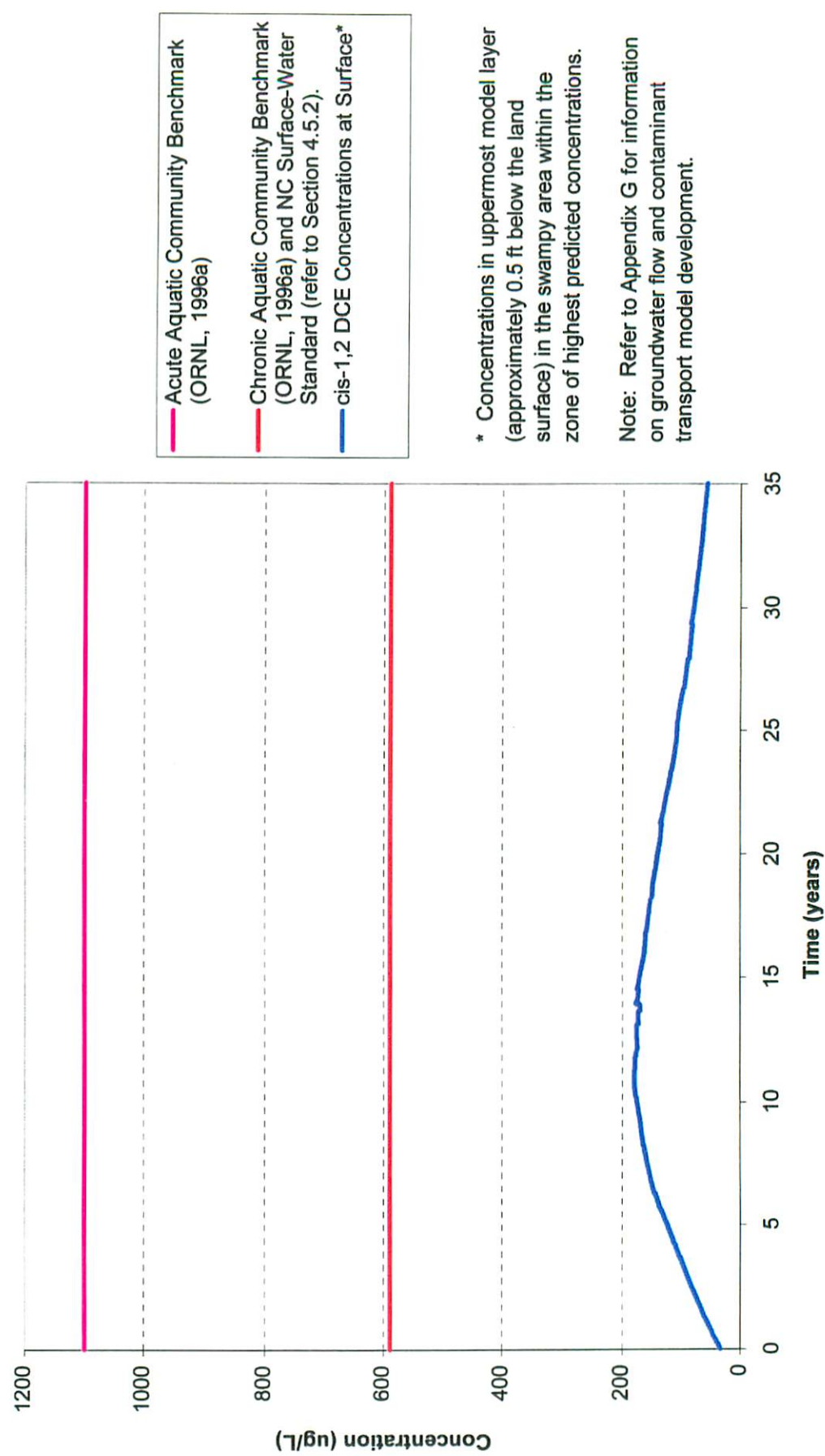


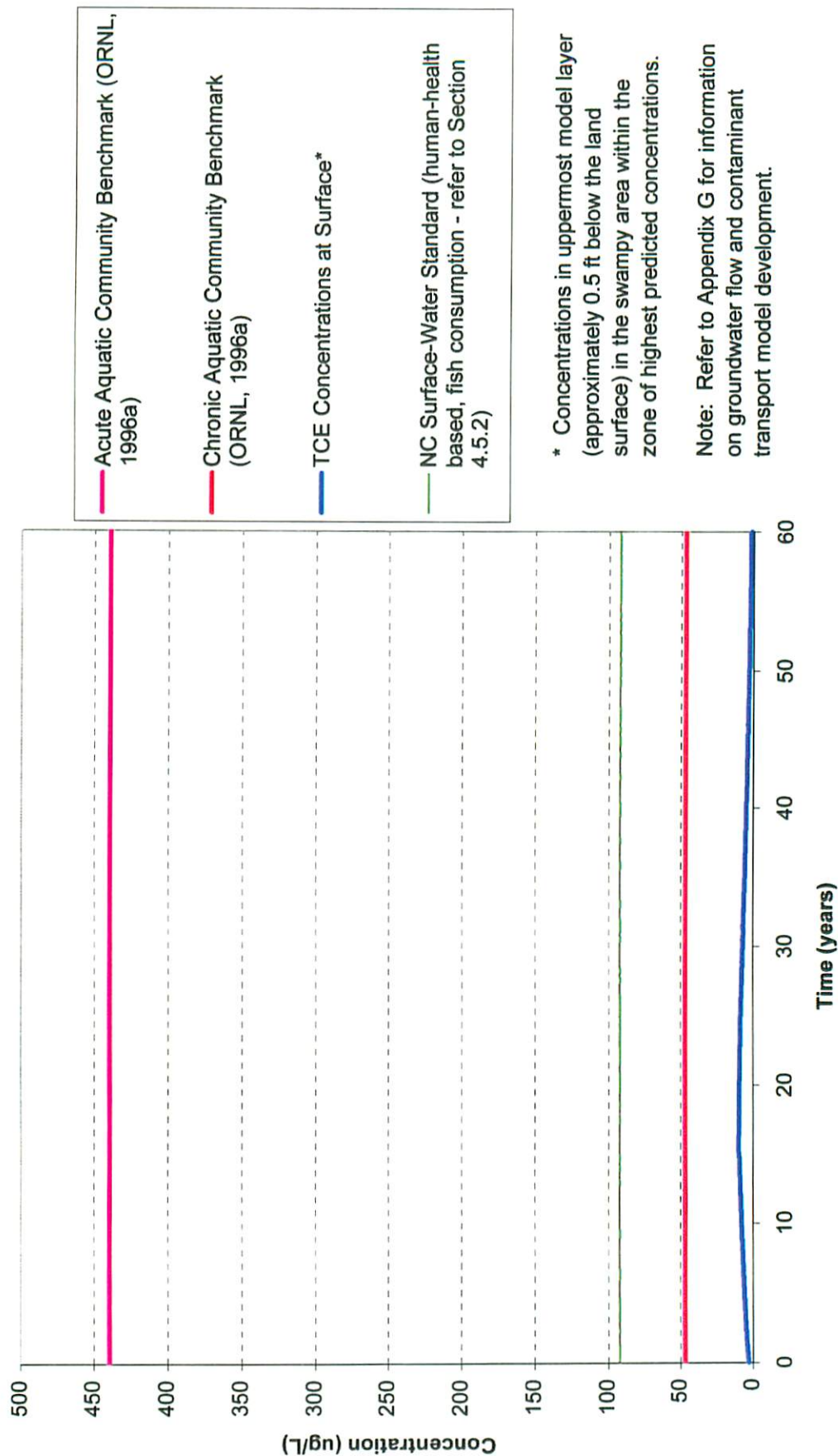
Figure 4-2 Comparison of Maximum Predicted cis-1,2 DCE Concentrations in Swamp Standing Water to Ecological Benchmarks -- 0 to 35 Years from Present



* Concentrations in uppermost model layer (approximately 0.5 ft below the land surface) in the swampy area within the zone of highest predicted concentrations.

Note: Refer to Appendix G for information on groundwater flow and contaminant transport model development.

Figure 4-3 Comparison of Maximum Predicted TCE Concentrations in Swamp Standing Water to Ecological Benchmarks -- 0 to 60 Years from Present



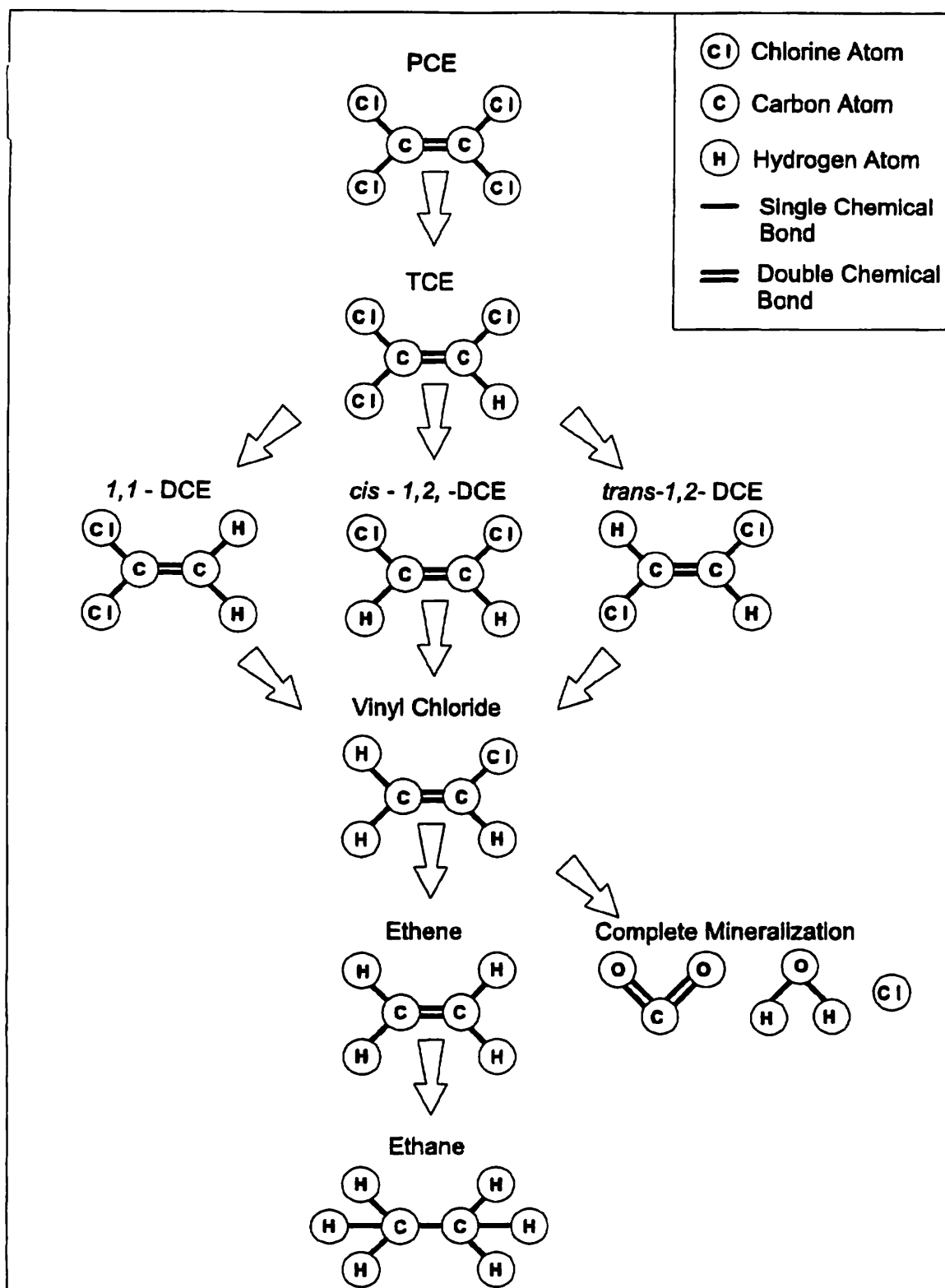


Figure 6-1. Reductive Dehalogenation of Chlorinated Ethenes (EPA, 1998a)

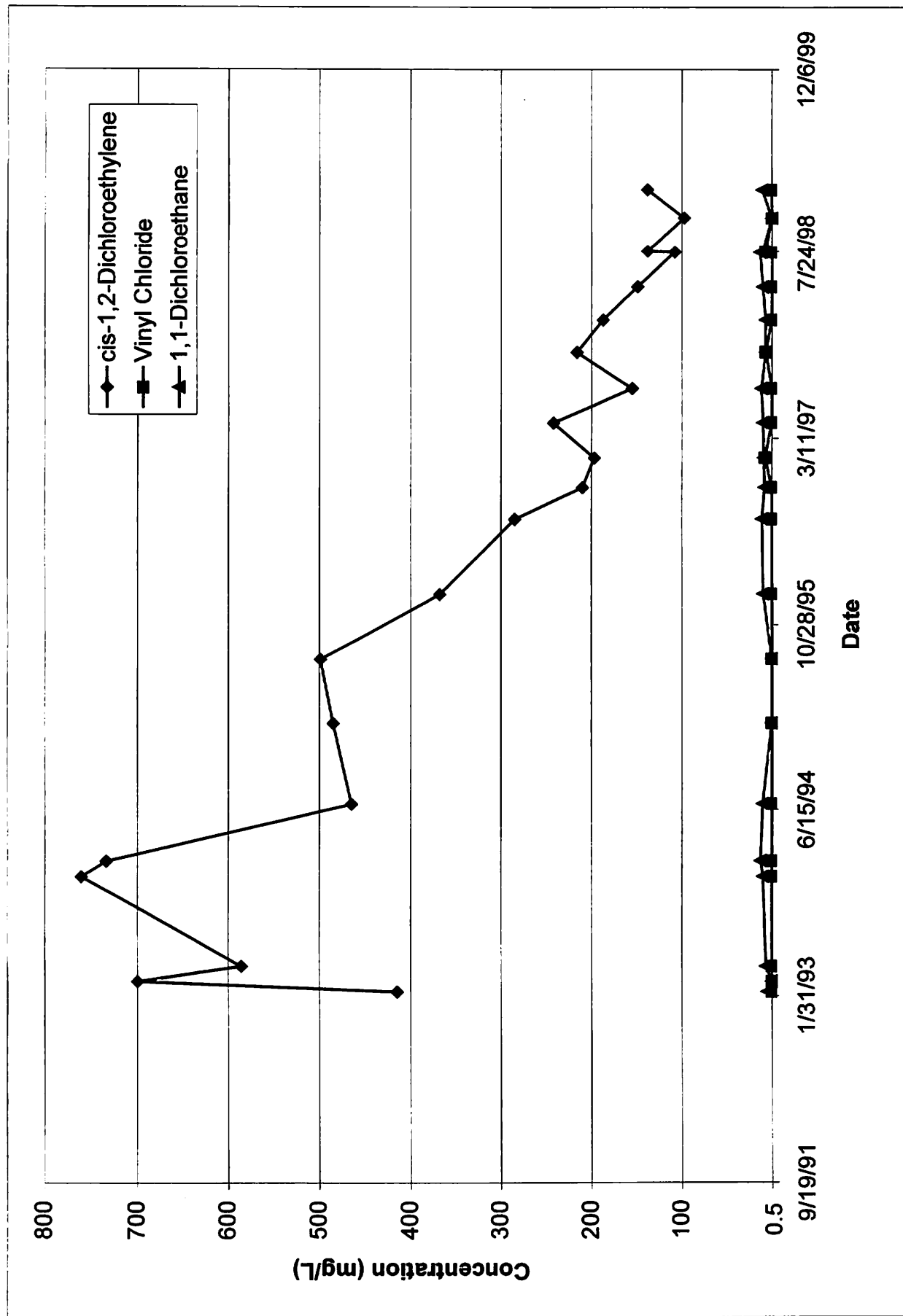


Figure 6-2. VOC Trends for Groundwater Samples From Well OB-5

Figure 6-3

Dissolved Oxygen in Groundwater

Northwest Site Area
GE - Wilmington, NC Site

Explanation

- Extent of GE property
- Swampy area
- Road/Trail

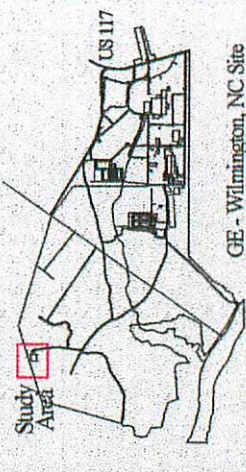
Stream location based on field reconnaissance.

Location of monitoring well or sampling point with dissolved oxygen concentration SWS-2 (mg/L) measured January 1999. Dissolved oxygen measured in the field by RTI using a calibrated YSI model 55 meter.

Inferred extent of dissolved oxygen in groundwater less than 1.0 mg/L.



INSET NOT TO SCALE



GE - Wilmington, NC Site



Map Preparation Date: 1/27/99

caf_1_26_99.apr

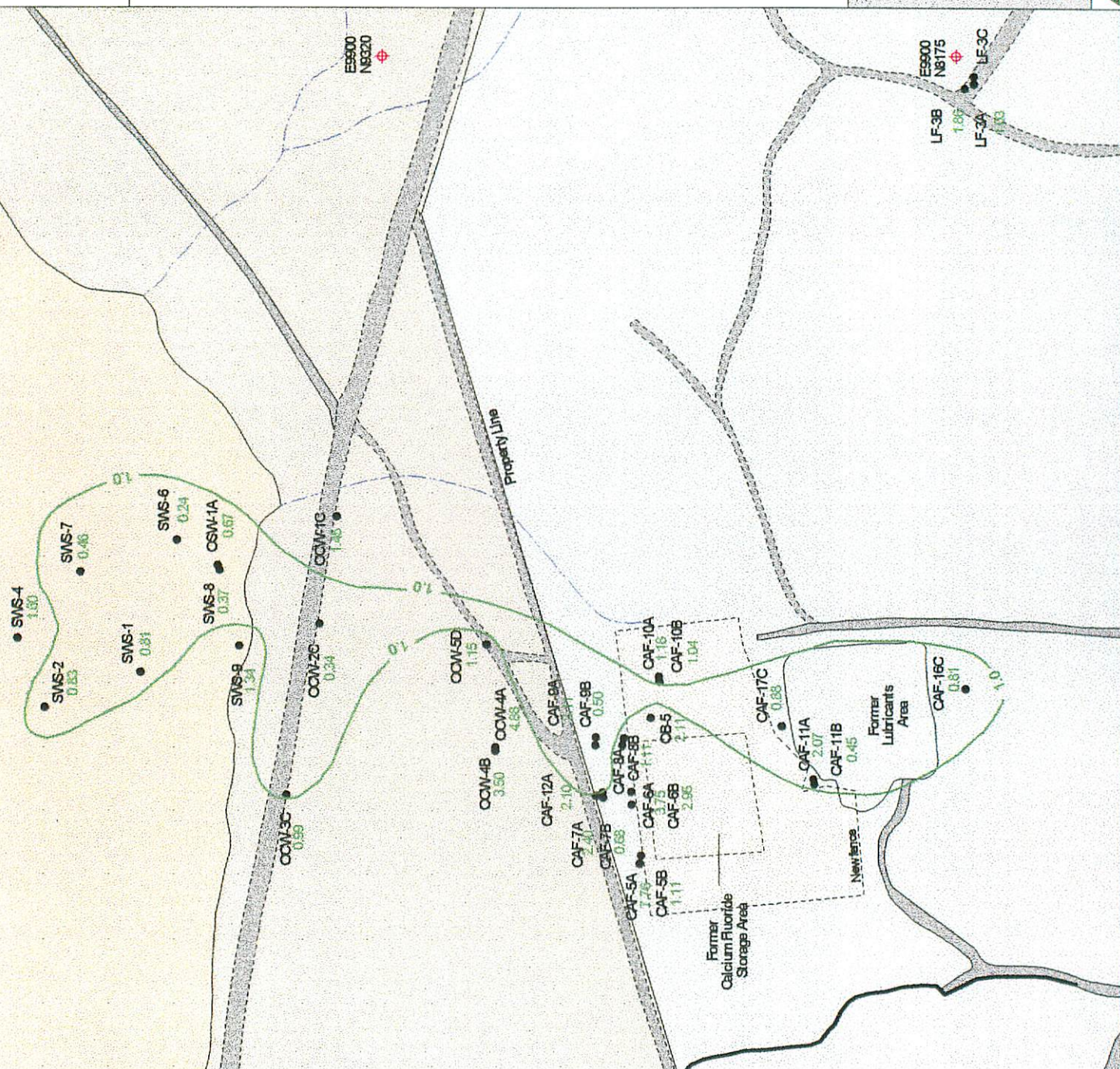


Figure 6-4

Ferrous Iron in Groundwater

Northwest Site Area
GE - Wilmington, NC Site

Explanation

- Extent of CF property
- Swampy area
- Road/Trail

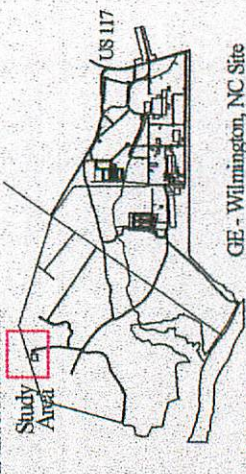
Stream location based on field reconnaissance

Location of monitoring well or sampling SWS-2 point with ferrous iron concentration (mg/L) measured January 1999. Ferrous iron measured in the field by RTI using Hach colorimetric method.

Inferred extent of ferrous iron concentration in groundwater.



INSET NOT TO SCALE



NE Cape Fear River



Map Preparation Date: 1/27/99

caf_1_26_99.apr

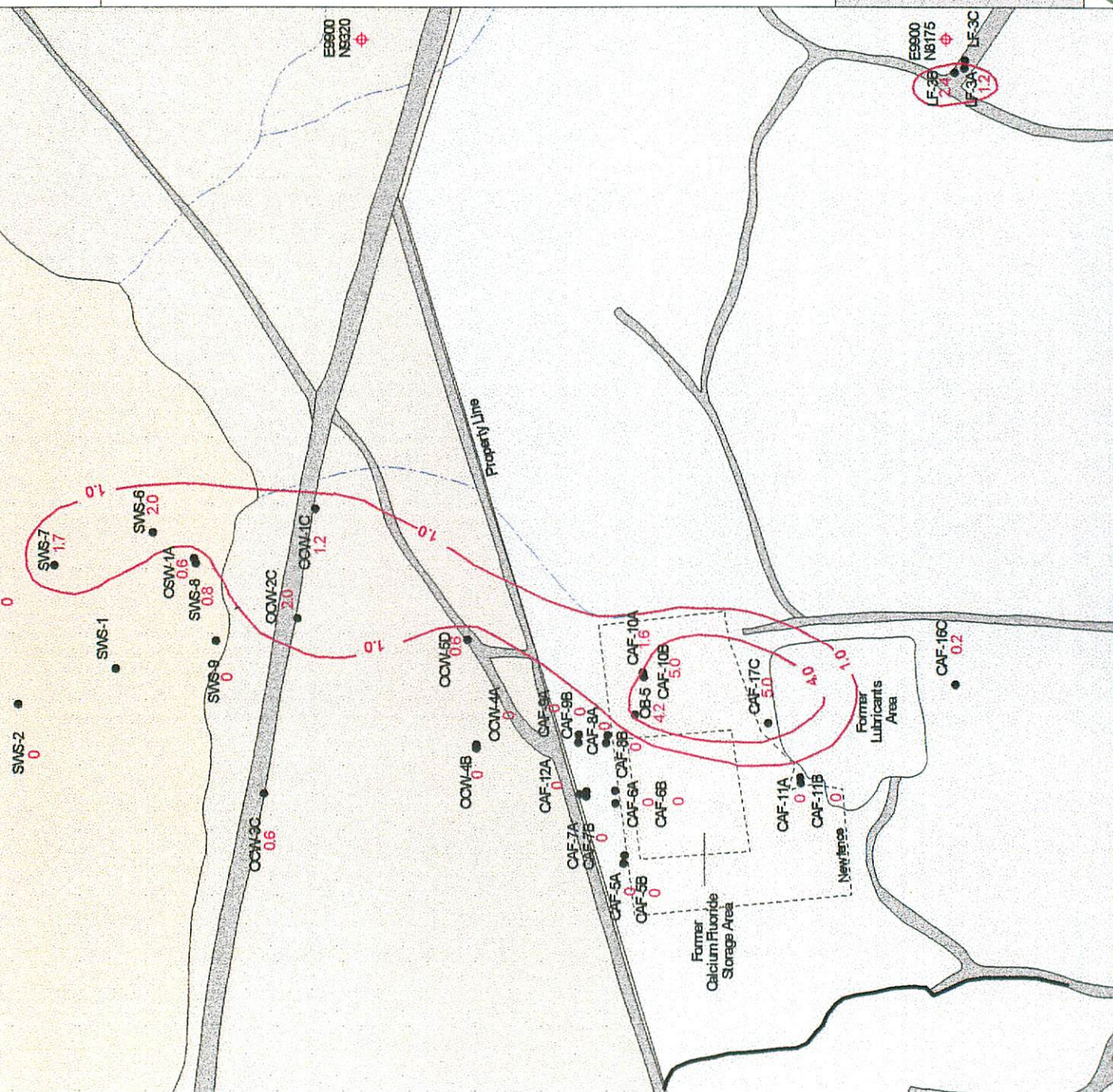


Figure 6-5

Groundwater Oxidation-Reduction Potential

Northwest Site Area
GE - Wilmington, NC Site

Explanation

- Extent of GE property
- Swampy area
- Road/Trail

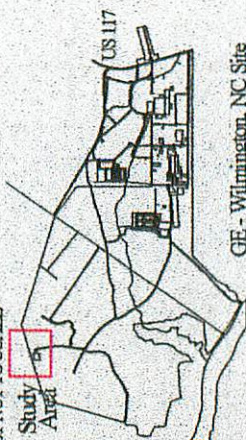
Stream location based on field reconnaissance.

- Location of monitoring well or sampling point with groundwater oxidation-reduction SWS-2 potential (mV) measured January 1999.

Inferred groundwater area of negative oxidation-reduction potential. Oxidation-reduction potential measured in the field by RII using a Cole-Parmer Ag-AgCl ORP Tester.



INSET NOT TO SCALE



NE Cape Fear River

GE - Wilmington, NC Site



Map Preparation Date: 1/27/99

caf 1 26 99.apr

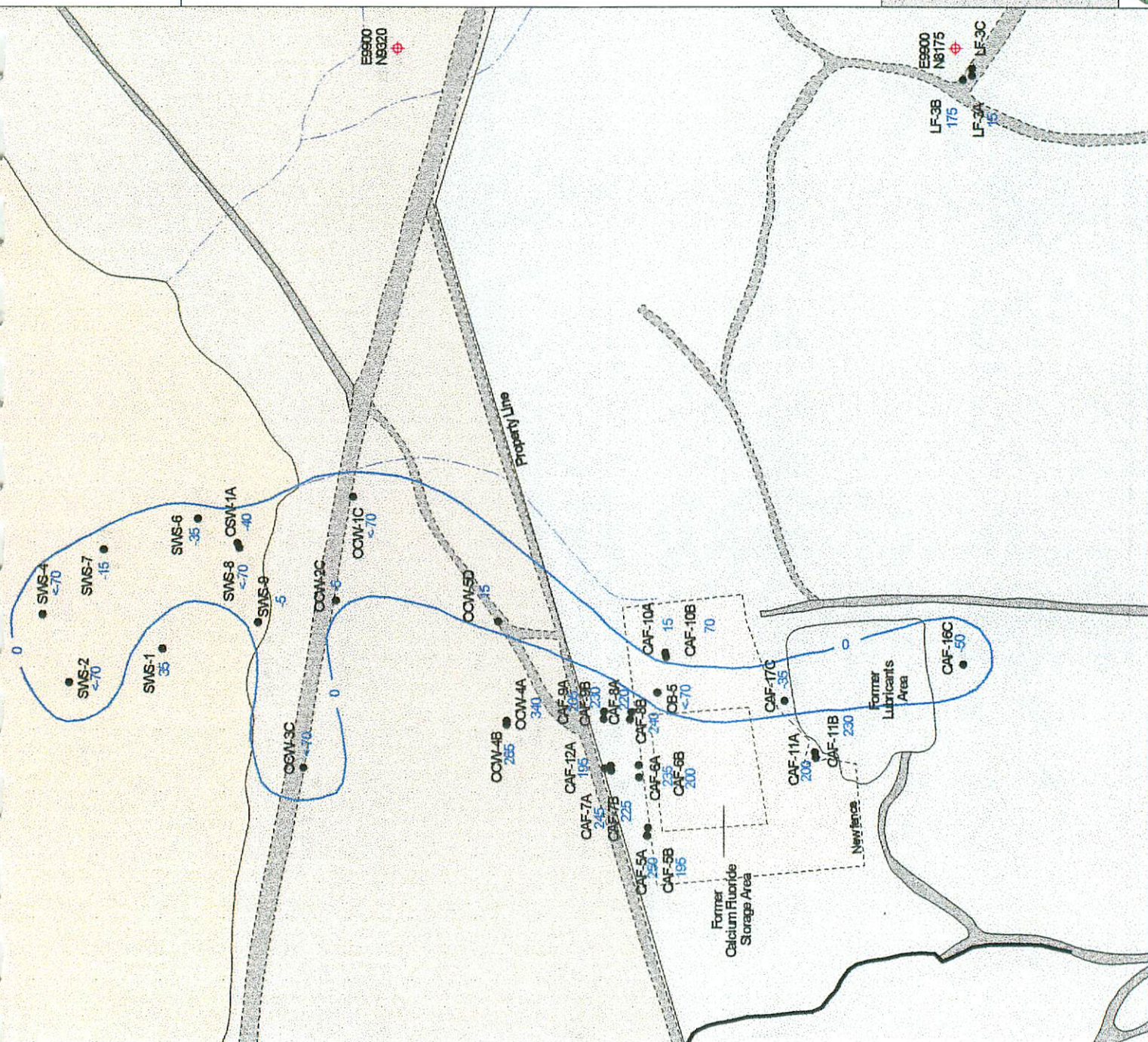
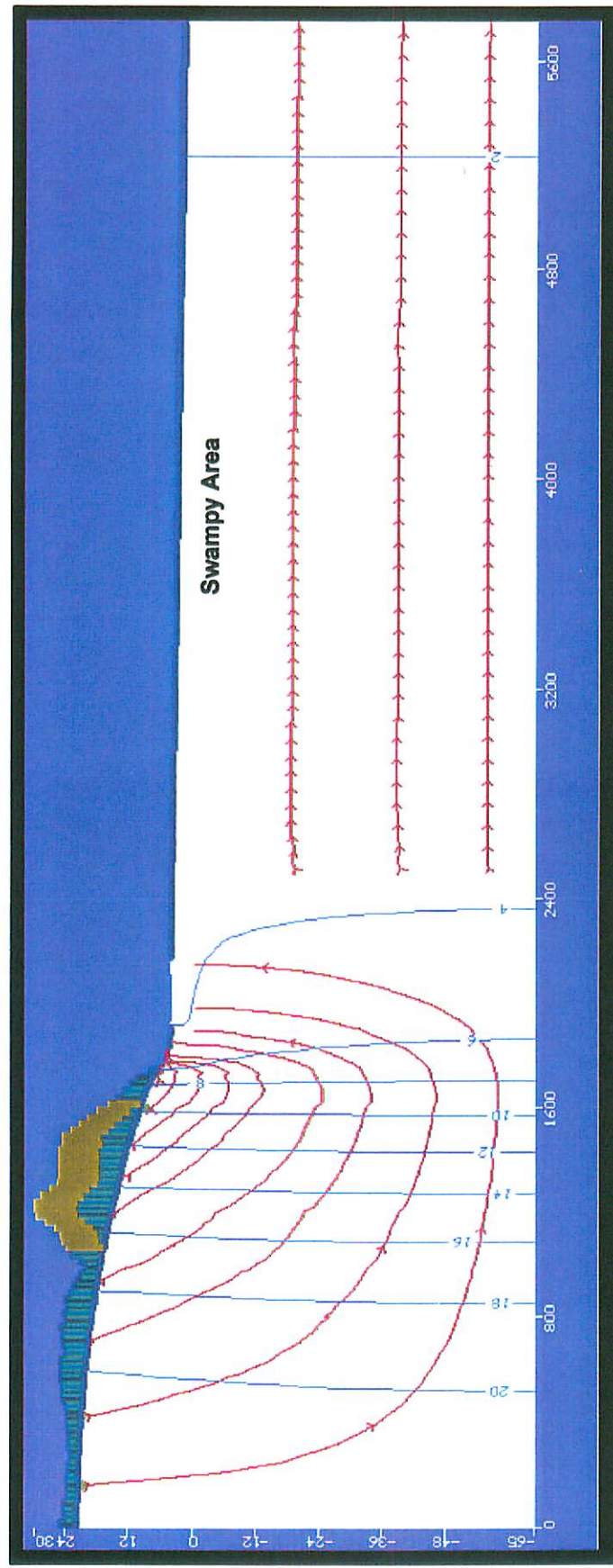


Figure 6-8 Vertical Cross Section Showing Simulated Groundwater Flow Pathlines and Equipotential Head Contours -- Northwest Site Area



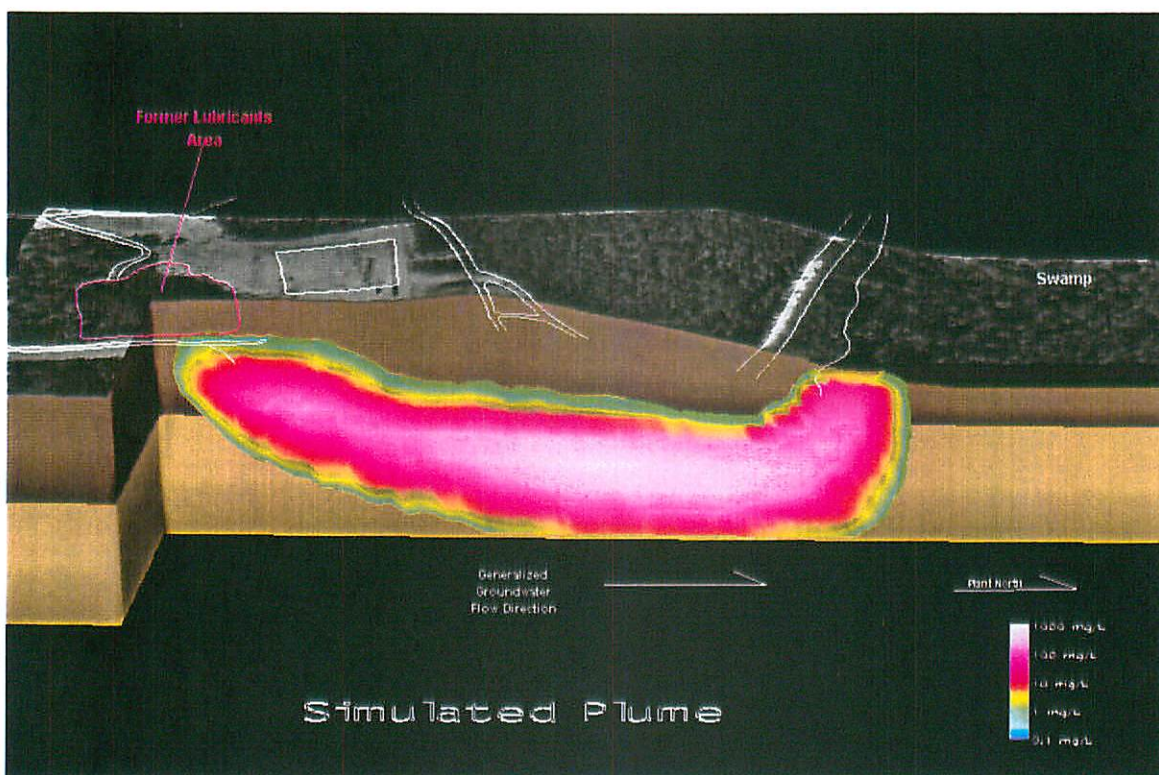
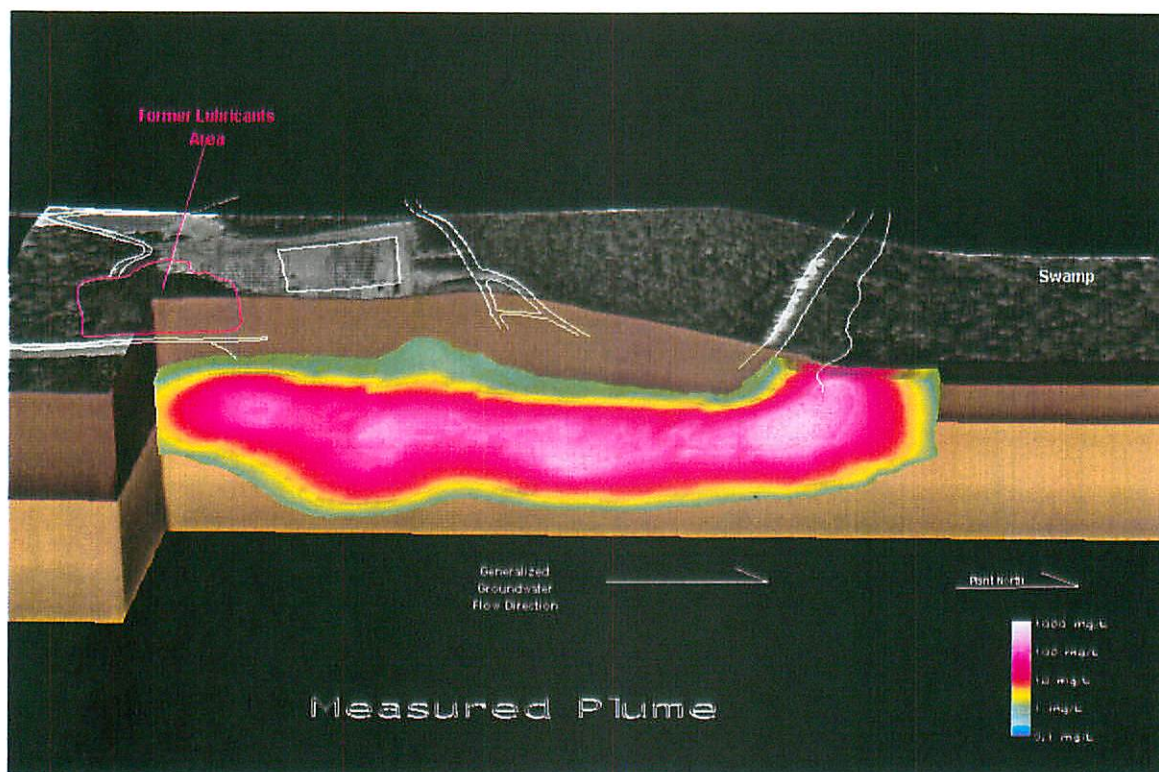
→ Plant North

- Simulated Flow pathlines (time of flow between arrows is 25 years)
- Simulated Equipotential lines (feet above mean sea level)

Notes:

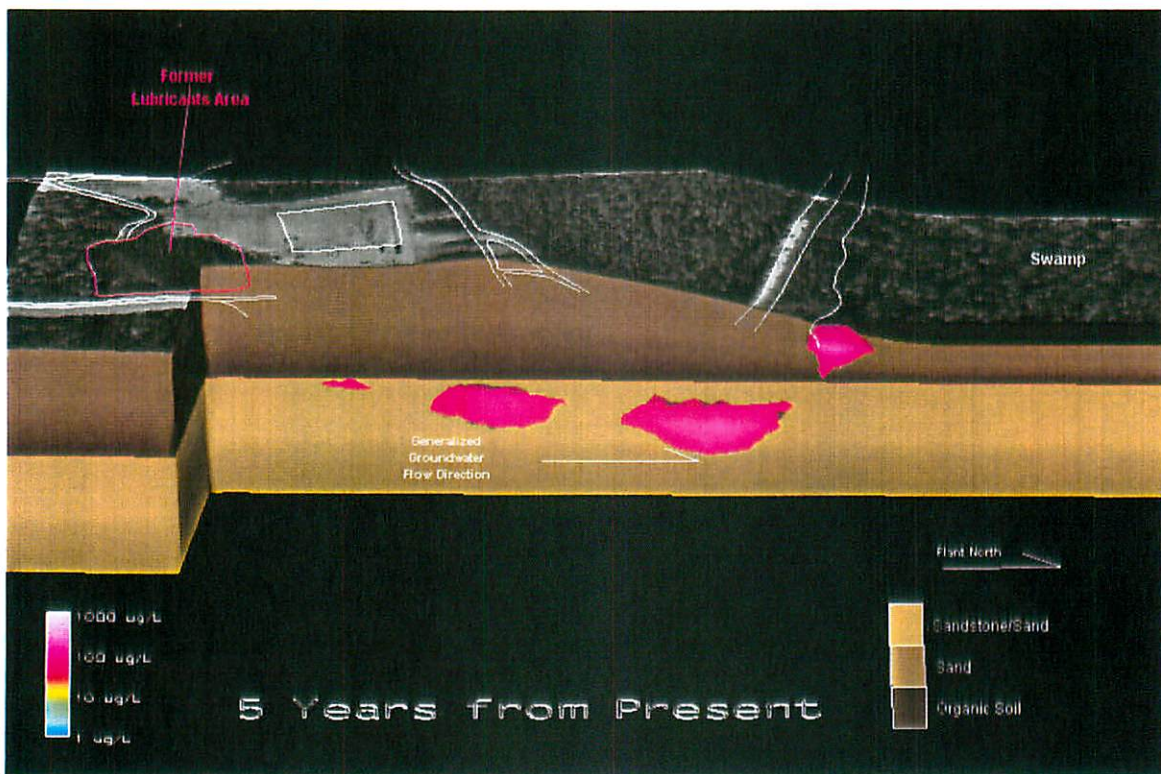
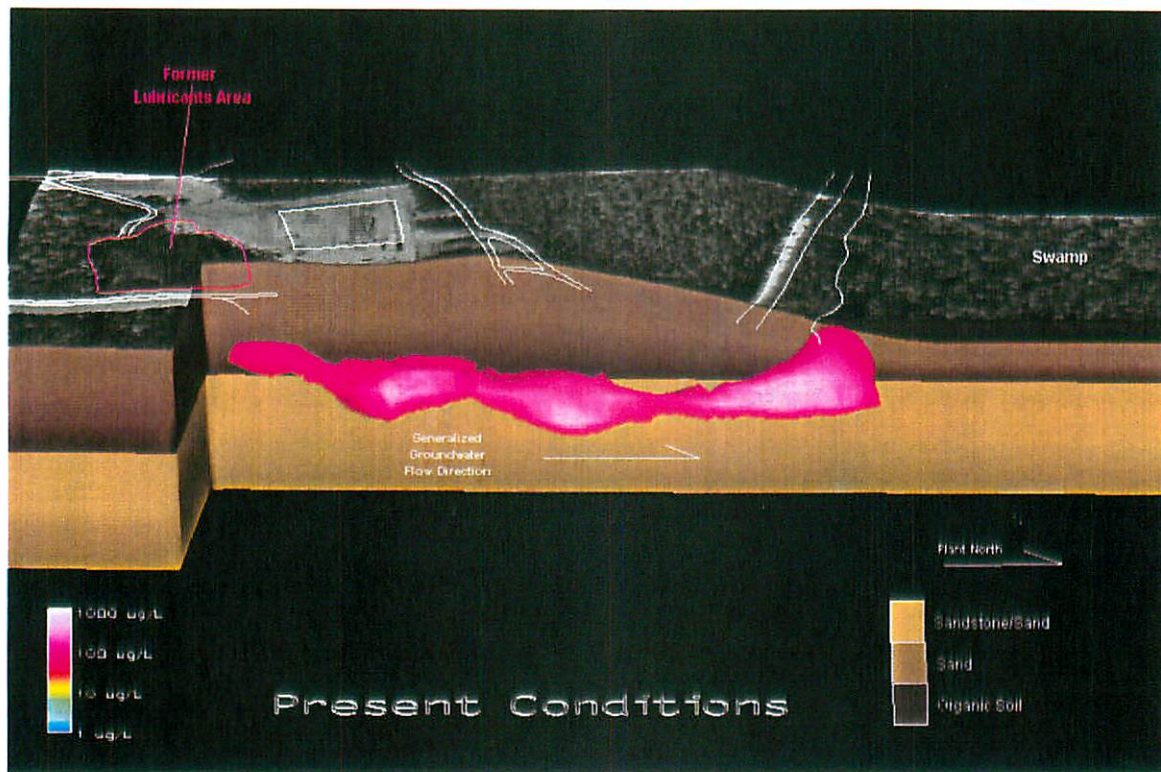
Vertical exaggeration of 20.
 Cross section oriented due north through area of interest.
 Refer to Appendix G for information on groundwater flow model development.

Figure 6-9 Comparison of Measured and Simulated cis-1,2 DCE Groundwater Plumes -- Current Conditions



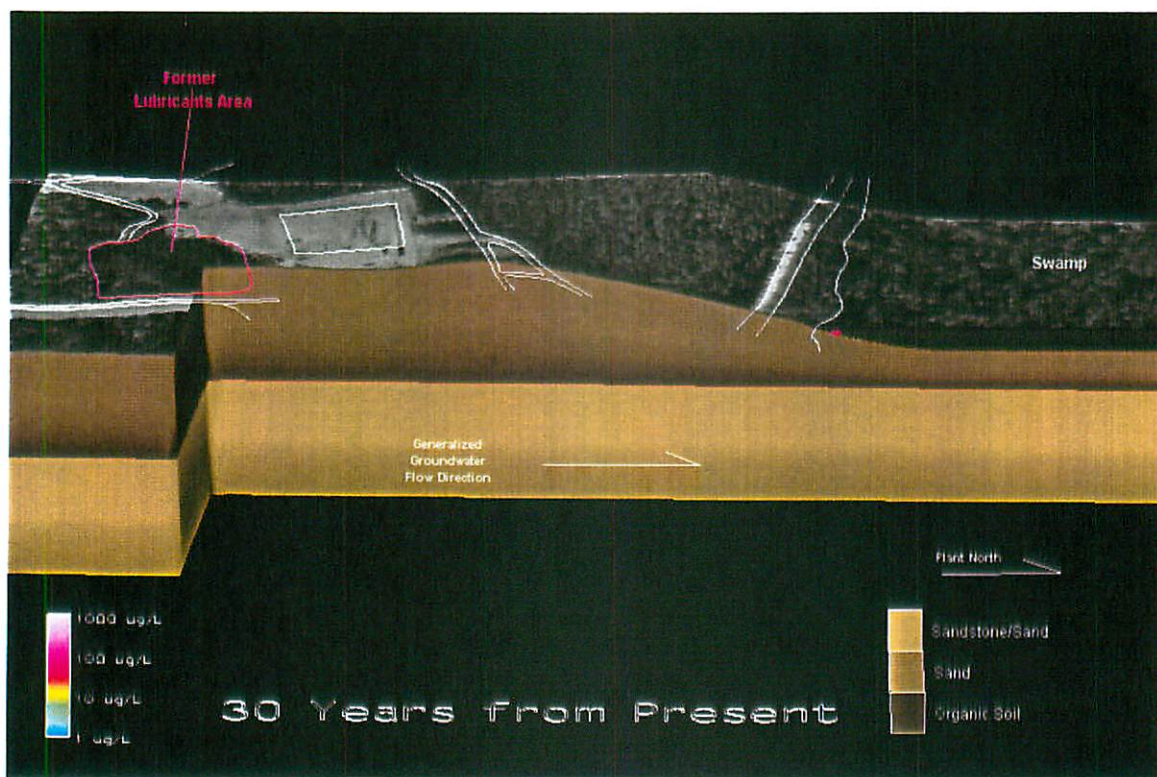
Note: Refer to Appendix G for information on groundwater flow and transport model development.

Figure 6-10 Predicted Distribution of cis-1,2 DCE (>70 µg/L) in Groundwater - 0 to 5 Years from Present - Northwest Site Area



Note: Refer to Appendix G for information on groundwater flow and transport model development.

Figure 6-11 Predicted Distribution of cis-1,2 DCE (>70 µg/L) in Groundwater - 15 to 30 Years from Present - Northwest Site Area



Note: Refer to Appendix G for information on groundwater flow and transport model development.

**Figure 6-12 Predicted cis-1,2 DCE Concentrations in the Swampy Area --
0 to 35 Years from Present**

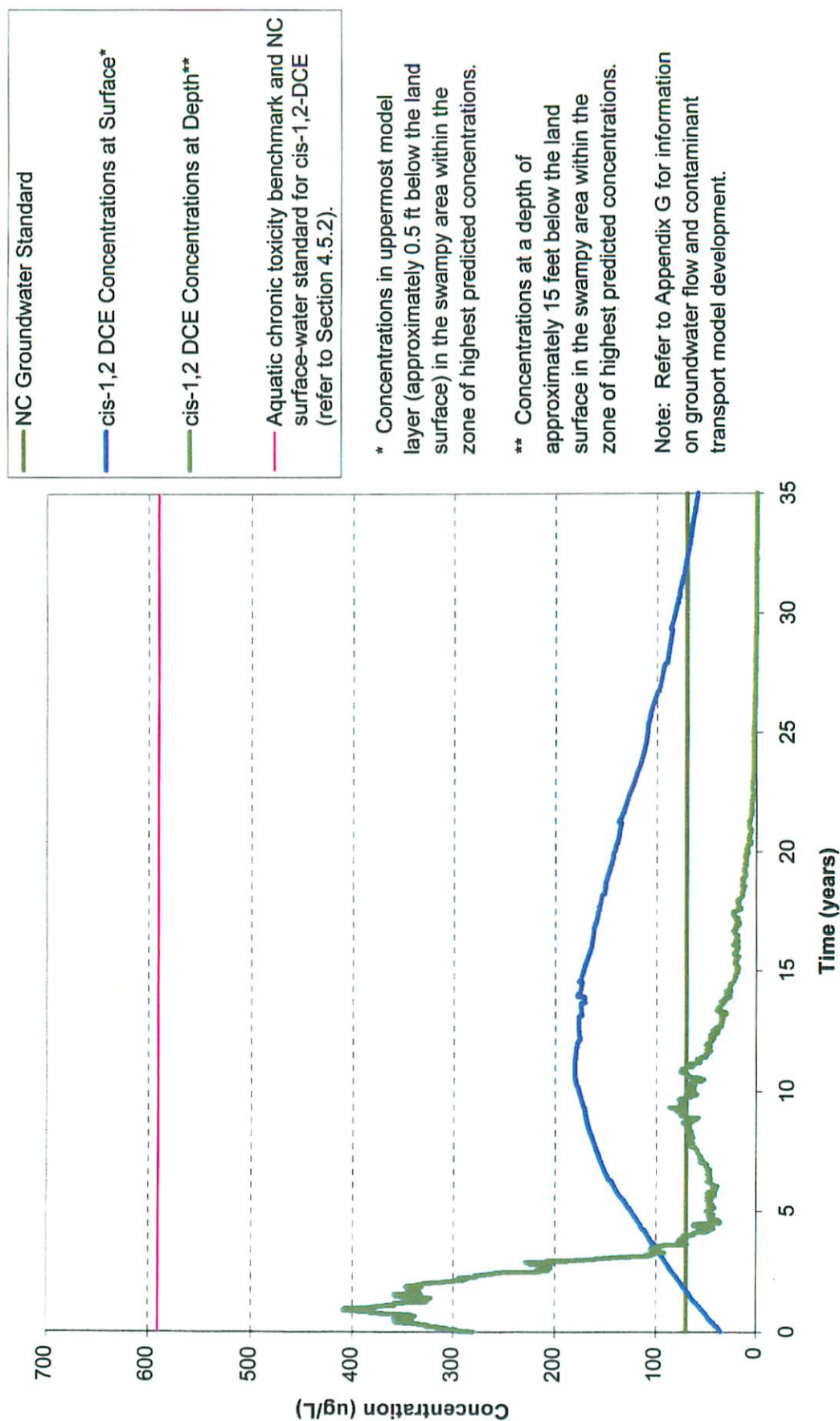
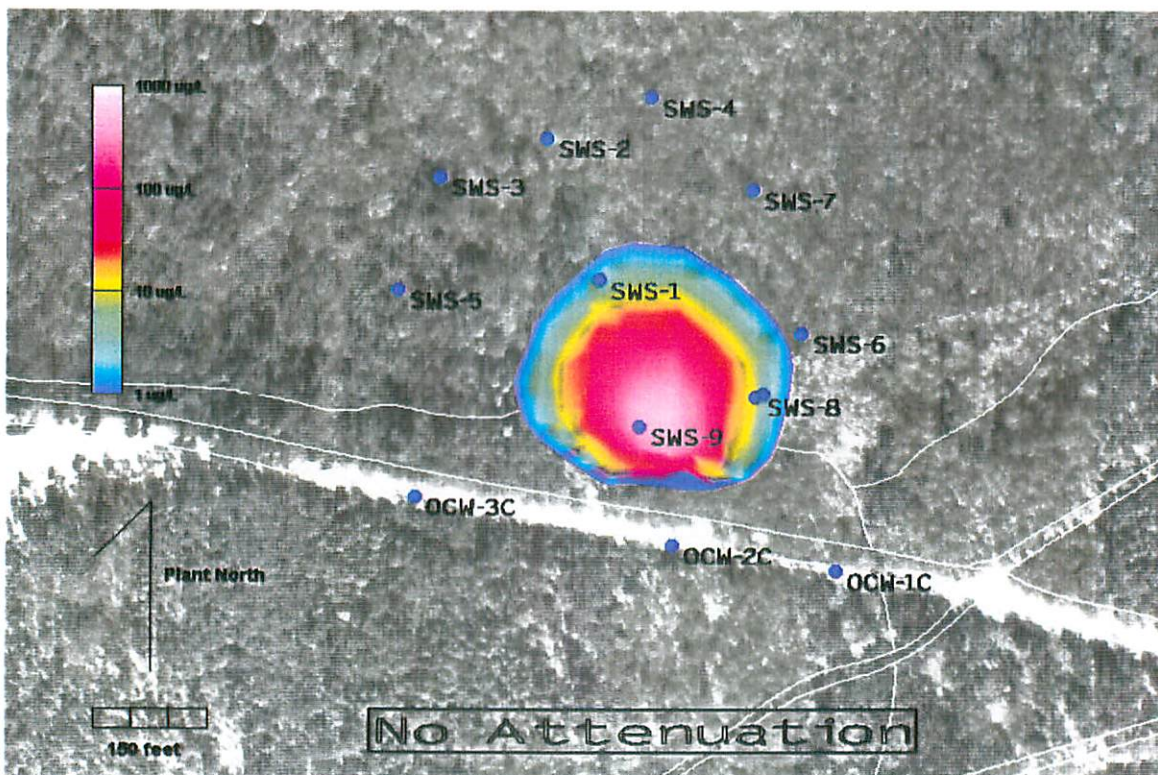
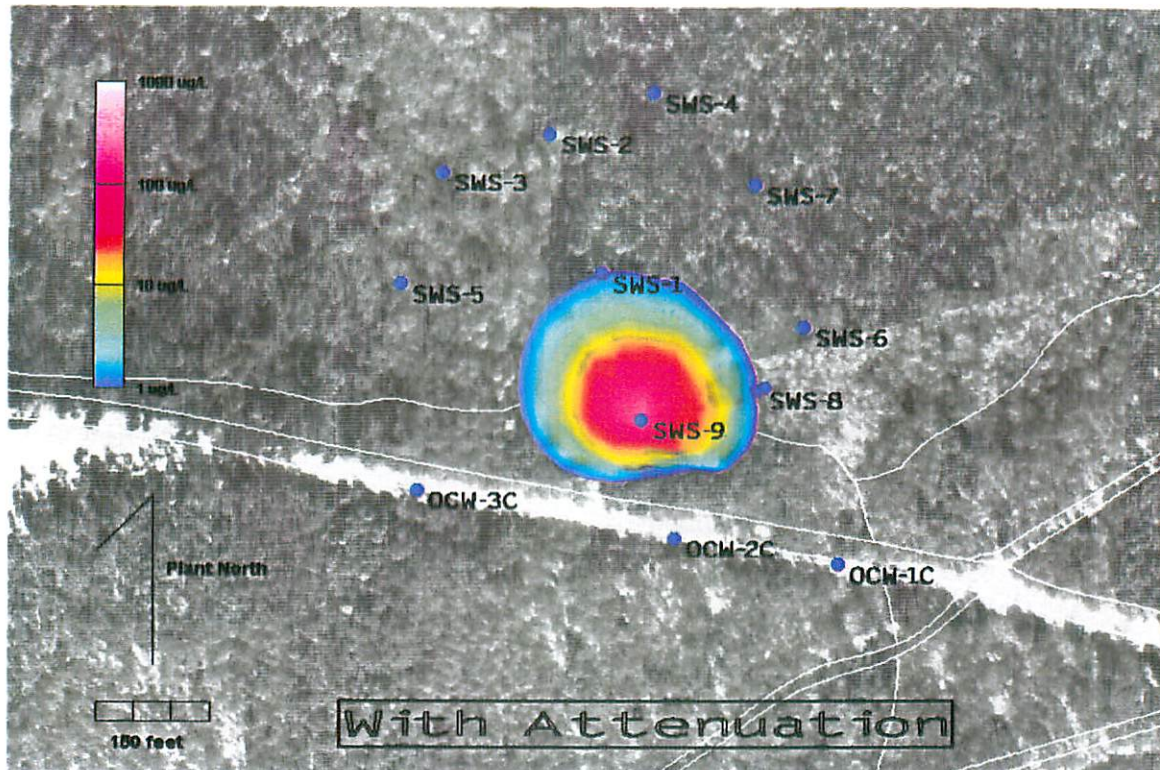
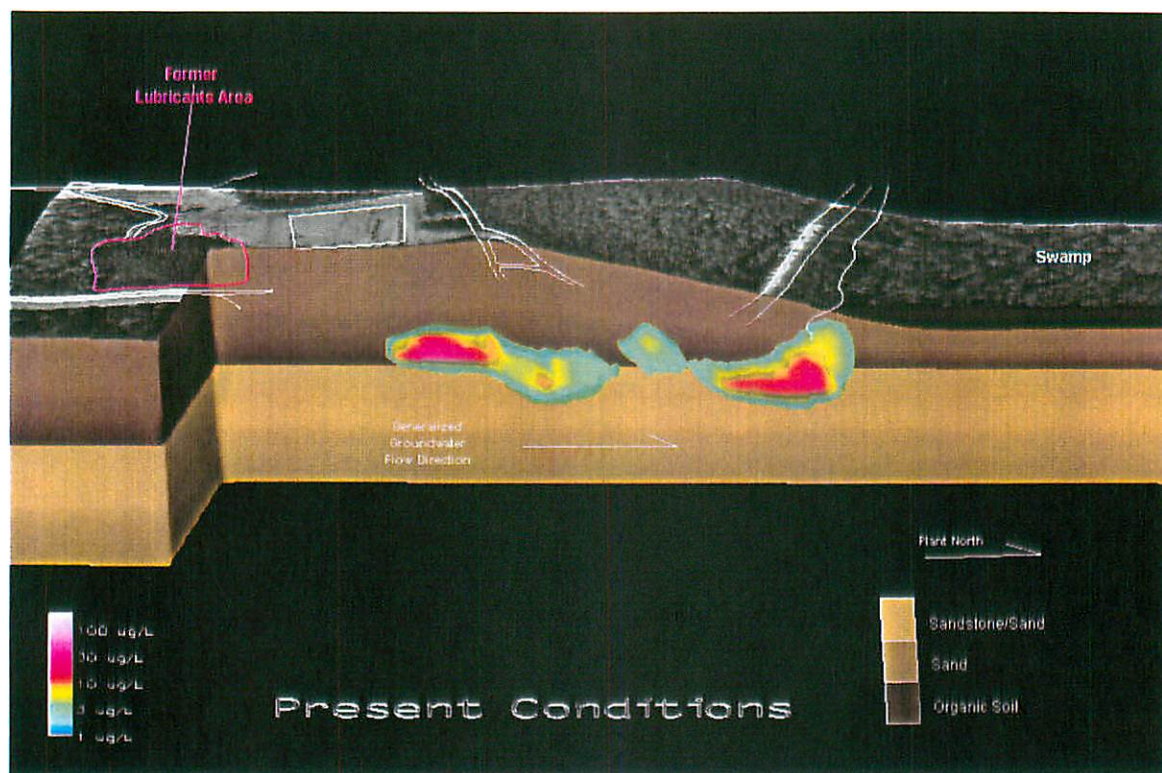


Figure 6-13 Maximum Predicted Surface Concentrations of cis-1,2-DCE in Swampy Area With and Without Natural Attenuation



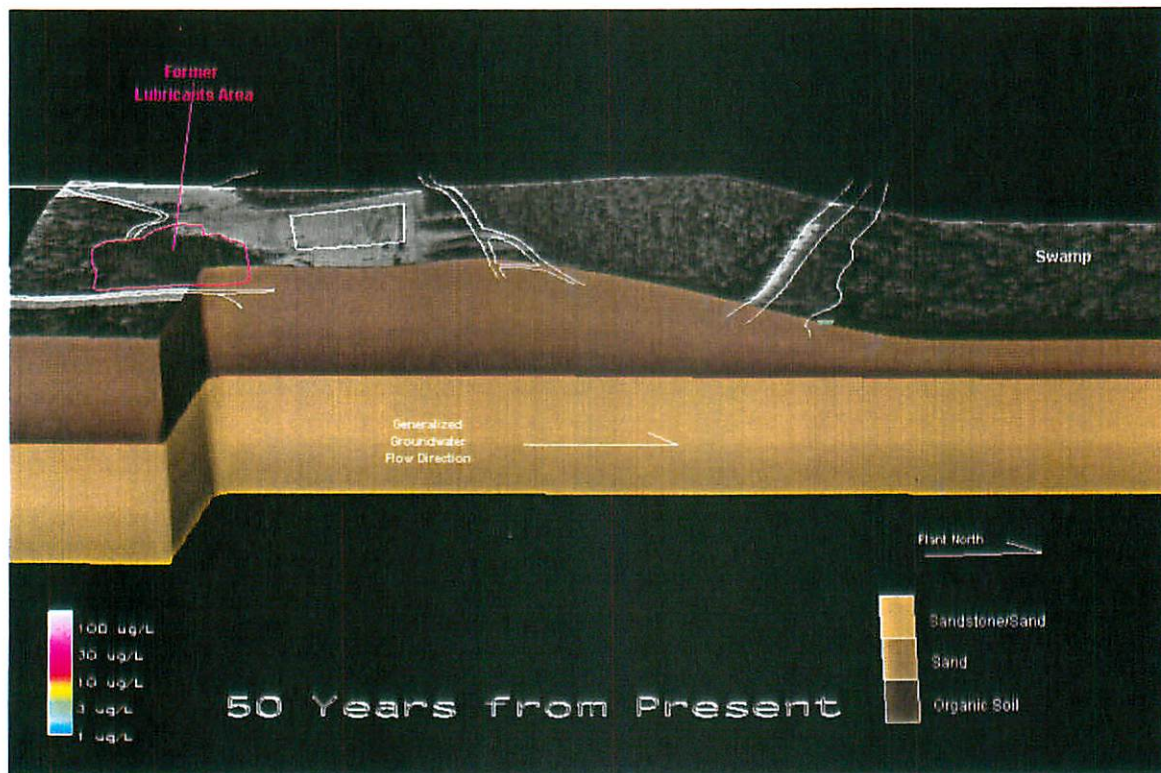
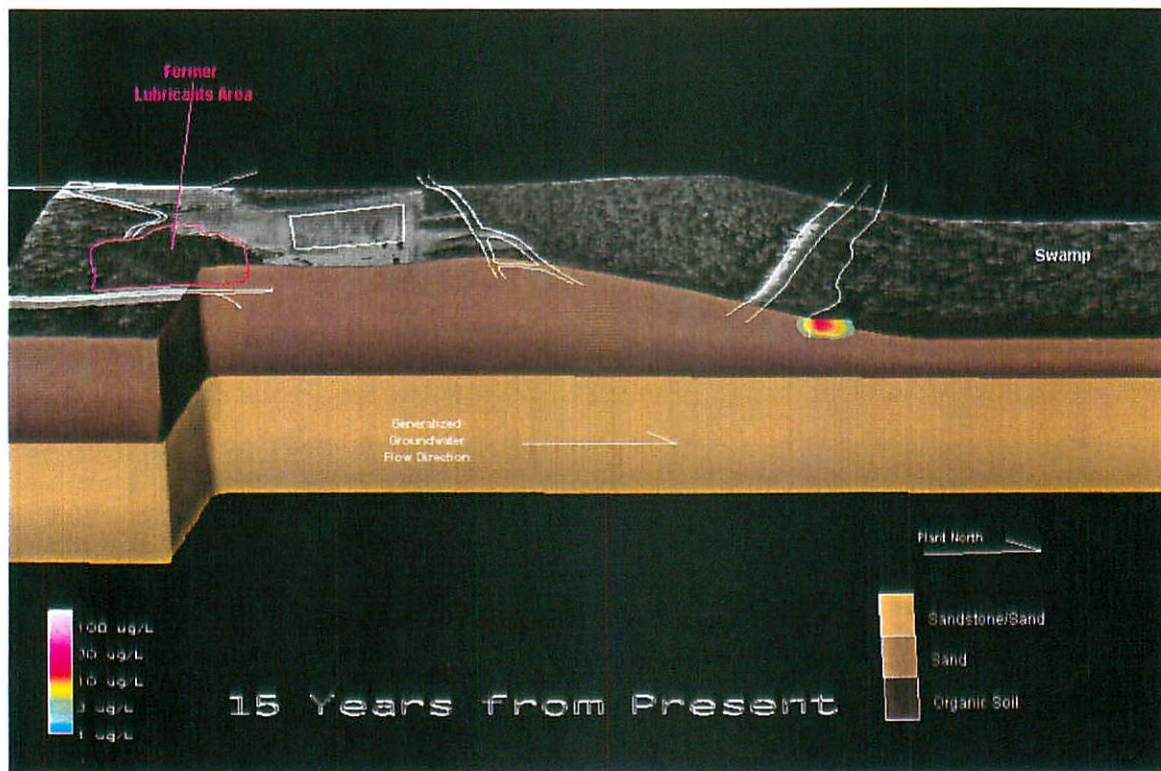
Note: Graphics indicate predicted maximum extent of contamination in uppermost model layer (0.5 feet below land surface). Maximum surface concentrations occurred after 11 and 2 years with and without attenuation, respectively, with the measured plume the initial conditions. Refer to Appendix G for information on model development.

Figure 6-14 Predicted Distribution of TCE ($>2.8 \mu\text{g/L}$) in Groundwater - 0 to 5 Years from Present - Northwest Site Area



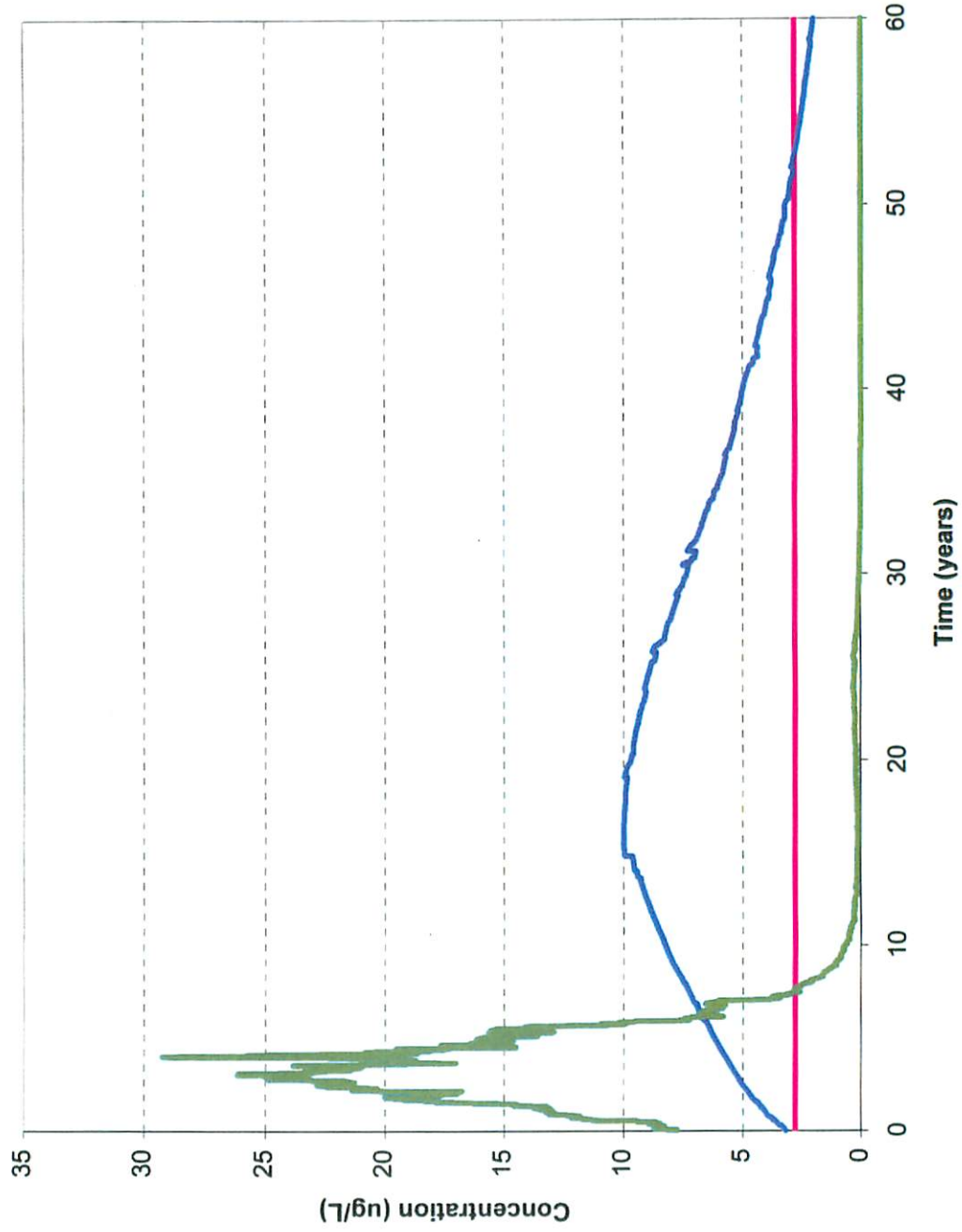
Note: Refer to Appendix G for information on groundwater flow and transport model development.

Figure 6-15 Predicted Distribution of TCE ($>2.8 \mu\text{g/L}$) in Groundwater - 15 to 50 Years from Present - Northwest Site Area



Note: Refer to Appendix G for information on groundwater flow and transport model development.

Figure 6-16 Predicted TCE Concentrations in the Swampy Area -- 0 to 60 Years from Present



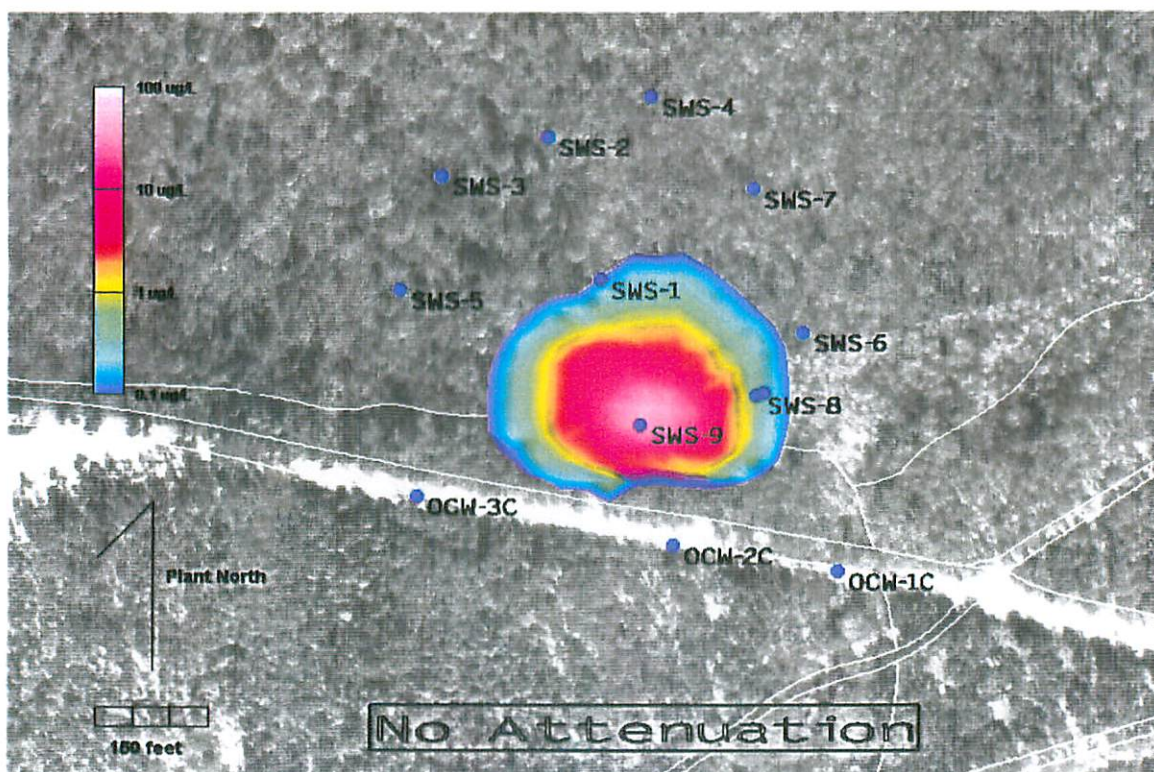
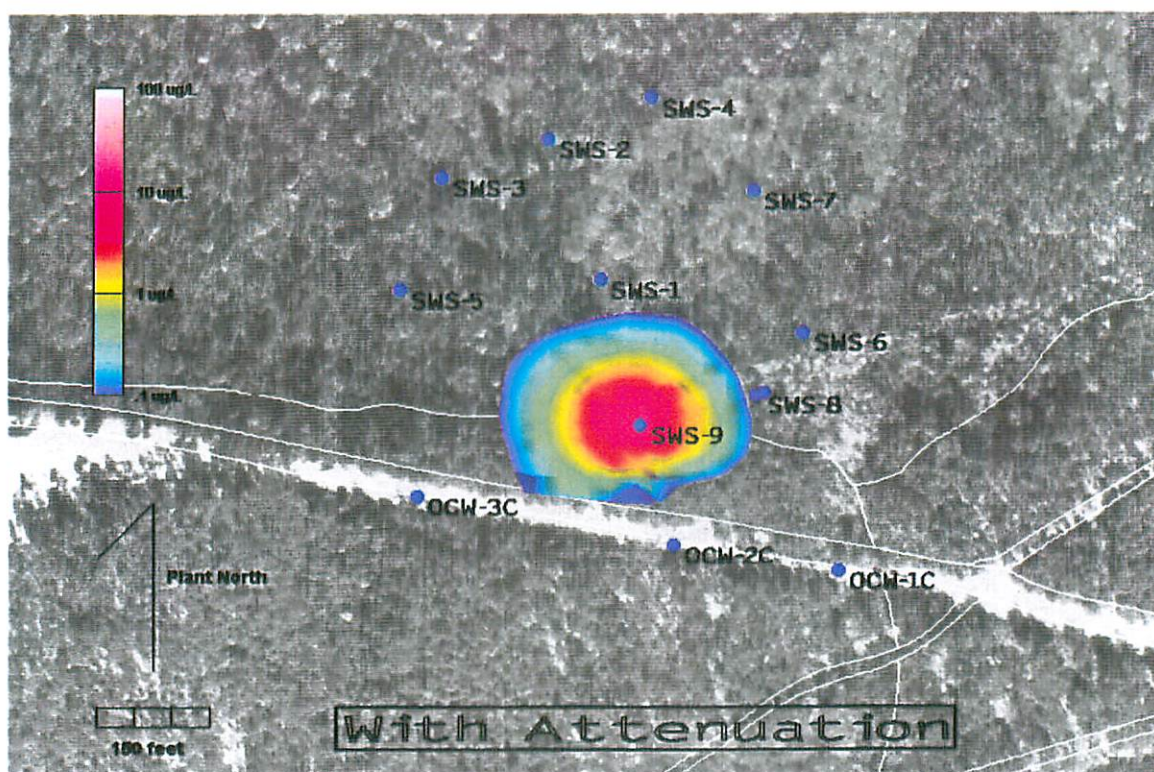
NC Groundwater Standard
 TCE Concentrations at Surface*
 TCE Concentrations at Depth**

* Concentrations in uppermost model layer (approximately 0.5 ft below the land surface) in the swampy area within the zone of highest predicted concentrations. NC surface-water standard for TCE (Class C) is 92.4 ug/L.

** Concentrations at a depth of approximately 15 feet below the land surface in the swampy area within the zone of highest predicted concentrations.

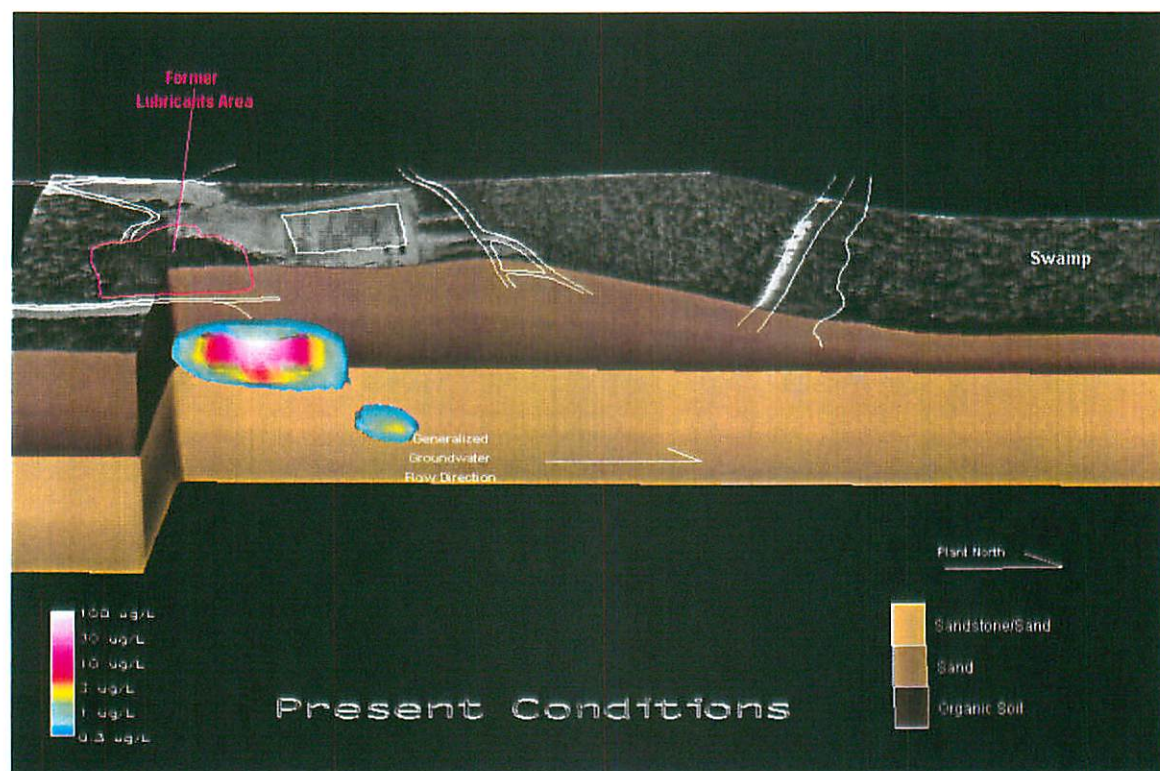
Note: Refer to Appendix G for information on groundwater flow and contaminant transport model development.

Figure 6-17 Maximum Predicted Surface Concentrations of TCE in Swampy Area With and Without Natural Attenuation



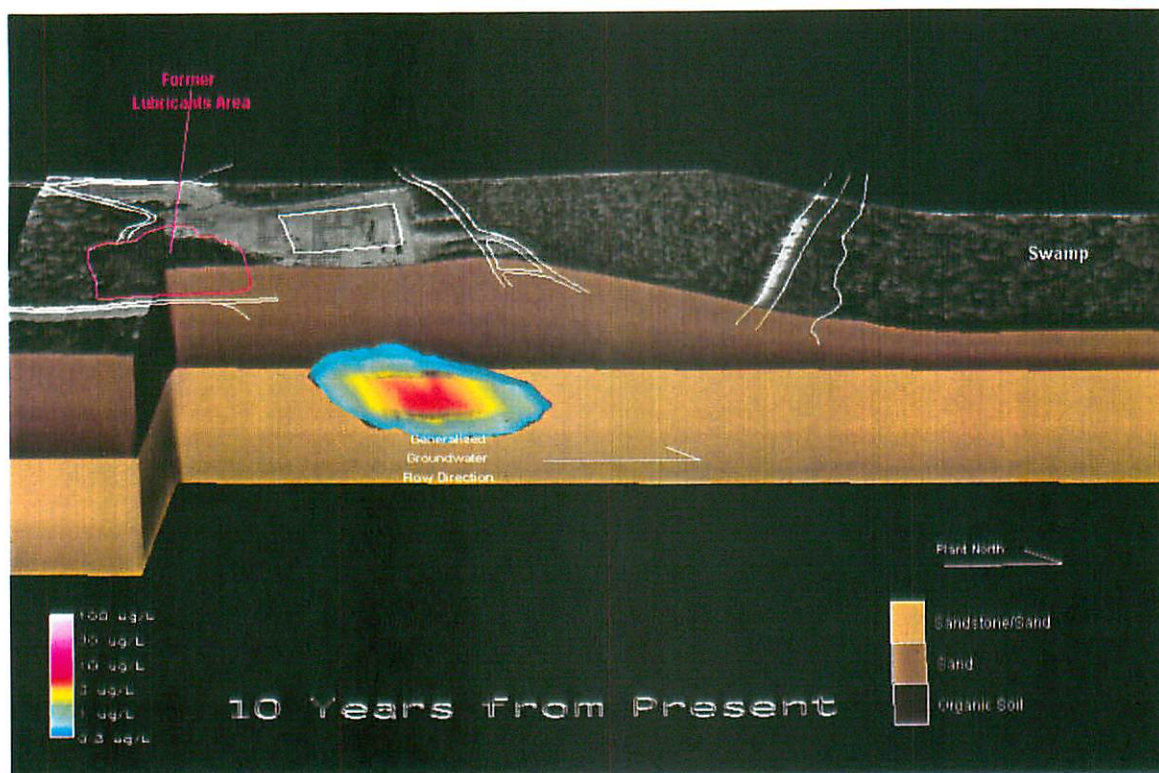
Note: Graphics indicate predicted maximum extent of contamination in uppermost model layer (0.5 feet below land surface). Maximum surface concentrations occurred after 18 and 3 years with and without attenuation, respectively, with the measured plume the initial conditions. Refer to Appendix G for information on model development.

Figure 6-18 Predicted Distribution of Vinyl Chloride ($>0.5 \mu\text{g/L}$) in Groundwater - 0 to 5 Years from Present - Northwest Site Area



Note: Refer to Appendix G for information on groundwater flow and transport model development.

Figure 6-19 Predicted Distribution of Vinyl Chloride ($>0.5 \mu\text{g/L}$) in Groundwater - 10 to 20 Years from Present - Northwest Site Area



Note: Refer to Appendix G for information on groundwater flow and transport model development.

Figure 6-20
Trends for Total Uranium in
CAF-A Series Wells - Former
NW-Calcium Fluoride Storage Area

EXPLANATION

● Monitoring well location and identifier
 CAF-5A

✦ Plant Coordinates

Note: Trends shown represent total uranium concentrations in unfiltered groundwater samples collected from 1/9/96 to 11/11/98. Analytical results used to develop trend charts are provided in Appendix C.

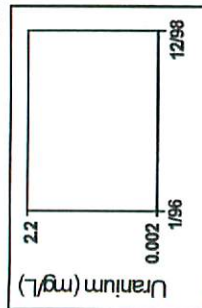
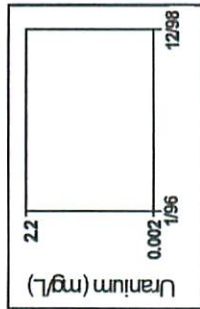
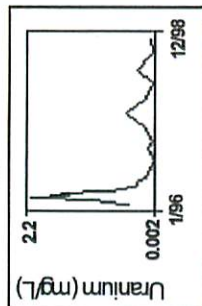
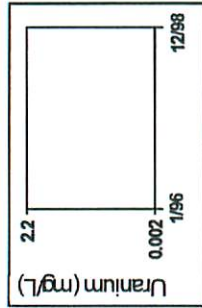
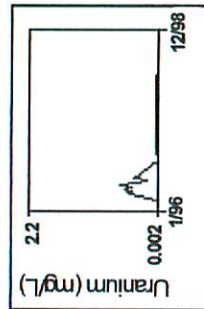
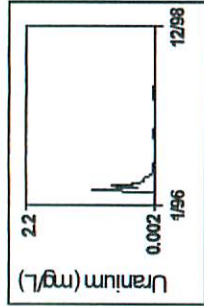
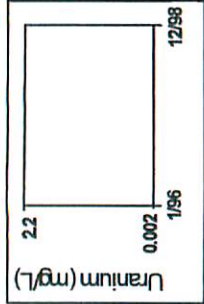
INSET NOT TO SCALE



NE Cape Fear River



PLANT NORTH



EB775
N6730

EB775
N6475

EB215
N6730

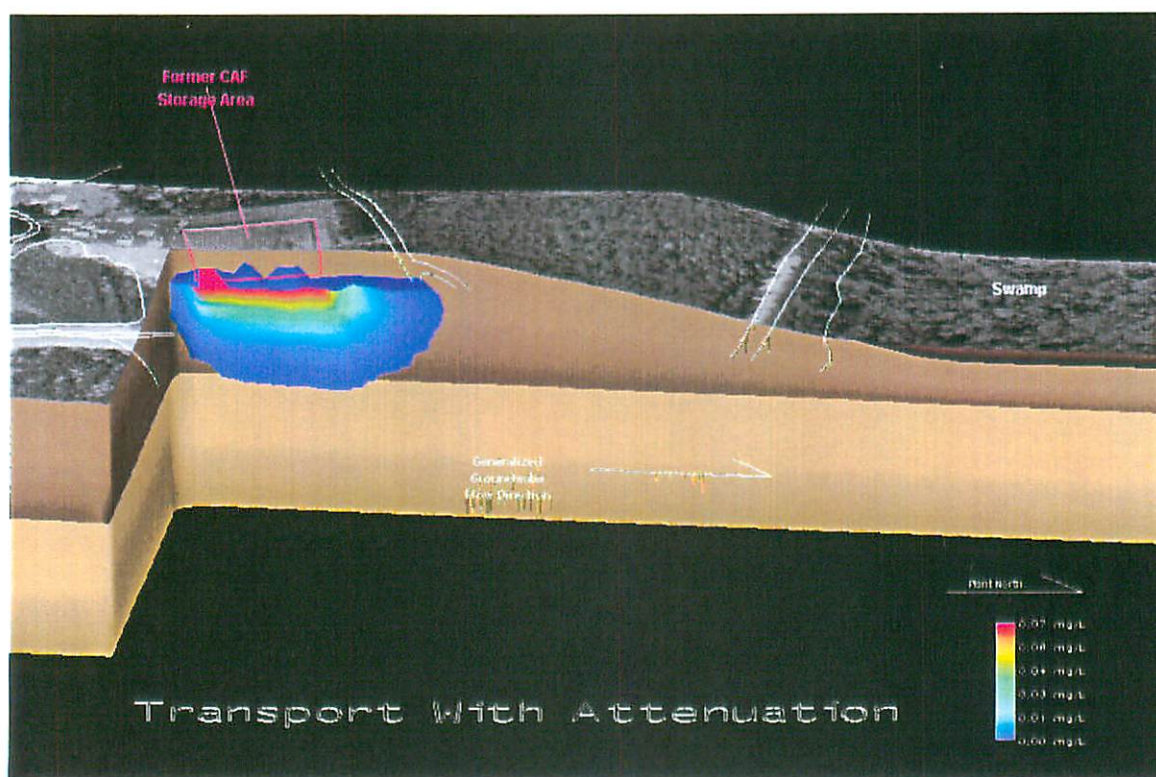
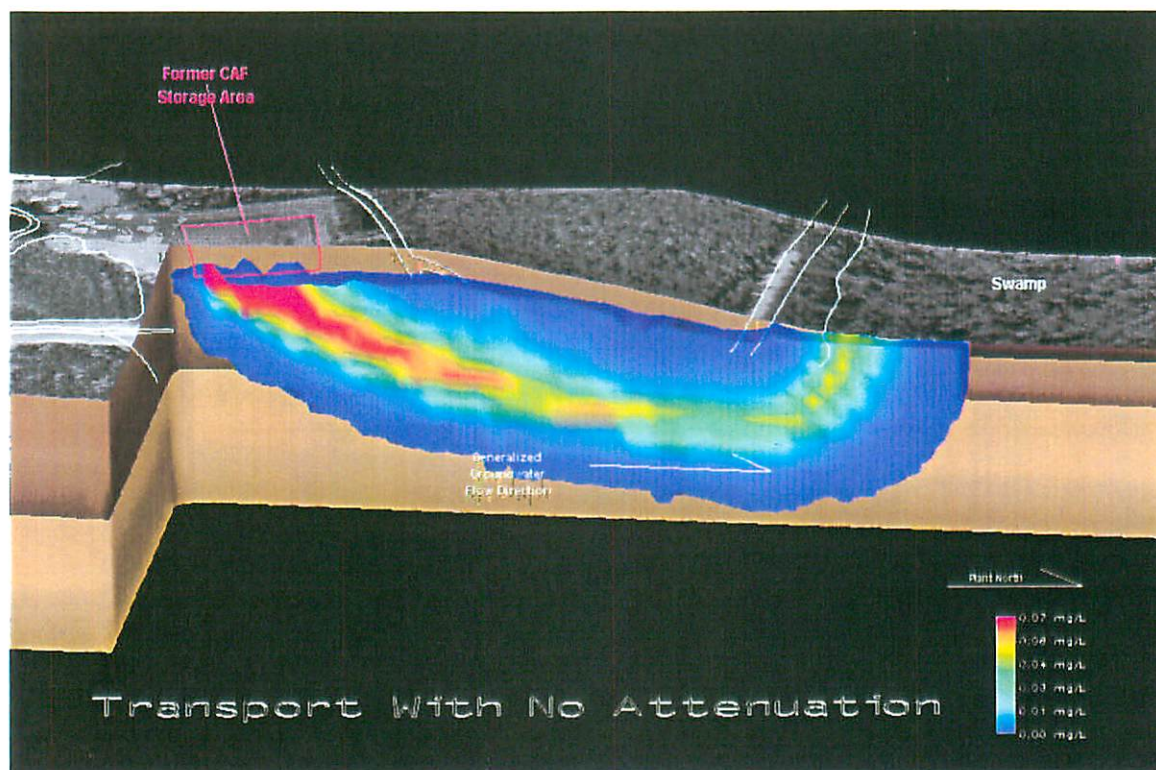
EB215
N6475

Former Calcium Fluoride Storage Area
 Generalized Groundwater Flow Direction

New Fence

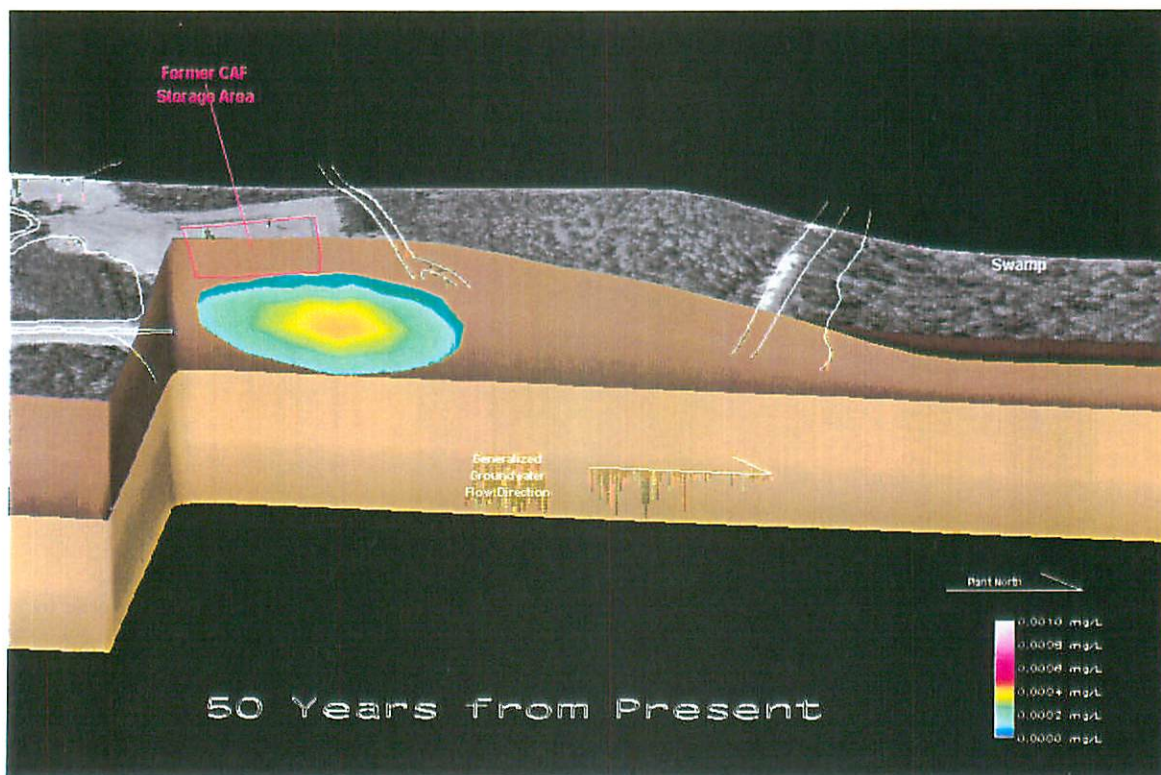
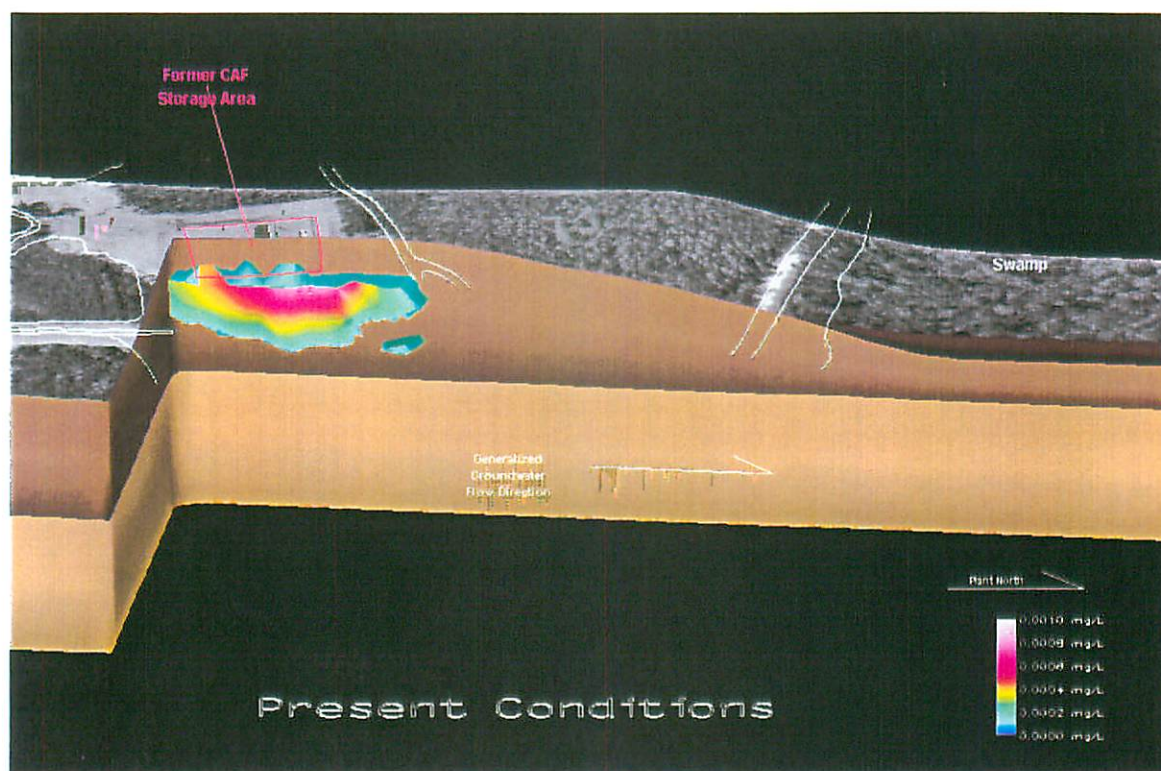


Figure 6-21 Modeled Distribution of $^{235}\text{Uranium}$ ($>0.00015\text{ mg/L}$) in Groundwater Without and With Natural Attenuation -- 30-Year Source Duration



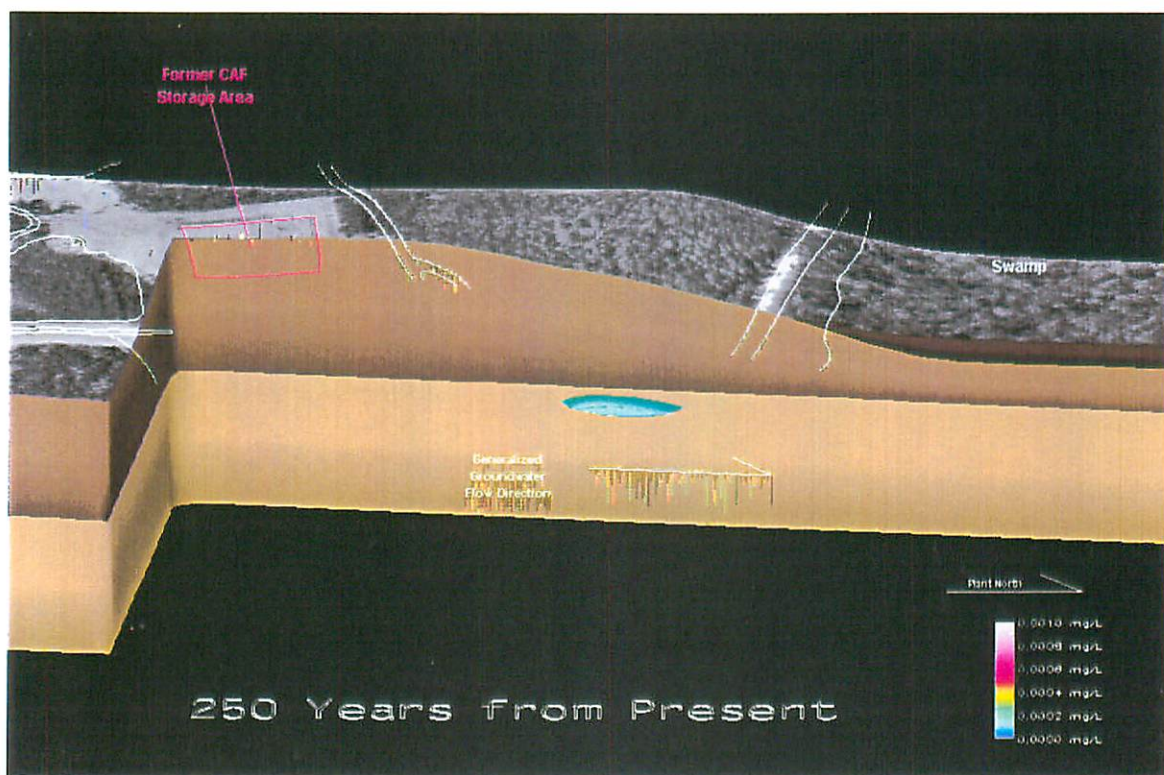
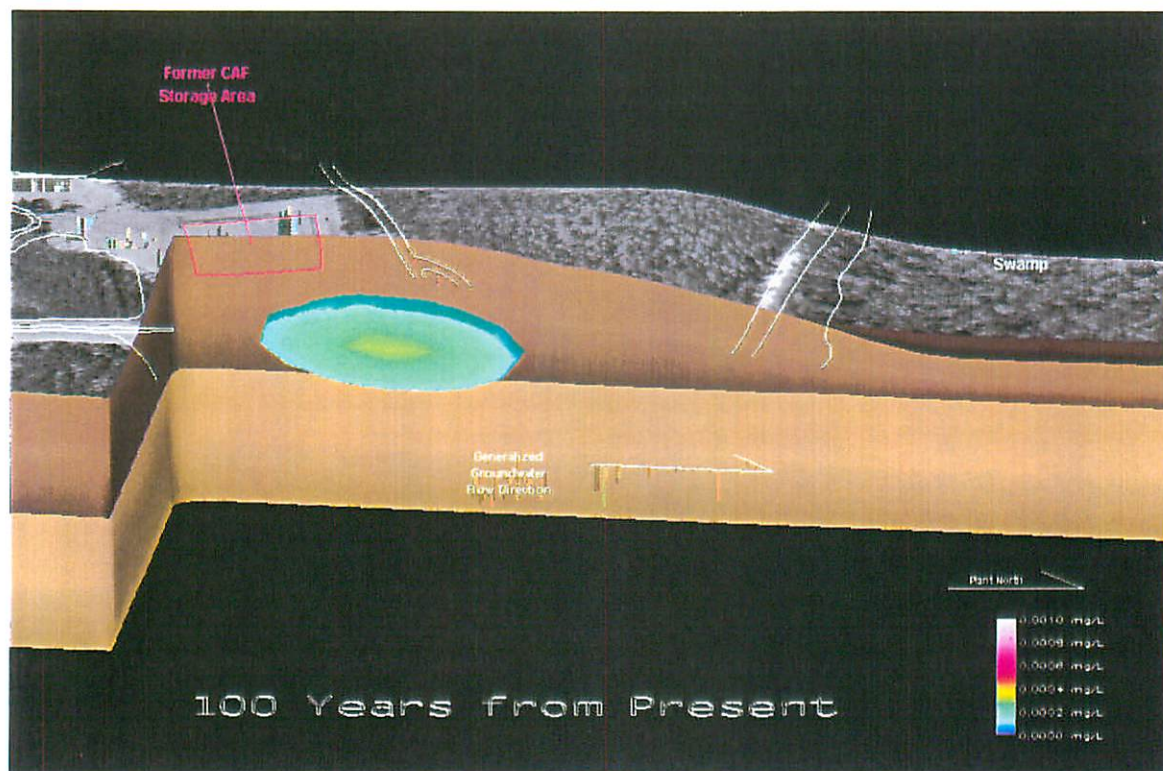
Note: Refer to Appendix G for information on groundwater flow and transport model development.

Figure 6-22 Predicted Distribution of $^{235}\text{Uranium}$ (>0.00015 mg/L) in Groundwater - 0 to 50 Years from Present - Northwest Site Area



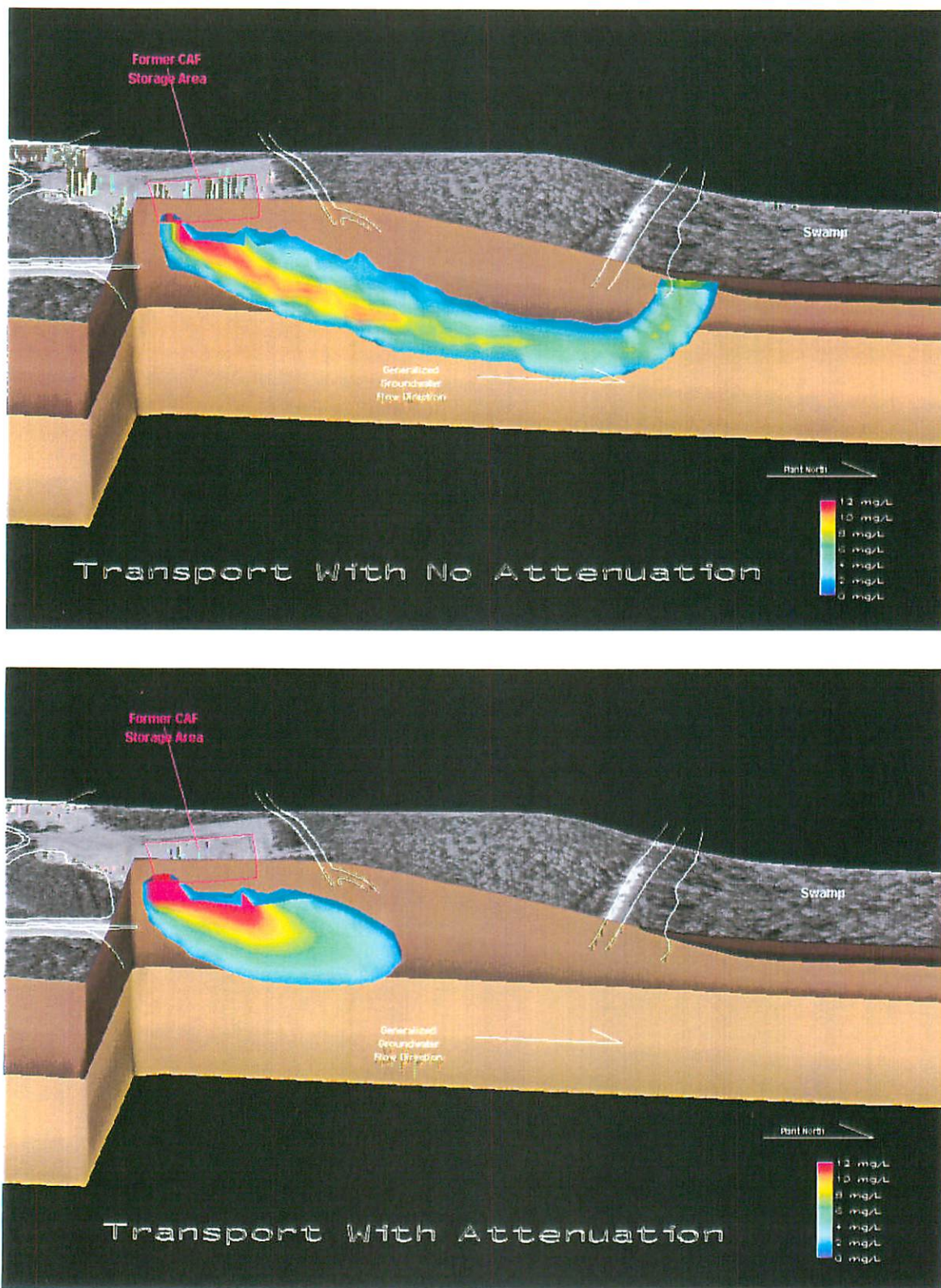
Note: Refer to Appendix G for information on groundwater flow and transport model development.

Figure 6-23 Predicted Distribution of $^{235}\text{Uranium}$ ($>0.00015\text{ mg/L}$) in Groundwater - 100 to 250 Years from Present - Northwest Site Area



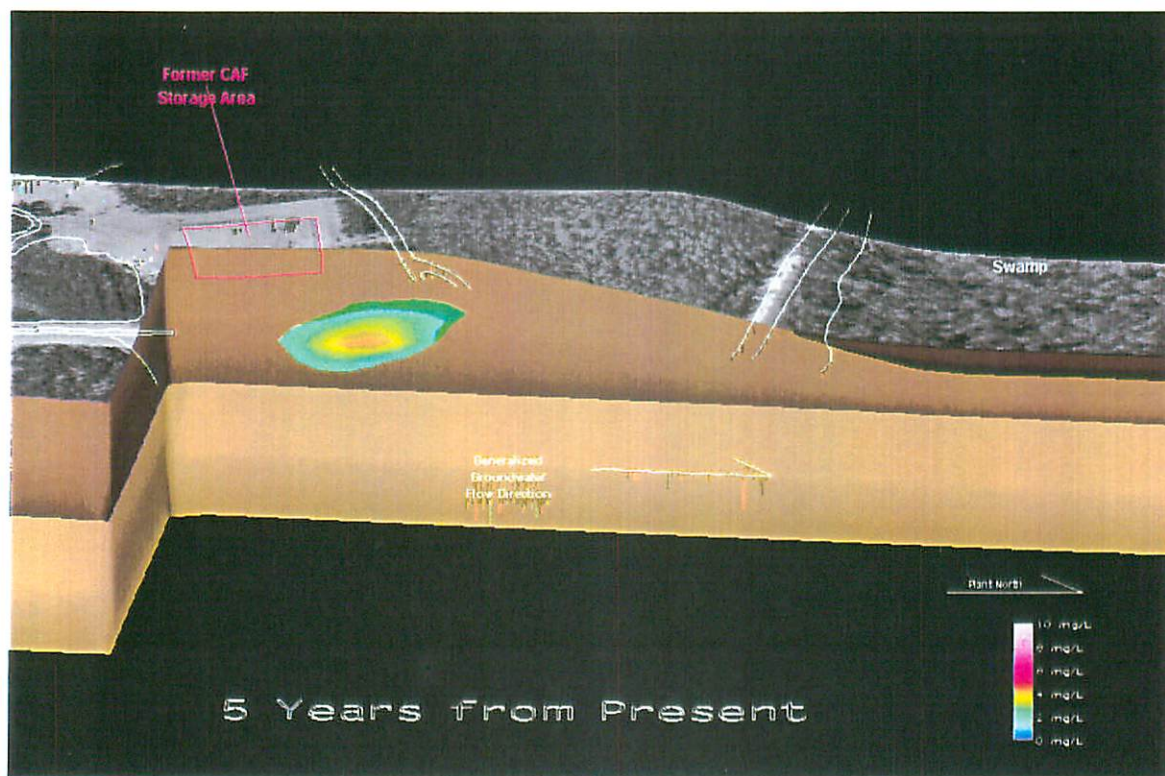
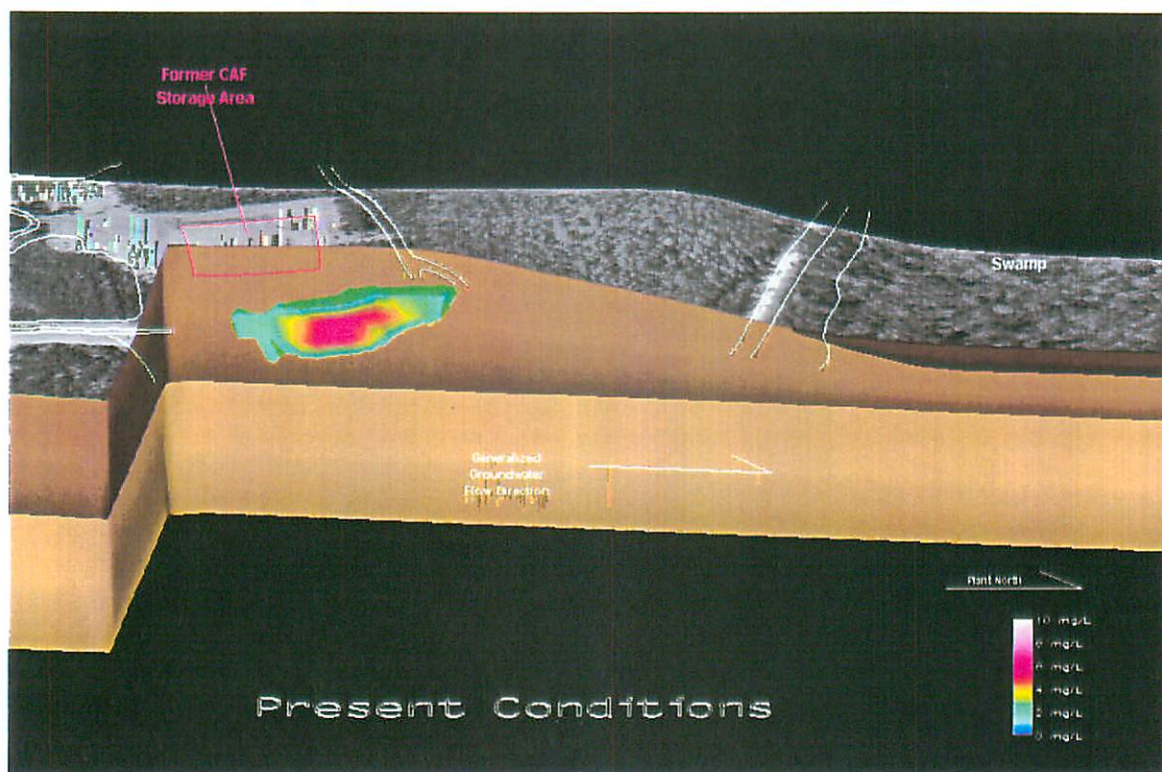
Note: Refer to Appendix G for information on groundwater flow and transport model development.

Figure 6-24 Modeled Distribution of Fluoride (>2 mg/L) in Groundwater Without and With Natural Attenuation -- 30-Year Source Duration



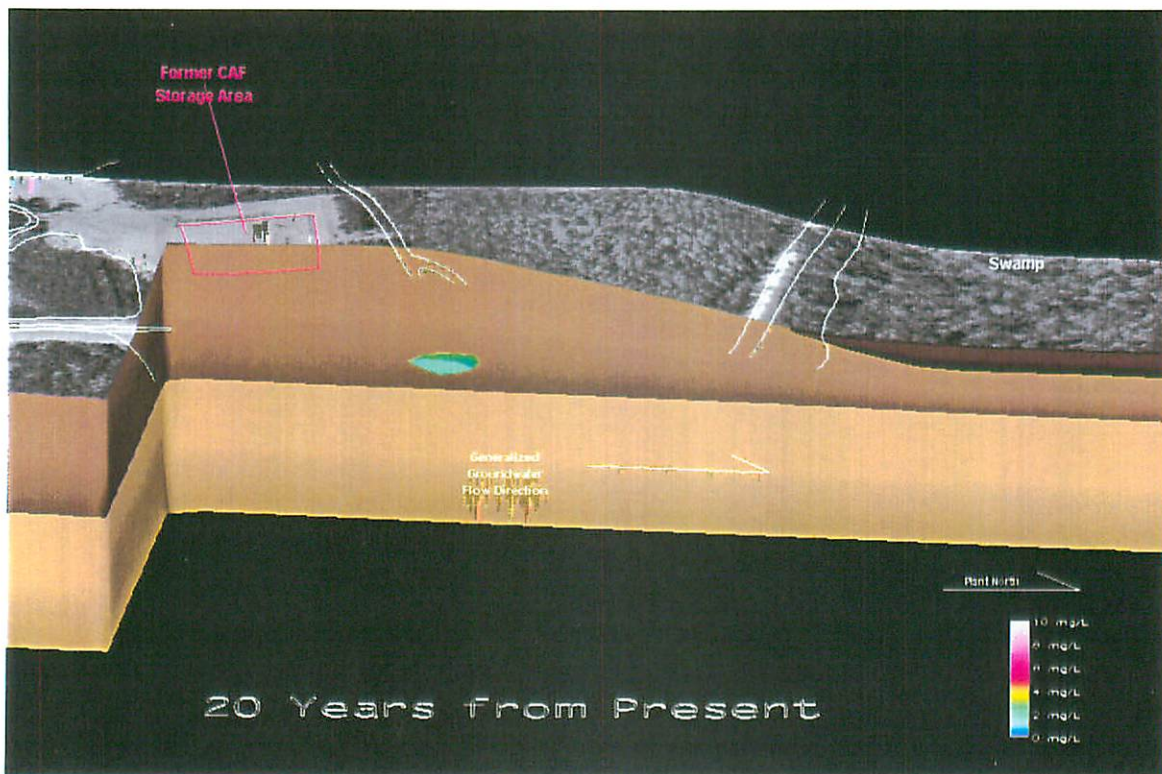
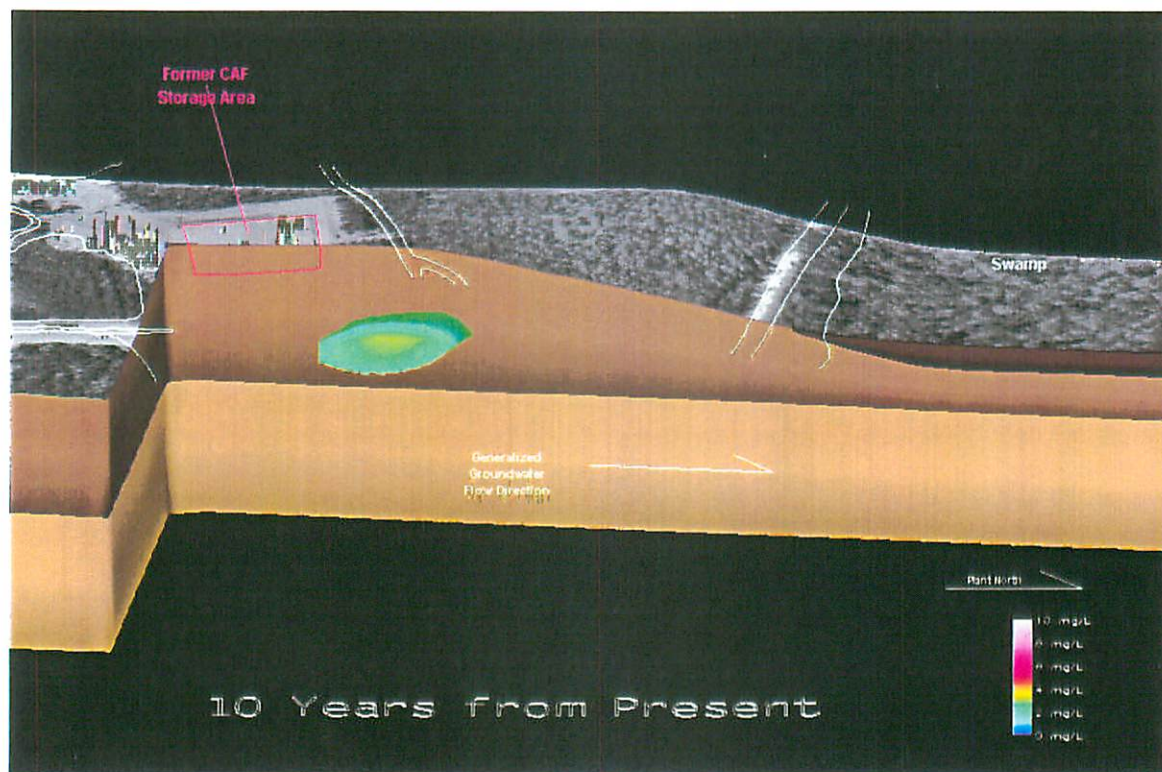
Note: Refer to Appendix G for information on groundwater flow and transport model development.

Figure 6-25 Predicted Distribution of Fluoride (>2 mg/L) in Groundwater - 0 to 5 Years from Present - Northwest Site Area

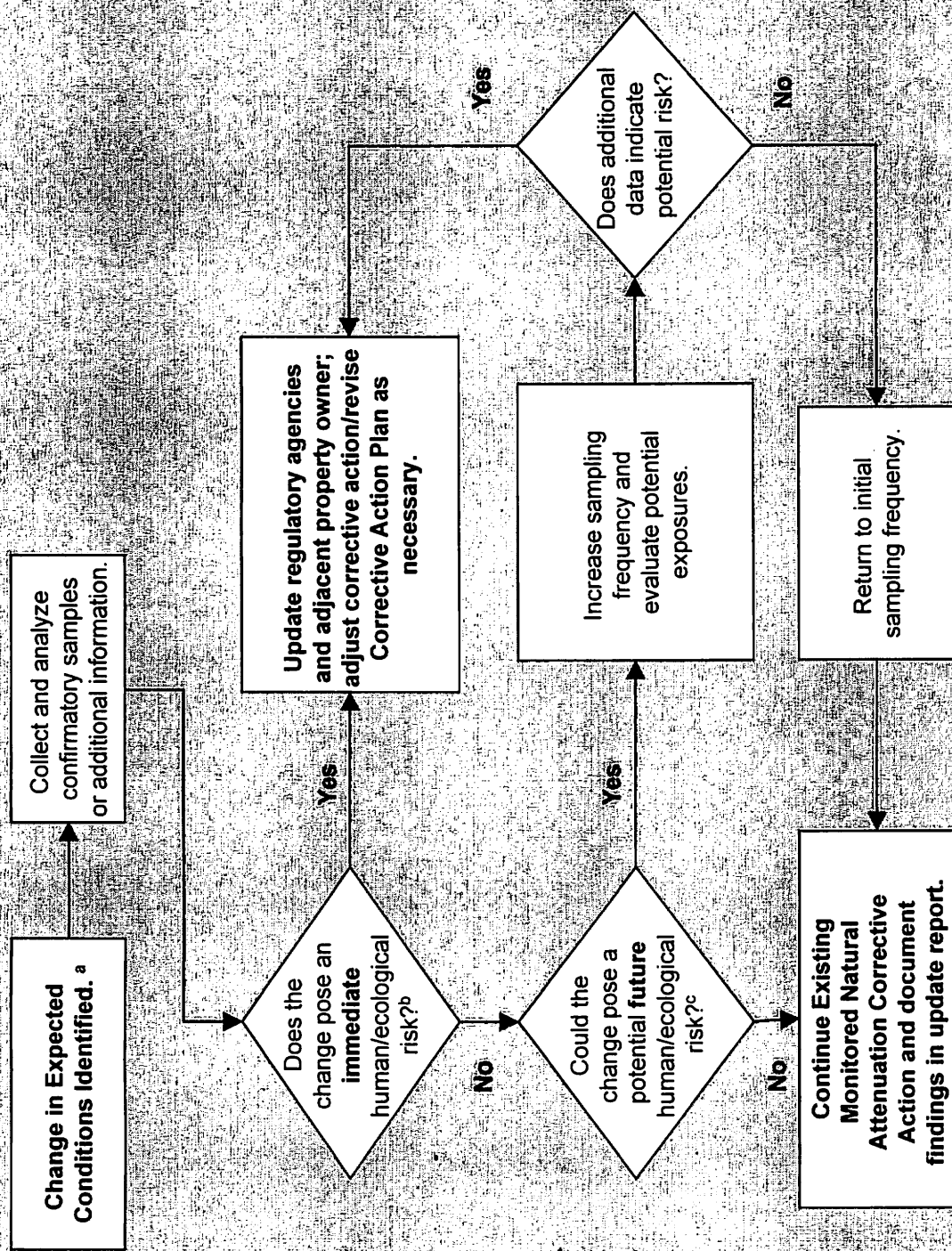


Note: Refer to Appendix G for information on groundwater flow and transport model development.

Figure 6-26 Predicted Distribution of Fluoride (>2 mg/L) in Groundwater - 10 to 20 Years from Present - Northwest Site Area



Note: Refer to Appendix G for information on groundwater flow and transport model development.



^a e.g., Changes in predicted levels of VOCs in surface water or groundwater, change in potential affected area ownership.

^b e.g., VOCs in excess of acute toxicity benchmarks.

^c e.g., Based on evaluation of analytical results modeling and potential exposure pathways/benchmarks.

Figure 7-1. Contingency Plan Flow Chart -- Northwest Site Area Natural Attenuation Corrective Action

Tables

Table 2-1. Summary of Assessment Activities - Northwest Site Area

Time Frame	Activity	Comments
February, 1993	Identification of former lubricants area and initial sampling of well OB-5.	VOCs detected in well OB-5. Well sampled 5 times between February 1993 and March 1994.
March, 1994	<i>Corrective Action Plan for Organic Compounds in Groundwater</i> (RTI, 1994) submitted to NC DENR.	Former lubricants area referenced as Area G.
October, 1994	GE initiates technical activities related to decommissioning of former NW-CaF ₂ storage area.	Technical approach for hydrogeologic characterization developed.
January-June, 1995	RTI begins hydrogeologic assessment of former NW-CaF ₂ storage area. A total of 13 CB-series borings drilled and 9 CPZ-series piezometers installed.	Assessment includes characterization of groundwater depth and flow direction, lithology, and initial source characterization.
April 6, 1995	Update Meeting with NC DENR	NC DENR notified of separate assessment of groundwater contamination by organic compounds <u>after</u> recovery of CaF ₂ material.
July, 1995	NFS conducts baseline sampling survey.	Characterization of baseline conditions at former NW-CaF ₂ storage area and along onsite transportation route prior to CaF ₂ recovery.
July, 1995	Three CB-series exploratory borings drilled downgradient of former NW-CaF ₂ storage area.	Porewater sampled in order to identify optimal screen intervals for wells to monitor inorganic contamination from former storage area.
September and December, 1995	New CAF-series monitoring wells installed.	Screen intervals based on results of porewater samples.
February, 1996	Routine sampling from CAF-series monitoring wells initiated.	Elevated uranium and fluoride concentrations noted in groundwater downgradient of former storage area
February, 1996	Geophysical survey completed in former NW-CaF ₂ storage area to investigate potential for buried metal objects and/or drums.	Some buried metal identified and located. Excavation at magnetic anomalies reveals no intact drums or other containers.

Table 2-1. Summary of Assessment Activities - Northwest Site Area (continued)

Time Frame	Activity	Comments
February, 1996	NFS conducts soil characterization within former NW-CaF ₂ storage area.	Purpose was to estimate volume of material above NRC limits to be excavated from former storage area.
February 27, 1996	Update Meeting with NC DENR	NC DENR provided with <i>Assessment and Recovery Activities Associated with the Northwest Calcium Fluoride Storage Area</i> (RTI Document No. 6103/014/01F).
February, 1996	Soil between CaF ₂ storage trenches sampled and analyzed for organic compounds and metals prior to excavation and offsite disposal.	No materials present at levels affecting offsite disposal of intertrench soils.
February-August, 1996	Excavation of CaF ₂ material and affected soil.	Over 12 million pounds of CaF ₂ and affected soil removed and archived in onsite warehouse.
March-April, 1996	Calculation of aquifer hydraulic conductivity	Calculations derived using multiple slug tests and regional flow patterns.
December 16, 1996	Update Meeting with NC DENR	NC DENR provided with <i>Technical Update of Hydrogeological and Groundwater Quality Conditions in the Vicinity of the Former NW-CaF₂ Storage Area</i> (RTI Document No. 6103/017/01F).
December, 1996 - February, 1997	Characterization of distribution coefficient (K _d) of uranium at former source area	Characterized using soil borings and wells installed in former storage area.
March, 1997	Surface-water, soil, and shallow swamp water samples collected downgradient of source areas	Evidence of VOC contamination in swamp identified.
March, 1997	One CB-series boring drilled for profiling of soil organic carbon	Soil organic carbon profile characterized.
March, 1997	Samples collected from CAF-series wells and analyzed for VOCs	VOCs detected only in easternmost CAF-series wells and CAF-11A
June-August, 1997	Five offsite and five onsite exploratory borings drilled.	Porewater samples collected and analyzed for organic and inorganic contaminants and to identify appropriate screen intervals for VOC monitoring wells.

Table 2-1. Summary of Assessment Activities - Northwest Site Area (continued)

Time Frame	Activity	Comments
August, 1997	Shallow swamp-water samples collected downgradient of source areas.	VOCs identified in swamp-water sample.
October, 1997	Two additional onsite (CB-series) exploratory borings drilled.	Borings drilled for characterization of VOCs in groundwater.
October 30, 1997	Update Meeting with NC DENR	NC DENR provided with <i>Update of Hydrogeological and Groundwater Quality Conditions in the Northwest Site Area</i> (RTI Document No. 6448-018/001/01F).
December, 1997	Geophysical survey conducted in former lubricants area (magnetic and electromagnetic surveys).	Survey performed to evaluate presence of drums prior to passive soil vapor investigation.
December, 1997 to January, 1998	Passive soil vapor (GORE-SORBER) survey performed in former lubricants area (44 locations)	Distribution of VOCs in former lubricants area delineated.
March, 1998	Two source area (CB-series) exploratory borings drilled in former lubricants area.	Contamination confirmed in former lubricants area.
May-June, 1998	Three additional offsite (OCB-series) exploratory borings drilled.	Borings installed to identify optimal placement of offsite wells (horizontally and vertically).
March-April, 1998	Two additional onsite CAF-series monitoring wells installed.	Wells installed upgradient and immediately downgradient of former lubricants area.
May 27, 1998	Update Meeting with NC DENR	NC DENR provided with <i>Update of Groundwater Quality Conditions in the Northwest Site Area</i> (RTI Document No. 6448-018/002/01F). Groundwater monitoring guideline value presented.
May-July, 1998	Seven offsite (OCW- and OSW-series) monitoring wells installed	Wells installed for monitoring of organic and inorganic constituents.
August 1998	Initial sampling of offsite and onsite wells in NW site area conducted.	Wells sampled for VOCs and inorganic constituents. Horizontal and vertical extent of groundwater contamination identified.
December 1998	Comprehensive Site Assessment for Northwest Site Area (CSA) submitted to DENR Wilmington Regional Office.	RTI Report No. 6448-018/003/01F submitted by GE on December 15, 1998.
January 1999	Additional aquifer permeability testing and natural-attenuation analyses.	Refer to Appendix B for slug-testing info and Section 6 for site-specific natural-attenuation data.

Table 4-1a. Summary of Inorganic Analyses From SWS-Series Sampling Points

Sample Location	Sample Date	Fluoride (mg/L)	Total Uranium (mg/L)		Gross Alpha (pCi/L)		Gross Beta (pCi/L)	
			Unfiltered	Filtered	Unfiltered	Filtered	Unfiltered	Filtered
SWS-1	8/19/97		<0.00015					
	11/11/98	0.02	0.000517	<0.00015	2	2	2.6	2
SWS-2	8/19/97		0.000384					
SWS-3	8/19/97		0.00041					
SWS-4	8/19/97		<0.00015					
SWS-5	8/20/97		<0.00015					
SWS-6	8/20/97		0.000263					
	11/11/98	0.06	0.000448	0.000253	2	3	24	14
SWS-7	8/20/97		0.000226					
SWS-8	8/11/98	0.05	<0.00015	<0.00015	4	4	3	3
	11/11/98	0.02	<0.00015	<0.00015	2	2	4.8	3.4
SWS-9	8/12/98	<0.02	0.00491 ^a	0.000462	2	2	3	3
	11/11/98	<0.02	0.000832	<0.00015	2	2	2.6	2

Shaded areas indicate samples not collected.

^aNeither ²³⁴U nor ²³⁵U detected in sample.

Table 4-1b. Summary of VOC Analyses From SWS-Series Sampling Points

Sample Location	Sample Date	TCE	cis-1,2-DCE	1,1-DCE	1,1-DCA	Toluene
SWS-1	8/19/97	<0.5	1.1	<0.5	<0.5	<0.5
	11/11/98	<0.5	<0.5	<0.5	<0.5	<0.5
	1/11/99	<0.5	0.65	<0.5	<0.5	<0.5
SWS-2	8/19/97	<0.5	<0.5	<0.5	<0.5	<0.5
	1/11/99	<0.5	<0.5	<0.5	<0.5	3.9
SWS-3	8/19/97	<0.5	<0.5	<0.5	<0.5	<0.5
SWS-4	8/19/97	<0.5	<0.5	<0.5	<0.5	<0.5
	1/11/99	<0.5	<0.5	<0.5	<0.5	<0.5
SWS-5	8/20/97	<0.5	<0.5	<0.5	<0.5	<0.5
SWS-6	8/20/97	<0.5	<0.5	<0.5	<0.5	<0.5
	11/11/98	<0.5	<0.5	<0.5	<0.5	<0.5
	1/11/99	<0.5	<0.5	<0.5	<0.5	<0.5
SWS-7	8/20/97	<0.5	<0.5	<0.5	<0.5	<0.5
	1/11/99	<0.5	<0.5	<0.5	<0.5	<0.5
SWS-8	7/14/98	<0.5	(0.15)	<0.5	<0.5	<0.5
	8/11/98	<0.5	<0.5	<0.5	<0.5	5.99
	11/11/98	<0.5	<0.5	<0.5	<0.5	<0.5
	1/11/99	<0.5	(0.12)	<0.5	<0.5	<0.5
SWS-9	8/12/98	30.4	562	1.09	(0.30)	(0.37)
	11/11/98	<0.5	8.47	<0.5	<0.5	<0.5
	1/11/99	(0.34)	440	<0.5	<0.5	15.0
	1/29/99	<0.5	251	<0.5	(0.37)	<0.5

Note: Values in parentheses are estimated concentrations between the minimum detection limit and the practical quantitation limit.

All values have units of ug/L.

DCE = dichloroethylene

DCA = dichloroethane

TCE = trichloroethylene

Table 4-1c. Summary of VOC Analyses From Standing-Water Sample (Surface Water)

Sample Location	Sample Date	TCE	cis-1,2-DCE	1,1-DCE	1,1-DCA	Toluene
SW-4	1/29/99	4.02	35.1	<0.5	<0.5	<0.5

All values have units of ug/L.

DCE = dichloroethylene

DCA = dichloroethane

TCE = trichloroethylene

Table 4-2. Published Benchmark Concentrations for Potential Ecological Receptors

Type of Effect	Effect Level	Benchmark	Units	Comments	Source
Trichloroethylene					
Piscivorous Mammals	Chronic	105 (Mink) 823 (River Otter)	µg/L (water) µg/L (water)	Based on induction of hepatic effects. Derived from LOAEL of 100 mg/kg-d. Normalizing for dose over duration and uncertainty factors (e.g., LOAEL to NOAEL and subchronic to chronic) lowered the value.	ORNL, 1996b
Amphibian	Acute	89,400	µg/L (water)	Based on the geometric mean of amphibian LC ₅₀ values measured in early life stage exposures.	EPA, 1996c
Soil Invertebrates	Chronic	79	mg/kg (soil)	Soil benchmark derived from LC ₂₅ for earthworm exposures to TCE.	CCME, 1997
Terrestrial Plants	Chronic	14	mg/kg (soil)	Terrestrial plant benchmark is based on the lowest LOEC identified for plants based on growth endpoints.	CCME, 1997
Aquatic Community	Acute	440	µg/L (water)	Secondary acute value derived using the NAWQC methodology. Data were not sufficient to develop a FAV.	ORNL, 1996a
Aquatic Community	Chronic	47	µg/L (water)	Secondary chronic value derived using the NAWQC methodology. Data were not sufficient to develop a FCV.	ORNL, 1996a
1,2-Dichloroethylene (both <i>cis</i> and <i>trans</i> isomer)					
Piscivorous Mammals	Chronic	2,990 (Mink) 23,500 (River Otter)	µg/L (water) µg/L (water)	Based on altered blood chemistry, organ weight, and hepatic function over a 90-day exposure duration. Derived from a subchronic NOAEL of 452 mg/kg-d. Application of uncertainty factors (e.g., subchronic to chronic) lowered the value.	ORNL, 1996b
Aquatic Community	Acute	1,100	µg/L (water)	Secondary acute value derived using the NAWQC methodology. Data were not sufficient to develop a FAV.	ORNL, 1996a
Aquatic Community	Chronic	590	µg/L (water)	Secondary chronic value derived using the NAWQC methodology. Data were not sufficient to develop a FCV.	ORNL, 1996a

LOAEL = Lowest Observed Adverse Effects Level

FCV = Final Chronic Value

LOEC = Lowest Observed Effects Concentration

LC_x = Lethal Concentration, where x is percent of population affected.

NOAEL = No Observed Adverse Effects Level

NAWQC = National Ambient Water Quality Criteria

FAV = Final Acute Value

Table 4-3. Comparison of VOC Concentrations in Swamp-Water Samples to Proposed Environmental Benchmarks

Sample Date	Sample Location				Published Benchmarks ^a (Aquatic Community - Acute)		Published Benchmarks ^a (Aquatic Community - Chronic)		Water-Quality Standards (WQSs) for Human Health ^b	
	SWS-9 (Swamp Pore Water [Groundwater])		SW-4(Swamp Standing Water [Surface Water])							
	TCE	cis-1,2-DCE	TCE	cis-1,2-DCE	TCE	cis-1,2-DCE	TCE	cis-1,2-DCE	TCE	cis-1,2-DCE
	8/12/98	30.4	562	--	--					
11/11/98	<0.5	8.47	--	--						
1/11/99	(0.34)	440	--	--	440	1,100	47	590	92.4	7,057
1/29/99	<0.5	251	4.02	35.1						

All units are ug/L.

-- = Sample not collected.

DCE = Dichloroethylene

TCE = Trichloroethylene

Values in parentheses are estimated concentrations between the minimum detection limit and the practical quantitation limit.

^a ORNL, 1996a

^b WQS for cis-1,2-DCE developed based on equation presented in Title 15A of the NC Administrative Code (T15A NCAC) Section 2B .0208 (a)(2)(A)(i) for fish-tissue consumption only. WQS value for TCE (fish-consumption) based on T15A NCAC 2B .0208 (a)(2)(B)(ix).

Table 5-1. NC DENR Conditions for Approval of a Natural-Attenuation CAP

Condition/Requirement per §.0106(l)	Applicability/Status in Northwest Site Area CAP
Documentation that the groundwater in the area of the plume has not been identified for future use or development by State or local planning agencies.	Development of adjacent property and associated groundwater use not planned by property owner or local water-supply officials (Section 4.3).
Sources of contamination and free product have been removed or controlled.	Former source areas controlled or not continuing as described in Section 3.0.
The contaminant must have the capacity to degrade or attenuate under site-specific conditions.	Technical information regarding contaminant degradation and attenuation provided in Section 6.0.
The time and direction of contaminant travel can be predicted with reasonable certainty.	Groundwater flow direction and velocity are described in CSA and in Section 2.0 and Appendix G of CAP.
Contaminant migration will not result in any violation of groundwater standards at any existing or foreseeable receptor.	No human receptors of groundwater contamination identified. Evaluation of potential risks from VOC plume migration to swampy area in Sections 4.5 and 6.0.
The contamination has not or will not migrate onto adjacent properties, or if so it: (1) has/will do so with consent of the adjacent property owner, or (2) the properties are served by an existing public water supply system.	Consent of adjacent property owner obtained (Section 4.4 and Appendix E).
Groundwater discharge may not result in a violation of a surface-water quality standard.	Contamination not detected in samples from downgradient stream (Section 4.2). Localized occurrence of VOCs detected in swampy-area standing water as described in Sections 4.5 and 6.0. Measured and predicted concentrations of VOCs in wetland surface water not expected to exceed lowest chronic aquatic ecotoxicity benchmarks and therefore surface-water standards (Sections 4.5 and 6.0)
A monitoring program sufficient to track the migration, degradation, and attenuation of the plume must be included.	Included in Section 7.0 and Appendices H and I.
Access to adjacent property for monitoring must be agreed to in writing.	Adjacent property access agreement provided in Appendix E.

Table 5-2. EPA Considerations for Evaluating a MNA Corrective-Action Approach

MNA Considerations Described in EPA Directive (EPA, 1997)	Applicability/Status in Northwest Site Area CAP
Whether the contaminants present can be effectively remediated by natural attenuation processes.	Discussed in Section 6.0.
Whether resulting transformation products pose a greater risk than parent contaminants.	No human receptors identified. Greater risk from transformation products not expected.
The source(s) of contamination have been or can be adequately controlled.	Former source areas controlled or not continuing to impact groundwater quality as described in Section 3.0.
Whether the plume is relatively stable and the potential for environmental conditions to change.	Technical issues relating to MNA presented in Section 6.0.
The impact of active remediation on the MNA component of the remedy.	Source removal at former NW-CaF ₂ storage area supports MNA of inorganic constituents.
Whether drinking water supplies, or other environmental resources could be adversely impacted as a result of the MNA option.	No drinking-water receptors of contamination identified as described in Section 4.3.
Whether the time frame of remediation is reasonable compared to more active methods.	Alternative active remediation methods may require decades of operation without reducing risks to health/environment.
Current and projected demand on the aquifer over the time frame that the remedy will remain in place.	Area downgradient of contamination not likely to be developed due to presence of wetlands.
Whether site-specific vehicles for and responsible institutions for implementing institutional controls are available.	Not applicable per NC regulations (or NRC regulations regarding free release of former NW-CaF ₂ storage area).

**Table 6-1. Summary of Natural-Attenuation Parameters Measured
in January 1999 - Northwest Site Area**

Well ID	Date Sampled	pH	Temperature (C)	DO (mg/L)	ORP (mV)	Ferrous Iron (mg/L)	Sulfate (mg/L)	Chloride (mg/L)	Alkalinity (mg/L)	TOC (mg/L)	Methane (mg/L)	Ethane (mg/L)	Ethane (mg/L)
CAF-5A	01/14/99	4.9	19.4	7.76	250	0	0	8	0	1.43	NM	NM	NM
CAF-5B		6.2	20	1.11	195	0	4	10	20	7.34	NM	NM	NM
CAF-6A	01/12/99	6.86	19.2	3.75	235	0	0	10	29	2.68	NM	NM	NM
CAF-6B		7.9	19.8	2.95	200	0	0	13	37	6.26	NM	NM	NM
CAF-7A		6.6	19.2	2.4	245	NM	0	10	25	4.93	NM	NM	NM
CAF-7B	01/14/99	7	19.8	0.68	225	0	10	7	38	6.18	NM	NM	NM
CAF-8A		7.7	18.3		220	0	1940	6	0	2.52	NM	NM	NM
CAF-8B		8	19.1	1.11	240	0	0	7	35	4.51	ug/L	<5	<5
CAF-9A	01/15/99	6.3	17.9	3.11	205	0	7	11	18	3.35	NM	NM	NM
CAF-9B		6.2	19.4	0.5	230	0	0	7	32	4.68	ug/L	<5	<5
CAF-10A		6.2	15.3	1.18	15	1.6	266	7	98	14.4	NM	NM	NM
CAF-10B		4.9	18.6	1.04	70	5	112	9	0	5.34	NM	NM	NM
CAF-11A	01/14/99	5.5	15.8	2.07	200	0	0	5	8	3.01	NM	NM	NM
CAF-11B		4.7	18.1	0.45	230	0	25	8	0	2.22	NM	NM	NM
CAF-12A		6.8	18.5	2.1	195	0	0	10	21	4.84	NM	NM	NM
CAF-16C	01/15/99	7.2	17.6	0.81	-50	0.2	0	6	133	3.85	1.285 ug/L	34	<5
CAF-17C		6.6	17.5	0.88	-35	5	0	13	358	21	5.72 mg/L	132	720
LF-3A		4.47	17.5	1.03	175	1.2	4	7	0	6.18	NM	NM	NM
LF-3B	01/13/99	6.01	18.3	1.86	15	2.4	0	4	39	3.35	NM	NM	NM
OB-5		6.6	18.6	2.11	-70	4.2	0	12	199	10.8	2.15 mg/L	560	4,172
OCW-1C		7.5	17.3	1.45	-70	1.2	0	8	166	5.09	2.838 ug/L	9	<5
OCW-2C	01/12/99	6.9	17.2	0.34	-5	2	7	5	142	6.84	0.41 mg/L	54	552
OCW-3C	01/13/99	7.64	17.1	0.99	-70	0.6	21	4	141	1.6	ug/L	20	16
OCW-4A		4.9	18.1	4.88	340	0	0	8	0	1.35	1.397 ug/L	<5	<5
OCW-4B	01/12/99	6.6	18.6	3.5	265	0	0	8	6	2.85	2.066 ug/L	<5	<5
OCW-5D		7.6	17.8	1.15	-15	0.6	0	6	168	5.26	ug/L	41	94
OSW-1A		7.09	16	0.67	-40	0.6	0	6	162	2.52	0.10 mg/L	31	9
SWS-1		6.55	12.3	0.81	35	NM	0	7	16	13.4	mg/L	<5	9
SWS-2		6.9	10.8	0.83	-70	0	0	10	132	16.1	8.37 mg/L	<5	<5
SWS-4		6.31	7.7	1.6	-70	0	0	9	55	19.8	8.12 mg/L	<5	<5
SWS-6	01/11/99	6.4	11.2	0.24	-35	2	0	9	132	9.84	3.66 mg/L	<5	<5
SWS-7		6.3	10.8	0.46	-15	1.7	0	9	132	14.1	7.92 mg/L	<5	<5
SWS-8		6.67	10.8	0.37	-70	0.8	0	8	127	9	2.1 mg/L	32	8
SWS-9		6.52	11.6	1.34	-5	0	0	6	12	3.82	3.07 mg/L	<5	129

DO = Dissolved oxygen.

NM = Not measured.

ORP = Oxidation-reduction potential

TOC = Total organic carbon.

Table 6-2. Quantitative Screening of Anaerobic Degradation Evidence in Northwest Site Area (based on EPA, 1998a)

Analyte	Concentration Range (in most concentrated zone)	Interpretation	Value (points)	NW Site Area Wells	
				CAF-17C	OCW-2C
Oxygen*	<0.5 mg/L	Anaerobic degradation tolerated, suppresses the reductive pathway at higher concentrations.	3	0	3
Oxygen*	<5 mg/L	Not tolerated; however, vinyl chloride may be oxidized aerobically.	-3	0	0
Nitrate*	>1 mg/L	At higher concentrations may complete with reductive pathway.	2	2	2
Iron II*	>1 mg/L	Reductive pathway possible; vinyl chloride may be oxidized under Fe(III)-reducing conditions.	3	3	3
Sulfate*	<20 mg/L	At higher concentrations may complete with reductive pathway.	2	2	2
Methane*	<0.5 mg/L >0.5 mg/L	Vinyl chloride oxidizes Ultimate reductive daughter product, vinyl chloride accumulates.	0 3	3	3
Oxidation Reduction Potential* (ORP) against Ag/AgCl electrode	<50 millivolts (mV) <-100 mV	Reductive pathways possible. Reductive pathway likely. <i>ORP measurements for CAF-17C and OCW-2C out of instrument range (-70 mV).</i>	1 2	2	2
pH*	5 < pH < 9 5 > pH > 9	Optimal range for reductive pathway. Outside optimal range for reductive pathway.	0 -2	0	0
TOC	> 20 mg/L	Carbon and energy sources; drives dechlorination; can be natural or anthropogenic.	2	2	0
Temperature*	>20°C	At T > 20°C biochemical process is accelerated.	1	0	0
Alkalinity	>2x background	Results from interaction between CO ₂ and aquifer minerals.	1	1	1

Table 6-2. Quantitative Screening of Anaerobic Degradation Evidence in Northwest Site Area (based on EPA, 1998a)
(continued)

Analyte	Concentration Range (in most concentrated zone)	Interpretation	Value (points)	NW Site Area Wells	
				CAF-17C	OCW-2C
BTEX*	> 0.1 mg/L	Carbon and energy source; drives dechlorination.	2	0	0
Trichloroethene*	--	Material released. Daughter product of tetrachloroethylene.	0 2	0	0
DCE*	--	Material released. Daughter product of TCE. If cis is > 80% of total DCE it is likely a daughter product 1,1-DCE can be chemical reaction product of TCA.	0 2	2	2
Vinyl Chloride*	--	Material released. Daughter product of DCE.	0 2	2	0
Ethene Ethane	>0.01 mg/L >0.01 mg/L	Daughter product of VC/ethene	2 3	2	0
Totals				21	18

* Required analysis.

Interpretation of Quantitative Screening Points (based on EPA, 1998a)

0 to 5 points	Inadequate evidence of reductive chlorination
6 to 14 points	limited evidence of reductive chlorination
15 to 20 points	Adequate evidence of reductive chlorination
>20 points	Strong evidence of reductive chlorination

Table 6-3. Summary of VOC Transport Parameters

Parameter	cis-1,2 DCE	TCE	Vinyl Chloride
Constituent Octanol-Water Distribution Coefficient (K_{ow})	30	195	13
Constituent Organic Carbon Distribution Coefficient (K_{oc}) (liter/kg)	46	177	25
Sand Organic Carbon Fraction (f_{oc})	0.001	0.001	0.001
Sand Distribution Coefficient (K_d) (L/kg)	0.046	0.177	0.025
Sand Retardation Coefficient (R)	1.2	1.9	1.1
Swamp Organic Carbon Fraction (f_{oc})	0.25	0.25	0.25
Swamp Distribution Coefficient (K_d) (L/kg)	11.5	44.2	6.29
Swamp Retardation Coefficient (R)	60.7	231	33.7
Longitudinal, Horizontal, Vertical Dispersivities (feet)	4, 0.3, 0.01	4, 0.3, 0.01	4, 0.3, 0.01
Biodegradation Rate (year ⁻¹)	0.2	0.11	0.16
Biodegradation Half Life (year)	3.5	6.3	4.3

Table 6-4. Predicted Maximum ²³⁵U and Estimated Total Uranium Concentrations in Groundwater - Northwest Site Area

Year	Maximum Simulated ²³⁵ U (mg/L)	Estimated Total Uranium ^a (mg/L)
0	0.0012	0.055
10	0.0008	0.036
20	0.0007	0.032
30	0.0006	0.027
40	0.0005	0.023
50	0.0005	0.023
60	0.00045	0.020
70	0.00035	0.016
80	0.0003	0.014
90	0.0003	0.014
100	0.0003	0.014
200	0.0002	0.009
250	0.00015	0.007

^a Based on percent-enrichment estimate of 2.2 (U-235/0.022).

Table 6-5. Estimated Distribution Coefficient for Uranium in Swampy Area North of Former NW-CaF₂ Storage Area

Sample IDs ^a		Total Uranium Concentration		Calculated K _d ^b (L/kg)
Soil	Water	Soil (mg/kg)	Water (mg/L)	
S-1	GW-1	0.176222	0.000858	205
S-2	GW-2	0.21412838	0.00148	145
S-3	GW-3	0.4886141	0.00665	73
S-4	GW-4	0.30867681	0.000194	1,591
S-5	GW-5	0.25822734	0.000180	1,435
S-6	GW-6	0.063972572	0.000173	370
S-7	GW-7	BPQL	BPQL	NA
S-8	GW-8	0.040074554	BPQL	NA
Mean				637

^a Samples collected March 17-18, 1997.

^b K_d = distribution coefficient (U_{soil}/U_{water}).

BPQL = Below practical quantitation limit (0.375,mg/kg-soil, 0.00015 mg/L-water).

Appendix A



General Electric Company
P.O. Box 780, Wilmington, NC 28402
910 675-5000

April 30, 1999

via hand delivery

Mr. Dave Weaver
c/o County Manager's Office
New Hanover County
320 Chestnut St.
Wilmington, N.C. 28401

Ms. Diane Harvell
c/o County Health Director's Office
New Hanover County
2029 S. 17th St.
Wilmington, N.C. 28401

Subject: Notice of Submittal of Corrective Action Plan (NW Site Area)
General Electric Company
3901 Castle Hayne Road
Wilmington, North Carolina 28401

Dear Mr. Weaver and Ms. Harvell:

Attached to this letter is a proposed Corrective Action Plan (CAP) which GE is submitting for review and approval by the Division of Water Quality (DWQ) of the North Carolina Department of Environment and Natural Resources (NCDENR). This CAP is provided under the provisions of the Department's groundwater rules, as codified as Subchapter 2L of Title 15A of the North Carolina Administrative Code (the "Groundwater Rules").

General Electric (GE) has identified groundwater contamination at the remote northwest area of its plant property. Based on our review of records and testing in the area, we have determined that material storage and disposal practices typical of the late 1960s are the likely sources of that contamination. GE has removed one of the former contaminant sources, and the other source is no longer contributing to groundwater contamination. Although there is some residual contamination in the groundwater, there is evidence that the contamination is being naturally degraded by natural conditions and processes.

Mr. Dave Weaver, c/o County Manager's Office
Ms. Diane Harvell, c/o County Health Director's Office
April 30, 1999
Page 2

As a result, GE believes it is appropriate that the process of natural degradation and attenuation of the groundwater contamination be allowed to continue, while being monitored by GE. Consequently, GE is proposing to DENR that the Company be allowed to pursue a natural attenuation CAP to address the groundwater contamination, as provided in §.0106 of the Groundwater Rules. It is expected that under the CAP the contamination will decrease over time due to natural processes (natural attenuation). Natural attenuation is considered to be a reasonable corrective action alternative for the area considering the insignificant threat to human health or the environment posed by the presence of the contamination. GE believes that alternative methods of addressing the contamination would likely be more intrusive and would interfere with the use of the affected properties.

Section .0114(b) of the Groundwater Rules requires that we notify the offices of the local Health Director and the County Manager in which the contaminant plume occurs, concurrently with the submittal of the proposed CAP to DENR. (We are also sending duplicates of this letter by certified mail as indicated by DENR rules.)

GE understands that DENR will consider the proposed CAP for at least 30 days, so that the Department may evaluate comments submitted by individuals interested in the request. If you would like to discuss this letter or the proposed CAP, please do not hesitate to contact me at (910)675-5721.

Sincerely,



Herbert R. Strickler, Manager
Site Environment, Health and Safety

Enclosure

cc: HRS-99-028
Dr. Charles Stehman - NCDENR
D. Dusenberry - NCDRP
RTI (c/o J. Reynolds)



Handwritten notes:
1. In 1991, the NC DENR
approved the CAP.

April 21, 1999

Mrs. Katharine Sledge
P.O. Box 523
253 N. Powell Blvd.
Whiteville, NC 28472

Dear Ms. Sledge,

Enclosed is a signed copy for your files of the notification letter dated March 30 that we discussed recently.

Per the State rules, GE is submitting a Corrective Action Plan (CAP) to NC DENR recommending "natural attenuation" as the proposed cleanup option. After NC DENR review of the CAP and upon their approval, GE will notify you of their approval.

It was a pleasure to meet with you recently. If you have any questions regarding this matter, please do not hesitate to call GE at (910) 675-5721.

Sincerely,

GE NUCLEAR ENERGY

Herbert R. Strickler, Manager
Site Environment, Health, & Safety

cc: HRS-99-025

bcc: C. Monetta
C. Case
T. Crawford
S. Murray
D. Brown
B. MacDonald
J. Batchler
RTI - J. Reynolds



General Electric Company
P.O. Box 1217
Wilmington, NC 28402

March 30, 1999

Mrs. Katharine Sledge
P.O. Box 523
253 N. Powell Blvd.
Whiteville, NC 28472

Reference: Consent for Corrective Action of Groundwater Contamination by
Natural Attenuation and Consent for Property Access
General Electric Company, Castle Hayne Road, Wilmington, NC

Dear Mrs. Sledge:

This letter is to provide you with further information about our work on the groundwater contamination that we have discussed previously and to request your permission to allow us to proceed with the work that we will be proposing to do in concurrence with North Carolina Department of Environment & Natural Resources (DENR). General Electric (GE) has identified groundwater contamination in the remote northwest (NW) area of our property, which is adjacent to a portion of your property off Castle Hayne Road.

GE believes the contamination resulted from material management practices typical of the late 1960s. There are two areas in the NW GE property from where the groundwater contaminants migrated. Material has been removed from one area and the other no longer contributes to the contamination in the groundwater. Environmental monitoring studies have shown that the groundwater contamination continues to degrade and decrease over time by natural processes.

Acting, based on your prior approval, GE collected several groundwater samples from your property for analysis. Several of the samples contained volatile organic compounds (VOCs). VOCs typically are found in degreasers or solutions like dry cleaning liquids. We detected in one of the monitoring wells which we installed on your property two VOCs, trichloroethylene (TCE) and dichloroethylene (DCE), at concentrations exceeding applicable North Carolina groundwater quality standards.

One sample of water taken from a soil boring on your property (near the GE boundary) also exhibited low levels of fluoride and uranium characteristic of the material formerly stored on our site. However, the levels of fluoride and uranium were not found above applicable standards in the monitoring wells on your property.

With DENR's concurrence, GE intends to pursue corrective action of the groundwater contamination using natural processes. This is an option available under North Carolina law with review and approval of the DENR. These natural processes, collectively referred to as natural attenuation, will decrease contaminant concentrations over time. Indeed, this is what has been happening to the contaminants already, as shown by the monitoring results. GE believes that natural attenuation is an appropriate

Mrs. Katharine Sledge
March 30, 1999
Page 2

remedy for your property considering the insignificant health and environmental risks posed by the contamination.

Based upon our familiarity with the property and through our discussion with you, we know that your property is used as a hunting preserve. Maintaining your property in an undisturbed condition for use as a hunting preserve minimizes any risks from the contamination. Any other alternative corrective action would be more intrusive and could interfere with the way your land is currently used. Should you plan to change the use or ownership of your land, GE would like the opportunity to review with you the progress of the natural cleanup process.

Consistent with the State's groundwater rules, GE seeks your consent that: (1) GE will pursue cleanup of the contamination on your property using natural attenuation processes, and (2) GE or its agent can access your property from time to time to collect samples for analysis. This access will allow continued evaluation of the natural attenuation processes.

If you consent to the above request, please sign and date a copy of this letter in the space provided below, and return the signed copy to me at the above return address. If there are any questions regarding this matter which you would like to discuss with DENR, you can call Dr. Charles Stehman (910*395-3900), Groundwater Supervisor in the Wilmington Regional Office. Dr. Stehman is very familiar with this site, as well as the procedures we are using to address the contamination. You should also feel free to contact me at (910) 675-5721 if you have any questions regarding this matter.

Sincerely,

GE NUCLEAR ENERGY





Herbert R. Strickler, Manager
Site Environment, Health & Safety

cc: HRS-99-013

GE has informed me that groundwater contamination is present on my property. I concur with GE's proposed natural attenuation corrective action and authorize GE and its agents to access my property from time to time to collect environmental samples for analysis to monitor this natural cleanup process.

Signed:


Mrs. Katharine Sledge
Date

Appendix B

Appendix B. Pneumatic Slug Testing Activities Northwest Site Area

Prepared by:
Michael I. Lowry
Jeff W. Reynolds, P.G., P.HG.

B.1 Background Information

Estimates of aquifer hydraulic conductivity (k) in the northwest site area have been obtained through the use of instantaneous displacement tests, commonly referred to as slug tests. An initial round of slug tests were performed in the CAF-B series wells in March 1996 using a solid plastic slug. Additional testing was performed in January 1999 to evaluate the hydraulic characteristics of the deeper, semi-consolidated sandstone (represented by well OCW-5D) and to evaluate conditions in a larger area of the northwest site area extending throughout the model domain.

The lithology of the deeper zones differs from that observed in the shallower sediments (where the CAF-B series slug tests were performed); the deeper zones contain thin, discontinuous zones of consolidated, calcareous sandstone with silt and void spaces in some areas. The deeper and more widely distributed monitoring wells included in the additional slug testing program were not present at the time of the initial slug testing activities. Results from all of the slug testing were integrated into the groundwater flow model of the site (Appendix G).

Results from the initial round of slug tests are provided in Appendix C of the *Comprehensive Site Assessment for the Northwest Site Area* (RTI, 1998). The minimum and maximum k values from this testing were 0.41 and 5.5 feet per day (ft/d), respectively. The geometric mean k values were 1.6 and 1.0 ft/day for the Hvorslev (1951) and Bouwer-Rice (1976) analysis methods, respectively. In the CSA, slug test results, grain-size analyses, and a regional water balance were considered in determining an overall mean k estimate of 9.1 ft/day (RTI, 1998).

B.2 Method Description

The additional slug testing performed in January 1999 included 8 monitoring wells located throughout the northwest site area (CAF-6B, CAF-16C, CAF-17C, OCW-2C, OCW-5D, LF-3A, LF-3B, and LF-3C). 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 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), 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 started a fraction of time prior to 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.

B.3 Data Analysis

The data were downloaded from the data logger onto a laptop PC and were plotted using Microsoft Excel. For the unconfined aquifer in the northwest site area, 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.

B.4 Results and Conclusions

Results from the additional slug testing activities were remarkably similar to earlier results, even in the deeper, semi-consolidated zones. The minimum and maximum k values for the additional testing were 0.82 and 6.7 ft/d, respectively. The geometric mean k values

for the Hvorslev and Bouwer-Rice analysis methods were 2.4 and 2.0 ft/d, respectively. In the deeper zones, the geometric mean k values (as measured in well OCW-5D) were 1.05 and 0.96 ft/d for the Hvorslev and Bouwer-Rice methods, respectively. Table 1 provides a summary of the k values determined during the additional slug testing program. The results of the additional slug tests indicate the following conclusions:

- The k of the shallower sediments is essentially the same as the k of the deeper zones.
- The k in the northwest site area ranges approximately over one order of magnitude between 0.4 and 6.7 ft/d, the minimum and maximum estimates for the slug tests conducted in the area, respectively.
- Combining the results from the March 1996 and the January 1999 slug testing activities, the geometric mean k estimates for the Hvorslev (1951) and the Bouwer-Rice (1976) analysis methods are 2.1 and 1.6 ft/d, respectively.

Considering the additional field evidence and the consistent nature of the aquifer analyses (excluding the grain-size analyses), an estimation of k and, therefore, average linear groundwater velocity, lower than those presented in the CSA (RTI, 1998) is warranted. Using the highest directly measured k value (6.7 ft/d), a conservative estimate of the average linear groundwater velocity in the northwest site area (upgradient of the swampy area) is on the order of 0.11 ft/d.

B.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
- RTI. 1998. Comprehensive Site Assessment for the Northwest Site Area. RTI Report No. 6448-018/003/01F.

Table 1 Slug Test Analysis Results Summary

Well	Hvorslev Analysis Result (ft/day)	Bouwer-Rice Analysis Result (ft/day)
CAF-16C	5.70	4.50
CAF-17C	6.60	4.40
LF-3A	6.70	3.90
LF-3B	1.04	1.51
LF-3C	3.30	3.48
OCW-2C	2.30	1.90
OCW-4B	1.40	0.82
OCW-5D Test 1	1.10	0.96
OCW-5D Test 2	1.00	0.91
OCW-5D Geometric Mean	1.05	0.93
All Wells Geometric Mean	2.4	2.0

CAF-16C Bouwer-Rice Analysis

Casing Radius	Rc	0.0833	ft
Screen Length	L	10	ft
Borehole Radius	Rw	0.375	ft
Initial Drawdown	So	7.2	ft
Water Column Height	H	44.6	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
------	-------

$$\ln Re/Rw = (1.1/\ln(H/Rw) + (A+B*\ln((D-H)/Rw))/(L/Rw))^{-1}$$

=	2.79
---	------

Point from time-drawdown curve used in solution:

Time	t	0.97	min
Drawdown	St	0.32	ft

$$\text{Hydraulic Conductivity} = (Rc^2 * (\ln Re/Rw)) / (2 * L * t * \ln(So/St))$$

=	0.00310675	ft/min
=	4.47	ft/day

CAF-16C Hvorslev Analysis

Well casing radius	r	0.0833	ft
Well bore radius	R	0.375	ft
Well screen length	L	10	ft
Time to %37 of initial head ch	To	0.2872	min

$$\text{Hydraulic Conductivity} = r^2 * \ln(L/R) / (2 * L * To)$$

=	0.00396644	ft/min
=	5.71	ft/day

CAF-17C Bouwer-Rice Analysis

Casing Radius	Rc	0.0833	ft
Screen Length	L	10	ft
Borehole Radius	Rw	0.375	ft
Initial Drawdown	So	8.085	ft
Water Column Height	H	38.95	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
------	-------

$$\ln Re/Rw = (1.1/\ln(H/Rw) + (A+B*\ln((D-H)/Rw))/(L/Rw))^{-1}$$

=	2.66
---	------

Point from time-drawdown curve used in solution:

Time	t	0.95	min
Drawdown	St	0.34	ft

$$\text{Hydraulic Conductivity} = (Rc^2 * (\ln Re/Rw)) / (2 * L * t * \ln(So/St))$$

=

0.00307419 ft/min

=

4.43 ft/day

CAF-17C Hvorslev Analysis

Well casing radius	r	0.0833	ft
Well bore radius	R	0.375	ft
Well screen length	L	10	ft
Time to %37 of initial head c	To	0.25	min

$$\text{Hydraulic Conductivity} = r^2 * \ln(L/R) / (2 * L * To)$$

=

0.00455665 ft/min

=

6.56 ft/day

LF-3A Bouwer-Rice Analysis

Casing Radius	Rc	0.0833	ft
Screen Length	L	5	ft
Borehole Radius	Rw	0.375	ft
Initial Drawdown	So	6.1	ft
Water Column Height	H	13.36	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
------	-------

$$\ln Re/Rw = (1.1/\ln(H/Rw) + (A+B*\ln((D-H)/Rw))/(L/Rw))^{-1}$$

=	1.60
---	------

Point from time-drawdown curve used in solution:

Time	t	0.97	min
Drawdown	St	0.58	ft

$$\text{Hydraulic Conductivity} = (Rc^2 * (\ln Re/Rw)) / (2 * L * t * \ln(So/St))$$

=	0.00269451	ft/min
=	3.88	ft/day

LF-3A Hvorslev Analysis

Well casing radius	r	0.0833	ft
Well bore radius	R	0.375	ft
Well screen length	L	5	ft
Time to %37 of initial head c	To	0.385	min

$$\text{Hydraulic Conductivity} = r^2 * \ln(L/R) / (2 * L * To)$$

=	0.00466846	ft/min
=	6.72	ft/day

LF-3B Bouwer-Rice Analysis

Casing Radius	Rc	0.0833	ft
Screen Length	L	5	ft
Borehole Radius	Rw	0.375	ft
Initial Drawdown	So	7.47	ft
Water Column Height	H	27.75	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
------	-------

$$\ln Re/Rw = (1.1/\ln(H/Rw) + (A+B*\ln((D-H)/Rw))/(L/Rw))^{-1}$$

=	1.80
---	------

Point from time-drawdown curve used in solution:

Time	t	0.97	min
Drawdown	St	4.26	ft

$$\text{Hydraulic Conductivity} = (Rc^2 * (\ln Re/Rw)) / (2 * L * t * \ln(So/St))$$

=	0.00072169	ft/min
=	1.04	ft/day

LF-3B Hvorslev Analysis

Well casing radius	r	0.0833	ft
Well bore radius	R	0.375	ft
Well screen length	L	5	ft
Time to %37 of initial head ch	To	1.71	min

$$\text{Hydraulic Conductivity} = r^2 * \ln(L/R) / (2 * L * To)$$

=	0.00105109	ft/min
=	1.51	ft/day

LF-3C Bouwer-Rice Analysis

Casing Radius	Rc	0.0833	ft
Screen Length	L	5	ft
Borehole Radius	Rw	0.375	ft
Initial Drawdown	So	8.2	ft
Water Column Height	H	49.52	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
------	-------

$$\ln Re/Rw = (1.1/\ln(H/Rw) + (A+B*\ln((D-H)/Rw))/(L/Rw))^{*-1}$$

=	2.47
---	------

Point from time-drawdown curve used in solution:

Time	t	0.98	min
Drawdown	St	2.22	ft

$$\text{Hydraulic Conductivity} = (Rc^2 * (\ln Re/Rw)) / (2 * L * t * \ln(So/St))$$

=

0.00228131 ft/min

=

3.29 ft/day

LF-3C Hvorslev Analysis

Well casing radius	r	0.0833	ft
Well bore radius	R	0.375	ft
Well screen length	L	5	ft
Time to %37 of initial head ch	To	0.743	min

$$\text{Hydraulic Conductivity} = r^2 * \ln(L/R) / (2 * L * To)$$

=

0.00241906 ft/min

=

3.48 ft/day

OCW-2C Bouwer-Rice Analysis

Casing Radius	Rc	0.0833	ft
Screen Length	L	10	ft
Borehole Radius	Rw	0.375	ft
Initial Drawdown	So	8.127	ft
Water Column Height	H	37.12	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
------	-------

$$\ln Re/Rw = (1.1/\ln(H/Rw) + (A+B*\ln((D-H)/Rw))/(L/Rw))^{-1}$$

=	2.62
---	------

Point from time-drawdown curve used in solution:

Time	t	0.97	min
Drawdown	St	2.07	ft

$$\text{Hydraulic Conductivity} = (Rc^2 * (\ln Re/Rw)) / (2 * L * t * \ln(So/St))$$

=

0.00128277	ft/min
1.85	ft/day

=

OCW-2C Hvorslev Analysis

Well casing radius	r	0.0833	ft
Well bore radius	R	0.375	ft
Well screen length	L	10	ft
Time to %37 of initial head c	To	0.7	min

$$\text{Hydraulic Conductivity} = r^2 * \ln(L/R) / (2 * L * To)$$

=

0.00162738	ft/min
2.34	ft/day

=

OCW-4B Bouwer-Rice Analysis

Casing Radius	Rc	0.0833	ft
Screen Length	L	10	ft
Borehole Radius	Rw	0.375	ft
Initial Drawdown	So	5.8	ft
Water Column Height	H	18.7	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
------	-------

$$\ln Re/Rw = (1.1/\ln(H/Rw) + (A+B*\ln((D-H)/Rw))/(L/Rw))^{-1}$$

=	2.29
---	------

Point from time-drawdown curve used in solution:

Time	t	2.2	min
Drawdown	St	1.2	ft

$$\text{Hydraulic Conductivity} = (Rc^2 * (\ln Re/Rw)) / (2 * L * t * \ln(So/St))$$

=	0.00056817	ft/min
=	0.82	ft/day

OCW-4B Hvorslev Analysis

Well casing radius	r	0.0833	ft
Well bore radius	R	0.375	ft
Well screen length	L	10	ft
Time to %37 of initial head c	To	1.15	min

$$\text{Hydraulic Conductivity} = r^2 * \ln(L/R) / (2 * L * To)$$

=	0.00099058	ft/min
=	1.43	ft/day

OCW-5D Test 1 Bouwer-Rice Analysis

Casing Radius	Rc	0.0833	ft
Screen Length	L	10	ft
Borehole Radius	Rw	0.375	ft
Initial Drawdown	So	7.84	ft
Water Column Height	H	68.79	ft
Dimensionless constant	A	2.3	
Dimensionless constant	B	0.42	
Saturated Thickness	D	70	ft

Parameter used to determine the constants A and B
(from graph in Bouwer, 1976)

L/Rw	26.67
------	-------

$$\ln Re/Rw = (1.1/\ln(H/Rw) + (A+B*\ln((D-H)/Rw))/(L/Rw))^{-1}$$

=	3.17
---	------

Point from time-drawdown curve used in solution:

Time	t	1.98	min
Drawdown	St	2.371	ft

$$\text{Hydraulic Conductivity} = (Rc^2 * (\ln Re/Rw)) / (2 * L * t * \ln(So/St))$$

=	0.00066366	ft/min
=	0.96	ft/day

OCW-5D Test 1 Hvorslev Analysis

Well casing radius	r	0.0833	ft
Well bore radius	R	0.375	ft
Well screen length	L	10	ft
Time to %37 of initial head ch	To	1.52	min

$$\text{Hydraulic Conductivity} = r^2 * \ln(L/R) / (2 * L * To)$$

=	0.00074945	ft/min
=	1.08	ft/day

OCW-5D Test 2 Bouwer-Rice Analysis

Casing Radius	Rc	0.0833	ft
Screen Length	L	10	ft
Borehole Radius	Rw	0.375	ft
Initial Drawdown	So	5.8	ft
Water Column Height	H	68.79	ft
Dimensionless constant	A	2.3	
Dimensionless constant	B	0.42	
Saturated Thickness	D	70	ft

Parameter used to determine the constants A and B
(from graph in Bouwer, 1976)

L/Rw	26.67
------	-------

$$\ln Re/Rw = (1.1/\ln(H/Rw) + (A+B*\ln((D-H)/Rw))/(L/Rw))^{-1}$$

=	3.17
---	------

Point from time-drawdown curve used in solution:

Time	t	2.55	min
Drawdown	St	1.33	ft

$$\text{Hydraulic Conductivity} = (Rc^2 * (\ln Re/Rw)) / (2 * L * t * \ln(So/St))$$

=

0.00063456 ft/min

=

0.91 ft/day

OCW-5D Test 2 Hvorslev Analysis

Well casing radius	r	0.0833	ft
Well bore radius	R	0.375	ft
Well screen length	L	10	ft
Time to %37 of initial head c	To	1.65	min

$$\text{Hydraulic Conductivity} = r^2 * \ln(L/R) / (2 * L * To)$$

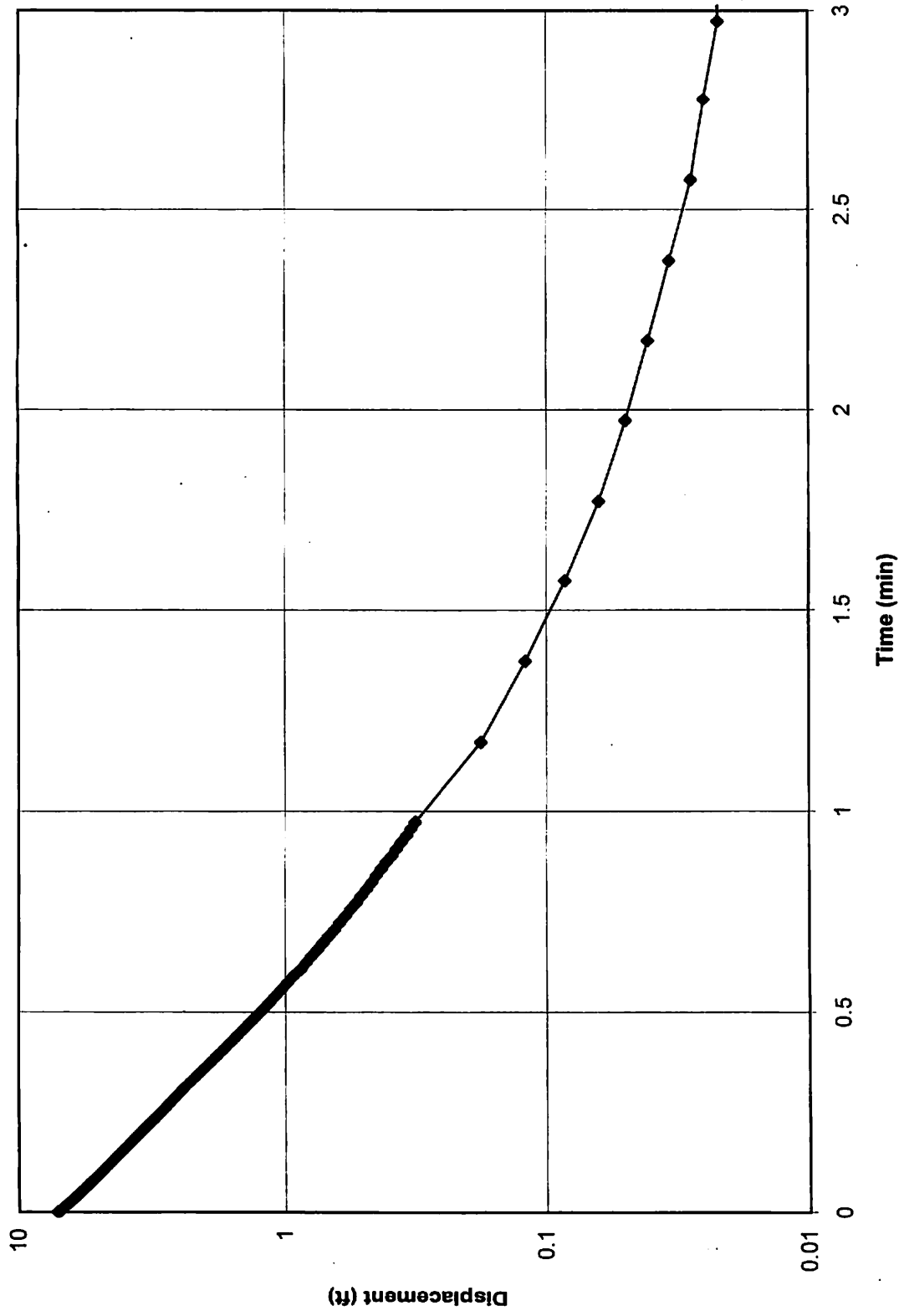
=

0.0006904 ft/min

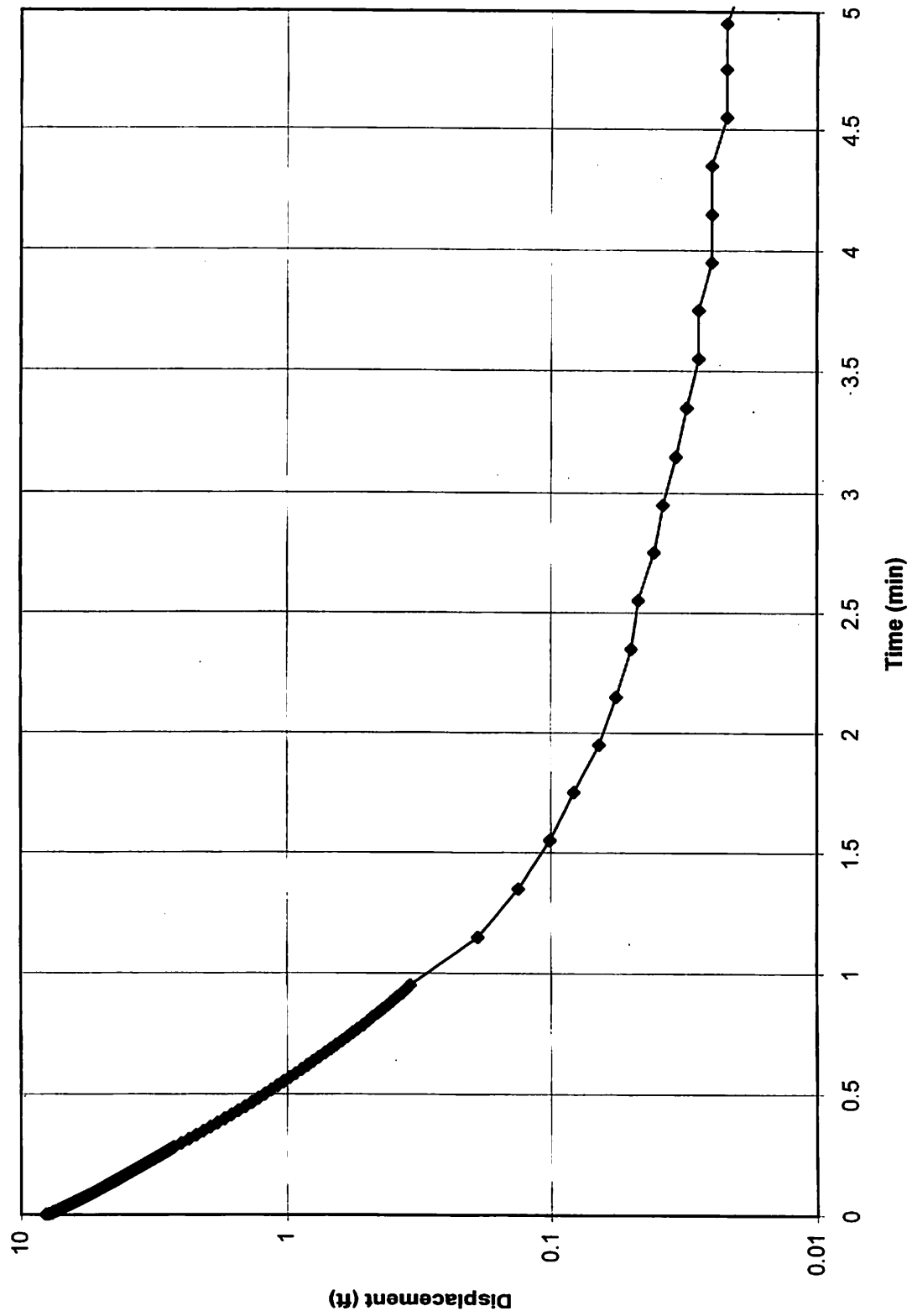
=

0.99 ft/day

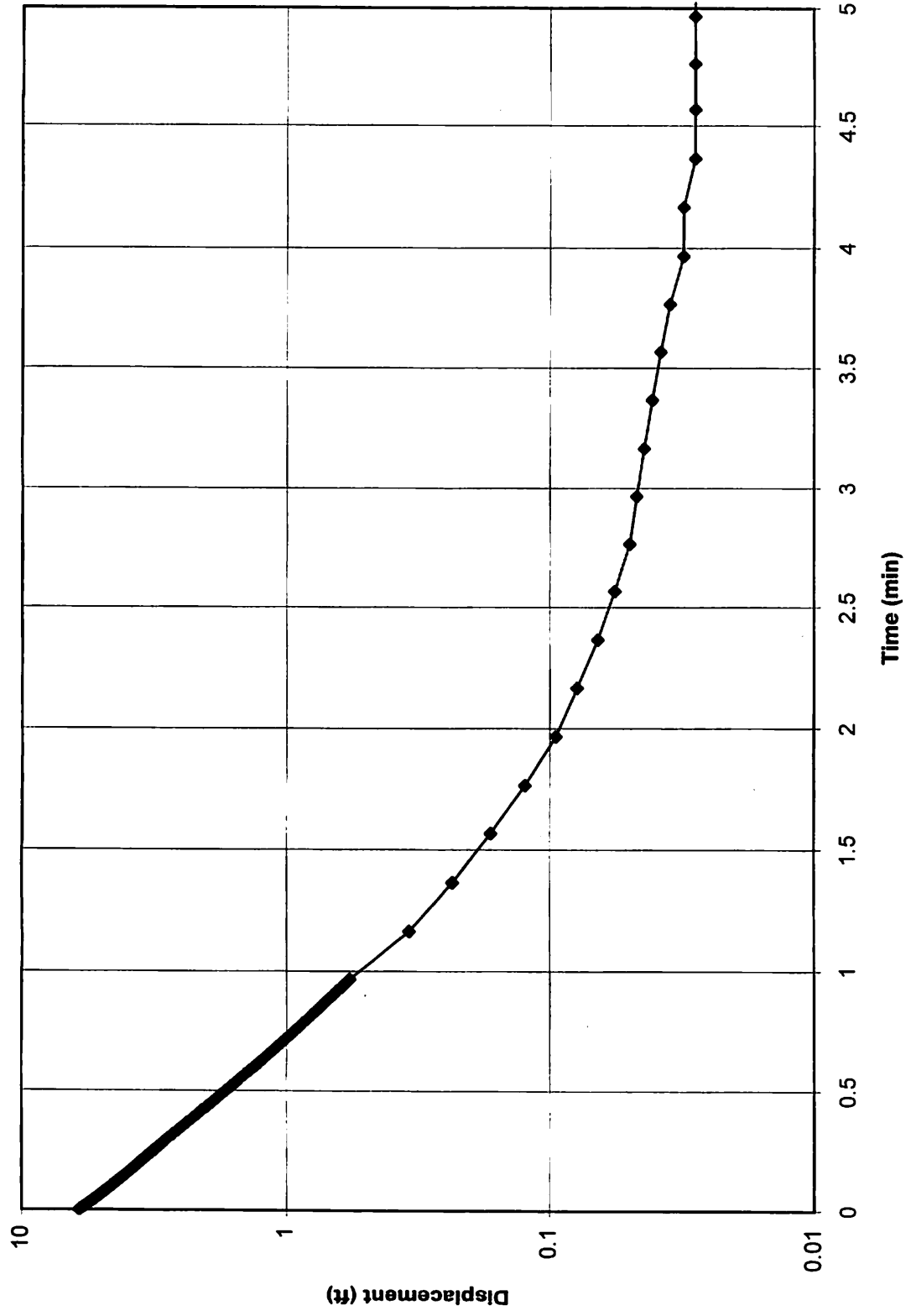
CAF-16C Slug Test



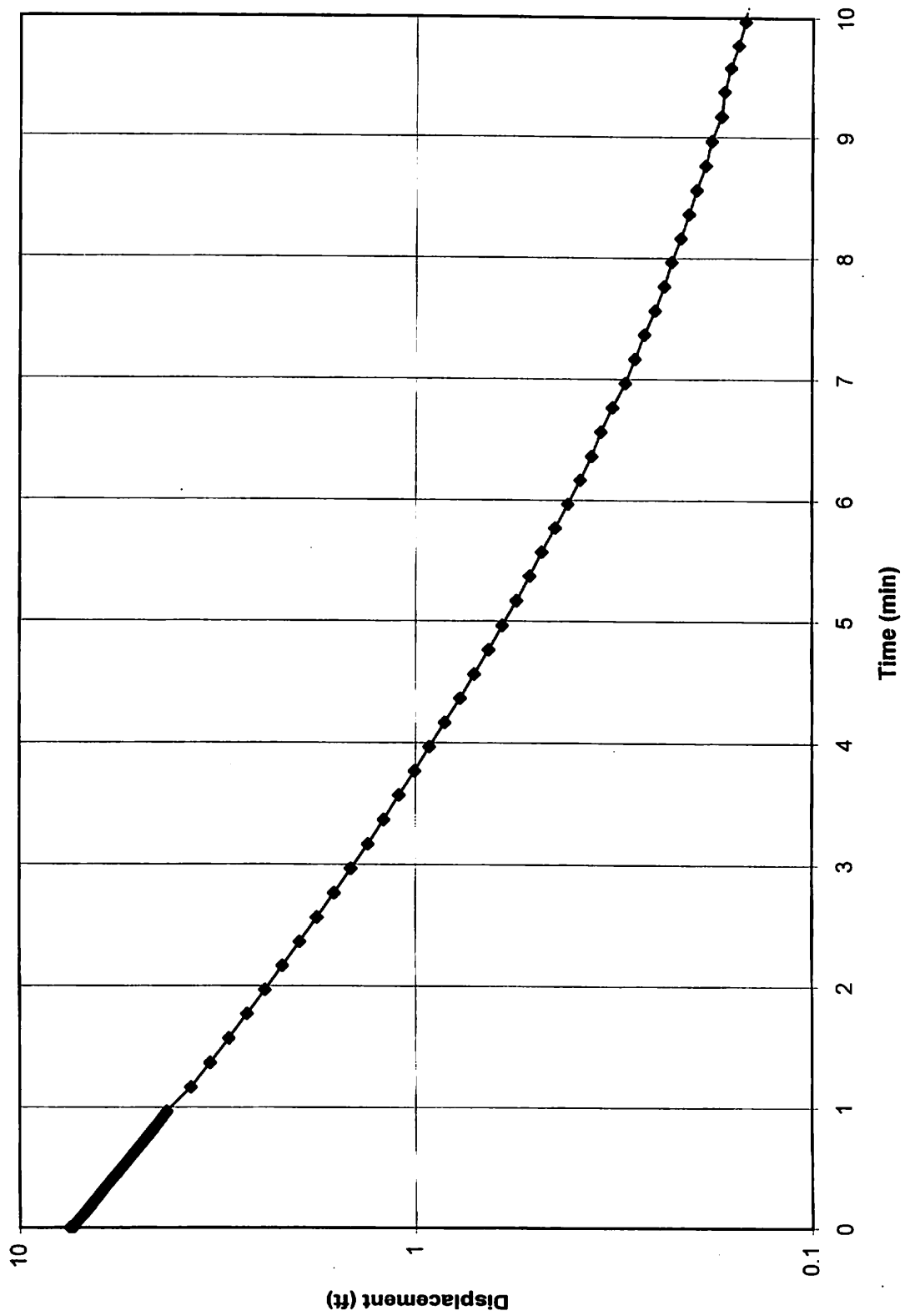
CAF-17C Slug Test



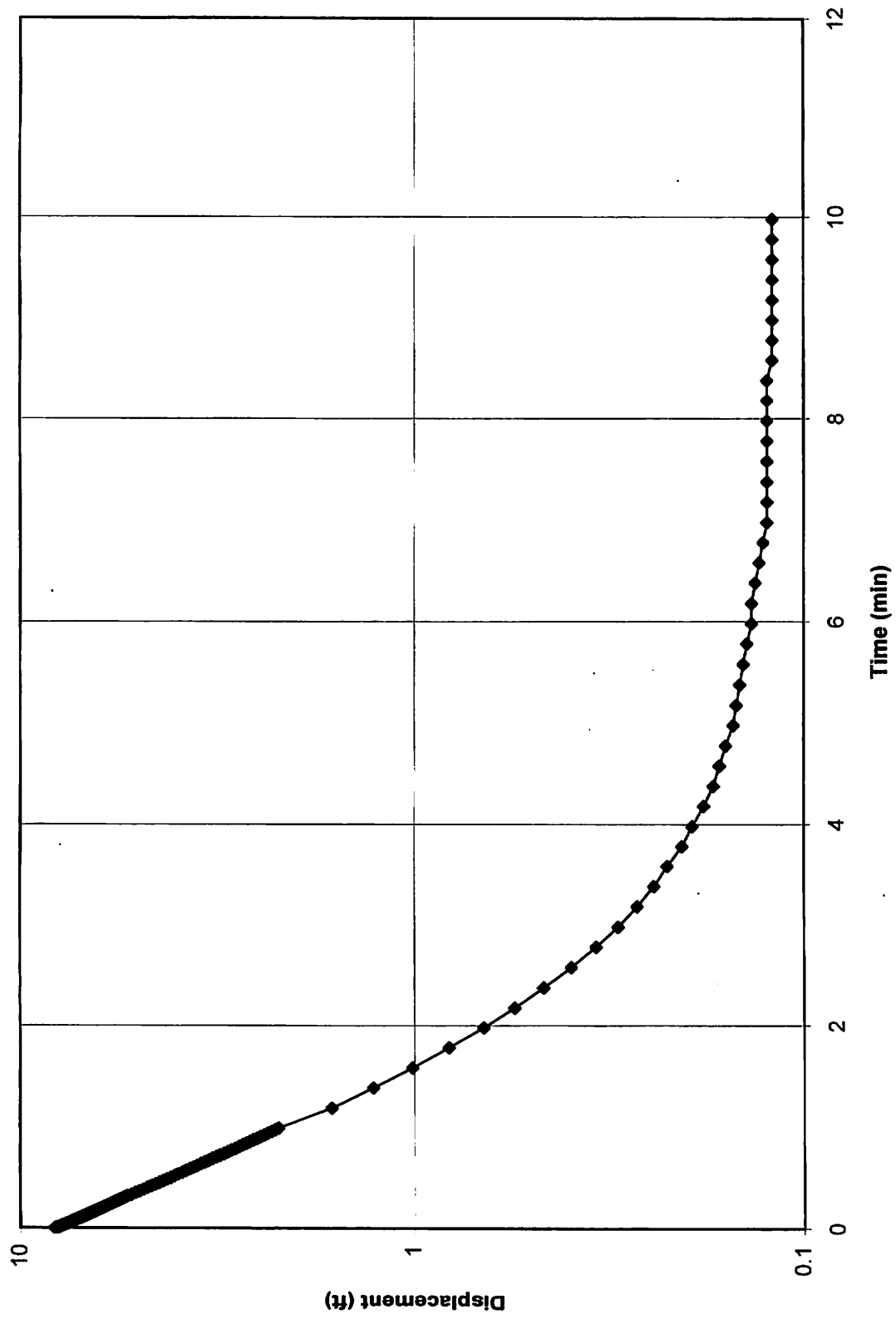
LF-3A Slug Test



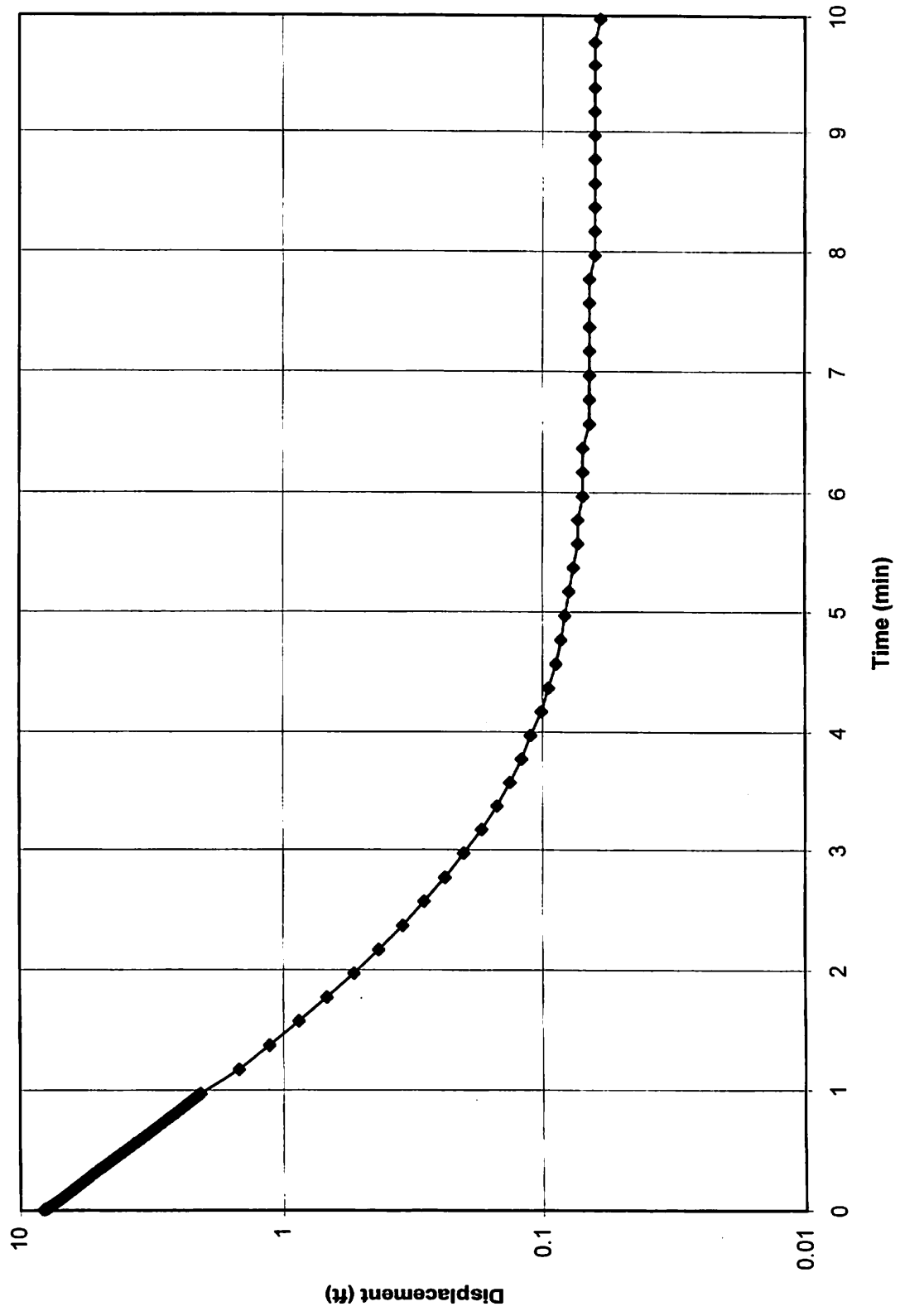
LF-3B Slug Test



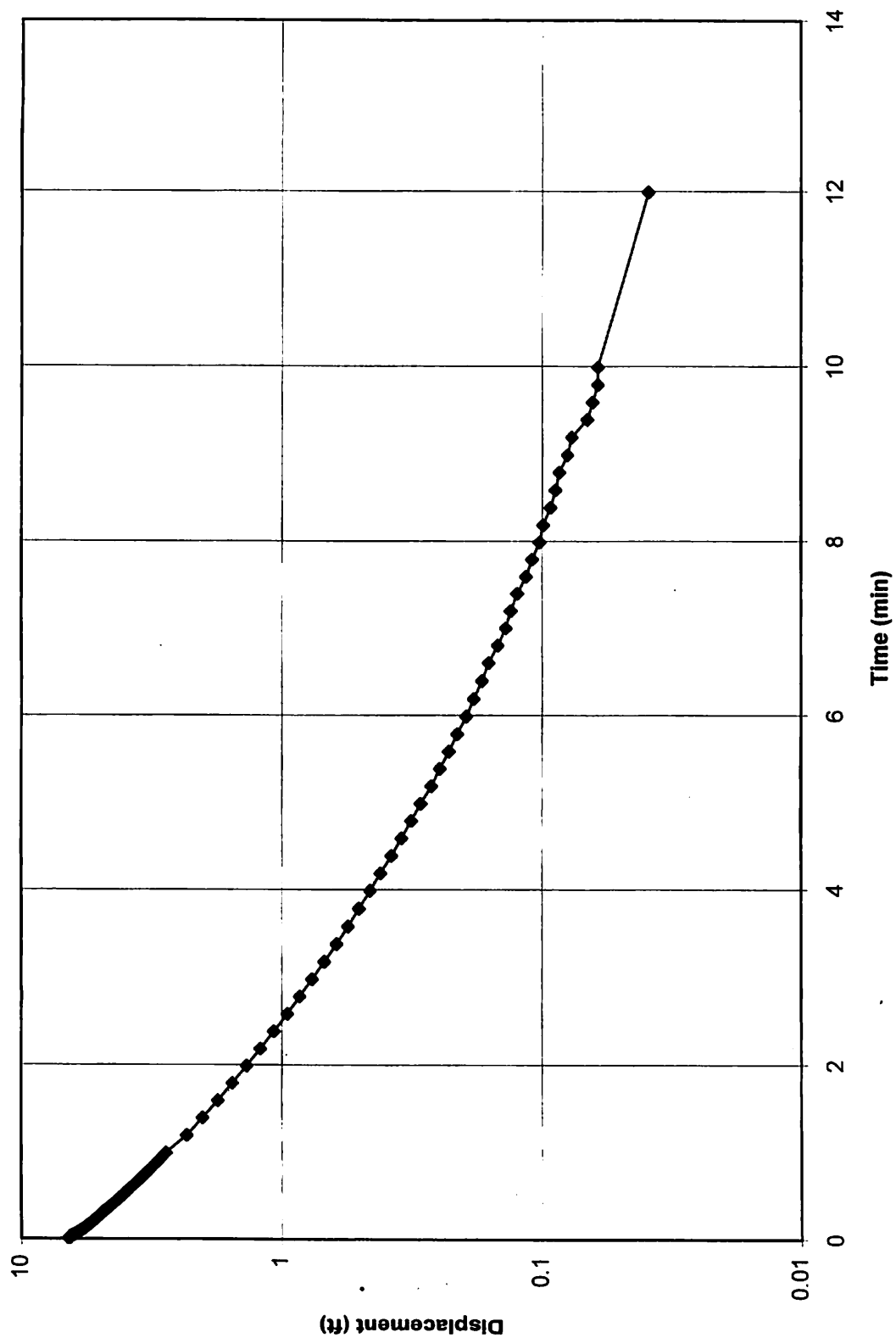
LF-3C Slug Test



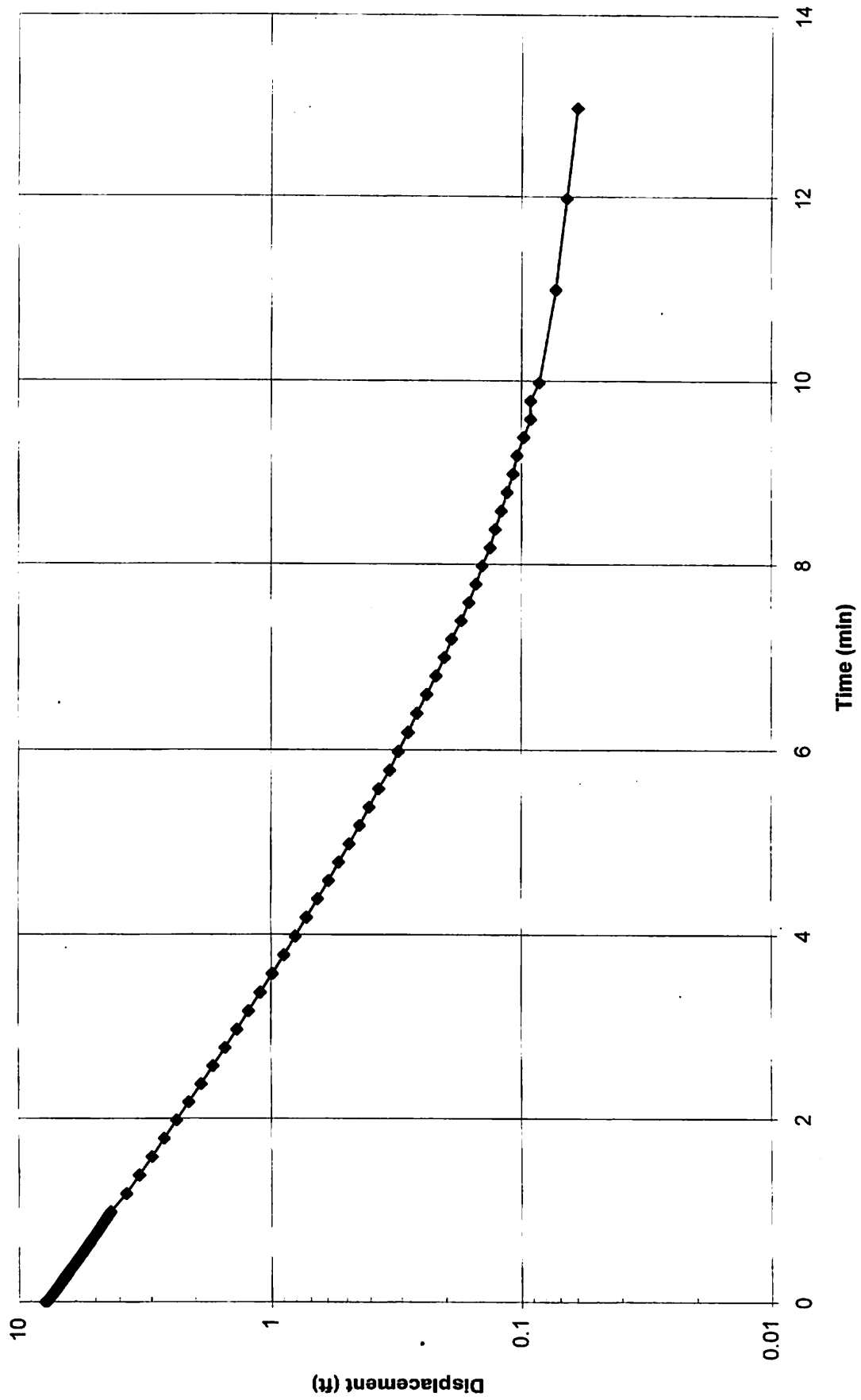
OCW-2C Slug Test



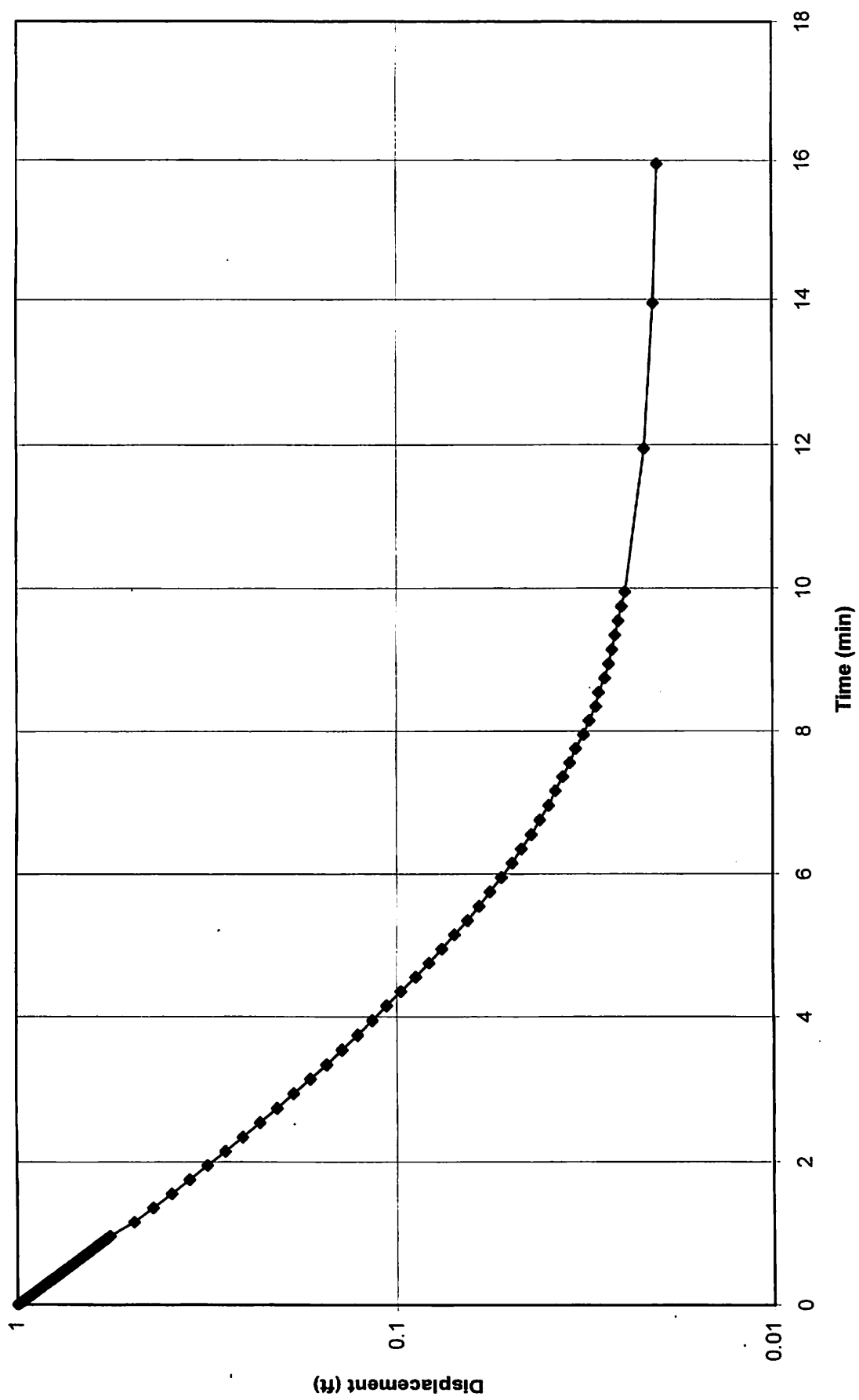
OCW-4B Slug Test



OCW-5D Slug Test 1



OCW-5D Slug Test 2



Appendix C

Part I. Inorganic Analyses (Fluoride, Uranium, and Gross Alpha/Gross Beta)

Notes:

Initial samples from the CAF-series wells (12/95) were analyzed for total uranium by GE's onsite Chemet laboratory using laser fluorescence spectrophotometry as described in Appendix L of the CSA report (RTI, 1998). Fluoride analyses were also performed by GE using an ion-selective probe. An entry of — indicates the constituent was not measured or calculated.

Samples collected on 1/9-10/96 (initial entry) were analyzed for total uranium by GE's Chemet laboratory using laser fluorescence spectrophotometry. Samples collected on 1/9-10/96 (second entry) were analyzed for total uranium and fluoride by Oxford Laboratories in Wilmington, NC, (Radioactive Materials License No. 065-738-1) using inductively coupled plasma - mass spectrometry (ICP-MS, EPA Method 200.8/SW-846 Method 9020) and ion-selective probe (Standard Method 4500-F-C), respectively. An entry of — indicates the constituent was not measured or calculated.

Uranium, fluoride, and gross-alpha/beta analyses from 2/1/96 to 5/13/96 were performed by CompuChem, Inc. in Research Triangle Park, NC (Radioactive Materials License No. 032-0734-2). Fluoride analyses were performed using an ion-selective probe and a Lachat Quickchem Flow Injection Analyzer. Uranium analyses were performed using alpha spectrometry, and gross-alpha/beta analyses were performed using gas-proportional counting. Total and isotopic uranium levels were reported by CompuChem as activity (pCi/L). RTI converted uranium activity (pCi/L) to concentration (mg/L) using procedures described in Appendix L of the CSA report (RTI, 1998). Isotopic abundances are not calculated when the converted total uranium concentration is below the assessment threshold concentration of 0.002 mg/L (refer to Appendix D of the Corrective Action Plan [CAP]). An entry of — indicates the constituent was not measured or calculated.

Uranium and fluoride analyses after May 13, 1996, were performed by Research Triangle Institute's Center for Environmental Measurements and Quality Assurance laboratory (Radioactive Materials license 032-0131-1) using ICP-MS and ion-selective probe, respectively. Total uranium is reported in mg/L. Isotopic concentrations are calculated only for samples with total uranium over RTI's practical quantitation limit (PQL) for calculating isotopic abundances (assessment threshold of 0.002 mg/L). Conversions from total uranium concentration (mg/L) to activity (pCi/L), performed by RTI using a specific activity of 1,370 pCi/mg (refer to Appendix L of the CSA report [RTI, 1998]). A data qualifier flag of J indicates the concentration is estimated. An entry of — indicates the constituent was not measured or calculated. An entry of BPQL indicates the isotope concentration was below the practical quantitation limit of 0.00015 mg/L.

Gross-alpha and gross-beta analyses after July 1996 were performed by Teledyne-Brown Engineering in Westbrook, New Jersey, using the gas-proportional counting method. Uncertainty ranges reported by Teledyne are not included for clarity.

Refer to the Quality Assurance Project Plan (QAPP)(Appendix I of this document) for analytical and quality assurance/quality control (QA/QC) procedures to be implemented during natural-attenuation monitoring.

[illegible][illegible]

CAF-5B

[illegible]

CAF-6A

[illegible]

CAF-6B

[illegible]

CAF-7A

[illegible]

CAF-7B

[illegible]

CAF-8A

[illegible]

CAF-8B

[illegible]

CAF-9A

[illegible]

CAF-9B

[illegible]

CA-10A

[illegible]

CAF-10B

[illegible]

[illegible][illegible]

CAF-11B

[illegible]

CAF-12A

[illegible]

CAF-13A									
Date Sampled	pH	Total Uranium (mg/L)	²³⁴ U (mg/L)	²³⁵ U (mg/L)	²³⁸ U (mg/L)	Total Uranium (pCi/L)	Fluoride (mg/L)	Gross Alpha (pCi/L)	Gross Beta (pCi/L)
1/7/97	6.7	0.221	BPQL	0.00542	0.216	302.77	3.8	160	40
2/26/97	6.4	1.78	0.00052	0.0661	1.72	3929.534	3.99	530	92
5/13/97	6.2	0.09908	BPQL	0.00223	0.09685	135.74	3.51	130	21
8/12/97	6.1	0.93306	0.00019	0.01874	0.91413	1519.623	2.74	510	66
11/10/97	6	0.436	BPQL	0.00914	0.427	597.32	3.15	460	110

CAF-14A									
Date Sampled	pH	Total Uranium (mg/L)	²³⁴ U (mg/L)	²³⁵ U (mg/L)	²³⁸ U (mg/L)	Total Uranium (pCi/L)	Fluoride (mg/L)	Gross Alpha (pCi/L)	Gross Beta (pCi/L)
3/5/97	7.2	0.22	BPQL	0.00429	0.216	301.4	4.38	260	28
5/13/97	7.2	0.30945	BPQL	0.00646	0.30299	423.947	5.1	340	15
8/12/97	6.7	0.47939	0.0001	0.00855	0.47073	793.521	7	210	37

CAF-15A									
Date Sampled	pH	Total Uranium (mg/L)	²³⁴ U (mg/L)	²³⁵ U (mg/L)	²³⁸ U (mg/L)	Total Uranium (pCi/L)	Fluoride (mg/L)	Gross Alpha (pCi/L)	Gross Beta (pCi/L)
3/5/97	5.6	0.106	BPQL	0.00201	0.104	145.22	2.02	110	16
5/13/97	7.1	0.51637	BPQL	0.01039	0.50596	707.427	4.23	550	38
8/12/97	6.7	0.99619	0.0002	0.01786	0.97813	1600.916	4.47	890	110
11/10/97	6.5	1.43	BPQL	0.0274	1.4	1959.1	3.91	800	360

[illegible][illegible][illegible]

Date Sampled	pH	Total Uranium (mg/L)	²³⁴ U (mg/L)	²³⁵ U (mg/L)	²³⁸ U (mg/L)	Total Uranium (pCi/L)	Fluoride (mg/L)	Gross Alpha (pCi/L)	Gross Beta (pCi/L)
8/12/98	4.7	0.00104	—	—	—	1.425	0.03	<2	<
11/10/98	5.5	0.00025	—	—	—	0.343	<0.02	<1	<
1/12/99	4.9	—	—	—	—	—	—	—	—

[illegible][illegible]

[illegible][illegible][illegible]

SWS-3									
Date Sampled	pH	Total Uranium (mg/L)	²³⁴ U (mg/L)	²³⁵ U (mg/L)	²³⁸ U (mg/L)	Total Uranium (pCi/L)	Fluoride (mg/L)	Gross Alpha (pCi/L)	Gross Beta (pCi/L)
8/19/97	---	0.00041	---	---	---	0.562	---	---	---

[illegible]

Part II. Volatile Organic Compound Analyses

Notes:

VOC Analyses were performed by Oxford Laboratories in Wilmington, North Carolina, using the purge and trap extraction/gas chromatographic procedure specified in Standard Method 6230D. All results are reported in $\mu\text{g/L}$. An entry of — indicates the compound was not detected above the method detection limit (MDL). Concentrations in parentheses indicate estimated concentrations between the minimum detection limit and the practical quantitation limit (PQL) (equivalent to a data-qualifier flag of "J"). The data-qualifier flag "UJ" indicates that the compound was not detected above the PQL but the PQL is approximate and may or may not represent the actual limit of quantitation necessary to accurately and precisely measure the analyte in the sample.

Refer to the Quality Assurance Project Plan (Appendix I of this document) for analytical and quality assurance/quality control procedures to be implemented during natural-attenuation monitoring.

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2099
1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2099	

[illegible]

[illegible]

Groundwater and Swamp-Water Monitoring Data - VOCs (ug/L)

Source	CAF-8A	CAF-8A	CAF-8B	CAF-8B	CAF-8B	CAF-8B	CAF-8B	CAF-8B	CAF-9A	CAF-9A	CAF-9A
Date Sampled	8/10/98	11/10/98	2/25/97	5/12/97	8/10/98	11/10/98	1/14/99		2/25/97	5/12/97	8/10/98
Time Sampled	17:03	12:15	14:56	14:50	19:05	11:21	16:17		14:05	15:32	18:55
Date Analyzed	8/18/98	11/12/98	2/27/97	5/20/97	8/18/98	11/12/98	1/20/99		2/27/97	5/20/97	8/18/98
Trichloroethylene	--	--	1.23	0.53	--	(0.15)	--		--	--	--
cis-1,2-Dichloroethylene	--	--	32.0	14.8	(0.32)	--	--		(0.18)	(0.13)	--
trans-1,2-Dichloroethylene	--	--	--	--	--	--	--		--	--	--
1,1-Dichloroethylene	--	--	--	--	--	--	--		--	--	--
Vinyl Chloride	--	--	--	--	--	--	--		--	--	--
1,1-Dichloroethane	--	--	--	--	--	--	--		--	--	--
Tetrachloroethylene	--	--	--	--	--	--	--		--	--	--
Benzene	--	--	--	--	--	--	--		--	--	--
Toluene	--	--	--	--	--	--	--		--	--	--
Ethylbenzene	--	--	--	--	--	--	--		--	--	--
Total Xylenes	--	--	--	--	--	--	--		--	--	--
Naphthalene	--	--	--	--	--	--	--		--	--	--
1,1,1-Trichloroethane	--	--	--	--	--	--	--		--	--	--
Carbon Tetrachloride	--	--	--	--	--	--	--		--	--	--
1,2-Dichloropropane	--	--	--	--	--	--	--		--	--	--
Dichlorodifluoromethane	--	--	--	--	--	--	--		--	--	--
Chloromethane	--	--	--	--	--	--	--		--	--	--
Bromomethane	--	--	--	--	--	--	--		--	--	--
Chloroethane	--	--	--	--	--	--	--		--	--	--
Fluorotrichloromethane	--	--	--	--	--	--	--		--	--	--
Dichloromethane	--	--	--	--	--	--	--		--	--	--
2,2-Dichloropropane	--	--	--	--	--	--	--		--	--	--
Chloroform	--	--	--	--	--	--	--		--	--	--
Bromochloromethane	--	--	--	--	--	--	--		--	--	--
1,1-Dichloropropene	--	--	--	--	--	--	--		--	--	--
1,2-Dichloroethane	--	--	--	--	--	--	--		--	--	--
Bromodichloromethane	--	--	--	--	--	--	--		--	--	--
Dibromomethane	--	UJ	--	--	--	UJ	--		--	--	--
1,3-Dichloropropene	--	--	--	--	--	--	--		--	--	--
1,1,2-Trichloroethane	--	--	--	--	--	--	--		--	--	--
1,3-Dichloropropane	--	--	--	--	--	--	--		--	--	--
Dibromochloromethane	--	--	--	--	--	--	--		--	--	--
Chlorobenzene	--	--	--	--	--	--	--		--	--	--
1,1,1,2-Tetrachloroethane	--	--	--	--	--	--	--		--	--	--
Styrene	--	--	--	--	--	--	--		--	--	--
Isopropylbenzene	--	--	--	--	--	--	--		--	--	--
Bromoform	--	--	--	--	--	--	--		--	--	--
1,1,2,2-Tetrachloroethane	--	--	--	--	--	--	--		--	--	--
1,2,3-Trichloropropane	--	--	--	--	--	--	--		--	--	--
n-Propylbenzene	--	--	--	--	--	--	--		--	--	--
Bromobenzene	--	--	--	--	--	--	--		--	--	--
1,3,5-Trimethylbenzene	--	--	--	--	--	--	--		--	--	--
o-Chlorotoluene	--	--	--	--	--	--	--		--	--	--
p-Chlorotoluene	--	--	--	--	--	--	--		--	--	--
tert-Butylbenzene	--	--	--	--	--	--	--		--	--	--
1,2,4-Trimethylbenzene	--	--	--	--	--	--	--		--	--	--
sec-Butylbenzene	--	--	--	--	--	--	--		--	--	--
p-Isopropyltoluene	--	--	--	--	--	--	--		--	--	--
m-Dichlorobenzene	--	--	--	--	--	--	--		--	--	--
p-Dichlorobenzene	--	--	--	--	--	--	--		--	--	--
n-Butylbenzene	--	--	--	--	--	--	--		--	--	--
o-Dichlorobenzene	--	--	--	--	--	--	--		--	--	--
1,2,4-Trichlorobenzene	--	--	--	--	--	--	--		--	--	--
Hexachlorobutadiene	--	--	--	--	--	--	--		--	--	--
1,2,3-Trichlorobenzene	--	--	--	--	--	--	--		--	--	--

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Groundwater and Swamp-Water Monitoring Data - VOCs (ug/L)

[illegible]

Groundwater and Swamp-Water Monitoring Data - VOCs (ug/L)

[illegible]

Groundwater and Swamp-Water Monitoring Data - VOCs (ug/L)

Source	CAF-16C	CAF-16C	CAF-16C	CAF-16C	CAF-17C	CAF-17C	CAF-17C	CAF-17C
Date Sampled	5/19/98	8/10/98	11/10/98	1/15/99	5/19/98	8/12/98	11/11/98	1/15/99
Time Sampled	12:36	12:15	8:01	11:10	12:30	10:09	14:59	10:20
Date Analyzed	5/20/98	8/17/98	11/12/98	1/19/99	5/20/98	8/19/98	11/13/98	1/20/99
Trichloroethylene	--	--	--	--	--	--	0.86	(0.35)
cis-1,2-Dichloroethylene	--	--	--	--	328.0	1162.0	740.0	764.0
trans-1,2-Dichloroethylene	--	--	--	--	--	1.18	1.08	0.88
1,1-Dichloroethylene	--	--	--	--	(0.38)	4.95	1.08	--
Vinyl Chloride	--	--	--	--	196.0	81.9	50.0	--
1,1-Dichloroethane	--	--	--	--	7.58	13.4	11.1	13.1
Tetrachloroethylene	--	--	--	--	--	--	--	--
Benzene	--	--	--	--	--	--	--	--
Toluene	--	--	--	--	--	0.94	--	0.62
Ethylbenzene	--	--	--	--	--	--	--	--
Total Xylenes	--	--	--	--	--	(0.43)	(0.48)	--
Naphthalene	--	--	--	--	--	--	0.66	0.92
1,1,1-Trichloroethane	--	--	--	--	--	--	--	--
Carbon Tetrachloride	--	--	--	--	--	--	--	--
1,2-Dichloropropane	--	--	--	--	--	--	--	--
Dichlorodifluoromethane	--	--	--	--	--	--	--	--
Chloromethane	--	--	--	--	--	--	--	--
Bromomethane	--	--	--	--	--	--	--	--
Chloroethane	--	--	--	--	--	--	--	--
Fluorotrichloromethane	--	--	--	--	--	--	--	--
Dichloromethane	--	--	--	--	--	--	--	--
2,2-Dichloropropane	--	--	--	--	--	--	--	--
Chloroform	--	--	--	--	--	--	--	--
Bromochloromethane	--	--	--	--	--	--	--	--
1,1-Dichloropropene	--	--	--	--	--	--	--	--
1,2-Dichloroethane	--	--	--	--	--	--	--	--
Bromodichloromethane	--	--	--	--	--	--	--	--
Dibromomethane	--	--	--	--	--	--	UJ	--
1,3-Dichloropropene	--	--	--	--	--	--	--	--
1,1,2-Trichloroethane	--	--	--	--	--	--	--	--
1,3-Dichloropropane	--	--	--	--	--	--	--	--
Dibromochloromethane	--	--	--	--	--	--	--	--
Chlorobenzene	--	--	--	--	--	--	--	--
1,1,1,2-Tetrachloroethane	--	--	--	--	--	--	--	--
Styrene	--	--	--	--	--	--	--	--
Isopropylbenzene	--	--	--	--	--	(0.17)	--	--
Bromoform	--	--	--	--	--	--	--	--
1,1,2,2-Tetrachloroethane	--	--	--	--	--	--	--	--
1,2,3-Trichloropropane	--	--	--	--	--	--	--	--
n-Propylbenzene	--	--	--	--	--	--	--	--
Bromobenzene	--	--	--	--	--	--	--	--
1,3,5-Trimethylbenzene	--	--	--	--	--	--	--	--
o-Chlorotoluene	--	--	--	--	--	--	--	--
p-Chlorotoluene	--	--	--	--	--	--	--	--
tert-Butylbenzene	--	--	--	--	--	(0.12)	--	(0.14)
1,2,4-Trimethylbenzene	--	--	--	--	--	(0.28)	(0.25)	--
sec-Butylbenzene	--	--	--	--	--	(0.21)	--	--
p-Isopropyltoluene	--	--	--	--	--	1.13	0.71	1.1
m-Dichlorobenzene	--	--	--	--	--	0.55	--	--
p-Dichlorobenzene	--	--	--	--	--	--	--	--
n-Butylbenzene	--	--	--	--	--	(0.47)	(0.27)	(0.46)
o-Dichlorobenzene	--	--	--	--	--	--	--	--
1,2,4-Trichlorobenzene	--	--	--	--	--	--	--	--
Hexachlorobutadiene	--	--	--	--	--	--	--	--
1,2,3-Trichlorobenzene	--	--	--	--	--	--	--	--

Groundwater and Swamp-Water Monitoring Data - VOCs (ug/L)

Source	LF-3A	LF-3B
Date Sampled	2/26/97	3/5/97
Time Sampled	14:05	15:10
Date Analyzed	2/28/97	3/10/97
Trichloroethylene	--	--
cis-1,2-Dichloroethylene	--	--
trans-1,2-Dichloroethylene	--	--
1,1-Dichloroethylene	--	--
Vinyl Chloride	--	--
1,1-Dichloroethane	--	--
Tetrachloroethylene	--	--
Benzene	--	--
Toluene	--	--
Ethylbenzene	--	--
Total Xylenes	--	--
Naphthalene	--	--
1,1,1-Trichloroethane	--	--
Carbon Tetrachloride	--	--
1,2-Dichloropropane	--	--
Dichlorodifluoromethane	--	--
Chloromethane	--	--
Bromomethane	--	--
Chloroethane	--	--
Fluorotrichloromethane	--	--
Dichloromethane	--	--
2,2-Dichloropropane	--	--
Chloroform	--	--
Bromochloromethane	--	--
1,1-Dichloropropene	--	--
1,2-Dichloroethane	--	--
Bromodichloromethane	--	--
Dibromomethane	--	--
1,3-Dichloropropene	--	--
1,1,2-Trichloroethane	--	--
1,3-Dichloropropane	--	--
Dibromochloromethane	--	--
Chlorobenzene	--	--
1,1,1,2-Tetrachloroethane	--	--
Styrene	--	--
Isopropylbenzene	--	--
Bromoform	--	--
1,1,2,2-Tetrachloroethane	--	--
1,2,3-Trichloropropane	--	--
n-Propylbenzene	--	--
Bromobenzene	--	--
1,3,5-Trimethylbenzene	--	--
o-Chlorotoluene	--	--
p-Chlorotoluene	--	--
tert-Butylbenzene	--	--
1,2,4-Trimethylbenzene	--	--
sec-Butylbenzene	--	--
p-Isopropyltoluene	--	--
m-Dichlorobenzene	--	--
p-Dichlorobenzene	--	--
n-Butylbenzene	--	--
o-Dichlorobenzene	--	--
1,2,4-Trichlorobenzene	--	--
Hexachlorobutadiene	--	--
1,2,3-Trichlorobenzene	--	--

Groundwater and Swamp-Water Monitoring Data - VOCs (ug/L)

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Groundwater and Swamp-Water Monitoring Data - VOCs (ug/L)

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Groundwater and Swamp-Water Monitoring Data - VOCs (ug/L)

Source	OB-5	OB-5	OB-5
Date Sampled	7/24/98	10/27/98	1/13/99
Time Sampled	11:24	11:44	12:15
Date Analyzed	7/31/98	10/31/98	1/20/99
Trichloroethylene	--	--	--
cis-1,2-Dichloroethylene	138.0	97.5	138.0
trans-1,2-Dichloroethylene	(0.37)	--	(0.21)
1,1-Dichloroethylene	--	--	--
Vinyl Chloride	7.25	--	--
1,1-Dichloroethane	10.2	--	10.7
Tetrachloroethylene	--	--	--
Benzene	--	--	--
Toluene	--	--	--
Ethylbenzene	--	--	--
Total Xylenes	--	--	--
Naphthalene	--	--	0.64
1,1,1-Trichloroethane	--	--	--
Carbon Tetrachloride	--	--	--
1,2-Dichloropropane	--	UJ	--
Dichlorodifluoromethane	--	--	--
Chloromethane	--	--	--
Bromomethane	--	--	--
Chloroethane	--	--	--
Fluorotrichloromethane	--	--	--
Dichloromethane	--	--	--
2,2-Dichloropropane	--	--	--
Chloroform	--	--	--
Bromochloromethane	--	--	--
1,1-Dichloropropene	--	--	--
1,2-Dichloroethane	--	--	--
Bromodichloromethane	--	--	--
Dibromomethane	--	--	--
1,3-Dichloropropene	--	--	--
1,1,2-Trichloroethane	--	UJ	--
1,3-Dichloropropane	--	--	--
Dibromochloromethane	--	--	--
Chlorobenzene	--	UJ	--
1,1,1,2-Tetrachloroethane	--	--	--
Styrene	--	--	--
Isopropylbenzene	--	--	--
Bromoform	--	UJ	--
1,1,2,2-Tetrachloroethane	UJ	UJ	--
1,2,3-Trichloropropane	--	--	--
n-Propylbenzene	--	--	--
Bromobenzene	--	--	--
1,3,5-Trimethylbenzene	--	--	--
o-Chlorotoluene	--	--	--
p-Chlorotoluene	--	--	--
tert-Butylbenzene	--	--	--
1,2,4-Trimethylbenzene	--	--	--
sec-Butylbenzene	--	--	--
p-Isopropyltoluene	--	--	--
m-Dichlorobenzene	--	--	--
p-Dichlorobenzene	--	--	--
n-Butylbenzene	--	--	--
o-Dichlorobenzene	--	--	--
1,2,4-Trichlorobenzene	--	--	--
Hexachlorobutadiene	--	--	--
1,2,3-Trichlorobenzene	--	--	--

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Groundwater and Swamp-Water Monitoring Data - VOCs (ug/L)

Source	OCW-4A	OCW-4A	OCW-4B	OCW-4B	OCW-5D	OCW-5D	OCW-5D	OCW-5D
Date Sampled	8/12/98	1/12/99	8/11/98	1/12/99	6/18/98	8/11/98	11/10/98	1/12/99
Time Sampled	9:31	15:15	17:19	15:02	15:45	17:07	16:32	14:14
Date Analyzed	8/19/98	1/20/99	8/19/98	1/20/99	6/19/98	8/19/98	11/13/98	1/20/99
Trichloroethylene	--	--	(0.38)	(0.3)	--	--	--	--
cis-1,2-Dichloroethylene	--	--	1.28	0.82	1.19	0.8	(0.26)	(0.21)
trans-1,2-Dichloroethylene	--	--	--	--	--	--	--	--
1,1-Dichloroethylene	--	--	--	--	--	--	--	--
Vinyl Chloride	--	--	--	--	--	--	--	--
1,1-Dichloroethane	--	--	--	--	--	--	--	--
Tetrachloroethylene	--	--	--	--	--	--	--	--
Benzene	--	--	--	--	--	--	--	--
Toluene	--	--	--	--	--	(0.2)	--	--
Ethylbenzene	--	--	--	--	--	--	--	--
Total Xylenes	--	--	--	--	--	--	--	--
Naphthalene	--	--	--	--	--	--	--	--
1,1,1-Trichloroethane	--	--	--	--	--	--	--	--
Carbon Tetrachloride	--	--	--	--	--	--	--	--
1,2-Dichloropropane	--	--	--	--	--	--	--	--
Dichlorodifluoromethane	--	--	--	--	--	--	--	--
Chloromethane	--	--	--	--	--	--	--	--
Bromomethane	--	--	--	--	--	--	--	--
Chloroethane	--	--	--	--	--	--	--	--
Fluorotrichloromethane	--	--	--	--	--	--	--	--
Dichloromethane	--	--	--	--	--	--	--	--
2,2-Dichloropropane	--	--	--	--	--	--	--	--
Chloroform	4.22	2.75	2.23	2.09	--	--	--	--
Bromochloromethane	--	--	--	--	--	--	--	--
1,1-Dichloropropene	--	--	--	--	--	--	--	--
1,2-Dichloroethane	--	--	--	--	--	--	--	--
Bromodichloromethane	--	--	--	--	--	--	--	--
Dibromomethane	--	--	--	--	--	--	UJ	--
1,3-Dichloropropene	--	--	--	--	--	--	--	--
1,1,2-Trichloroethane	--	--	--	--	--	--	--	--
1,3-Dichloropropane	--	--	--	--	--	--	--	--
Dibromochloromethane	--	--	--	--	--	--	--	--
Chlorobenzene	--	--	--	--	--	--	--	--
1,1,1,2-Tetrachloroethane	--	--	--	--	--	--	--	--
Styrene	--	--	--	--	--	--	--	--
Isopropylbenzene	--	--	--	--	--	--	--	--
Bromoform	--	--	--	--	--	--	--	--
1,1,2,2-Tetrachloroethane	--	--	--	--	--	--	--	--
1,2,3-Trichloropropane	--	--	--	--	--	--	--	--
n-Propylbenzene	--	--	--	--	--	--	--	--
Bromobenzene	--	--	--	--	--	--	--	--
1,3,5-Trimethylbenzene	--	--	--	--	--	--	--	--
o-Chlorotoluene	--	--	--	--	--	--	--	--
p-Chlorotoluene	--	--	--	--	--	--	--	--
tert-Butylbenzene	--	--	--	--	--	--	--	--
1,2,4-Trimethylbenzene	--	--	--	--	--	--	--	--
sec-Butylbenzene	--	--	--	--	--	--	--	--
p-Isopropyltoluene	--	--	--	--	--	--	--	--
m-Dichlorobenzene	--	--	--	--	--	--	--	--
p-Dichlorobenzene	--	--	--	--	--	--	--	--
n-Butylbenzene	--	--	--	--	--	--	--	--
o-Dichlorobenzene	--	--	--	--	--	--	--	--
1,2,4-Trichlorobenzene	--	--	--	--	--	--	--	--
Hexachlorobutadiene	--	--	--	--	--	--	--	--
1,2,3-Trichlorobenzene	--	--	--	--	--	--	--	--

Groundwater and Swamp-Water Monitoring Data - VOCs (ug/L)

Source	OSW-1A	OSW-1A	OSW-1A	OSW-1A	OSW-1A
Date Sampled	7/14/98	7/15/98	8/11/98	11/11/98	1/11/99
Time Sampled	15:00	10:16	11:34	10:13	14:38
Date Analyzed	7/16/98	7/16/98	8/19/98	11/13/98	1/20/99
Trichloroethylene	--	--	--	--	--
cis-1,2-Dichloroethylene	--	0.99	0.85	1.32	1.46
trans-1,2-Dichloroethylene	--	--	--	--	--
1,1-Dichloroethylene	--	--	--	--	--
Vinyl Chloride	--	--	--	--	--
1,1-Dichloroethane	--	--	--	--	--
Tetrachloroethylene	--	--	--	--	--
Benzene	--	--	--	--	--
Toluene	--	--	--	--	--
Ethylbenzene	--	--	--	--	--
Total Xylenes	--	--	--	--	--
Naphthalene	--	--	--	--	--
1,1,1-Trichloroethane	--	--	--	--	--
Carbon Tetrachloride	--	--	--	--	--
1,2-Dichloropropane	--	--	--	--	--
Dichlorodifluoromethane	--	--	--	--	--
Chloromethane	--	--	--	--	--
Bromomethane	--	--	--	--	--
Chloroethane	--	--	--	--	--
Fluorotrichloromethane	--	--	--	--	--
Dichloromethane	--	--	--	--	--
2,2-Dichloropropane	--	--	--	--	--
Chloroform	--	--	--	--	--
Bromochloromethane	--	--	--	--	--
1,1-Dichloropropene	--	--	--	--	--
1,2-Dichloroethane	--	--	--	--	--
Bromodichloromethane	--	--	--	--	--
Dibromomethane	--	--	--	UJ	--
1,3-Dichloropropene	--	--	--	--	--
1,1,2-Trichloroethane	--	--	--	--	--
1,3-Dichloropropane	--	--	--	--	--
Dibromochloromethane	--	--	--	--	--
Chlorobenzene	--	--	--	--	--
1,1,1,2-Tetrachloroethane	--	--	--	--	--
Styrene	--	--	--	--	--
Isopropylbenzene	--	--	--	--	--
Bromoform	--	--	--	--	--
1,1,2,2-Tetrachloroethane	--	--	--	--	--
1,2,3-Trichloropropane	--	--	--	--	--
n-Propylbenzene	--	--	--	--	--
Bromobenzene	--	--	--	--	--
1,3,5-Trimethylbenzene	--	--	--	--	--
o-Chlorotoluene	--	--	--	--	--
p-Chlorotoluene	--	--	--	--	--
tert-Butylbenzene	--	--	--	--	--
1,2,4-Trimethylbenzene	--	--	--	--	--
sec-Butylbenzene	--	--	--	--	--
p-Isopropyltoluene	--	--	--	--	--
m-Dichlorobenzene	--	--	--	--	--
p-Dichlorobenzene	--	--	--	--	--
n-Butylbenzene	--	--	--	--	--
o-Dichlorobenzene	--	--	--	--	--
1,2,4-Trichlorobenzene	--	--	--	--	--
Hexachlorobutadiene	--	--	--	--	--
1,2,3-Trichlorobenzene	--	--	--	--	--

Groundwater and Swamp-Water Monitoring Data - VOCs (ug/L)

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Groundwater and Swamp-Water Monitoring Data - VOCs (ug/L)

[illegible]

Groundwater and Swamp-Water Monitoring Data - VOCs (ug/L)

Source	SWS-9	SWS-9	SWS-9
Date Sampled	8/12/98	11/11/98	1/11/99
Time Sampled	14:50	8:30	11:30
Date Analyzed	8/19/98	11/13/98	1/20/99
Trichloroethylene	30.4	--	(0.34)
cis-1,2-Dichloroethylene	562.0	8.47	440.0
trans-1,2-Dichloroethylene	--	--	2.04
1,1-Dichloroethylene	1.09	--	--
Vinyl Chloride	--	--	--
1,1-Dichloroethane	(0.3)	--	--
Tetrachloroethylene	--	--	--
Benzene	--	--	--
Toluene	(0.37)	--	15.0
Ethylbenzene	--	--	--
Total Xylenes	--	--	--
Naphthalene	--	--	--
1,1,1-Trichloroethane	--	--	--
Carbon Tetrachloride	--	--	--
1,2-Dichloropropane	--	--	--
Dichlorodifluoromethane	--	--	--
Chloromethane	--	--	--
Bromomethane	--	--	--
Chloroethane	--	--	--
Fluorotrichloromethane	--	--	--
Dichloromethane	--	--	--
2,2-Dichloropropane	--	--	--
Chloroform	--	--	--
Bromochloromethane	--	--	--
1,1-Dichloropropene	--	--	--
1,2-Dichloroethane	--	--	--
Bromodichloromethane	--	--	--
Dibromomethane	--	UJ	--
1,3-Dichloropropene	--	--	--
1,1,2-Trichloroethane	--	--	--
1,3-Dichloropropane	--	--	--
Dibromochloromethane	--	--	--
Chlorobenzene	--	--	--
1,1,1,2-Tetrachloroethane	--	--	--
Styrene	--	--	--
Isopropylbenzene	--	--	--
Bromoform	--	--	--
1,1,2,2-Tetrachloroethane	--	--	--
1,2,3-Trichloropropane	--	--	--
n-Propylbenzene	--	--	--
Bromobenzene	--	--	--
1,3,5-Trimethylbenzene	--	--	--
o-Chlorotoluene	--	--	--
p-Chlorotoluene	--	--	--
tert-Butylbenzene	--	--	--
1,2,4-Trimethylbenzene	--	--	--
sec-Butylbenzene	--	--	--
p-Isopropyltoluene	--	--	--
m-Dichlorobenzene	--	--	--
p-Dichlorobenzene	--	--	--
n-Butylbenzene	--	--	--
o-Dichlorobenzene	--	--	--
1,2,4-Trichlorobenzene	--	--	--
Hexachlorobutadiene	--	--	--
1,2,3-Trichlorobenzene	--	--	--

Appendix D

State of North Carolina
Department of Environment,
Health and Natural Resources
Wilmington Regional Office
Division of Water Quality
Groundwater Section



James B. Hunt, Jr., Governor
Wayne McDevitt, Secretary

October 16, 1998

CERTIFIED MAIL Z 153 116 412
RETURN RECEIPT REQUESTED

Mr. H.R. Strickler, Manager of Environmental
Protection and Industrial Safety
General Electric Company
P.O. Box 780 (M/C J-26)
Wilmington, NC 28402

SUBJECT: Assessment Threshold Concentrations
 Former Northwest CAF₂ Storage Area
 Wilmington, North Carolina
 New Hanover County

Dear Mr. Strickler:

Thank you for your September 1, 1998 written response to the concerns raised in our August 11, 1998 correspondence to you. We also appreciate the copies of the ICP-MS (inductively coupled plasma mass spectroscopy) and LFS (laser fluorescence spectrophotometry) laboratory method descriptions as we requested. After reviewing your letter, the laboratory method descriptions, and the project history, I offer you the following comments.

During the course of this project, a great deal of time has been spent attempting to establish an assessment criterion for the former northwest CAF₂ storage area based either on background concentrations of uranium or isotopic ratios of uranium. We understand and appreciate that General Electric (GE) is concerned that the assessment and remediation activities that are required by the Division could cause GE to expend valuable resources addressing natural concentrations of uranium because our 15A NCAC 2L (2L) rules do not specify a numeric standard. Based on your September 1, 1998 letter, our previous conversations, and correspondences, we understand that GE does not believe obtaining a background concentration would be useful for the completion of the assessment. Another option, which has been discussed, was that GE propose an interim standard to our Division Director for adoption into the 2L rules.

Your September 1, 1998 letter proposes that the assessment threshold concentration be set at 0.002 mg/L using the ICP-MS method. Due to analytical method limitations on accuracy below the 0.002 mg/L limit, you proposed to only perform isotopic ratios on values detected above this limit.

Mr. H.R. Strickler
October 16, 1998
Page Two

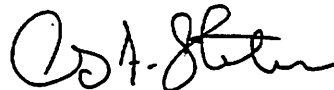
In support of GE's point that background concentrations of uranium should not be used to assess groundwater conditions in the former northwest CAF₂ storage area, you cited 15A NCAC 2L .0202 (b)(3). We obviously agree with the point you make in your September 1, 1998 letter, that isotopic ratios determined to date are not "naturally occurring".

As previously explained, the use of background concentrations of naturally occurring uranium was intended to assist GE in determining an alternate assessment threshold value. Given GE's objection to establishing and utilizing a background uranium concentration in determining an assessment threshold value, we will default to 15A NCAC 2L .0202 (c) which establishes that any concentration above detection limits, which is not naturally occurring, exceeds the groundwater quality standards as listed in 2L. It is our understanding that the ICP-MS method which you have been using for the assessment of this area has a practical quantitation limit (pql) of 0.00015 mg/L. The pql of the ICP-MS method (0.00015 mg/L) is the assessment threshold value which should be used at your site. We also concur with your proposal to only perform isotopic values on concentrations that exceed 0.002 mg/L, due to method accuracy limitations below this value.

Your September 1, 1998 letter clarified that GE believes it can meet the schedule set in it's May 27, 1998 submission to our office. We look forward to receiving the Comprehensive Site Assessment and Corrective Action Plan which will be submitted to our office sometime in the fourth quarter of this year.

Thank you again for your response to our August 11, 1998 correspondence. I sincerely hope that this letter clarifies our expectations regarding the assessment threshold values for this project. If you have any questions, please contact myself or Bruce Parris at (910) 395-3900.

Yours very truly,



Charlie Stehman, Ph.D., P.G.
Environmental Regional Supervisor I

CFS\BRP\tdc

cc: WiRO-GWS
Arthur Mouberry, CO-GWS
Preston Howard, Div. Dir. - DWQ
Ed Beck, WiRO-WQS
Dale Dusenbury, DRP
Tom Crawford, GE
Scott Murray, GE
Joe Alexander, RTI
Jeff Reynolds, RTI



General Electric Company
P.O. Box 780, Wilmington, NC 28402
910 675-5000

September 1, 1998

Charles Stehman, Ph.D., P.G.
North Carolina Department of
Environment and Natural Resources
Wilmington Regional Office
127 Cardinal Drive Extension
Wilmington, North Carolina 28405

SUBJECT: Assessment and Corrective Actions
Former General Electric Northwest CAF₂ Storage Area
Wilmington, North Carolina
New Hanover County

Dear Dr. Stehman:

Thank you for your letter of August 11, 1998, regarding GE's ongoing work associated with the Company's former northwest CAF₂ storage area.

First, let me assure NC DENR that GE has no intention of using the Groundwater Monitoring Guideline value (GMGV) proposed by Tom Potter and GE, or any other similar number, as a sole basis for seeking to end groundwater monitoring activities at and around the plant. Any request to halt or reduce sampling would be submitted to your office for review before implementation and would be based on factors that underlie the groundwater rules and applicable standards.

The GMGV proposed by GE is not intended to establish a background concentration but, rather, provide a health risk based reference number to aid in evaluating potential groundwater impacts associated with activities previously conducted at the NW area.

While GE does not disagree that information sufficient to establish a background concentration for uranium has not yet been presented, we provided what we believed to be a thorough explanation at our May 27 meeting. The purpose of this letter, in addition to providing the response you requested, is to reiterate the reasons why GE does not think that background data is necessary or appropriate for this situation and, as a consequence, to request that you and your staff reconsider the request for background data.

The acquisition and development of information on background levels of uranium does not appear to address the principal issue, that is: how best to define the horizontal and vertical extent of the plume. GE continues to believe that the GMGV, as discussed in Mr. Dusenbury's

Charlie Stehman, Ph.D., P.G.
September 1, 1998
Page 2

letter to you of July 24, provides an efficient measure to demonstrate the extent of the plume. Furthermore, GE believes that the use of the GMGV obviates the need for background data.

The contaminant levels involved in the NW area pose little or no health risk. Determination of the isotopic values involved at the levels found in the area does not impact our assessment of the health risk from either a radiological and toxicological standpoint. Allocations of resources necessary to determining background and isotopic ratios at these levels will, however, divert resources from other activities without producing a measurable benefit and without improving our understanding of groundwater conditions.

In regard to the groundwater conditions present in the NW area, based upon - prior to material removal - groundwater sampling, the isotopic ratios determined to date are not naturally occurring. This fact - that there are ratios of uranium isotopes in the groundwater not present in nature - makes the use of data on naturally occurring (or "background") concentrations of these isotopes not relevant under § .0202(b)(3) of the groundwater rules, 15A NCAC 2L.0202(b)(3).

Relying on isotopic information to assess groundwater conditions makes the practical quantitation limit (PQL) for total uranium (in the measurement of those isotopes) - the other pertinent fact under § .0202(b)(1) of the groundwater rules, 15A NCAC 2L .0202(b)(3). An offsite lab informs us that, for an ICP procedure used in performing isotopic analysis, the PQL for total uranium is 0.002 mg/L. To date, the groundwater offsite sample results for uranium have been less than this number (0.002 mg/L) [note - additional samples have been taken in new offsite wells and results are pending]. Please also note that the PQL for typical samples routinely analyzed by the GE-Wilmington lab using another method (laser fluorescence spectrophotometry) is 0.02 mg/L total uranium.

Given the inevitable variability and imprecision that would be involved in trying to determine some type of background level for naturally-occurring uranium in a heterogeneous geologic environment, as well as its arguable irrelevance to the issue, GE believes that the PQL (0.002 mg/l) provides an adequate and defensible basis for determining the horizontal and vertical extent of the plume. Of course, a practical and scientifically defensible approach to the elevated levels of uranium would be to follow a purely risk-based method of analysis, as described in Tom Potter's May 11, 1998 report, given the difficulty of determining background levels of uranium at and around the plant.

Consequently, we would request that the Agency reconsider the directive in your August 11 letter to provide background information and instead allow isotopic analyses if the total uranium values are greater than the PQL of 0.002 mg/L. This 0.002 mg/L value could be used as the assessment threshold concentration for this project. Should the Agency continue to insist on this background information, we would request additional time to submit that information, as well as opportunities to discuss the policy implications of being required to provide that information. In any event, we will be following up with you or your office about that issue, as well as to see whether further information is required in connection with this request for reconsideration.

Charlie Stehman, Ph.D., P.G.
September 1, 1998
Page 3

In response to the other items in your letter, this letter is to confirm that GE will provide your office with information on the laboratory methods (ICP-MS, inductively coupled plasma mass spectroscopy or laser fluorescence spectrophotometry) that labs use to analyze groundwater samples for uranium or uranium isotopes. If desired, we can also provide supporting information that establishes the PQL for these laboratory methods to measure uranium and uranium isotopes.

In terms of the questions your letter appears to raise about the completion and submittal of a Comprehensive Site Assessment (CSA) and Corrective Action Plan (CAP) for the project, GE believes it can still meet the proposed schedule dates that the Company submitted to DENR on May 27, 1998, for the submittal of the CSA and CAP. As directed in your letter, however, should delays in the schedule for the submittal of the CSA or CAP appear likely, the Company will submit in writing to your office a request for a time extension.

We assume that this letter will provide a sufficient response to your letter, such that the Agency will not conclude there is a basis for issuing a Notice of Violation (NOV) or taking any other similar enforcement or other action. If our understanding is not correct, we would appreciate being informed of that fact by your office in time to allow further communications prior to the second deadline set in your letter.

Thank you in advance for your consideration and that of your staff.

Sincerely,

GE NUCLEAR ENERGY



Herbert R. Strickler, Manager
Site EHS

cc: Ed Beck, WIRO-WQS
Dale Dusenbury, DRP
Scott Murray
Joe Alexander, RTI
Arthur Mouberry, CO-GWS
Preston Howard, Div. Dir. - DWQ
HRS98-050

Appendix E



March 30, 1999

Mrs. Katharine Sledge
P.O. Box 523
253 N. Powell Blvd.
Whiteville, NC 28472

Reference: Consent for Corrective Action of Groundwater Contamination by
Natural Attenuation and Consent for Property Access
General Electric Company, Castle Hayne Road, Wilmington, NC

Dear Mrs. Sledge:

This letter is to provide you with further information about our work on the groundwater contamination that we have discussed previously and to request your permission to allow us to proceed with the work that we will be proposing to do in concurrence with North Carolina Department of Environment & Natural Resources (DENR). General Electric (GE) has identified groundwater contamination in the remote northwest (NW) area of our property, which is adjacent to a portion of your property off Castle Hayne Road.

GE believes the contamination resulted from material management practices typical of the late 1960s. There are two areas in the NW GE property from where the groundwater contaminants migrated. Material has been removed from one area and the other no longer contributes to the contamination in the groundwater. Environmental monitoring studies have shown that the groundwater contamination continues to degrade and decrease over time by natural processes.

Acting, based on your prior approval, GE collected several groundwater samples from your property for analysis. Several of the samples contained volatile organic compounds (VOCs). VOCs typically are found in degreasers or solutions like dry cleaning liquids. We detected in one of the monitoring wells which we installed on your property two VOCs, trichloroethylene (TCE) and dichloroethylene (DCE), at concentrations exceeding applicable North Carolina groundwater quality standards.

One sample of water taken from a soil boring on your property (near the GE boundary) also exhibited low levels of fluoride and uranium characteristic of the material formerly stored on our site. However, the levels of fluoride and uranium were not found above applicable standards in the monitoring wells on your property.

With DENR's concurrence, GE intends to pursue corrective action of the groundwater contamination using natural processes. This is an option available under North Carolina law with review and approval of the DENR. These natural processes, collectively referred to as natural attenuation, will decrease contaminant concentrations over time. Indeed, this is what has been happening to the contaminants already, as shown by the monitoring results. GE believes that natural attenuation is an appropriate

remedy for your property considering the insignificant health and environmental risks posed by the contamination.

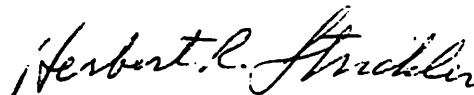
Based upon our familiarity with the property and through our discussion with you, we know that your property is used as a hunting preserve. Maintaining your property in an undisturbed condition for use as a hunting preserve minimizes any risks from the contamination. Any other alternative corrective action would be more intrusive and could interfere with the way your land is currently used. Should you plan to change the use or ownership of your land, GE would like the opportunity to review with you the progress of the natural cleanup process.

Consistent with the State's groundwater rules, GE seeks your consent that: (1) GE will pursue cleanup of the contamination on your property using natural attenuation processes, and (2) GE or its agent can access your property from time to time to collect samples for analysis. This access will allow continued evaluation of the natural attenuation processes.

If you consent to the above request, please sign and date a copy of this letter in the space provided below, and return the signed copy to me at the above return address. If there are any questions regarding this matter which you would like to discuss with DENR, you can call Dr. Charles Stehman (910*395-3900), Groundwater Supervisor in the Wilmington Regional Office. Dr. Stehman is very familiar with this site, as well as the procedures we are using to address the contamination. You should also feel free to contact me at (910) 675-5721 if you have any questions regarding this matter.

Sincerely,

GE NUCLEAR ENERGY




Herbert R. Strickler, Manager
Site Environment, Health & Safety

cc: HRS-99-013

GE has informed me that groundwater contamination is present on my property. I concur with GE's proposed natural attenuation corrective action and authorize GE and its agents to access my property from time to time to collect environmental samples for analysis to monitor this natural cleanup process.

Signed:


Mrs. Katharine Sledge
Date

Appendix F

New Hanover Co Flemington 1992 Water Supply System Report

Important information regarding the SWSP database

The information in this State Water Supply Plan database has been submitted by local government water systems in their 1992 Water Supply System Reports and maps which are part of their adopted Local Water Supply Plans pursuant to G.S. 143-355(l). Plans in this database are labeled either "adopted" or "draft" plans.

Plans labeled "adopted" have been reviewed by the State Division of Water Resources for internal consistency, general reasonableness, and completeness and have been acknowledged by DWR as meeting the minimum requirements of the law. Plans labeled "draft" have not yet completed this process.

None of the data has been field verified. Consistency between plans has not been considered. The State Water Supply Plan database is still receiving data. Information in the database may be corrected or updated at any time by the local government. This data will be updated at least once every five years. DWR assumes no liability for damages caused by inaccuracies in this data. DWR makes no warranty, expressed or implied, as to the accuracy of the information presented, nor does the fact of distribution constitute such a warranty.

Table of Contents

General Information

Water Use Information

Surface Water Supply Sources

Ground Water Supply Sources

12 Hour Yield

System Interconnections

10 Year Projected Water Use

Future Sources

Wastewater Discharge Information

Water Conservation

Water Supply Planning Assistance Needs

GENERAL INFORMATION

Status of Plan: Adopted Plan

PWS Identification Number: 04-65-191

River Basin Name: Northeast Cape Fear (2-5)

Name of System: New Hanover Co Flemington

County: New Hanover

Ownership: Authority

The 1992 population: 108

The 2000 projected population: 110

The 2010 projected population: 114

The 2020 projected population: 118

Are populations seasonal?: N

1992 WATER USE INFORMATION

Total water use: 76.860 mg

Average annual daily water use: 0.210 mgd

Maximum daily water use: 0.389 mgd

Type of water use in mgd:

1992 SYSTEM INTERCONNECTIONS

There were no other water intake or outflow connections reported for this system in 1992

10 YEAR PROJECTED WATER USE

Is the present water source sufficient for the needs through the year 2002? Y

1992 FUTURE SOURCES

There were no future sources of water reported for this system in 1992

1992 WASTEWATER DISCHARGE INFORMATION

No wastewater discharge permit information was reported for this system in 1992

1992 WATER CONSERVATION

Does the system flush or work hydrants? Y

Does the system have a valve exercise program? Y

Does the system have an active leak detection program? N

Does the system have a water conservation plumbing code? Y

In 1992, did the system provide water conservation information to customers? N

Was water use restricted during 1992? N

Has water use ever been restricted in the past 10 years? N

Year Water use (mgd) Population

1970 0.000 0

1980 0.000 0

Does the system have a drought or water conservation ordinance? N

Does the system have an active meter replacement program? Y

1992 WATER SUPPLY PLANNING ASSISTANCE NEEDS

Does the system need technical assistance in developing a local water supply plan? N

Does the system need technical assistance with a leak detection program? N

Does the system need technical assistance with any other supply or use problems? N

Retrieve Additional system data for New Hanover Co Flemington from the Division of Environmental Health, Public Water Supply Section (Caution: this link may be slow)



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Residential: 0.008
Non-residential: 0.181
Bulk Sales: 0.000
Unaccounted for: 0.000

Average monthly water use in mgd:

Jan.	0.176	Apr.	0.182	July	0.213	Oct.	0.248
Feb.	0.201	May	0.217	Aug.	0.220	Nov.	0.221
Mar.	0.165	June	0.213	Sep.	0.224	Dec.	0.250

2000 Projected water use: 0.217 mgd

2010 Projected water use: 0.258 mgd

2020 Projected water use: 0.308 mgd

1992 SURFACE WATER SUPPLY SOURCES

There were no reported surface water intakes for this system in 1992

1992 GROUND WATER SUPPLY SOURCES

Name of well: 1

Well depth: 45

Casing depth: 25

Screen depth: Top: 25.0 Bottom: 45.0

Latitude: 0° 0' 0" Longitude: 0° 0' 0"

Average daily withdrawal: 0.129 mgd Number of days: 366

Safe yield: 0.288

Formation or aquifer: Surficial

Regular, Emergency, or Temporary: Regular

Name of well: 2

Well depth: 50

Casing depth: 25

Screen depth: Top: 25.0 Bottom: 46.0

Latitude: 0° 0' 0" Longitude: 0° 0' 0"

Average daily withdrawal: 0.034 mgd Number of days: 366

Safe yield: 0.288

Formation or aquifer: Surficial

Regular, Emergency, or Temporary: Regular

Name of well: 3

Well depth: 55

Casing depth: 20

Screen depth: Top: 20.0 Bottom: 55.0

Latitude: 0° 0' 0" Longitude: 0° 0' 0"

Average daily withdrawal: 0.047 mgd Number of days: 366

Safe yield: 0.288

Formation or aquifer: Surficial

Regular, Emergency, or Temporary: Regular

12 Hour Yield

What is the combined 12-hour yield of all wells in the system?: 0.4320 mgd

New Hanover Co Airport 1992 Water Supply System Report

Important information regarding the SWSP database

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Table of Contents

General Information

Water Use Information

Surface Water Supply Sources

Ground Water Supply Sources

System Interconnections

10 Year Projected Water Use

Future Sources

Wastewater Discharge Information

Water Conservation

Water Supply Planning Assistance Needs

GENERAL INFORMATION

Status of Plan: Adopted Plan

PWS Identification Number: 04-65-510

River Basin Name: Cape Fear (2-3)

Name of System: New Hanover Co Airport

County: New Hanover

Ownership: Authority

The 1992 population: 0

The 2000 projected population: 0

The 2010 projected population: 0

The 2020 projected population: 0

Are populations seasonal?:

1992 WATER USE INFORMATION

Total water use: 6.980 mg

Average annual daily water use: 0.019 mgd

Maximum daily water use: 0.000 mgd

Type of water use in mgd:

Residential: 0.000
Non-residential: 0.019
Bulk Sales: 0.000
Unaccounted for: 0.000

Average monthly water use in mgd:

Jan.	0.000	Apr.	0.000	July	0.000	Oct.	0.000
Feb.	0.000	May	0.000	Aug.	0.000	Nov.	0.000
Mar.	0.000	June	0.000	Sep.	0.000	Dec.	0.000

2000 Projected water use: 0.020 mgd
2010 Projected water use: 0.024 mgd
2020 Projected water use: 0.029 mgd

1992 SURFACE WATER SUPPLY SOURCES

There were no reported surface water intakes for this system in 1992

1992 GROUND WATER SUPPLY SOURCES

There were no reported ground water intakes for this system in 1992

1992 SYSTEM INTERCONNECTIONS

Supplier name: Wilmington
Receiver name: New Hanover Co/airport
Average daily water transferred: 0.019 mgd **No. of days:** 366
Contract amount: 1.440 mgd
Regular, Emergency, or Temporary: Regular

10 YEAR PROJECTED WATER USE

Is the present water source sufficient for the needs through the year 2002? Y

1992 FUTURE SOURCES

There were no future sources of water reported for this system in 1992

1992 WASTEWATER DISCHARGE INFORMATION

Discharge permit number:
Permit capacity: 0.0000 mgd
Design capacity: 0.0000 mgd
1992 Average annual daily discharge: 0.000 mgd
Receiving stream: Wilmington Wwtp
latitude: 0° 0' 0" **longitude:** 0° 0' 0"

List average daily wastewater discharge in mgd by month.

Jan.	0.000	Apr.	0.000	July	0.000	Oct.	0.000
Feb.	0.000	May	0.000	Aug.	0.000	Nov.	0.000
Mar.	0.000	June	0.000	Sep.	0.000	Dec.	0.000

1992 WATER CONSERVATION

Does the system flush or work hydrants? Y

Does the system have a valve exercise program? N

Does the system have an active leak detection program? N

Does the system have a water conservation plumbing code? N

In 1992, did the system provide water conservation information to customers? N

Was water use restricted during 1992? N

Has water use ever been restricted in the past 10 years? N

Year Water use (mgd) Population

1970 0.013 0

1980 0.017 0

Does the system have a drought or water conservation ordinance? N

Does the system have an active meter replacement program? N

1992 WATER SUPPLY PLANNING ASSISTANCE NEEDS

Does the system need technical assistance in developing a local water supply plan? N

Does the system need technical assistance with a leak detection program? N

Does the system need technical assistance with any other supply or use problems? N

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Wilmington 1992 Water Supply System Report

Important information regarding the SWSP database

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Table of Contents

General Information

Water Use Information

Surface Water Supply Sources

Off-Stream Raw Water Storage

Ground Water Supply Sources

System Interconnections

10 Year Projected Water Use

Future Sources

Wastewater Discharge Information

Water Conservation

Water Supply Planning Assistance Needs

GENERAL INFORMATION

Status of Plan: Adopted Plan

PWS Identification Number: 04-65-010

River Basin Name: Cape Fear (2-3)

Name of System: Wilmington

County: New Hanover

Ownership: Municipality

The 1992 population: 57,213

The 2000 projected population: 84,500

The 2010 projected population: 85,000

The 2020 projected population: 86,500

Are populations seasonal?: N

1992 WATER USE INFORMATION

Total water use: 3518.000 mg

Average annual daily water use: 9.610 mgd

Maximum daily water use: 13.022 mgd

Type of water use in mgd:

Residential: 5.020
Non-residential: 2.190
Bulk Sales: 0.000
Unaccounted for: 2.400

Average monthly water use in mgd:

Jan.	8.194	Apr.	9.333	July	11.347	Oct.	9.820
Feb.	8.759	May	9.874	Aug.	10.807	Nov.	9.417
Mar.	8.613	June	9.888	Sep.	10.489	Dec.	8.752

2000 Projected water use: 19.300 mgd
2010 Projected water use: 19.400 mgd
2020 Projected water use: 19.700 mgd

1992 SURFACE WATER SUPPLY SOURCES

Name of stream/reservoir: Cape Fear River **Stream or Reservoir?** Stream
Drainage area: 0.000 square miles
Location: latitude: 34° 24' 24" longitude: 78° 18' 10"
Average daily withdrawal: 9.620 mgd **No. of days:** 366
Safe yield: 20 yr: 104.000 50 yr.: 288.000
Safe yield qualifier: 7Q10 (F)
On-stream raw water storage: 0.000 mg
Regular, Emergency, or Temporary: Regular

OFF-STREAM RAW WATER STORAGE

Total off-stream storage capacity in mg: 0.000

1992 GROUND WATER SUPPLY SOURCES

There were no reported ground water intakes for this system in 1992

1992 SYSTEM INTERCONNECTIONS

There were no other water intake or outflow connections reported for this system in 1992

10 YEAR PROJECTED WATER USE

Is the present water source sufficient for the needs through the year 2002? Y

1992 FUTURE SOURCES

There were no future sources of water reported for this system in 1992

1992 WASTEWATER DISCHARGE INFORMATION

Discharge permit number: NC0002879
Permit capacity: 0.0000 mgd

Design capacity: 1.5000 mgd
 1992 Average annual daily discharge: 0.211 mgd
 Receiving stream: Ne Cape Fear River
 latitude: 34° 15' 23" longitude: 77° 56' 53"

Discharge permit number: NC0023765
 Permit capacity: 8.0000 mgd
 Design capacity: 8.0000 mgd
 1992 Average annual daily discharge: 4.549 mgd
 Receiving stream: Ne Cape Fear River
 latitude: 34° 15' 55" longitude: 77° 55' 19"

Discharge permit number: NC0023973
 Permit capacity: 12.0000 mgd
 Design capacity: 12.0000 mgd
 1992 Average annual daily discharge: 7.141 mgd
 Receiving stream: Cape Fear River
 latitude: 34° 9' 55" longitude: 77° 56' 55"

List average daily wastewater discharge in mgd by month.

Jan.	11.540	Apr.	11.525	July	11.872	Oct.	11.651
Feb.	11.279	May	11.055	Aug.	14.641	Nov.	11.455
Mar.	11.666	June	12.176	Sep.	11.990	Dec.	11.966

1992 WATER CONSERVATION

Does the system flush or work hydrants? Y
 Does the system have a valve exercise program? Y
 Does the system have an active leak detection program? Y
 Does the system have a water conservation plumbing code? Y
 In 1992, did the system provide water conservation information to customers? Y
 Was water use restricted during 1992? N
 Has water use ever been restricted in the past 10 years? Y

Year Water use (mgd) Population

1970 8.107 41,000

1980 8.951 44,000

Does the system have a drought or water conservation ordinance? Y
 Does the system have an active meter replacement program? Y

1992 WATER SUPPLY PLANNING ASSISTANCE NEEDS

Does the system need technical assistance in developing a local water supply plan? N
 Does the system need technical assistance with a leak detection program? N
 Does the system need technical assistance with any other supply or use problems? N

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Appendix G

Appendix G. Groundwater Flow and Contaminant Transport Modeling Information Northwest Site Area

Prepared by:
Michael I. Lowry
Jeff W. Reynolds, P.G., P.HG.

G.1 Introduction

Modeling activities performed to simulate groundwater flow and contaminant fate and transport in the northwest site area of the General Electric (GE) facility in Wilmington, North Carolina, are described in this document. This document was prepared as Appendix G of a Corrective Action Plan (CAP) that was developed by Research Triangle Institute (RTI) to identify and implement a remedy for groundwater contamination identified in the northwest site area.

The modeling activities described in this document were performed as a component of the investigation to evaluate the feasibility of using a monitored natural attenuation (MNA) corrective action approach to address groundwater contamination identified in the northwest site area. The primary goal of the modeling effort was to understand the transport of the groundwater constituents of concern and to predict their future migration patterns. Specific objectives of the modeling effort included the following:

- Refine the conceptual model describing the hydrogeology and the transport of groundwater contaminants at the site;
- Develop a quantitative, numerical groundwater flow model for the area that is consistent with the site conceptual model;
- Calibrate the flow model to measured site conditions;
- Develop numerical models describing 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.

In order to save space, numerous figures found in the body of the CAP are not reproduced in this document, but instead are referenced (e.g., CAP Figure 1-1).

G.2 Background Information

Groundwater contamination identified in the remote northwest area of the GE-Wilmington site consists of volatile organic compounds (VOCs) and inorganic constituents. This contamination is associated with historical storage and handling of calcium fluoride (CaF_2) (containing low levels of uranium) and lubricants (apparently contaminated with small quantities of the VOC trichloroethylene [TCE]) in unlined trenches at two adjacent locations. These past practices were typical of the late 1960s when the site was developed and resulted in groundwater concentrations of the following materials above North Carolina standards: TCE, its degradation products cis-1,2-dichloroethylene (cis-1,2-DCE) and vinyl chloride, and fluoride. In addition, low levels of uranium exhibiting non-natural isotopic ratios (delineated by the distribution of the isotope ^{235}U) have also been detected in shallow groundwater. GE has completed voluntary recovery of the CaF_2 material, and there is evidence that the VOCs are degrading naturally. The results of the assessment activities conducted in the northwest site area are described in the *Comprehensive Site Assessment (CSA) for the Northwest Site Area* (RTI, 1998) and are described in the text of the CAP.

G.3 Conceptual Model

The northwest site area is located in the remote northwest corner of the GE-Wilmington site. The two former source areas are positioned on the eastern flank of a relic sand dune that forms a topographically prominent sand peninsula that is surrounded on three sides by low-lying swampy areas (CAP Figures 1-1 and 1-2). The topographic relief at the site is approximately 40 feet. The highest elevations lie at the uppermost point of the relic dune and the lowest elevations occur in the swampy area just north of the former source areas on the adjacent property. Land elevations in the swampy area range from

approximately five and zero feet above mean sea level (msl), decreasing to the north toward Prince George Creek and the Northeast Cape Fear River.

The surficial relic sand dune deposits primarily consist of medium-grained sands. These sands fine downward, and a zone of intermittent calcareous sandstone is evident at a depth of approximately 35 feet below land surface. The deeper sand and sandstone units are typical of the Peedee Formation. Voids have also been encountered while drilling into the sandstone unit. A distinct boundary does not exist between the layers; instead, the layers grade from one unit to the next. There are no continuous and extensive clay layers or distinct confining units in the northwest site area.

A swampy area is located to the north of the former source areas as shown in CAP Figure 1-2. Soils within the swampy area are a highly organic mixture of partially degraded vegetation and silty organic soil (muck). Near the interface of the swampy area with the sandy peninsula, the organic muck extends to a depth of approximately 9 feet below land surface. The thickness of the organic muck further north into the swampy area is unknown but is generally inferred to thicken northward.

Figure G.1 provides a three-dimensional view of the stratigraphy underlying the site. This (and subsequent) three-dimensional representations of site conditions contain a vertical slice through the geologic layers underlying the site, including, in order of increasing depth: the highly organic swamp sediments (dark brown), the upper unconsolidated sand (medium brown), and the deeper rocky sandstone unit (light brown). The vertical cut through the geologic layers is approximately parallel to the generalized groundwater flow direction, oriented 5 degrees east of plant north. The digital aerial photograph of the area is projected onto the surface elevations, and the former source areas and the property line are indicated. The white lines represent unpaved roads in the area. The view is oriented approximately towards the west (in plant coordinates) and at an angle downward approximately 22 degrees from horizontal.

G.3.1 Groundwater Flow

Groundwater flow at the site originates in the upland area where rainwater recharges the water table. The groundwater flows from this recharge zone and discharges into the surrounding swampy area. Large and local-scale groundwater contour maps of the area

are provided in CAP Figures 2-2 and 2-3, respectively. As CAP Figure 2-2 indicates, a generally east-west trending groundwater divide bisects the peninsula just south of the former lubricants area. Groundwater south of this groundwater divide flows to the south, discharging into the swampy area to the south. Groundwater in the former source areas flows toward the north, discharging into the swampy area to the north. The resulting groundwater flow patterns have generally followed this pattern throughout the measurement period.

Water-table elevations have fluctuated over a range of approximately 4 feet during the period of observation (Figure G.2). Because these data include a particularly wet summer in which two hurricanes struck the area, typical water-table fluctuations may be lower than the 4-foot range evident in Figure G.2.

CAP Figure 2-4 provides a conceptual visualization of the flow system. As this figure indicates, vertical groundwater flow is an important component of this system. The vertical hydraulic gradient exceeds the horizontal gradient in some upland recharge areas and throughout the swamp discharge area. The horizontal hydraulic gradient in the upland area is approximately 0.005, while the vertical gradient ranges from 0.005 to 0.03 downward. In the swampy area, the horizontal gradient is on the order of 0.0007, while the vertical gradient is approximately 0.15 upward (e.g., 0.146 between monitoring points SWS-8 and OSW-1A). As an example of the strong upward gradients in the swamp, the static water level in well OSW-1A (approximately 15 feet deep) is actually above the land surface. The estimated horizontal gradient in the swamp considers the measured groundwater elevation of about 4 feet msl at the swamp boundary and the elevation of Prince George Creek (approximately 1 foot msl), located 4,500 feet to the north. With the low horizontal gradients and the strong upward vertical gradients, the swampy area serves as a hydraulic boundary, limiting the potential for lateral migration of contaminants from this area.

G.3.2 Hydrogeologic Parameters

This section describes hydrogeologic parameters used in the flow and transport models that are based on site-specific data and analyses or literature values. These estimates were derived independent of the modeling effort. Sections G.4.3 and G.5.3 discuss

additional input parameters that were estimated during the development of the flow and transport models.

G.3.2.1 Hydraulic Conductivity. The hydraulic conductivity (k) has been estimated at the site using instantaneous displacement (i.e., slug) tests. An initial round of slug tests was performed in the CAF-B series wells in March 1996. Additional testing was performed in January 1999 to evaluate the hydraulic characteristics of the deeper, semi-consolidated sandstone and to evaluate conditions over a larger area of the model domain.

Results from the January 1999 slug testing activities were similar to earlier results, even in the deeper, rocky zone. The minimum and maximum k values for the additional testing were 0.82 and 6.7 feet/day, respectively, and the geometric mean k values for the Hvorslev and Bouwer-Rice analysis methods were 2.4 and 2.0 feet/day, respectively. In the deeper rocky zone, the geometric mean k values (as measured in well OCW-5D) were 1.05 and 0.96 feet/day for the Hvorslev and Bouwer-Rice methods, respectively. The results of the slug testing program provide the following conclusions:

- The k of the shallower sediments is very similar to the k of the deeper rocky zone.
- The k in the northwest site area ranges approximately over one order of magnitude between 0.4 and 6.7 feet per day (ft/d), the minimum and maximum estimates for the slug tests conducted in the area, respectively.
- Combining the results from the March 1996 and the January 1999 slug testing activities, the overall geometric mean k estimates for the Hvorslev (1951) and the Bouwer-Rice (1976) analysis methods are 2.1 and 1.6 ft/d, respectively.

More detailed discussion of the methods and results of the slug testing program can be found in the CSA (RTI, 1998) and in Appendix B of the CAP document.

The flow modeling of the northwest site area includes only steady-state simulations. Therefore, the flow modeling does not have a temporal component, and storage properties are not required.

G.3.2.2 Sorption of VOCs. The effectiveness of sorption at attenuating the VOCs (trichloroethylene [TCE], dichloroethylene [DCE], and vinyl chloride) was estimated using hydrophobic theory. Hydrophobic theory involves the use of the measured soil organic carbon fraction (f_{oc}), constituent-specific octanol-water partition coefficients (K_{ow}), and organic carbon distribution coefficients (K_{oc}). This methodology uses these parameters to estimate sorption distribution coefficients (K_d) for each constituent of concern. Details of the approach are documented in de Marsily (1986). The sorption parameters were estimated with site-specific and accepted literature values, which were not varied during the transport model calibration. Table G.1 lists the parameter estimates based on hydrophobic theory and the resulting distribution and retardation coefficients.

The f_{oc} of multiple soil samples collected from the sand unit and from the swampy area was measured. The f_{oc} for the sand unit was generally very low and less than the detection limit of 0.0019. The f_{oc} of the swampy area was very high with an average of 0.25, reflecting the presence of organic material in the muck soil.

G.3.3 Hydrogeologic Boundaries

The principal hydrogeologic boundaries for the system, as described in Section G.3.1, are the recharge zone in the upland relic dune deposits and the discharge zone in the swampy area. These boundaries dominate the flow patterns at the site. A very small contribution of groundwater may flow into the local system from the east along the groundwater divide, as indicated by the groundwater contours in CAP Figure 2-2. However, the majority of the groundwater entering the system is derived directly from recharge.

Groundwater discharges into a small stream (shown in CAP Figure 2-3) that originates at the northeast corner of the former NW-CaF₂ storage area parking/staging area and flows toward the swampy area to the north. A slight influence on the shallow groundwater flow is inferred based on the interception of groundwater by the shallow stream. However, influence of the stream on deeper groundwater flow patterns is not expected. Groundwater discharging into the swampy area collects into numerous puddles and small streams that evaporate or coalesce and flow slowly north toward Prince George Creek and the Northeast Cape Fear River. Most of the groundwater in the swamp discharges to the surface and flows as surface runoff toward the creek and the river. Due to the minimal horizontal hydraulic gradients in the swamp, horizontal groundwater flow is very slow in the swamp sediments. Prince George Creek and the Northeast Cape Fear River act as

hydrogeologic boundaries for horizontal groundwater flow within the swamp soil. The river likely influences regional flow that occurs within deeper intervals than the zone of concern for this investigation. The hydrogeologic influence of Prince George Creek and the Northeast Cape Fear River on the local flow system of interest in this study is minimal.

The Wilmington area receives approximately 50 inches of rain per year. A percentage of this rainfall reaches the unconfined aquifer through infiltration. The amount that reaches the unconfined aquifer depends on many factors, including seasonal effects, vegetation, land cover, land slope, moisture content, and soil type. An approximate water budget presented in the CSA (RTI, 1998) estimated the recharge in the area to be 15 in/year, which is 30 percent of the total rainfall. Recharge estimates are inherently uncertain; therefore the recharge was varied during flow model calibration to minimize the differences between measured and simulated groundwater elevations (described in Section G.4).

G.4 Flow Model Development

This section describes the development of the groundwater flow model, including the code, the finite-difference grid, input parameters, and boundary conditions.

G.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 used. MODFLOW can solve both steady-state and transient simulations. Simulation output includes water-balance calculations and head files 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 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.

G.4.2 Finite-Difference Grid

The model domain includes the area of concern (between the former source areas and the swamp discharge area) and the relevant hydrogeologic boundaries (Figure G.3). The

model extends from the drainage divide in the south to Prince George Creek in the north. Flow does not occur across a drainage divide; therefore this location is a natural no-flow hydrogeologic boundary for the model. Although the influence of Prince George Creek on conditions at the site is minimal, this natural hydrogeologic boundary is included for completeness. The lateral edges of the model are approximately perpendicular to the groundwater contours (Figure G.3); therefore, the lateral edges correspond approximately with groundwater flow paths. Groundwater does not flow perpendicular to flow paths, therefore the lateral edges of the model represent valid no-flow boundaries for the flow system. The entire grid is rotated 5.2 degrees east of plant north so that the grid is aligned with the groundwater flow paths. The lateral edges are far enough apart to encompass the former source areas and the measured downgradient plumes.

The spacing of the finite-difference rows and columns is shown in Figure G.4. Relatively fine grid spacing is often required for accurate transport modeling. Therefore, the grid spacing was relatively fine in the area encompassing the measured groundwater impacts (between the former source areas and the swamp). In this area, the grid row spacing was 25 feet, and the grid column spacing was 34.2 feet. In order to decrease computer memory and processing requirements, the grid-row spacing was increased in the swampy area north of the measured impacts. A coarser grid is adequate in this area, because groundwater flow in this area is very slow. Also, the delineated contaminant plumes do not extend to this area, making transport modeling unnecessary in this area. With the grid spacing described above, the finite-difference grid contains a total of 30 columns and 132 rows.

The cross section in Figure G.5 shows the vertical discretization of the model grid. Due to the importance and prevalence of vertical flow components in this groundwater system, a relatively fine vertical discretization was used to more accurately model vertical flow. The vertical discretization of the finite-difference grid was developed using the following surfaces: the surface topography, the interface between the sand and the sandstone, and the model bottom (Figure G.6). The surface topography (based on US Geological Survey [USGS] topographic and site-survey data) formed the top of the uppermost model layer. The sand/sandstone interface (based on boring logs) formed the top of the seventh model layer from the top. Six layers were placed at equal vertical spacings between the top and the seventh layer. Five layers were placed between the sand/sandstone interface and the bottom of the model, which was set to a constant elevation of -65 feet msl (below the

deepest measurement of contamination). The discretization in the upper model zones is somewhat finer than in the lower zones in order to capture the increasingly prevalent vertical flow components in the upper model layers.

The model bottom elevation (-65 msl) was sufficiently deep to encompass the zone of concern. However, the bottom elevation had an impact on the depth of the flow patterns. Therefore, the bottom elevation was varied slightly during model calibration as described in Section G.4.5. With the vertical discretization described above, the model contains a total of 11 layers. The entire finite-difference grid, thus, contains a total of 43,560 cells (11 layers X 30 columns X 132 rows).

G.4.3 Input Parameters

Table G.2 provides a comprehensive list of the flow model input parameters, including the input values and a basis for the parameters. Some of the input parameters listed in this table are discussed in Section G.3.3. Other parameters were derived during flow model calibration as discussed in Section G.4.5.

G.4.4 Boundary Conditions

As discussed in Section G.3.4, the recharge in the upland areas and the discharge into the swampy area represent the primary hydrogeologic boundaries to the system. This section discusses each of these and the additional boundary conditions within the flow model.

G.4.4.1 Recharge. Recharge is represented through a recharge boundary in MODFLOW, which delivers a specified flux of groundwater into the top of the model. This recharge boundary extends throughout the upland area of the model.

G.4.4.2 Swampy Area Seepage-Face Boundary. The discharge into the swampy area is a seepage-face boundary, where groundwater percolates out of the subsurface and collects into seeps at the surface, which then evaporate, transpire, or flow and coalesce as surface runoff. At a seepage-face boundary, the pressure head is equal to zero (atmospheric pressure), and the total head thus equals the elevation (total head = elevation + pressure head). Seepage faces can be represented in MODFLOW with drain boundaries. A drain boundary only allows groundwater to leave the system. 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 leave or enter the system through the drain. Likewise, the flux of water leaving the system increases as the piezometric head increases relative to the drain elevation. Consistent with a seepage-face boundary, the drain elevations in the model representing the seepage faces are set to the ground surface elevations.

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 seepage face boundaries, the conductance is set to a high enough value 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 system and are inactive if the piezometric head falls below the drain elevation.

As Figure G.7 shows, the seepage face (drain) boundary extends throughout the swampy area and into the upland area to the edge of the 20-foot msl topographic contour. Extending the drain into the upland area allows the model to include discharge into the small tributary stream that runs from the former NW-CaF₂ storage area to the swamp. In areas where the water table is below the surface elevation, the drains are inactive and do not affect the system. However, where the water table is above the ground surface, groundwater discharges into the stream.

G.4.4.3 Prince George Creek Specified-Head Boundary. Prince George Creek is simulated with a specified head boundary, as shown in Figure G.7. The elevation of this boundary was estimated to be 1 foot based on the topographic contour map. The depth of Prince George Creek was estimated to be 9 feet; therefore the specified head boundary extends through the upper two model layers. This boundary was included for completeness and to evaluate horizontal flow conditions in the swamp, even though the creek has minimal impact on flow conditions in the study area.

G.4.4.4 No-Flow Boundaries. The lateral boundaries of the model were specified as no-flow boundaries, because these boundaries correspond approximately with groundwater flow paths. Also, the bottom of the model was a no-flow boundary, because there is no evidence of interaction between the local groundwater flow system of interest and deeper groundwater flow. A small area of no-flow boundaries is present to the north of Prince

George Creek. The model does not describe flow in this region. Therefore, making this area a no-flow boundary improves computer memory and performance efficiency.

G.4.5 Flow Model Calibration

G.4.5.1 Flow Calibration Data Set. The goal of model calibration is to minimize the differences (i.e., error) between measured and simulated values. For the flow model, simulated groundwater elevations were compared with elevations measured on August 10, 1998 (CAP Figure 2-3). This set of groundwater elevation data is complete and representative of typical groundwater conditions at the site. Also, the elevation data were not measured following extreme weather events (e.g., after a hurricane) and thus are representative of average conditions.

G.4.5.2 Flow 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, (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 and summing the 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).

G.4.5.3 Flow Calibration Procedures. Table G.3 documents the objectives, input parameters, and results of the 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 inherent uncertainty. Other parameters varied during calibration of the flow model included the hydraulic conductivity of the sandstone and the hydraulic conductivity of the swamp sediments.

During simulations Nwa2 and Nwa3, decreasing the initial estimate for the sandstone conductivity significantly improved the calibration. The initial estimate of 14 ft/day was conservatively higher than measured values at the site. However, during this initial phase of modeling, conductivity data for the sandstone was unavailable (the January 1999 field event documented in Appendix B of the CAP had not yet taken place). The sandstone conductivity of 4 ft/day resulting from calibration is closer to the conductivity of 1 ft/day that was measured during the January 1999 field event.

During simulation Nwa4, increasing the conductivity of the swamp sediments significantly improved the calibration. An increased swamp conductivity allows more groundwater to flow through the system; therefore, the recharge was increased. The greater flux in the sand necessitated an increased gradient in the sand. This increased gradient decreased the systematic error in the head distribution where heads near the swamp area were generally too high relative to heads closer to the former source area.

The final modification to the model during calibration is documented in simulation Nwa7, where the drain boundaries were extended into the upland area to represent discharge into a small stream. This change necessitated a small increase in recharge but otherwise did not impact the results significantly. Simulation Nwa7 is in bold in Table 6.3, because it is the final calibrated flow model used for subsequent transport modeling.

The remaining simulations documented in Table G.3 describe analyses of the sensitivity to various model inputs, including decreasing the swamp thickness (Nwa5), slightly decreasing the sand conductivity (Nwa6), and varying the model bottom elevation (Nwa8 and Nwa9). Varying these model inputs produced relatively little change in the results. Therefore, the original calibrated model configuration (Nwa7) was maintained in each case.

G.4.5.4 Flow Calibration Results. The cross section in Figure G.8 shows the good agreement between the measured and simulated head distributions for the calibrated flow model. Figure G.9 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 (0.9954) is very close to the ideal result of 1.0. Also, the R^2 error (0.9366) is close to the ideal result of 1.0. The calibration statistics are provided in Table G.3 under simulation Nwa7. All of the calibration results indicate very good agreement between measured and simulated groundwater elevations.

G.4.6 Flow Model Results

The cross section in CAP Figure 6-8 shows flow paths and travel times for groundwater flow in the study area. The results confirm that vertical flow is prevalent in this groundwater system. Travel times from the former source areas to the swamp discharge area are between 20 and 45 years. Also, groundwater discharge into the swamp occurs over a relatively small area near the boundary between the swamp and the upland area. Farther north into the swamp and beyond this primary discharge area, most of the flow is horizontal and very slow (on the order of 3 feet/year).

G.5 Transport Model Development

This section describes the development of the transport model, including the code, the finite-difference grid, input parameters, and boundary conditions.

G.5.1 Code Description

The transport model code, MT3D⁹⁶, is a three-dimensional, block-centered, finite-difference numerical model developed by S.S. Papadopoulos & Associates, Inc. The model is widely tested and used. MT3D⁹⁶ can simulate the advection, dispersion, sorption, and first-order degradation of dissolved constituents in groundwater. MT3D⁹⁶ directly uses results from MODFLOW for the flow field. The MT3D⁹⁶ pre- and post-processor Visual MODFLOW was used to prepare input files and to analyze the results.

G.5.2 Finite-Difference Grid

For most of the simulations, the finite difference grid was identical with the grid used in the calibrated flow model documented in Section G.4.2. However, for the cis-1,2-DCE and TCE simulations described below, the grid was refined in the vertical dimension. For these simulations, the uppermost two layers were each divided into four layers, yielding a total of 17 layers. Refining the grid allowed accurate simulation of the sorption of VOCs onto the highly organic swamp sediments. Refining the grid for the remaining constituents was not necessary, because only cis-1,2-DCE and TCE are predicted to reach the swamp sediments. Refining the grid vertically did not have an impact on the flow modeling results.

G.5.3 Input Parameters

G.5.3.1 VOC Input Parameters. Table G.4 summarizes the final (post-calibration) transport modeling input parameters for the VOCs of interest (TCE, DCE, and vinyl chloride). The sorption parameters were estimated using hydrophobic theory, as described in Section G.3.2.2. The dispersivity estimates were established during the calibration as described in Section G.5.5. The biodegradation rates were the main parameters adjusted during calibration for the VOCs, as described in Section G.5.5.

G.5.3.2 Fluoride and ²³⁵U Input Parameters. Table G.5 summarizes the transport modeling input parameters for the inorganic contaminants (i.e., ²³⁵U and fluoride). In order

to be conservative, first-order decay (biodegradation) was not included for the inorganic simulations. The calibration was achieved by varying the effectiveness of sorption. Table G.5 contains the final (post-calibration) parameter values.

Transport of uranium and fluoride in the subsurface is complex and is likely subject to multiple, interrelated attenuation mechanisms at the site, including sorption, dispersion, and precipitation reactions. It is uncertain which exact combination of mechanisms is responsible for the attenuation of uranium and fluoride. However, based on the relatively non-extensive distribution of the ^{235}U and fluoride plumes, it is clear that natural attenuation is limiting their migration. The model attributes most of the attenuation to sorption (except for the attenuation due to dispersion). Therefore, sorption in the model is a "lumped parameter" mechanism that may represent multiple attenuation mechanisms simultaneously. This treatment simplifies the complex geochemistry, which is necessary for practical modeling of the complex reactions. However, because sorption is not a destructive attenuation mechanism (sorption, unlike degradation, does not remove mass from the system), this treatment is conservative. For example, given consistent geochemical conditions, precipitation may remove the compound permanently from the system. In contrast, sorbed constituents may desorb over time, re-entering the groundwater. Therefore, modeling multiple potential attenuation mechanisms as sorption is a simplification necessary for practical modeling; however, this treatment is also considered to be conservative.

G.5.4 Boundary Conditions

The transport model uses the flow model velocity field directly. Therefore, the transport model is subject to all of the flow boundary conditions, including the swamp drain boundaries and recharge. In addition, some of the calibration simulations discussed in Section G.5.5 include specified concentration boundaries to represent the former source areas. These simulations represent conditions prior to the source removal or depletion. Because the former sources have been removed or depleted, none of the predictive simulations described in Section G.6 include source boundary conditions.

G.5.5 Transport Model Calibration

Calibration of the transport model was achieved by comparing simulated concentrations with current concentrations measured at the site. Based on the operational history of the site, it is believed that the sources originated approximately 30 years ago. Therefore, the

calibration simulations represent conditions over the past 30 years for comparison with current conditions.

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 fully reconstruct. Given the complexity of transport processes and site operational histories, transport modeling is inherently uncertain. Therefore, transport model calibration often relies on more qualitative 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.

G.5.5.1 VOC Transport Model Calibration. Calibration of the VOC models involved comparing the measured cis-1,2-DCE plume with model results after a 30-year time period. This analysis only considered cis-1,2-DCE, because this constituent is the most prevalent VOC at the site with the broadest extent. Also, cis-1,2-DCE is continuous from the former source area to the swamp, unlike TCE and vinyl chloride.

For the cis-1,2-DCE calibration simulation, a constant source concentration of 65 mg/L was specified for the lubricants area for a period of 15 years. While this concentration exceeds the maximum measured concentration at the site (9.1 mg/L in OCB-1), it is considered a reasonable estimate for conditions prior to the depletion of the source for which direct measurements are unavailable.

The initial estimates of the longitudinal, transverse, and vertical dispersivities were 5 feet, 0.5 foot, and 0.05 foot, respectively. These values were based on the convention that the longitudinal dispersivity tends to be between one and ten percent of the plume scale, and the transverse dispersivity tends to be approximately one order of magnitude lower than the longitudinal dispersivity. The vertical dispersivity was set to a lower value, considering the depositional layering in the aquifer material, which would tend to decrease vertical dispersion. The initial estimates were decreased slightly during calibration to provide a better match with measured conditions. The resulting dispersivities were 4 feet,

0.3 foot, and 0.01 foot in the longitudinal, horizontal, and vertical directions, respectively. Considering the longitudinal dispersivity is only 0.3 percent of the VOC plume length (approximately 1,200 feet), the estimated dispersivities are relatively low and, therefore, conservative in estimating future migration patterns.

The calibrated cis-1,2-DCE biodegradation rate of 0.11 year^{-1} (a half-life of 6.3 years) is relatively low and conservative. In fact, the average field-scale biodegradation rate for cis-1,2-DCE compiled by EPA's Office of Research and Development is 1.6 year^{-1} (a half-life of 0.43 year) (EPA, 1998). Although the modeled biodegradation rate for the site is comparatively low, there is compelling evidence that biodegradation is active at the site, as described in Section 6.1.2.2 of the CAP. Therefore, the modeled biodegradation rate is conservative in estimating potential future migration patterns.

The favorable comparison between the measured and the simulated plume extents for cis-1,2-DCE is shown in Figure G.10. The simulated plume is at a slightly lower elevation than the measured plume. However, the general agreement between the results is favorable.

Because TCE and vinyl chloride are not present over the entire area of concern and due to their capacity for complex biotransformations, a separate calibration for each of these constituents was not performed. The sorption parameter estimates for TCE and vinyl chloride were independent of the model as described in Section G.3.2.2. Also, following the EPA-documented range of biodegradation rates for TCE, cis-1,2-DCE, and vinyl chloride (EPA, 1998), the biodegradation rates for TCE and vinyl chloride were estimated to be close to the rate for cis-1,2-DCE (Table G.4). The biodegradation rates for TCE and vinyl chloride used in the transport model were well below the average field-scale biodegradation rates compiled by EPA's Office of Research and Development of 1.1 and 1.3 year^{-1} (half-lives of 0.63 and 0.53 year), respectively (EPA, 1998). Therefore, the modeled biodegradation rates are conservative in estimating potential future migration patterns of TCE and vinyl chloride.

After the calibration procedure described above, predictive simulations evaluated the future migration patterns for each of the VOCs included in the transport modeling. The setup for these simulations included the measured distribution of the VOCs as initial conditions and no source. The sorption, biodegradation, and dispersion parameters

corresponded to the calibrated values shown in Table G.4. Results of the predictive VOC simulations are presented in Section G.6.

G.5.5.2 Fluoride Transport Model Calibration. In order to be conservative, no first-order degradation was included in the fluoride transport model. The calibration was achieved by varying the effectiveness of sorption to produce a reasonable match between the measured and simulated concentration distributions. For the fluoride calibration simulation, a constant source concentration of 12 mg/L was specified for the former CaF_2 storage area. Because the source material was present during the monitoring period, the specified source concentration in the model was based on the highest levels measured in the area. Also, the calibration simulations included the specified source for a period of 30 years, because the CaF_2 source material was present throughout this period. The predictive simulations documented in Section G.6 do not include a source, because the CaF_2 material and surrounding soils have since been removed.

Figure G.11 shows the favorable comparison between the measured and simulated fluoride distributions. As this figure indicates, the overall extent of migration is very similar for the simulated and measured plumes. The simulated plume has higher concentrations near the source area. These higher concentrations result from the remaining presence of the source in the simulation. The measured plume represents current conditions, following the removal of the source. Therefore, the elevated concentrations in the source area are not present in the measured plume. The favorable match in Figure G.11 was achieved by adjusting the sorption distribution coefficient to give a final retardation coefficient of 4.1 for the calibrated simulation, as listed in Table G.5. This value indicates that the fluoride migrates approximately 4.1 times slower than the groundwater.

G.5.5.3 ²³⁵Uranium Transport Model Calibration. In order to be conservative, no first-order degradation was included in the uranium transport model. The calibration was achieved by varying the effectiveness of sorption to produce a reasonable match between the measured and simulated concentration distributions. For the ²³⁵U calibration simulation, a constant source of 0.07 mg/L was specified for 30 years within the CaF_2 storage area. Because the source material was present during the monitoring effort, the specified source concentration in the model was based on the highest levels measured in the area. Also, the calibration simulations included the specified source for a period of 30 years, because CaF_2 source material was present throughout this period. The

predictive simulations documented in Section G.6 do not include a source, because the CaF_2 material and surrounding soils have since been removed.

Figure G.12 shows the favorable comparison between the measured and simulated ^{235}U distributions. As this figure indicates, the overall extent of migration is very similar for the simulated and measured plumes. The simulated plume has higher concentrations near the source area. These higher concentrations result from the remaining presence of the source in the simulation. The measured plume represents current conditions, following the removal of the source. Therefore, the elevated concentrations in the source area are not present in the measured plume. The favorable comparison in Figure G.12 was achieved by adjusting the sorption distribution coefficient to give a final retardation coefficient of 19.2 for the calibrated simulation, as listed in Table G.5. This value indicates that the ^{235}U migrates approximately 19.2 times slower than the groundwater. The calibrated value for the distribution coefficient, K_d , which controls sorption, was 3.51 L/kg for the sand and the sandstone. This K_d value is actually significantly less than the value of 10 L/kg estimated using site-specific soil and groundwater data, as described in Section 6.2.2.3 of the CAP. The lower K_d value used in the model predicts less sorption and is, therefore, more conservative.

G.6 Results and Predictive Simulations

G.6.1 cis-1,2-DCE Predictive Simulations

CAP Figures 6-10 and 6-11 show the steady decline in cis-1,2-DCE concentrations over time, with the 70- $\mu\text{g/L}$ plume dissipating in the aquifer between 5 and 15 years from present. Due to the significant sorption onto the highly organic swamp soils, the cis-1,2-DCE remains in the groundwater contacting these sediments for a longer time period. However, between 30 and 35 years, the cis-1,2-DCE concentrations are expected to attenuate below the NC groundwater standard of 70 $\mu\text{g/L}$. CAP Figure 6-12 shows the breakthrough of cis-1,2-DCE concentrations in groundwater at a depth just below the swampy-area land surface as well as at a depth of approximately 15 feet (in the sand below the swamp sediments). As this figure indicates, the surficial concentrations are expected to increase to a maximum of about 180 $\mu\text{g/L}$ approximately 11 years after current conditions. A comparison of these curves indicates that the swamp acts as a geochemical boundary, significantly decreasing the maximum surface concentrations relative to the

maximum concentrations at depth. Nevertheless, cis-1,2-DCE remains in the shallow swamp sediments for a longer time period due to the strong sorption to the highly organic swampy-area soils.

CAP Figure 6-13 shows the predicted maximum concentrations of cis-1,2-DCE in the groundwater just below the surface in the swampy area. For a conservative comparison, the maximum concentrations of cis-1,2-DCE with no attenuation are also shown in CAP Figure 6-13. The model setup was identical for the two results shown in this figure, except that sorption and biodegradation were not activated for the bottom graphic (i.e., no attenuation). The results demonstrate that even with the conservative assumption of no future attenuation from current conditions, the impacts are confined within a relatively small area, which is within the existing monitoring network.

G.6.2 TCE Predictive Simulations

CAP Figures 6-14 and 6-15 show the predicted distribution of TCE from present conditions into the future. These figures describe the steady decline in TCE concentrations over time, with the 2.8 µg/L plume expected to dissipate in the aquifer between 5 and 10 years from present. Due to its sorption onto the highly organic swamp soils, the TCE remains in groundwater adjacent to these sediments for a longer time period. However, between 50 and 55 years (not shown) the TCE is predicted to attenuate below the NC groundwater standard of 2.8 µg/L. CAP Figure 6-16 shows the breakthrough of TCE concentrations in groundwater just below the surface in the swamp. As this figure indicates, the predicted concentrations increase to a maximum of about 10 µg/L approximately 18 years after current conditions. The concentrations at a depth of 15 feet (in the sand below the swamp sediments) are shown in CAP Figure 6-16 for comparison. Comparing these curves indicates that the swamp acts as a geochemical boundary, decreasing the maximum surface concentrations relative to the maximum concentrations at depth. Nevertheless, the TCE remains in the swamp sediments longer due to its sorption to the highly organic swampy-area soils. Also, TCE remains in these soils longer than cis-1,2-DCE, because TCE sorbs more strongly to organic matter than cis-1,2-DCE.

CAP Figure 6-17 shows the predicted maximum concentrations of TCE in the groundwater just below the surface in the swamp. For a conservative comparison, the maximum concentrations of TCE with no attenuation are also shown in CAP Figure 6-17. The model setup was identical for the two distributions, except that sorption and biodegradation were

not considered in the bottom graphic (i.e., no attenuation). The results show that even with the conservative assumption of no attenuation from current conditions, the impacts would be confined within a relatively small area within the existing monitoring network.

G.6.3 Vinyl Chloride Predictive Simulations

CAP Figures 6-18 and 6-19 show the predicted distribution of vinyl chloride from present conditions into the future. These figures show the steady decline in vinyl chloride concentrations over time, with the plume expected to dissipate below 0.5 µg/L between 20 and 25 years from present. Vinyl chloride exceeding the typical analytical PQL of 0.5 µg/L is predicted to attenuate prior to reaching the swamp sediments.

G.6.4 Fluoride Predictive Simulations

CAP Figures 6-25 and 6-26 show the predicted distribution of fluoride from present conditions into the future. These figures show the steady decline in fluoride concentrations over time. After 25 years (not shown), the 2.0-mg/L plume is fully dissipated. The results indicate that fluoride fully attenuates below the NC groundwater standard of 2.0 mg/L before reaching the swampy area to the north of the site.

G.6.4.1 Fluoride Simulations Demonstrating Natural Attenuation. The modeling results presented in CAP Figure 6-24 indicate the effectiveness of natural attenuation at limiting the migration of fluoride at the site. The simulation results shown in this figure represent conditions at the site over the last 30 years. Therefore, the model setup for these simulations includes a constant source concentration of 12 mg/L (based on highest levels measured in the area) for 30 years within the CaF₂ storage area. The difference in the two simulation results shown in CAP Figure 6-24 is that the upper graphic represents the plume configuration that would be present with no attenuation (other than dispersion) limiting the plume migration. The lower graphic shows conditions with the additional attenuation mechanism of sorption limiting the plume extent. The plume extent with no attenuation is clearly well outside the area where impacts have been measured. In contrast, the plume extent with attenuation provides a good match with the measured plume. In summary, the model results presented in CAP Figure 6-24 show that natural attenuation is active and limits the migration of fluoride at the site.

G.6.5 Uranium Predictive Simulations

CAP Figures 6-22 and 6-23 in the CAP show the predicted distribution of ^{235}U from present conditions into the future. These figures show the steady decline in uranium concentrations over time. After 260 years, the 0.00015 mg/L plume is fully dissipated. However, the maximum predicted total uranium concentration (based on 2.2 percent enrichment), is expected to be below the groundwater monitoring guideline value (GMGV) developed by Potter (1998) in 10 years. The maximum predicted total uranium concentration is expected to be below the EPA's proposed drinking-water standard of 0.02 mg/L (Federal Register, 1991) after approximately 60 years. Although the migration of uranium at the site is slow due to attenuation, the modeling results predict that ^{235}U will be below the PQL of 0.00015 mg/L before reaching the swampy area to the north of the site.

G.6.5.1 Uranium Simulations Demonstrating Natural Attenuation. CAP Figure 6-21 illustrates the effectiveness of natural-attenuation processes at limiting the migration of uranium at the site. The simulations in this figure represent conditions over the last thirty years at the site. Thus, the model setup for these simulations includes a constant source concentration of 0.07 mg/L (the highest measured ^{235}U concentration) for 30 years within the CaF_2 storage area. The difference in the two simulation results shown in CAP Figure 6-21 is that the upper diagram represents the plume configuration that would be present with no attenuation (other than dispersion) limiting the plume migration. The lower diagram shows the extent of the ^{235}U plume with the additional attenuation mechanism of sorption limiting the plume extent. The plume extent with no attenuation is clearly outside the area where impacts have been measured. In contrast, the plume extent with attenuation provides a good match with the measured plume. In summary, the model results presented in CAP Figure 6-21 show that natural attenuation is active and is limiting the migration of uranium at the site.

G.7 Summary and Conclusions

The following primary conclusions summarize the northwest area modeling work described in this document:

- A numerical model of groundwater flow conditions in the northwest site area was developed and successfully calibrated to measured site conditions.
- Groundwater flow travel times from the former source areas to the swamp discharge area are between 20 and 45 years.
- Groundwater discharge into the swamp from the study area occurs over a relatively small area near the boundary between the swamp and the upland area. Beyond this primary discharge area (i.e., farther north into the swamp), most of the groundwater flow is horizontal and very slow (on the order of 3 feet/year).
- Numerical models were developed describing the fate and transport of the constituents of concern in groundwater. These models were successfully calibrated to measured site conditions.
- Concentrations of cis-1,2-DCE concentrations are predicted to continue to decrease over time, with the 70- $\mu\text{g/L}$ plume dissipating in the sand aquifer groundwater between 5 and 15 years from present. Due to the strong sorption onto the highly organic swamp soils, the cis-1,2-DCE remains in the groundwater contacting these sediments for a longer time period. However, between 30 and 35 years from present, the cis-1,2-DCE concentrations in the swampy area groundwater are expected to attenuate below the NC groundwater standard of 70 $\mu\text{g/L}$.
- Surficial concentrations of cis-1,2-DCE in the swamp are expected to increase to a maximum of about 180 $\mu\text{g/L}$ approximately 11 years from present. The surficial concentrations of cis-1,2-DCE are not expected to exceed chronic ecotoxicity benchmarks for aquatic communities or applicable NC surface-water standards (i.e., pose minimal human health or ecological risks).
- Concentrations of TCE concentrations are predicted to continue to decrease over time, with the 2.8- $\mu\text{g/L}$ plume dissipating in the sand

aquifer groundwater between 5 and 10 years from present. Due to the strong sorption onto the highly organic swamp soils, the TCE remains in the groundwater contacting these sediments for a longer time period. However, between 50 and 55 years, the TCE concentrations in the swamp area groundwater are expected to attenuate below the NC groundwater standard of 2.8 µg/L.

- Surficial concentrations of TCE in the swamp are expected to increase to a maximum of about 10 µg/L approximately 18 years from present. The surficial concentrations of TCE are not expected to exceed applicable NC surface-water standards (i.e., pose minimal human health or ecological risks).
- Vinyl chloride in the sand aquifer groundwater is predicted to attenuate below the typical PQL of 0.5 µg/L before reaching the swamp and within 25 years from present.
- Fluoride in the sand aquifer groundwater is predicted to attenuate below the NC groundwater standard of 2 mg/L before reaching the swamp and within 25 years from present.
- ²³⁵U in the sand aquifer groundwater is predicted to attenuate below the PQL of 0.00015 mg/L before reaching the swamp and within 260 years from present. However, the maximum predicted total uranium concentration (based on 2.2 percent enrichment), is expected to be below the groundwater monitoring guideline value (GMGV) developed by Potter (1998) in 10 years. The maximum predicted total uranium concentration in groundwater is expected to be below the EPA's proposed drinking-water standard of 0.02 mg/L (Federal Register, 1991) after approximately 60 years.
- Without any attenuation mechanisms (other than dispersion), the current predicted ²³⁵U and fluoride plumes extend well outside the measured extent of these constituents, which indicates (considering the current mapped extent) that natural attenuation is effectively limiting their migration.

G.8 References

- Brady, Nyle C. 1990. *The Nature and Properties of Soils*. 10th ed. MacMillan Publishing Company, New York.
- 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.
- DeMarsily, G. 1986. *Quantitative Hydrogeology - Groundwater Hydrology for Engineers*. Academic Press. San Diego, CA.
- EPA. 1998. *Seminars - Monitored Natural Attenuation for Ground Water*. Office of Research and Development. Report No. EPA/625/K-98/001. Washington, DC.
- Federal Register. 1991. *National Primary Drinking Water Regulations; Radionuclides; Proposed Rule*. Federal Register v. 56, No 138. July 18, 1991.
- Freeze, R.A. and J.A. Cherry, 1979. *Groundwater*. Prentice-Hall, Englewood Cliffs, New Jersey.
- Giese, G.L., J.L. Eimers and R.W. Coble. 1991. *Simulation of Ground-Water Flow in the Coastal Plain Aquifer System of North Carolina*. U.S. Geological Survey -File-Report 90-372.
- Hvorslev, M.J. 1951. *Time Lag and Soil Permeability in Ground-Water Observations*. Bulletin 36. US Army Corps of Engineers
- McDonald, M.G. and A.W. Harbaugh. 1988. *A Modular Three-Dimensional Finite-Difference Ground-Water Flow Model*. Techniques of Water-Resources Investigations of the US Geological Survey. Book 6. Chapter A1.
- Montgomery, John H. and Linda M. Welkom. 1989. *Groundwater Chemicals Desk Reference*. Lewis Publishers. Chelsea, Michigan.
- Potter, T.E., 1998. *"Groundwater Monitoring Guideline Value for Uranium - Former Northwest Calcium Fluoride Storage Area"*, Consultant's Report to General Electric. Washington, D.C.
- RTI. 1998. *Comprehensive Site Assessment Report for the Northwest Site Area*. RTI Report 6448-018/003/01F.

Figures - Appendix G

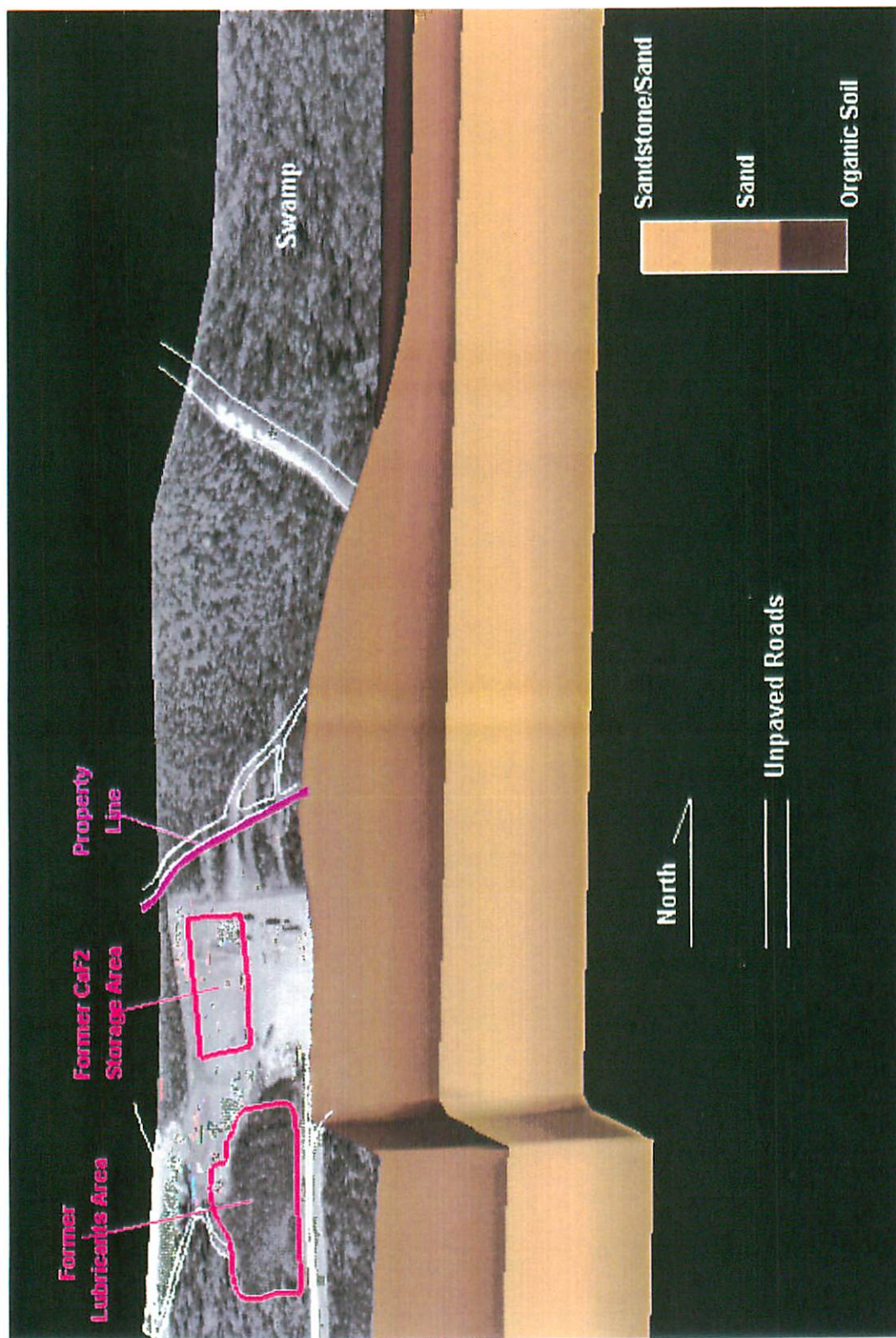


Figure G.1 Generalized Stratigraphy of the Northwest Site Area

Vertical Exaggeration = 5x

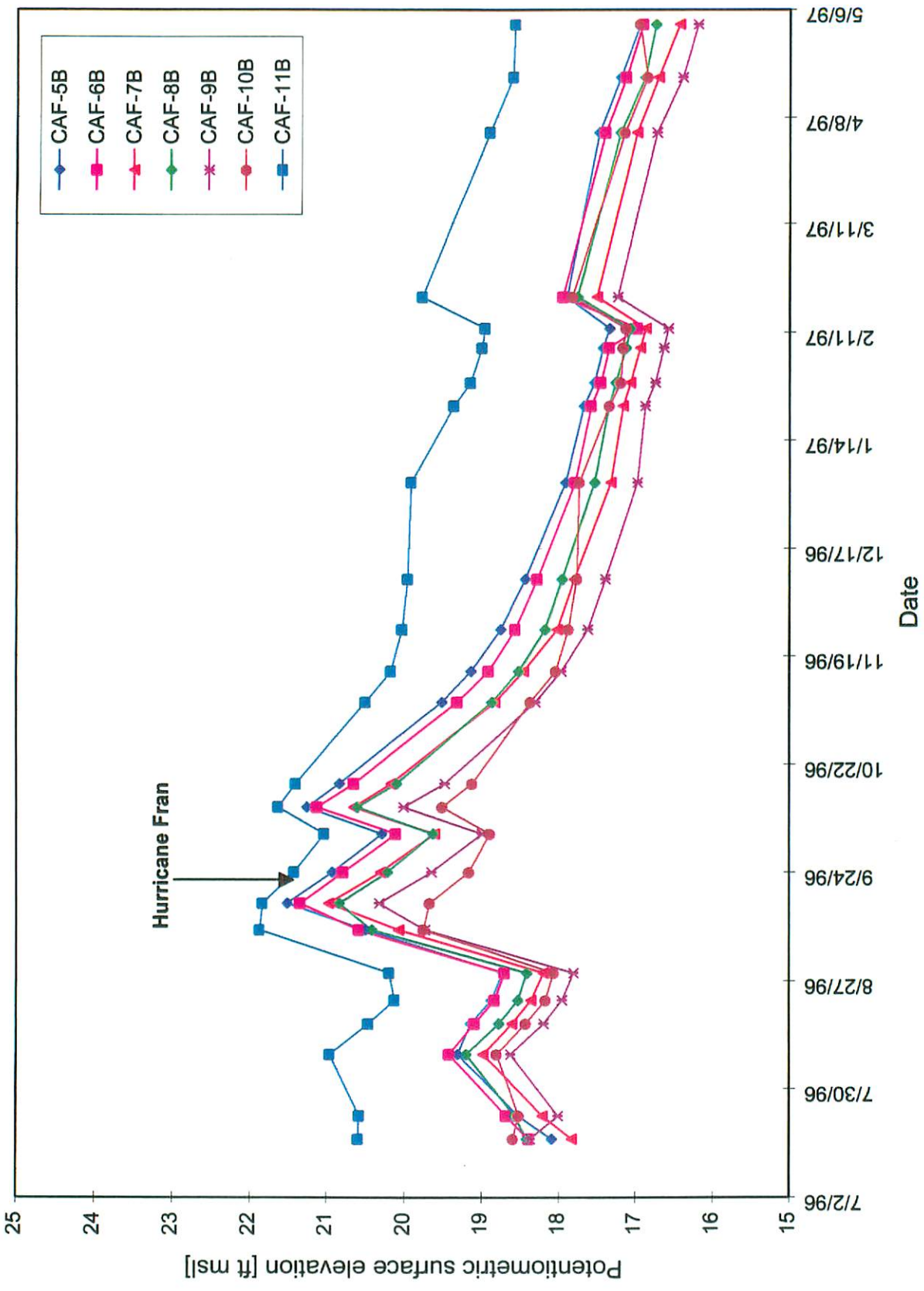


Figure G.2 Northwest Site Area Monitoring-Well Hydrographs

Figure G.3

Extent of the Model Domain

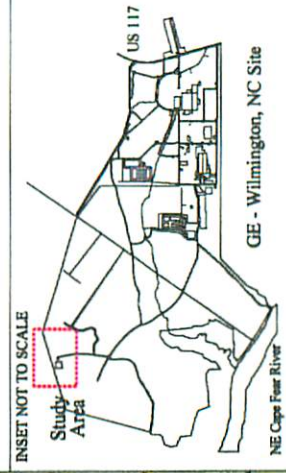
GE - Wilmington, NC Site

EXPLANATION

Model Extent
Potentiometric Elevations

Note: Elevation contours based on data collected on September 28, 1998

Source: USGS orthophotographic map. Castle Hayne, NC quadrangle, 1970



Date: 3/12/99

model_setup.apr

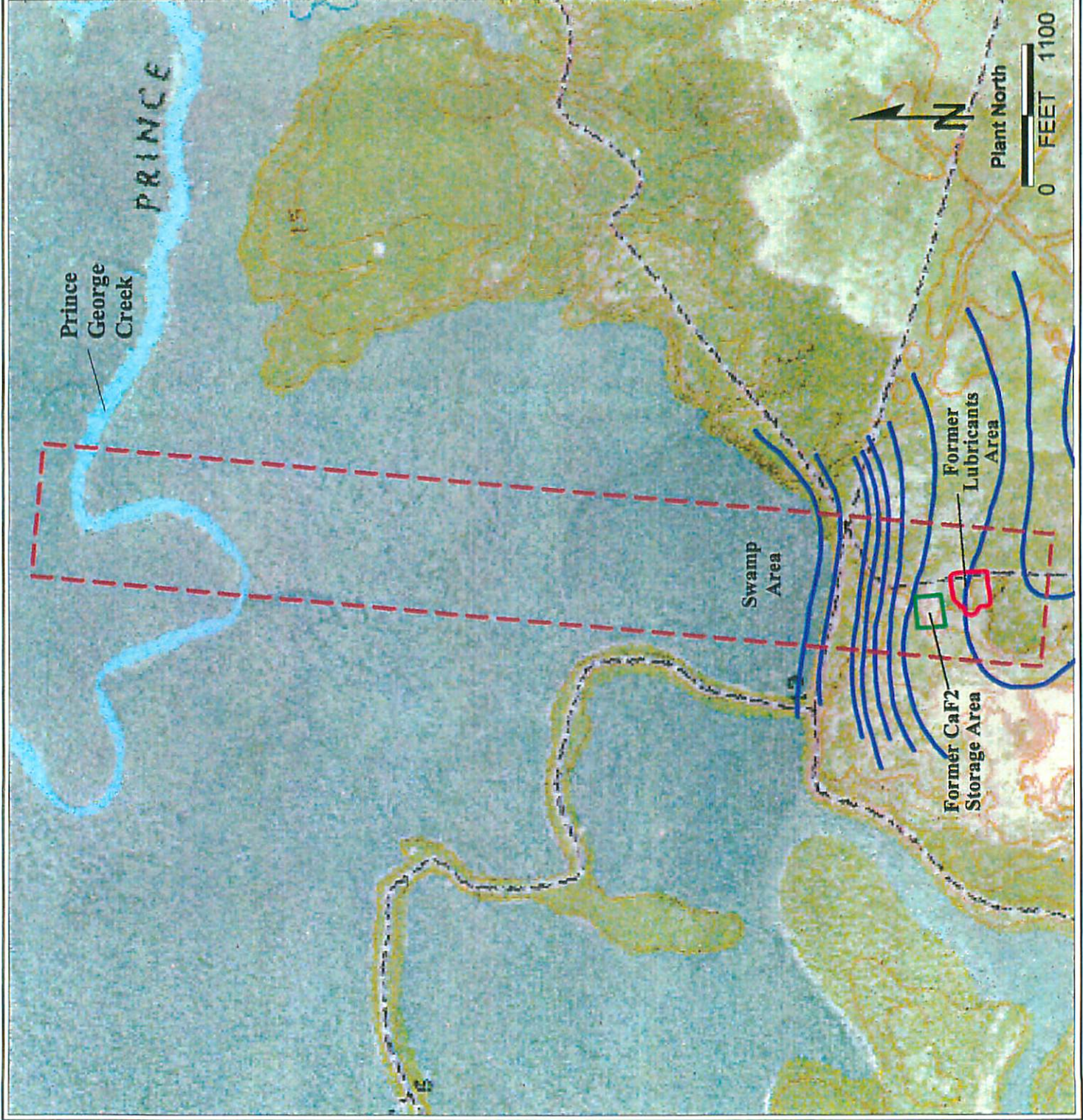


Figure G.4

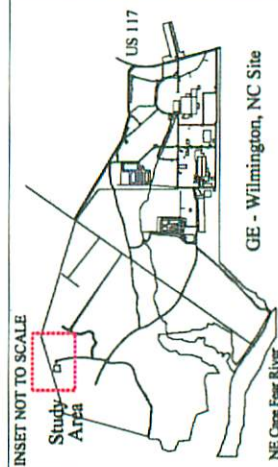
Model Finite-Difference Grid

GE - Wilmington, NC Site

EXPLANATION

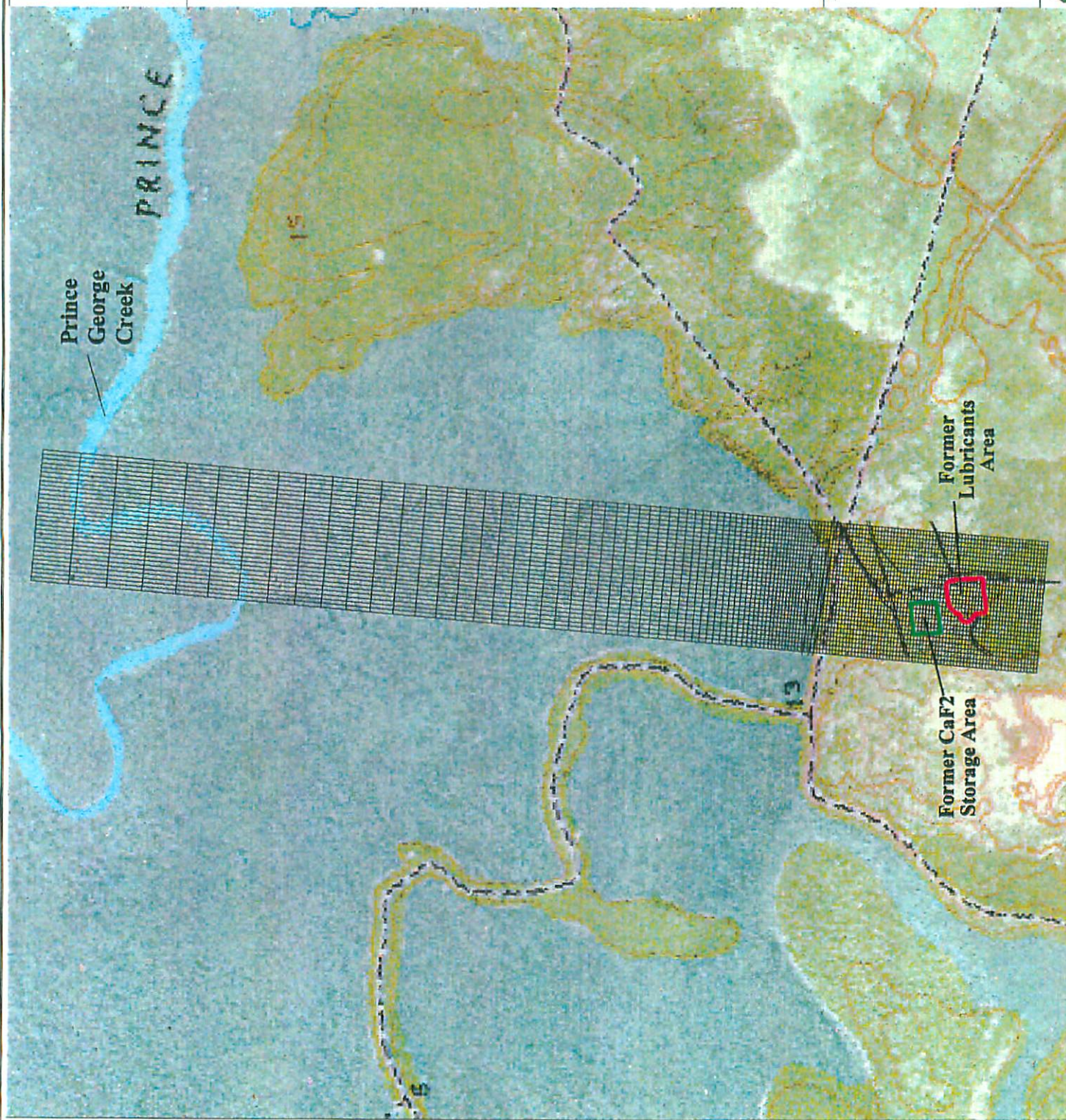
Model Grid

Source: USGS orthophotographic map.
Castle Hayne, NC quadrangle, 1970



Date: 3/12/99

model_setup.apr



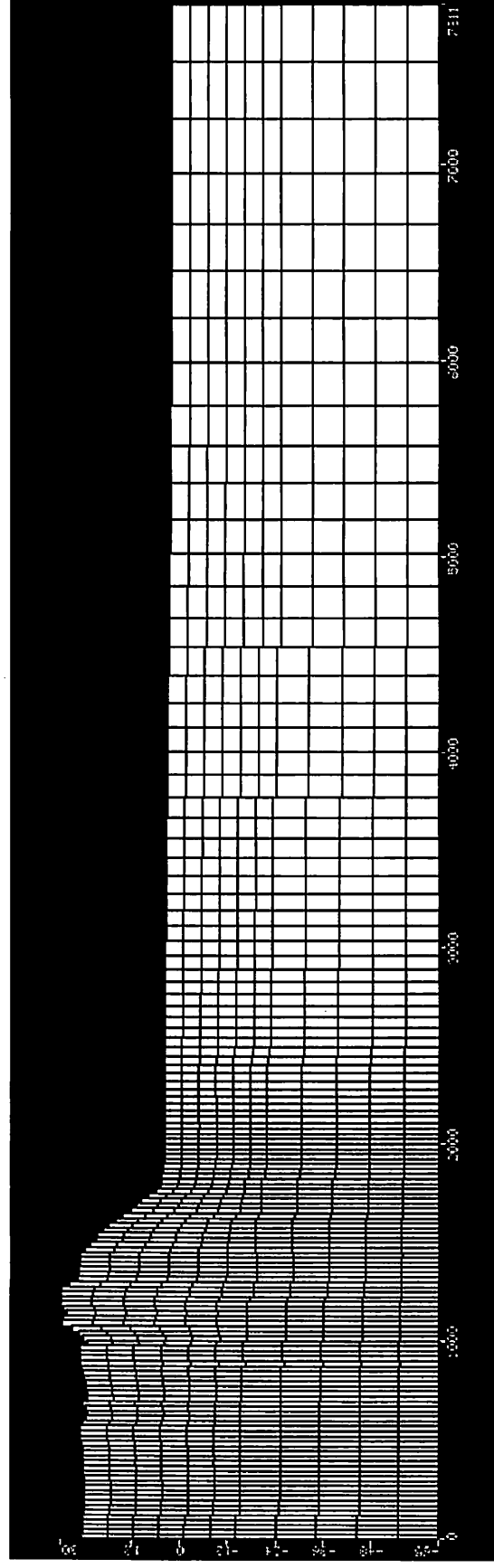


Figure G.5 Vertical Finite-Difference Grid Discretization

Vertical Exaggeration = 20x

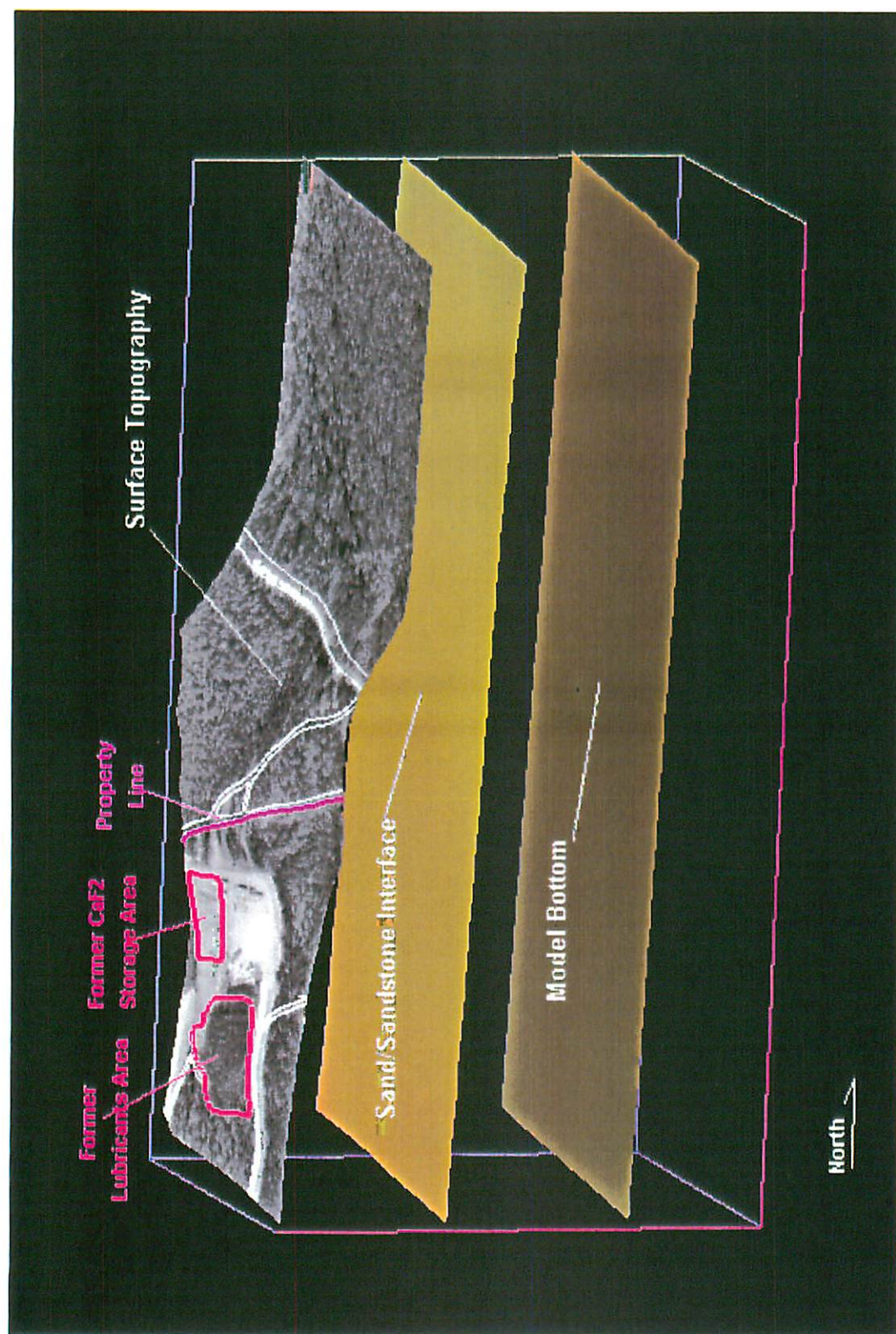


Figure G.6 Hydrogeologic Layers Used to Construct the Model

Vertical Exaggeration = 10x

Figure G.7

Model Boundary Conditions

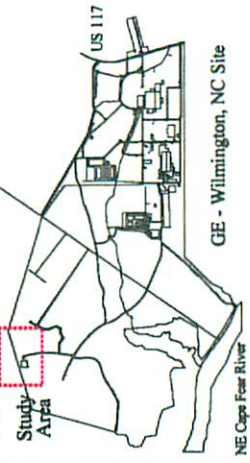
GE - Wilmington, NC Site

EXPLANATION

-  Model Extent
-  Seepage-Face Boundaries
-  No Flow Boundaries
-  Constant Head Boundaries

Source: USGS orthophotographic map.
Castle Hayne, NC quadrangle, 1970

INSET NOT TO SCALE



Date: 3/12/99 model_setup.apr

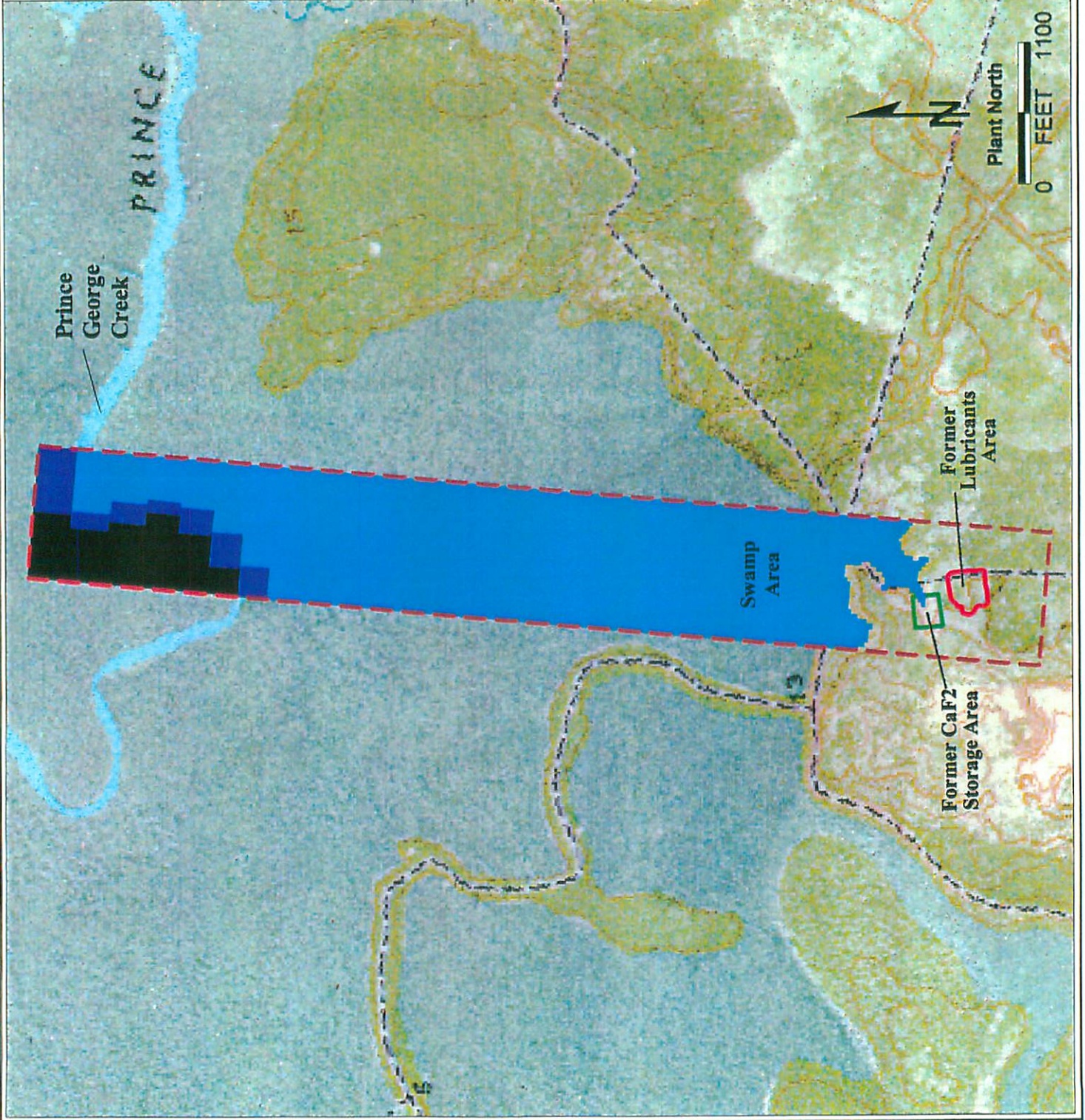
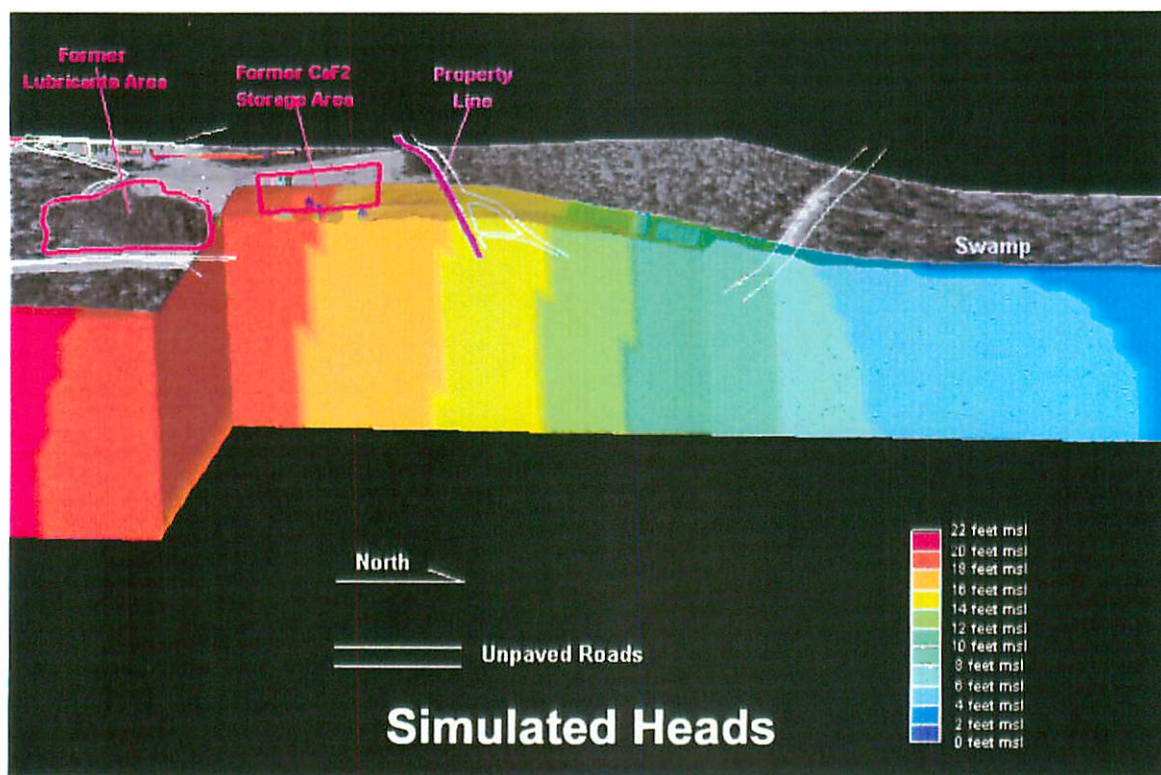
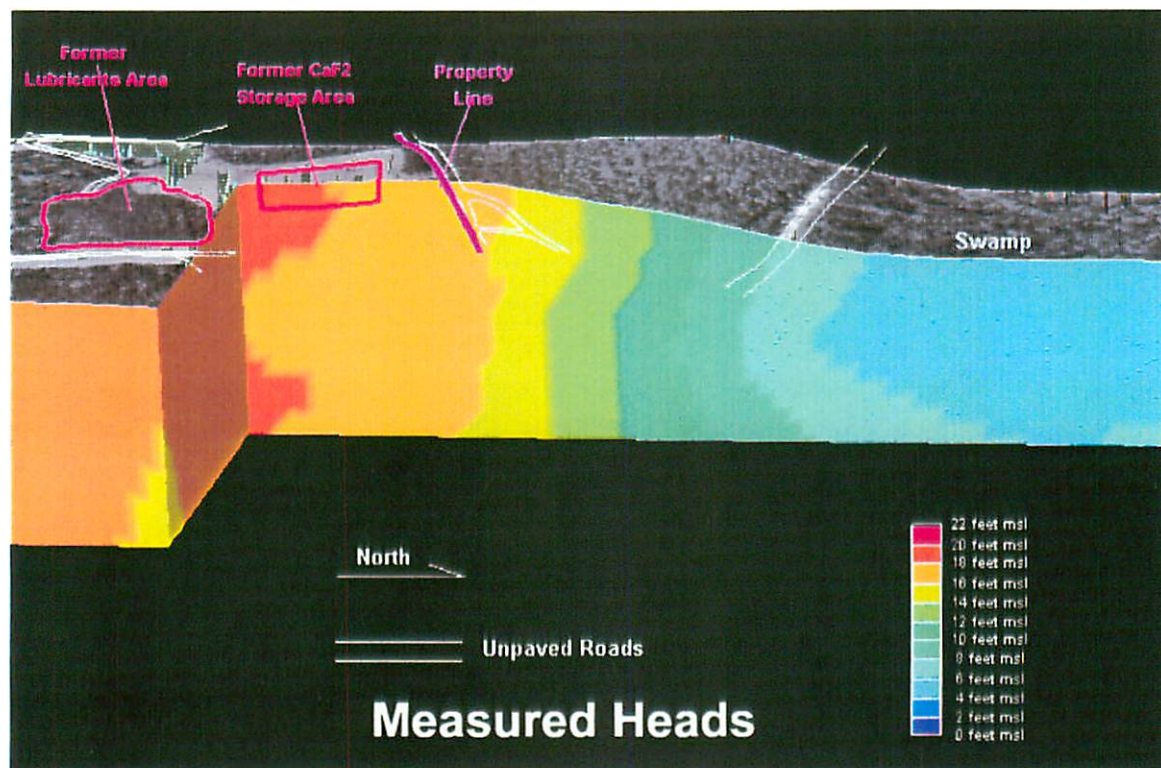


Figure G.8 Comparison of Measured and Simulated Hydraulic Head Distributions



Vertical Exaggeration = 5x

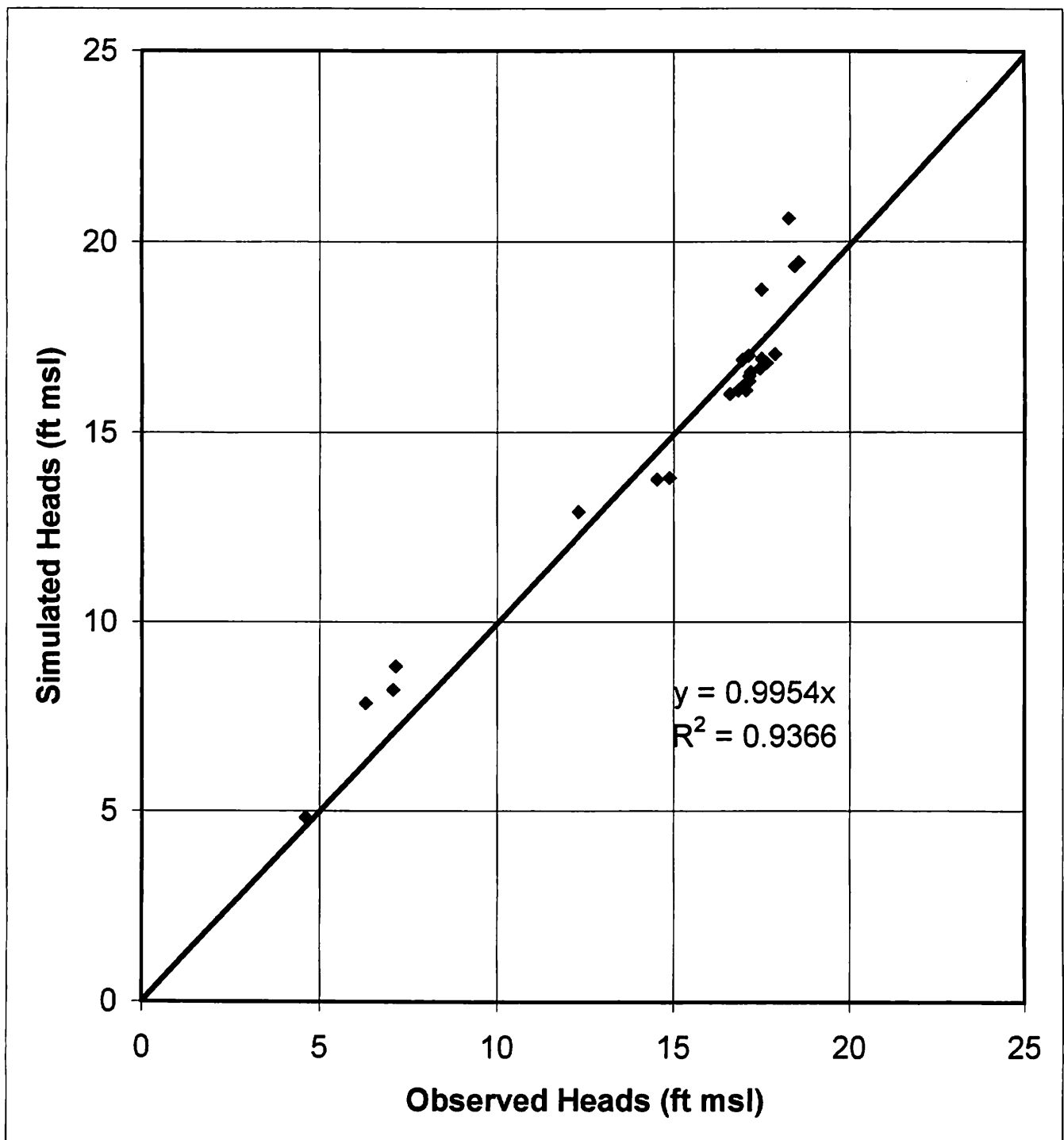
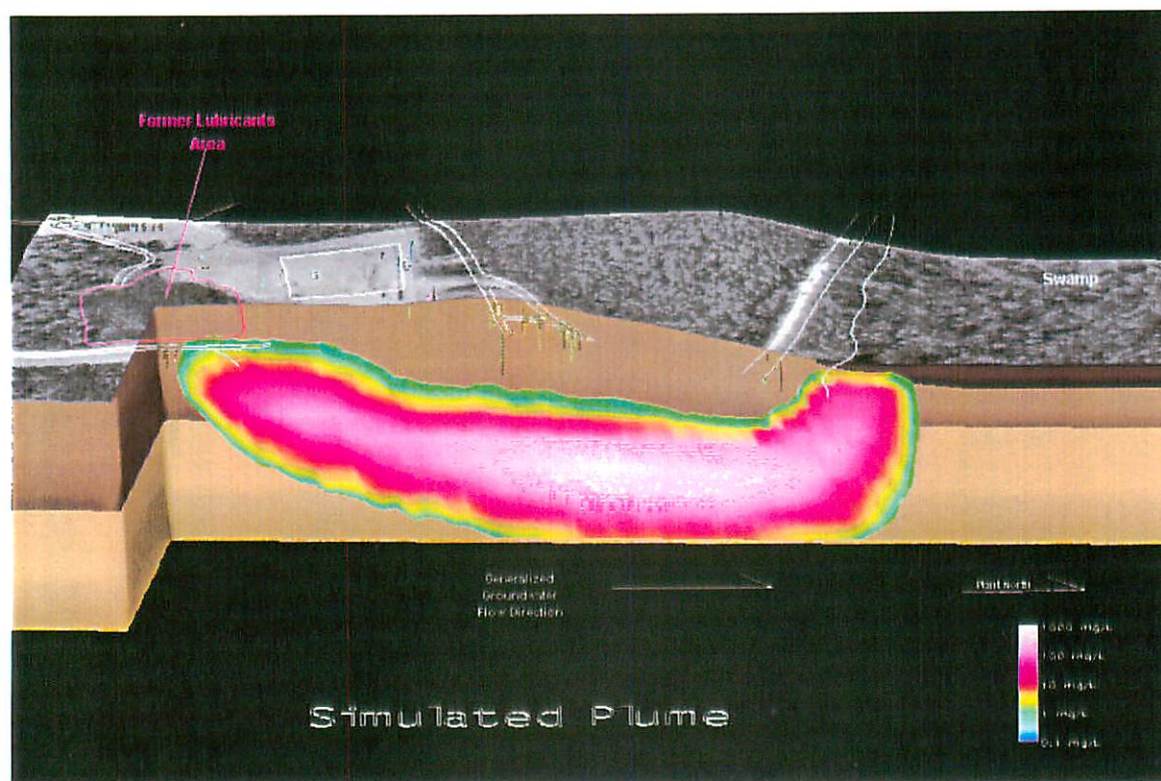
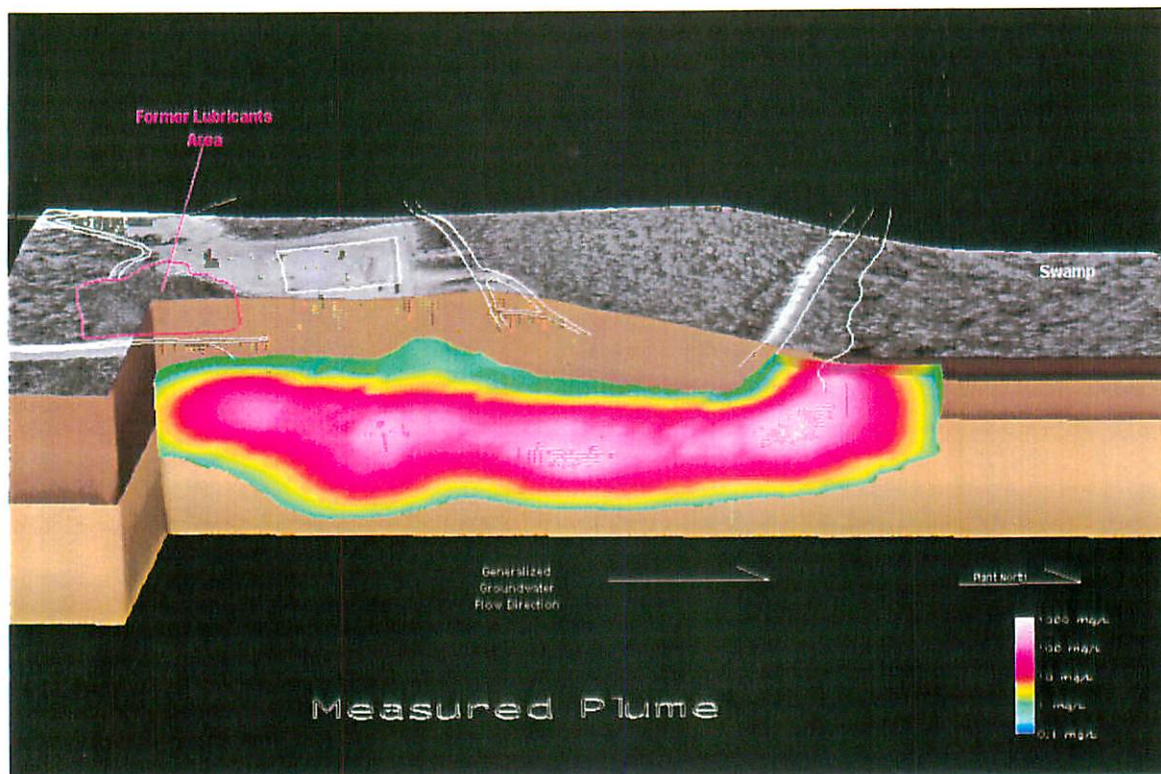


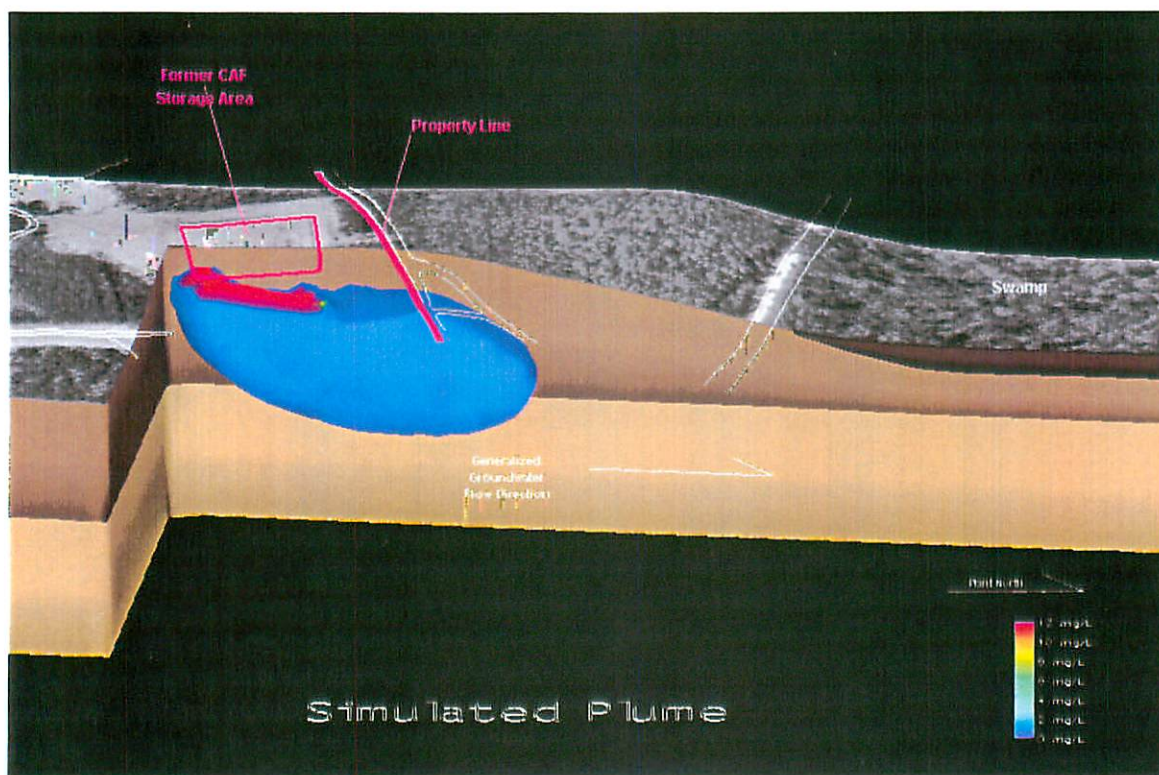
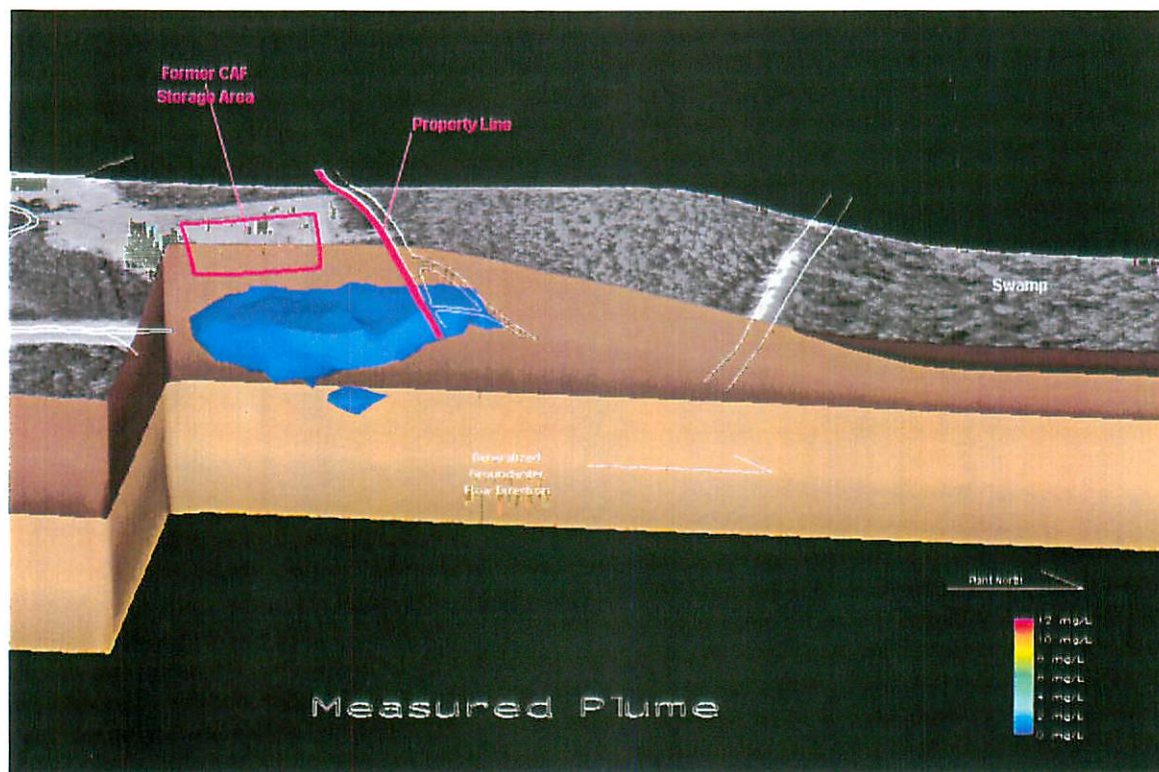
Figure G.9 Flow Model Calibration Curve

Figure G.10 Comparison of Measured and Simulated cis-1,2 DCE Groundwater Plumes -- Current Conditions



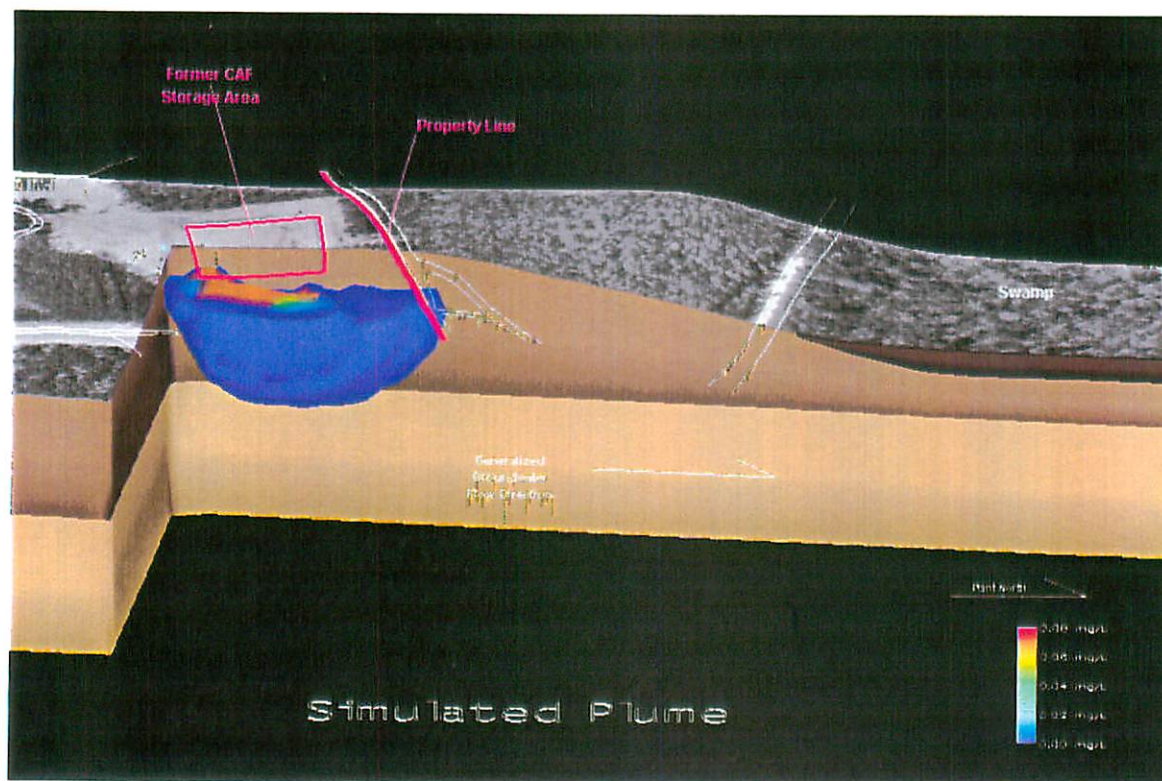
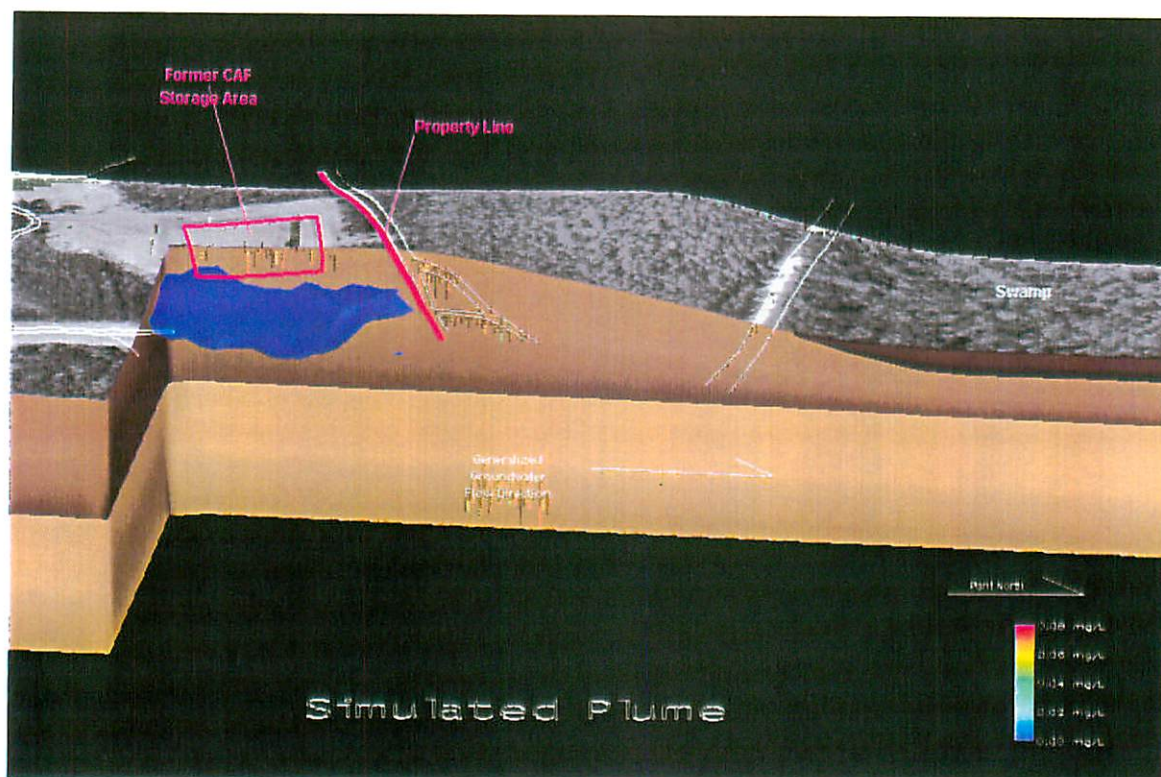
Vertical Exaggeration = 5x

Figure G.11 Comparison of the Measured and Simulated Fluoride Plumes Greater than 1 mg/L at Present Conditions



Vertical exaggeration = 5x.

Figure G.12 Comparison of the Measured and Simulated ^{235}U Plumes Greater than 0.00015 mg/L at Present Conditions



Vertical exaggeration = 5x.

Tables - Appendix G

Table G.1 VOC Sorption Parameters

Parameter	Cis-1,2 DCE	TCE	Vinyl Chloride	Basis
Constituent Octanol-Water Distribution Coefficient (K_{ow})	30	195	13	Montgomery and Welkom (1990)
Constituent Organic Carbon Distribution Coefficient (K_{oc}) (liter/kg)	46	177	25	Hydrophobic Theory (de Marsily, 1986)
Sand Organic Carbon Fraction (f_{oc})	0.001	0.001	0.001	Measured (RTI, 1998)
Sand Distribution Coefficient (K_d) (L/kg)	0.046	0.177	0.025	Calculated ¹
Sand Bulk Density (ρ_b) (g/cm ³)	1.56	1.56	1.56	Brady (1990)
Porosity (n)	0.3	0.3	0.3	Typical for fine to medium sands.
Sand Retardation Coefficient (R)	1.2	1.9	1.1	Calculated ²
Swamp Organic Carbon Fraction (f_{oc})	0.25	0.25	0.25	Measured (RTI, 1998)
Swamp Distribution Coefficient (K_d) (L/kg)	11.5	44.2	6.29	Calculated ¹
Swamp Bulk Density (g/cm ³)	1.56	1.56	1.56	Estimated Equal to Sand Value
Swamp Retardation Coefficient (R)	60.7	231	33.7	Calculated ²

¹ $K_d = (f_{oc}) (K_{oc})$

² $R = 1 + (\rho_b/n) (K_d)$

Table G.2 Summary of Flow Model Parameters

Parameter	Value	Basis
Horizontal Hydraulic Conductivity — Sand	3 feet/day	Slightly higher than slug test results to accommodate potential scale effects (conservative).
Horizontal Hydraulic Conductivity — Sandstone	4 feet/day	Slightly higher than slug test results to accommodate potential scale effects (conservative).
Horizontal Hydraulic Conductivity — Swamp Organic Soil	1 foot/day	Estimated during calibration.
Vertical to Horizontal Hydraulic Conductivity Ratio	0.1	Typical value for depositional environments. (Freeze and Cherry, 1979)
Porosity	0.3	Typical value for fine to medium sands.
Recharge — upland area	11.6 inch/year	Estimated during calibration. Consistent with USGS estimates of recharge to coastal plain unconfined aquifers (Giese et al., 1991)
Recharge — swamp	0 inches/year	Rainwater collects as surface runoff in the swamp and does not recharge.
Swamp Drain Boundary Elevations	Topographic Elevations	Representative of seepage-face discharge boundaries.
Swamp Drain Conductance	2000 ft ² /day	Estimated during calibration. (High enough for the drains to act as specified head discharge boundaries.)
Prince George Creek Elevation	1 foot msl	USGS Castle Hayne, NC 1:24000 Topographic Map
Prince George Creek Depth	9 feet	Estimated

Table G.3 Flow Model Calibration Simulations (page 1 of 4)

Simulation	Objective	Input Parameters	Results
Nwa1	Initial conductivity estimates. Vary recharge to minimize calibration errors.	Recharge _{sand} : 20 in/year Recharge _{swamp} : 0 in/year K _{h,swamp} : 0.1 ft/day; K _{v,swamp} : 0.01 ft/day K _{h,sand} : 3 ft/day; K _{v,sand} : 0.3 ft/day K _{h,stone} : 14 ft/day; K _{v,stone} : 1.4 ft/day Swamp Thickness: 9 ft	Mean error: 0.1006 Mean absolute error: 1.278 RMS error: 1.712 Scaled RMS error: 12.31 A systematic error is evident in the calibration curve; the modeled heads near the swamp are too high.
Nwa2	Determine if decreasing K _{v,stone} will improve the calibration. After decreasing K _{v,stone} vary recharge to minimize calibration errors.	Recharge _{sand} : 18 in/year Recharge _{swamp} : 0 in/year K _{h,swamp} : 0.1 ft/day; K _{v,swamp} : 0.01 ft/day K _{h,sand} : 3 ft/day; K _{v,sand} : 0.3 ft/day K _{h,stone} : 14 ft/day; K _{v,stone} : 0.1 ft/day Swamp Thickness: 9 ft	Mean error: -0.1414 Mean absolute error: 1.349 RMS error: 1.674 Scaled RMS error: 12.0357 Had to decrease recharge to compensate for the lowered vertical conductivity in the sandstone. Decreasing the vertical conductivity of the sandstone, alone, has a relatively small impact on the results. The systematic error (with the modeled heads near the swamp being too high) is still evident in the calibration curve.
Nwa3	Determine if decreasing K _{h,stone} and K _{v,stone} will improve the calibration. After decreasing K _{h,stone} vary recharge to minimize calibration errors.	Recharge _{sand} : 9.5 in/year Recharge _{swamp} : 0 in/year K _{h,swamp} : 0.1 ft/day; K _{v,swamp} : 0.01 ft/day K _{h,sand} : 3 ft/day; K _{v,sand} : 0.3 ft/day K _{h,stone} : 4 ft/day; K _{v,stone} : 0.4 ft/day Swamp Thickness: 9 ft	Mean error: 0.133537 Mean absolute error: 1.08424 RMS error: 1.3276 Scaled RMS error: 9.544 Had to decrease recharge to compensate for the lowered conductivity in the sandstone. Decreasing the conductivity of the sandstone significantly improves the calibration. The systematic error (with the modeled heads near the swamp being too high) is still evident in the calibration curve, but it is less evident.

Table G.3 Flow Model Calibration Simulations (page 2 of 4)

Nwa4	<p>Determine if increasing $K_{h, \text{swamp}}$ and $K_{v, \text{swamp}}$ will improve the calibration. After increasing $K_{h, \text{swamp}}$ and $K_{v, \text{swamp}}$, vary recharge to minimize calibration errors.</p>	<p>Recharge_{sand}: 11.3 in/year Recharge_{swamp}: 0 in/year $K_{h, \text{swamp}}$: 1 ft/day; $K_{v, \text{swamp}}$: 0.1 ft/day $K_{h, \text{sand}}$: 3 ft/day; $K_{v, \text{sand}}$: 0.3 ft/day $K_{h, \text{stone}}$: 4 ft/day; $K_{v, \text{stone}}$: 0.4 ft/day Swamp Thickness: 9 ft</p>	<p>Mean error: -0.01404 Mean absolute error: 0.8580 RMS error: 0.9763 Scaled RMS error: 7.0186 Maximum Residual: 2.23 (CAF-16C) Minimum Residual: -1.10 (OCW-4A)</p> <p>Increasing the swamp conductivity significantly improves the calibration. The systematic error (with the modeled heads near the swamp being too high) is almost eliminated. With an increased swamp conductivity, more groundwater can flow through the system, so the recharge was increased. The greater flux in the sand necessitated an increased gradient in the sand. This increased gradient helps to eliminate the systematic error in the head distribution. Increased recharge to compensate for the increased conductivity in the swamp.</p>
Nwa5	<p>Determine if decreasing the thickness of the swamp will improve the calibration. After decreasing the swamp thickness, vary recharge to minimize calibration errors.</p>	<p>Recharge_{sand}: 11.5 in/year Recharge_{swamp}: 0 in/year $K_{h, \text{swamp}}$: 1 ft/day; $K_{v, \text{swamp}}$: 0.1 ft/day $K_{h, \text{sand}}$: 3 ft/day; $K_{v, \text{sand}}$: 0.3 ft/day $K_{h, \text{stone}}$: 4 ft/day; $K_{v, \text{stone}}$: 0.4 ft/day Swamp Thickness: 4.5 ft</p>	<p>Mean error: -0.03848 Mean absolute error: 0.8165 RMS error: 0.9609 Scaled RMS error: 6.9083 Maximum Residual: 2.47 (CAF-16C) Minimum Residual: -1.10 (OCW-4A)</p> <p>Decreasing the swamp thickness from 9 to 4.5 ft gives a negligible improvement in the calibration. Increased recharge to compensate for the decreased swamp thickness. Maintained Nwa4 parameters to allow more recharge into the system.</p>

Table G.3 Flow Model Calibration Simulations (page 3 of 4)

Nwa6	<p>Determine if decreasing the sand conductivity will improve the calibration. After decreasing the swamp thickness, vary recharge to minimize calibration errors.</p>	<p>Recharge_{sand}: 8.4 in/year Recharge_{swamp}: 0 in/year $K_{h,swamp}$: 1 ft/day; $K_{v,swamp}$: 0.1 ft/day $K_{h,sand}$: 1 ft/day; $K_{v,sand}$: 0.1 ft/day $K_{h,stone}$: 4 ft/day; $K_{v,stone}$: 0.4 ft/day Swamp Thickness: 4.5 ft</p>	<p>Mean error: 0.11363 Mean absolute Error: 0.7615 RMS error: 0.9212 Scaled RMS error: 6.6226 Maximum Residual: 1.96 (OCW-1C) Minimum Residual: -0.80 (OCW-4A)</p> <p>Decreasing the sand conductivity gives a small improvement on the calibration. The recharge has to be decreased to compensate for the lower conductivity. Maintained Nwa4 parameters in order to be conservative and to allow more recharge into the system.</p>
Nwa7	<p>Extend the drain boundaries into the upland area to represent the stream. After adding the drain boundaries, vary recharge to minimize calibration errors.</p>	<p>Recharge_{sand}: 11.6 in/year Recharge_{swamp}: 0 in/year $K_{h,swamp}$: 1 ft/day; $K_{v,swamp}$: 0.1 ft/day $K_{h,sand}$: 3 ft/day; $K_{v,sand}$: 0.3 ft/day $K_{h,stone}$: 4 ft/day; $K_{v,stone}$: 0.4 ft/day Swamp Thickness: 9 ft</p>	<p>Mean error: 0.03303 Mean absolute error: 0.8500 RMS error: 0.9831 Scaled RMS error: 7.0679 Maximum Residual: 2.37 (CAF-16C) Minimum Residual: -1.09 (OCW-4A)</p> <p>Some groundwater discharges into the stream, necessitating a small increase in the recharge. Negligible change in the calibration statistics. This simulation is the calibrated flow model used for future transport simulations.</p>

Table G.3 Flow Model Calibration Simulations (page 4 of 4)

Nwa8	<p>Decrease the bottom elevation to determine the sensitivity. After decreasing the bottom elevation, vary recharge to minimize calibration errors.</p>	<p>Recharge_{sand}: 13.5 in/year Recharge_{swamp}: 0 in/year $K_{h,swamp}$: 1 ft/day; $K_{v,swamp}$: 0.1 ft/day $K_{h,sand}$: 3 ft/day; $K_{v,sand}$: 0.3 ft/day $K_{h,stone}$: 4 ft/day; $K_{v,stone}$: 0.4 ft/day Swamp Thickness: 9 ft</p>	<p>Mean error: -0.0232 Mean absolute error: 0.8784 RMS error: 0.9903 Scaled RMS error: 7.11959 Maximum Residual: 2.13 (CAF-16C) Minimum Residual: -1.08 (OCW-4A) Increased recharge to compensate for the lower bottom elevation. Essentially the same quality of calibration as Nwa7 was achieved. However the flow cell between the source and discharge areas is deeper. Maintained Nwa7 setup.</p>
Nwa9	<p>Increase the bottom elevation to determine the sensitivity. After increasing the bottom elevation, vary recharge to minimize calibration errors.</p>	<p>Recharge_{sand}: 9.35 in/year Recharge_{swamp}: 0 in/year $K_{h,swamp}$: 1 ft/day; $K_{v,swamp}$: 0.1 ft/day $K_{h,sand}$: 3 ft/day; $K_{v,sand}$: 0.3 ft/day $K_{h,stone}$: 4 ft/day; $K_{v,stone}$: 0.4 ft/day Swamp Thickness: 9 ft</p>	<p>Mean error: -0.0241 Mean absolute error: 0.8575 RMS error: 0.9844 Scaled RMS error: 7.0768 Maximum Residual: 2.44 (CAF-16C) Minimum Residual: -1.19 (OCW-4A) Decreased recharge to compensate for the higher bottom elevation. Essentially the same quality of calibration as Nwa7 was achieved. However the flow cell between the source and discharge areas is shallower. Maintained Nwa7 setup.</p>

Table G.4 Summary of VOC Transport Parameters

Parameter	Cis-1,2 DCE	TCE	Vinyl Chloride	Basis
Sand Bulk Density (g/cm ³)	1.56	1.56	1.56	(Brady, 1990)
Sand Distribution Coefficient (K _d) (L/kg)	0.046	0.177	0.025	Hydrophobic Theory (de Marsily, 1986)
Sand Retardation Coefficient (R)	1.2	1.9	1.1	Hydrophobic Theory
Swamp Bulk Density (g/cm ³)	1.56	1.56	1.56	Estimated Equal to Sand Value
Swamp Distribution Coefficient (K _d) (L/kg)	11.5	44.2	6.29	Hydrophobic Theory
Swamp Retardation Coefficient (R)	60.7	231	33.7	Hydrophobic Theory
Longitudinal, Horizontal, Vertical Dispersivities (feet)	4, 0.3, 0.01	4, 0.3, 0.01	4, 0.3, 0.01	Calibration
Biodegradation Rate (year ⁻¹)	0.2	0.11	0.16	Calibration
Biodegradation Half Life (year)	3.5	6.3	4.3	Calibration

Table G.5 Summary of Inorganic Transport Parameters

Parameter	²³⁵ Uranium	Fluoride	Basis
Sand Distribution Coefficient (K _d) (L/kg)	3.51	0.6	Calibration
Sand Retardation Coefficient (R)	19.2	4.12	Calibration
Swamp Distribution Coefficient (K _d) (L/kg)	100	50	Estimated (Less than in CAP Section 6.2.2.3)
Swamp Retardation Coefficient (R)	521	261	Estimated (Less than in CAP Section 6.2.2.3)
Longitudinal, Horizontal, Vertical Dispersivities (feet)	4, 0.3, 0.01	4, 0.3, 0.01	Calibration
Biodegradation Rate (year ⁻¹)	none	none	-

Appendix H

**Groundwater and Surface-Water Field Sampling Plan
Monitored Natural Attenuation Corrective Action
for the Northwest Site Area
General Electric - Wilmington, NC**

Prepared for:

General Electric Company
Wilmington, North Carolina

Prepared by:

Andrew D. Stahl, P.G., C.P.G.
Jeff W. Reynolds, P.G., P.H.G.
Carolyn C. Keith
Scott A. Guthrie
Jerry T. Conrad

Geosciences Department
Center for Environmental Measurements and Quality Assurance



March 31, 1999

**Groundwater and Surface Water Field Sampling Plan
Monitored Natural Attenuation Corrective Action
for the Northwest Site Area
General Electric - Wilmington, NC**

Responsible Party: General Electric Company
Post Office Box 760
Wilmington, North Carolina 28402

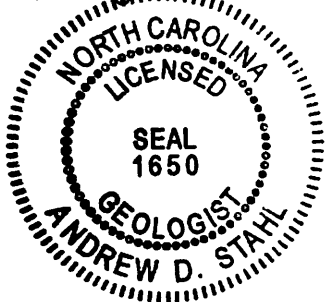
Contact: Herbert R. Strickler, Manager
Site Environment, Health, and Safety
(910)675-5721

Prepared by: Research Triangle Institute
Geosciences Department
PO Box 12194
Research Triangle Park, NC 27709
(919)541-8758

Reviewed by:



Andrew D. Stahl, P.G., C.P.G.
Hydrogeologist
Licensed NC Geologist No. 1650
AIPG Certified Professional
Geologist No. 9070



Jeff W. Reynolds, P.G., P.H.G.
Project Hydrogeologist
Licensed NC Geologist No. 1075
AIH Professional Hydrogeologist No. 1467



Table of Contents

1.0 Introduction	1
2.0 Background Information	3
2.1 Groundwater Flow	3
2.2 Magnitude and Extent of Contamination	4
3.0 Objectives of the Sampling and Analysis Program	5
4.0 Sampling Plan Rationale	6
4.1 Media Monitored and Sampling Locations	6
4.2 Analyte List	7
4.3 Field Methods and Procedures	8
5.0 Sampling Locations	12
6.0 Laboratory Analyses, Sample Containers, and Preservatives	13
7.0 Field Methods and Procedures	16
7.1 Preparation for Field Activities	16
7.2 Sample Collection and Field Measurement Procedures	17
7.2.1 Sampling Groundwater from Monitoring Wells	19
7.2.1.1 Groundwater Level Measurement and Purge Volume Calculation	19
7.2.1.2 Groundwater Sample Collection	21
7.2.2 Swamp Pore-Water Sample Collection	21
7.2.3 Surface-Water Sample Collection	22
7.2.4 Field Parameter Measurements	22
7.3 Sample Handling and Custody	22
7.4 Field Quality Control Samples	24
7.4.1 Field Duplicate Samples	25
7.4.2 Field Blanks	25
7.4.3 Trip Blanks	25
7.4.4 Triplicate Samples for Matrix Spike/Matrix Spike Duplicate Analyses	26
7.4.5 Performance Evaluation Samples	26

7.4.6 PE Sample Dilution Water	26
7.5 Field Documentation	27
7.5.1 Sample Numbering System	27
7.5.2 Field Documents	28
7.5.2.1 Field Instrument Calibration Records	28
7.5.2.2 Sampling Record Form	28
7.5.2.3 Chain-of-Custody Form	28
7.5.2.4 Sample Container Labels and Custody Seals	28
7.5.2.5 Field Notebook	28
7.6 Handling and Disposal of Investigative-Derived Waste	29
8.0 References	30

List of Figures

1. Sampling Locations

List of Tables

1. Range of Contaminant Concentrations
2. Monitoring-Well Construction and Pump Details
3. Sampling and Analysis Schedule, Quarterly Sampling Event
4. Sampling and Analysis Schedule, Annual Sampling Event
5. Quarterly Sample Collection Plan Summary
6. Annual Sample Collection Plan Summary
7. Disposition of Purge Water

List of Attachments

Example Field Forms

Sample Sequence and Identifier Form
Example Completed Sample Sequence and Identifier Form
Field Instrument Calibration Records
Field Sampling Record
CET Chain-of-Custody Form
Generic RTI Chain-of-Custody Form
Sample Container Label and Custody Seal

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 4 Swamp Pore-Water Sample Collection
- 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 10 Field Measurement of Water-Sample Ferrous Iron Content
- SOP 11 Screening Samples and Packing Sample Coolers for Shipping

List of Acronyms and Abbreviations.

APG	Analytical Products Group, Inc.
CaF ₂	calcium fluoride
CAP	Corrective Action Plan
CET	Chemical & Environmental Technology, Inc.
cis-1,2-DCE	cis-1,2-dichloroethylene
COC	chain-of-custody
CSA	Comprehensive Site Assessment Report (RTI, 1998)
DENR	North Carolina Department of Environment and Natural Resources
DO	dissolved oxygen
DWQ	North Carolina Division of Water Quality
EPA	U.S. Environmental Protection Agency
FSP	Field Sampling Plan
GE	General Electric
HCl	hydrochloric acid
HNO ₃	nitric acid
HPS	High Purity Standards
H ₂ SO ₄	sulfuric acid
MNA	monitored natural attenuation

MS	matrix spike
MSD	matrix spike duplicate
NCAC	North Carolina Administrative Code
NIST	National Institute of Standards and Technology
ORP	oxidation/reduction potential
PE	performance evaluation
PVC	polyvinyl chloride
QA	quality assurance
QAPP	Quality Assurance Project Plan
QC	quality control
RTI	Research Triangle Institute
SM	<i>Standard Methods for the Evaluation of Water and Waste Water</i> (APHA, et al., 1992)
SNM	special nuclear material
SOP	standard operating procedure
SW-846	<i>Test Methods for Evaluating Solid Waste, Physical/Chemical Methods</i> (EPA, 1996)
TCE	trichloroethylene
TOC	total organic carbon
²³⁵ U	uranium isotope 235
VOA	volatile organic analysis
VOC	volatile organic compound

1.0 Introduction

The General Electric (GE) facility in Wilmington, North Carolina, encompasses over 1,600 acres of land and is located on US Highway 117 approximately 6 miles north of Wilmington and approximately 3 miles south of Castle Hayne, North Carolina. The facility extends westward from US Highway 117 to the Northeast Cape Fear River (see Figure 1 inset). There are currently two principal manufacturing activities conducted at the GE-Wilmington site: nuclear fuel and components, and aircraft engine parts.

The Research Triangle Institute (RTI) has prepared this Field Sampling Plan (FSP) for monitoring groundwater contamination identified in a remote northwest area of the GE-Wilmington facility. The contamination identified in the northwest site area is associated with former material disposal activities typical of the late 1960s when the GE site was developed. Assessment and monitoring activities have been performed in the northwest site area, and the activities described in this FSP are a continuation of these efforts. Offsite assessment activities have also been performed with approval of the adjacent property owner, and continuation of these offsite assessment activities also are governed by this FSP. This document is included as Appendix H of a Corrective Action Plan (CAP) that was prepared in general accordance with guidelines designated by the North Carolina Department of Environment and Natural Resources (DENR) (DENR, 1998) and is in accordance with regulations specified in Title 15A of the North Carolina Administrative Code (T15A NCAC) Subchapter 2L Section .0106. The Quality Assurance Project Plan (QAPP) prepared for this monitoring program is included in the CAP as Appendix I. This FSP adopts by reference the quality assurance (QA) and quality control (QC) requirements presented in the QAPP.

A Comprehensive Site Assessment Report (CSA) dated December 11, 1998, was prepared by RTI and submitted to DENR (RTI, 1998). The CSA presents detailed information regarding site history, geologic and hydrogeologic framework, contaminant characteristics, previous sampling and analysis activities, extent of contamination, potential exposure

pathways, and potential receptors. As this FSP is designed as a self-standing document, pertinent CSA excerpts regarding background information are included as appropriate in the following sections.

2.0 Background Information

Groundwater contamination identified in the remote northwest area of the GE-Wilmington site consists of volatile organic compounds (VOCs) and inorganic constituents. This contamination is associated with historical storage of calcium fluoride (CaF_2) (containing low levels of uranium) and the disposal of lubricants (apparently contaminated with small quantities of trichloroethylene [TCE]) in unlined trenches at two adjacent locations in the northwest site area. These past practices resulted in groundwater concentrations of the following materials above North Carolina standards: TCE and two of its degradation products (cis-1,2-dichloroethylene [cis-1,2-DCE] and vinyl chloride), and fluoride. In addition, low levels of uranium exhibiting non-natural isotopic ratios (delineated by the distribution of the isotope ^{235}U) have also been detected in shallow groundwater. GE has completed voluntary recovery of the CaF_2 material, and there is evidence that the VOCs are degrading naturally. The CSA (RTI, 1998) presents detailed information regarding groundwater flow and the magnitude and extent of contamination in the northwest site area. The following subsections provide a brief summary of these topics.

2.1 Groundwater Flow

The two former source areas are positioned on the eastern flank of a relic sand dune that forms a topographically prominent area and sand peninsula that is surrounded on three sides by low-lying swampy areas. Groundwater flows toward the north from the CaF_2 storage area and the former lubricants area and, under the influence of a vertical upward hydraulic gradient, discharges offsite into the swampy area.

There are no continuous and extensive clay layers or distinct confining units in the northwest site area. The area is composed primarily of undifferentiated sands down to approximately 30 feet below land surface. A rocky zone is present below this layer, containing a mixture of semi-consolidated sandstone and unconsolidated fine sand. Some voids have been encountered in this material but hydraulic testing has revealed little

difference between the permeability of the aquifer in the deeper rocky sections and that of the overlying sandy aquifer.

2.2 Magnitude and Extent of Contamination

A comprehensive hydrogeologic assessment was performed to evaluate the horizontal and vertical extent of contaminated soil and groundwater. During the assessment, a network of monitoring wells was established at locations onsite as well as on the adjoining property. Table 1 presents the range of concentrations of the analytes to be monitored at each of the locations included in this FSP.

The extent of fluoride and uranium exhibiting non-natural isotopic ratios is inferred to be just beyond the GE property line and limited to the relatively shallow portion of the aquifer.

Groundwater contamination by VOCs is more widespread than the inorganic constituents, extending off of the GE site and into a swampy area north of the source area. The horizontal extent of VOC impacts into the swampy area has been delineated in shallow groundwater samples; clean groundwater has been detected in shallow groundwater beyond the leading edge of the plume. There is no evidence of free-phase contamination in the northwest site area. The vertical extent of VOCs in groundwater has been delineated; VOCs extend somewhat deeper into the rocky sections of the aquifer and have not been detected above NC groundwater standards at depths greater than 56 feet below land surface.

3.0 Objectives of the Sampling and Analysis Program

As described in the CAP, monitored natural attenuation (MNA) was selected as the appropriate remedial alternative for the northwest site area. As implied by the name of the proposed corrective-action approach, monitoring is the most important component of this remedial approach. The sampling and analysis activities described in this FSP are designed to monitor the fate and transport of the identified contamination. The objective of this monitoring is to verify that natural-attenuation processes are occurring and that these processes are reducing the mass, toxicity, volume, concentration, and/or mobility of the contamination. Natural-attenuation processes collectively include contaminant biodegradation, dispersion, dilution, sorption, volatilization, and chemical or biological stabilization, transformation, or destruction. Detailed summaries of properties affecting the fate and subsurface transport of the contaminants are described in the CSA (RTI, 1998) and in the CAP.

Specifically, the monitoring program described in this FSP is designed to meet the requirements of T15A NCAC 2L Sections .0106(I)(7) and .0110. In addition, the monitoring program is intended to demonstrate the effectiveness of the corrective action by meeting U.S. Environmental Protection Agency (EPA) expectations for MNA monitoring. Based on EPA (1997), the monitoring program is expected to:

- ▶ Demonstrate that natural attenuation is occurring as expected;
- ▶ Identify toxic transformation products, if applicable;
- ▶ Evaluate whether the contaminant plume is expanding in size;
- ▶ Confirm the finding of no impact to downgradient receptors;
- ▶ Detect new releases of contaminants that could impact effectiveness;
- ▶ Demonstrate the efficacy of institutional controls, if applicable;
- ▶ Detect changes in environmental conditions that may reduce the efficacy of the natural-attenuation processes; and
- ▶ Evaluate attainment of cleanup objectives.

4.0 Sampling Plan Rationale

Aqueous samples of various environmental media will be collected four times each year (quarterly) as described in this FSP. Every fourth quarter (annual sampling event) additional analyses are prescribed. 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 groundwater, surface water (streams), swamp pore water, and swamp standing water. Monitoring of these waters enables evaluation of contaminant fate and transport and verification that downgradient receptors are not being impacted. The sample locations are shown in Figure 1 and described in Section 5.0. Table 2 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 groundwater near the contaminant source (or previous source area),
- ▶ in groundwater at various depths within the aquifer,
- ▶ in shallow groundwater (swamp pore water) where it discharges to swamp sediment,
- ▶ in surface water where swamp pore water mixes with and becomes swamp standing water, and
- ▶ in surface-water streams that flow throughout the swampy area.

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 plumes are not expanding laterally.

4.2 Analyte List

Section 6.0 describes the laboratory analytical methods selected for this monitoring program. Samples will be collected for analysis of one or more of the following sets of parameters: VOCs, fluoride, total uranium, and gross alpha/beta activity. Tables 3 and 4 indicate the analyses to be performed on each sample collected during quarterly and annual sampling events, respectively. These analyte lists have been established based on available knowledge of the former source areas. This analytical plan not only provides for monitoring of the list of detected contaminants, but enables detection of potential degradation or transformation products.

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. In addition to these laboratory analyses, a sample of water collected from each quarterly monitoring location will also be analyzed in the field for the following parameters:

- ▶ pH,
- ▶ temperature,
- ▶ specific conductance,
- ▶ oxidation/reduction potential (ORP),
- ▶ dissolved oxygen (DO), and
- ▶ ferrous iron.

As the CAP describes, these field 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.

Annually, surface-water sampling points will be incorporated. Furthermore, samples collected from VOC-monitoring locations analysis also will be analyzed for the following parameters once per year (see Table 4):

- ▶ alkalinity,
- ▶ chloride,
- ▶ sulfate,
- ▶ total organic carbon (TOC),
- ▶ methane,
- ▶ ethane, and
- ▶ ethene.

Similar to the field parameters, these analytes also 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.

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. Bladder pumps will be dedicated to all but one well. The dedicated tubing attached to each pump is lined with Teflon which will not adsorb and desorb contaminants. Groundwater from wells not outfitted with a dedicated bladder pump and the surface-water and swamp-water samples will be collected using other dedicated or disposable equipment.
- ▶ The specified sampling procedures minimize the potential that VOCs will be lost from samples. The attached SOPs stipulate that water to be sampled is not subjected to turbulent conditions or unnecessary depressurization that might induce volatilization of organic contaminants from the sample to the atmosphere. These procedures include purging wells and sampling groundwater at low-flow rates, ensuring that the water submitted for laboratory analysis from each well is representative of aquifer conditions rather than being water that has been stagnant in the well, and checking that filled sample vials contain no air bubbles.
- ▶ 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. Disposable tubing will be used to purge water from the one well not equipped with a dedicated pump, and new disposable bailers will be used to collect the groundwater sample from that

well. New disposable polyethylene containers will be used to purge water from the swamp pore-water (SWS-series) sampling devices before the samples are collected directly into new sample containers. Surface-water samples will be collected directly into new sample containers. These protocol preclude the introduction of contaminants from one sample to the next from improperly decontaminated sampling equipment.

- ▶ Samples will be collected in order of increasing contaminant concentrations.
Based on historical data, samples will be collected in order of increasing contamination. Because all sampling equipment is either dedicated or disposable, the reason for this protocol is not to prevent cross contamination in the field. Rather, the intent is to log the samples on the chain-of-custody (COC) form in the order that the laboratory should analyze the samples to minimize the chance that higher levels of contaminants might carry-over in the analytical instruments and affect the analytical results of subsequent, potentially cleaner, samples.
- ▶ Six 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 (summaries of the QC sampling plans for the quarterly and annual sampling events are presented in Tables 5 and 6, respectively):
 - blind field duplicates,
 - blind field blanks,
 - blind performance evaluation (PE) samples,
 - PE sample dilution water (analyzed only if necessary),
 - trip blanks, and
 - triplicate samples specified for matrix spike (MS) and MS duplicate (MSD) analysis.

- ▶ Strict protocol regarding field documentation and sample handling, preservation, and custody will be followed. These procedures, detailed in Section 7.0, 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 of the northwest site area showing each of the sampling locations included in this monitoring program. The categories of sampling locations are as follows:

Medium/Device	Position		Number of Locations	Figure 1 Symbol
Groundwater Monitoring Well	Onsite	Shallow Aquifer*	8	Dot
		Deeper Aquifer*	10	
	Offsite	Shallow Aquifer*	2	
		Deeper Aquifer*	5	
Swamp Pore Water (also swamp standing water, if necessary)	Offsite		5	Triangle
Surface Water	Onsite		1	Square
	Offsite		3	

* Shallow aquifer wells are defined as those that have screens positioned where the water table at times is situated within the screened interval. These wells typically have the suffix "A". Deeper aquifer wells are defined as those that have screens that are fully submerged below the water table. These wells typically have the suffix "B", "C", or "D", depending on total well depth.

For quarterly sampling events, the red sampling locations shown in Figure 1 are specified as VOC monitoring points, blue sampling locations are specified as inorganics (fluoride, uranium, and gross alpha/beta activity) monitoring points, and the green sampling locations are specified for monitoring of both VOCs and inorganics. Three offsite wells, OCW-1C, OCW-2C, and OCW-3C, are shown in red as quarterly sampling locations for VOCs. As indicated in Figure 1 by an asterisk, however, groundwater from these three wells also will be analyzed for the inorganic parameters during the annual sampling event. The sampling and analysis schedules for the quarterly and annual sampling events are listed in Tables 3 and 4, respectively.

6.0 Laboratory Analyses, Sample Containers, and Preservatives

Four separate laboratories will analyze samples collected during the quarterly sampling events. These four laboratories plus one additional laboratory will analyze samples collected during the annual sampling events. Each of these laboratories has demonstrated acceptable qualifications and experience to perform the respective analytical methods, is certified by the Certification Section of the NC Division of Water Quality (DWQ) Chemistry Laboratory under 15A NCAC 2H .0800 for the utilized method if such certification is required, and is allowed to receive special nuclear material (SNM) if the laboratory is to receive samples potentially classified as such. Tables 3 and 4 list the analytical methods each laboratory will perform for the quarterly and annual sampling events, respectively. The QAPP (CAP Appendix I) presents further information regarding the selected analytical methods. A summary of the analytical methods and laboratories selected for this monitoring program is as follows:

Laboratory Name/Location	Analytes	Method	Event	Receiving SNM?
Chemical & Environmental Technology, Inc. (CET)/Cary, NC	VOCs	EPA SW-846 Method 8021B	Quarterly and Annual	No
	Alkalinity	Standard Methods (SM) 2320B	Annual	
	Chloride	SM 4500 Cl-C	Annual	
	Sulfate	SM 4500-SO ₄ -C	Annual	
	TOC	SM 5310-C	Annual	
Oxford Laboratory/ Wilmington, NC	Fluoride	EPA Method 340.2	Quarterly and Annual	Yes
Research Triangle Institute/RTP, NC	Total Uranium	EPA Method 200.8	Quarterly and Annual	Yes
Microseeps/ Pittsburgh, PA	Methane, Ethane, Ethene	AM 18.02 (internal laboratory method)	Annual	No
Teledyne Brown Engineering/ Westwood, NJ	Gross Alpha and Gross Beta	PRO-032-1 (internal laboratory method)	Quarterly and Annual	Yes

For the quarterly and annual sampling events, respectively, Tables 3 and 4 also present the required sample containers for each set of analytes. CET will provide unused certified-clean containers (40-mL glass vials and 1-L polyethylene bottles) for the samples that they will be analyzing. Each 40-mL volatile organic analysis (VOA) vial provided by CET has been dosed by the manufacturer with hydrochloric acid (HCl) preservative. Similarly, the 40-mL VOA vials provided by CET for annual TOC analyses will come pre-preserved with sulfuric acid (H_2SO_4). For the annual analyses of methane, ethane, and ethene, 40-mL amber glass vials will be provided by Microseeps. RTI purchases new certified-clean 250-mL and 2-L polyethylene bottles from scientific equipment vendors (e.g., Cole Parmer or VWR Scientific) for the remaining analyses listed on Tables 3 and 4.

Samples to be analyzed for total uranium and gross alpha/gross beta activity must be preserved with nitric acid (HNO_3). RTI purchases certified reagent-grade HNO_3 from a scientific equipment vendor and creates a 50-percent HNO_3 dilution using laboratory-purified water obtained from RTI. As discussed in Section 7.2, RTI adds the appropriate amount of 50-percent HNO_3 to the appropriate sample bottles in the field immediately after the sample has been collected.

Per our understanding of GE's internal screening protocol for SNM, sub-samples of the water collected from locations that, during the previous quarter, showed a total uranium concentration exceeding 0.02 mg/L (currently, only monitoring wells CAF-6A and CAF-6B fall into this category) 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 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 each PE sample vendor with containers to be filled with the PE sample. The PE vendors then send the PE samples in these containers to the RTI Lead Field Geologist for inclusion in the sample delivery group. A supply of new certified-clean 250-mL polyethylene bottles is submitted to High Purity Standards (HPS) of Charleston, South Carolina, for further cleaning according to their internal protocol. HPS retains this stock of bottles for use in providing

PE samples each quarter to RTI for total uranium and fluoride analyses. Each quarter, RTI sends Analytical Products Group, Inc. (APG), of Belpre, Ohio, new certified-clean VOA vials pre-preserved with HCl that were provided to RTI by CET. APG fills three of the provided vials with the VOC PE sample and three separate vials with a sample of the water used to dilute their stock solution to the final PE sample concentration. These samples are returned to the RTI Lead Field Geologist for inclusion in the sample delivery group. The PE sample dilution water is not submitted to the laboratory blind, is initially placed on hold, and is only analyzed if warranted by the PE sample analytical results.

7.0 Field Methods and Procedures

SOPs 1 through 11, attached to this FSP, supplement the following discussion of 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 250-mL, 2-L polyethylene bottles, and nitric acid. As needed, place orders with a scientific equipment vendor for additional supplies.
		Check supply of pre-acidified 40-mL glass vials, pre-printed sample bottle labels, pre-printed COC forms, custody seals, and packing materials. As needed, request additional supplies from CET.
		As needed, replenish supplies of generic COC forms, sample bottle labels, sample coolers, and packing/shipping materials.
	QA Officer	Prepare requisition to purchase the VOC PE sample from APG, and the uranium and fluoride PE samples from HPS.
		For annual sampling events, prepare requisition to retain Microseeps service.
4 weeks	Lead Field Geologist	For annual sampling events, contact Microseeps and request shipment of 40-mL amber glass vials.
	QA Officer	Contact both PE sample vendors to indicate the timing of PE sample delivery.
3 weeks	Lead Field Geologist	Referring to Tables 3 and 5 for quarterly events or to Tables 4 and 6 for annual events, 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 40-mL glass vials pre-acidified with HCl to APG for preparation of VOC PE sample and PE sample dilution water (blank).
		For quarterly sampling events, request shipment from CET of trip blanks and purified water for collection of field blanks.
		For annual sampling events, request shipment from CET of 40-mL glass vials pre-acidified with H ₂ SO ₄ (for TOC analyses), 1-L polyethylene bottles, trip blanks, and purified water for collection of field blanks.
		Request shipment from RTI Laboratory of laboratory-purified water to collect field blanks for fluoride and total uranium analyses.
1 week	Lead Field Geologist	Verify receipt (or requested timing of shipment) of required PE samples and sampling/packaging/shipping supplies.
		Inform additional laboratories of upcoming sampling event—contact RTI Laboratory, Oxford Laboratory, Teledyne Brown Engineering, and GE Chemet Laboratory (Chemet screens selected samples for SNM status).
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 of the FSP describes the protocol for collecting groundwater, swamp pore-water, and surface-water samples and the procedures for measuring field parameters. The following paragraphs describe general sample collection protocol that apply to sampling of groundwater, swamp pore water, and surface water.

- Tables 5 and 6 list the QC samples that will be collected during the quarterly and annual sampling events, respectively (see Section 7.4 for further discussion). When more than one container is required to comprise a primary sample (e.g., three 40-mL vials comprise a single sample for VOC analysis) or to comprise a QC pair of samples (e.g., a primary-duplicate sample pair, or a sample collected in triplicate for MS/MSD analyses), approximately one third of each sample bottle will be filled at a time (sample containers will be filled directly without use of an intermediary container), alternating between each of the bottles that are required until all bottles are full.

- ▶ VOA vials (for VOC and methane/ethane/ethene analyses) will be filled with no headspace but, because the "empty" vials already contain the HCl preservative, they are not to be excessively overfilled. (Similarly, "empty" vials to be filled for annual TOC analyses already contain the H₂SO₄ preservative, and these vials also are not to be excessively overfilled.) Each 40-mL VOA vial will be inspected for headspace by securing the Teflon-lined cap, inverting the bottle, tapping the bottle against a hard surface, inspecting for the presence of air bubbles, and adding additional sample to the vial if bubbles are observed.
- ▶ Samples to be analyzed for total and isotopic uranium and gross alpha/gross beta activity must be preserved with HNO₃, and the containers to be filled for these analyses are not provided with HNO₃ already added. RTI purchases certified reagent-grade HNO₃ from a scientific equipment vendor and creates a 50-percent HNO₃ dilution using laboratory-purified (deionized) water obtained from RTI. Immediately after each sample for these analyses is collected, 50-percent HNO₃ will be added to each sample bottle in the field using a dropper bottle dedicated for this use. The amount of HNO₃ required to lower the sample pH to less than 2 is listed below, and verification of proper pH will be performed in the field using pH test-strip paper.

Bottle Size	Approximate Amount of 50% HNO ₃
40 mL (only samples that require SNM screening at the GE Chemet Laboratory)	2 to 4 drops
250 mL	3 to 8 drops
2 L	3 to 4 mL

7.2.1 Sampling Groundwater from Monitoring Wells. Except for monitoring well OSW-1A, each monitoring well included in this program is equipped with a dedicated QED Well Wizard bladder pump and Teflon-lined tubing. These pumps will be used for purging and collecting water samples as described in SOP 1. The shallow wells are equipped with QED model T1200 pumps, and the deeper wells are equipped with model T1500 pumps. Low flow rates can be sustained that minimize the potential for turbulent conditions to develop in the well that might cause a loss of VOCs from the water to the atmosphere. As described in SOP 1, an electric water-level meter will be used during purging to verify that the pumping rate is inducing negligible drawdown in the deeper wells. Well OSW-1A is purged using a peristaltic pump as described in SOP 2, and VOC samples then are collected with a disposable polyethylene bailer. The three peristaltic pumps that may be used have maximum pumping rates that range from 0.2 to 0.4 liters per minute. The OSW-1A tubing used with the peristaltic pump is dedicated to that well.

7.2.1.1 Groundwater Level Measurement and Purge Volume Calculation. 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 map the configuration of the water table and to calculate the amount of water that must be purged from shallow monitoring wells before groundwater samples are collected.

The shallow monitoring wells included in this monitoring program listed in Table 2 have a suffix "A," and these wells typically 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:

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

where

PV_s = purge volume for shallow well, in liters

SD = screen diameter, in inches

SB = depth to bottom of screen (see Table 2), in feet below top of casing

WD = measured depth to water, in feet below top of casing.

Based on the historical high and low water levels measured for each of the shallow monitoring wells included in this monitoring program, the purge volumes calculated using the above equation range from 5.2 to 23.5 liters.

The deeper monitoring wells included in this monitoring program listed in Table 2 have a suffix "B," "C," or "D," 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 Section 7.2.2 and in SOPs 1 and 2, 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:

$$PV_d = 3 \cdot \pi \cdot (SD+24)^2 \cdot SL \cdot 28.32$$

where

PV_d = purge volume for deeper well, in liters

SD = screen diameter, in inches

SL = screen length, in feet.

All the deeper wells listed in Table 2 except OB-5 have 10-foot long, 2-inch diameter screens. The calculated PV_d for these wells is 18.6 liters. With an 18-foot long, 6-inch diameter screen, the calculated PV_d for well OB-5 is 300 liters.

7.2.1.2 Groundwater Sample Collection. After the prescribed volume of purge water has been removed from the well, pump operation will continue and groundwater samples will be collected. The required sample bottles shown for each well in Tables 3 and 4 for the quarterly and annual sampling events, respectively, will be filled. Sample bottles other than those prescribed for VOCs will be filled first. After these bottles are filled, the pumping rate will be reduced to a target rate of 0.1 liter per minute, and the 40-mL VOA vials will be filled (and, for annual sampling events, amber vials will be filled for analysis of methane, ethane, and ethene). Additional samples will be collected for GE's internal SNM screening protocol, as necessary (see SOP 11).

7.2.2 Swamp Pore-Water Sample Collection. Each of the five locations where swamp pore-water samples will be collected are equipped with a 3-foot long, 6-inch diameter polyvinyl chloride (PVC) pipe driven into the sediment. The lower portion of these pipes is filled with sand which acts as a filter to prevent the swamp sediment from being disturbed and entrained into the sample. A schematic of these devices and detailed sampling procedures are presented in SOP 4. In general, an unused disposable polyethylene bottle is used to bail down the water level inside the PVC pipe to the sand layer. Swamp pore water then flows up through the open pipe bottom, through the sand, and fills the open space of the pipe above the sand where it is then collected directly into the appropriate sample containers. As "empty" sample containers that already contain preservative are inserted into the pipe for sample collection, the containers will be kept inclined such that the preservative does not spill from the container. If the water to be sampled is not deep enough, containers without preservative will be used for initial collection, and the sample then will be transferred into the pre-preserved containers. Samples to be analyzed for VOC analysis (and for annual methane, ethane, and ethene analyses) will be allowed to flow into the VOA vials at a slow, non-turbulent rate by slowly submerging the lower lip of the vial beneath the water surface and gradually tilting the vial vertically until nearly full. Then, the sample container caps will be used to bail small amounts of sample from the pipe in order to completely fill the VOA vials.

7.2.3 Surface-Water Sample Collection. Stakes have been placed at the approximate locations shown on Figure 1 where surface-water samples will be collected. In addition to sampling surface water at these four locations, the procedures described in this section also apply to the collection of standing swamp water adjacent to swamp pore-water sampling station SWS-9.

Surface-water samples will be collected as described in SOP 5. The samples will be collected directly into the appropriate sample containers. As "empty" sample containers that already contain preservative are filled, the containers will be kept inclined so that the preservative does not spill from the container. If the water to be sampled is not deep enough, unpreserved containers will be used for initial collection, and the sample then will be transferred into the pre-preserved containers. Samples to be analyzed for VOCs will be allowed to flow into the VOA vials at a slow, non-turbulent rate by slowly submerging the lower lip of the vial beneath the water surface and gradually tilting the vial vertically until nearly full. Then, the sample container caps will be used to bail small amounts of surface water in order to completely fill the VOA vials.

7.2.4 Field Parameter Measurements. After each of the sample containers required for laboratory analysis is filled, additional water will be produced to first rinse and then fill a polyethylene beaker. Except for the surface-water samples, measurements of the following field parameters will be performed on water collected in the beaker:

- ▶ pH (see SOP 6),
- ▶ temperature (see SOP 7),
- ▶ specific conductance (see SOP 7),
- ▶ oxidation/reduction potential (see SOP 8),
- ▶ dissolved oxygen (see SOP 9), and
- ▶ ferrous iron (see SOP 10).

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 using waterproof adhesive labels. At a minimum, the label will indicate the sample identification number, the date and time the sample was

collected, and the requested analytical method(s). Samples to be analyzed for total uranium and gross alpha/gross beta activity will be preserved with 50-percent HNO_3 as described in Sections 6.0 and 7.2. Glass containers will be securely packed in plastic bubble wrap or foam packing. Except for uranium and gross alpha/beta activity samples, the containers then 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 $4 \pm 2^\circ\text{C}$. As currently required by the NC DWQ Chemistry Laboratory, the samples will be stored and maintained between 0.1 and 4.4°C while at the laboratory. Uranium and gross alpha/beta activity samples 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 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. CET will be providing project-specific pre-printed COC forms. RTI's generic COC form will be used for the samples being submitted to each of the other laboratories. Copies of these COC forms are 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. The procedure includes packing a small container of water next to the samples being submitted to CET to serve as a "temperature

blank." Upon receipt of the samples, CET will measure the temperature of this small container of water and record the temperature on the COC form.

As described in SOP 11, the COC form will be placed in a plastic bag and shipped with samples inside the cooler. After the samples, ice, 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 fluoride analysis will be hand delivered to Oxford Laboratory 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 times exceedances, missing or improper sample labeling, temperature-blank measurement above 6 °C, or frozen water samples.

As discussed in Sections 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 (currently, only monitoring wells CAF-6A and CAF-6B fall into this category) 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. SOP 11 describes GE's SNM screening and shipment approval processes as they pertain to environmental samples.

7.4 Field Quality Control Samples

Tables 5 and 6 are sample collection plan summaries presenting the field QC samples scheduled for this monitoring program. These field QC samples are part of the overall QA/QC program, the purpose of which is to produce data of known quality that satisfy the

project objectives. The QAPP prepared for this monitoring program (CAP Appendix I) describes both the laboratory and field aspects of the QA/QC program. The following paragraphs supplement the discussion presented in the QAPP regarding field QC samples.

7.4.1 Field Duplicate Samples. Field duplicate samples will be collected and analyzed to evaluate sampling and analytical precision. Procedures for duplicate sample collection are discussed in Section 7.2. One duplicate sample will be collected each sampling event for each analyte set except for gross alpha/gross beta activity. 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). CET will provide laboratory-purified water for preparing the field blanks to be analyzed for VOCs. Laboratory-purified water obtained from RTI will be used for preparing the field blanks to be analyzed for fluoride 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 (see Tables 3 and 4), adding the same chemical preservatives as used for the primary samples, and submitting the field blanks blind to the laboratories for analysis. One field equipment blank will be collected each sampling event for VOC analysis, and one field equipment blank will be collected each sampling event for analysis of fluoride and uranium. Separate field blanks will be prepared for these two sets of analytes because the former source area for fluoride and uranium is different than the VOC source area, and an effort will be made to collect field blanks at sampling locations near these former source areas.

7.4.3 Trip Blanks. The primary purpose of trip blanks is to detect additional sources of VOC contamination that could potentially influence contaminant values reported in field samples, both quantitatively and qualitatively. Trip blanks serve as a mechanism of control for sample bottle preparation, blank water quality, and sample handling. Each trip blank

consists of two VOA vials filled by CET in their laboratory with laboratory-purified water. The trip blank will be sent to the site in one of the coolers to be used during sampling and returned from the site in the cooler with the collected field samples in an effort to simulate sample handling conditions. One trip blank will be included in each cooler transporting samples for VOC analysis.

7.4.4 Triplicate Samples for Matrix Spike/Matrix Spike Duplicate Analyses. As explained in the QAPP (CAP Appendix I), for those analytical methods that require MS/MSD analyses, the laboratories will be required to perform these QC checks on samples collected at the GE site (as opposed to performing these analyses on samples that are grouped in the same analytical batch but were collected at other clients' sites). Except for VOC analysis, the primary sample provides ample volume for performing these analyses. For VOC MS/MSD analyses, the field team must collect one sample in triplicate for every 20 primary samples (i.e., nine 40-mL VOC vials must be filled rather than only three vials). The extra six vials are considered part of the same sample and, therefore, are not submitted blind and are identified to the laboratory with the same sample identification number as shown on the accompanying three vials.

7.4.5 Performance Evaluation Samples. One set of PE samples will be submitted to the laboratories during each sampling event for analysis of VOCs, fluoride, 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 APG (VOC PE sample) and by HPS (fluoride and uranium PE samples) using National Institute of Standards and Technology (NIST) traceable standards. Sections 6.0 and 7.1 describe the procedures for providing these vendors 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, CAP Appendix I) to evaluate laboratory accuracy.

7.4.6 PE Sample Dilution Water. For the VOC PE sample, APG also will provide three vials filled with a sample of the water used to dilute their stock solution to the final PE sample concentration. The PE sample dilution water is not submitted to the laboratory

blind, is initially placed on hold, and is only analyzed if warranted by the PE sample analytical results as determined by the RTI QA Officer and Project Leader.

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, swamp-water sampling station identifiers, 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 of the bottles to be filled for a particular sample for all of the required analytical methods. For example, six bottles are to be filled when sampling monitoring well CAF-9A during a quarterly sampling event (see Table 3). Three of these bottles and one COC form will be submitted to CET, and one bottle and one COC form will be submitted to each of the other three laboratories listed in Table 3. All six of these bottles and all four COC forms will refer to this sample by the same sample identification number. 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. As presented in Section 7.1, approximately 3 weeks before each sampling event, the RTI Lead Field Geologist will prepare this form for the RTI Project Leader review and approval. An example of a completed form also is attached to this FSP. The form is filled out by listing each of the scheduled sampling locations in approximate order of increasing analyte concentrations while interspersing the blind QC samples as separate entries. 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 identifying which sample(s) will be specified for MS/MSD analysis (see Section 7.4.4) and by checking off the analytical methods that apply to each sample using the information shown in Tables 3 and 4. After approving the completed form, the Project Leader will provide a copy of the form to the QA

Officer and Database Specialist to facilitate data validation and proper data management, respectively.

7.5.2 Field Documents. The following subsections describe the field documents that will be maintained throughout this monitoring program.

7.5.2.1 Field Instrument Calibration 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 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 or obtaining a replacement instrument.

7.5.2.2 Sampling Record Form. Attached to this FSP is a blank Sampling Record Form. A 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 Lead Field Geologist will submit the completed forms to the Project Leader who in turn will provide copies to the Database Specialist and see that the originals are properly filed.

7.5.2.3 Chain-of-Custody Form. COC forms will be maintained as described in Section 7.3. Blank copies of the two COC forms to be used for this project are attached to this FSP. The original copy of each COC form is submitted along with the analytical report by the laboratory. The Lead Field Geologist and the laboratory each retain copies of the COC form.

7.5.2.4 Sample Container Labels and Custody Seals. Sample container labels and custody seals will be maintained as described in Section 7.3. Example copies of these labels and seals are attached to this FSP.

7.5.2.5 Field Notebook. A daily field report will serve as a diary of field activities and will record pertinent data that are not included on the other forms described above. A daily field report will be maintained by each sampling team leader in a bound field notebook.

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 Handling and Disposal of Investigative-Derived Waste

Purge water extracted from sampling points and monitoring wells in the northwest site area will either be discharged to the ground surface (if contaminants of interest are below threshold levels/NC groundwater standards) or containerized for appropriate disposal by GE. Table 7 summarized 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.

North Carolina Department of Environment and Natural Resources (DENR). 1998. *Groundwater Section Guidelines for the Investigation and Remediation of Soil and Groundwater: Vol I - Sources Other Than Petroleum Underground Storage Tanks*. Division of Water Quality, Groundwater Section.

Research Triangle Institute (RTI). 1998. *Comprehensive Site Assessment Report for the Northwest Site Area*. RTI Report 6448-018/003/01F.

U.S. Environmental Protection Agency (EPA). 1996. *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW-846*, Third Edition and updates, Office of Solid Waste and Emergency Response, U.S. Environmental Protection Agency, Washington, D.C.

_____. 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

Figure 1

Sampling Locations

Northwest Site Area Field Sampling Plan

GE - Wilmington, NC Site

Explanation

- Monitoring well
- ▲ Swamp-water monitoring point
- Surface-water monitoring point
- + Plant coordinates

Specified Analyses

Red = VOCs monitoring

Blue = Inorganics monitoring

Green = Both VOCs and inorganics monitoring

Stream location based on field reconnaissance (dashed where inferred).

Extent of GE property

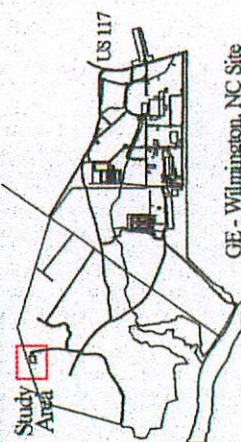
Swampy area

Road/Trail

Fenced area

* In addition to quarterly analyses for VOCs, samples from wells OCW-1C, OCW-2C, and OCW-3C will be analyzed for inorganic parameters during annual sampling events.

INSET NOT TO SCALE



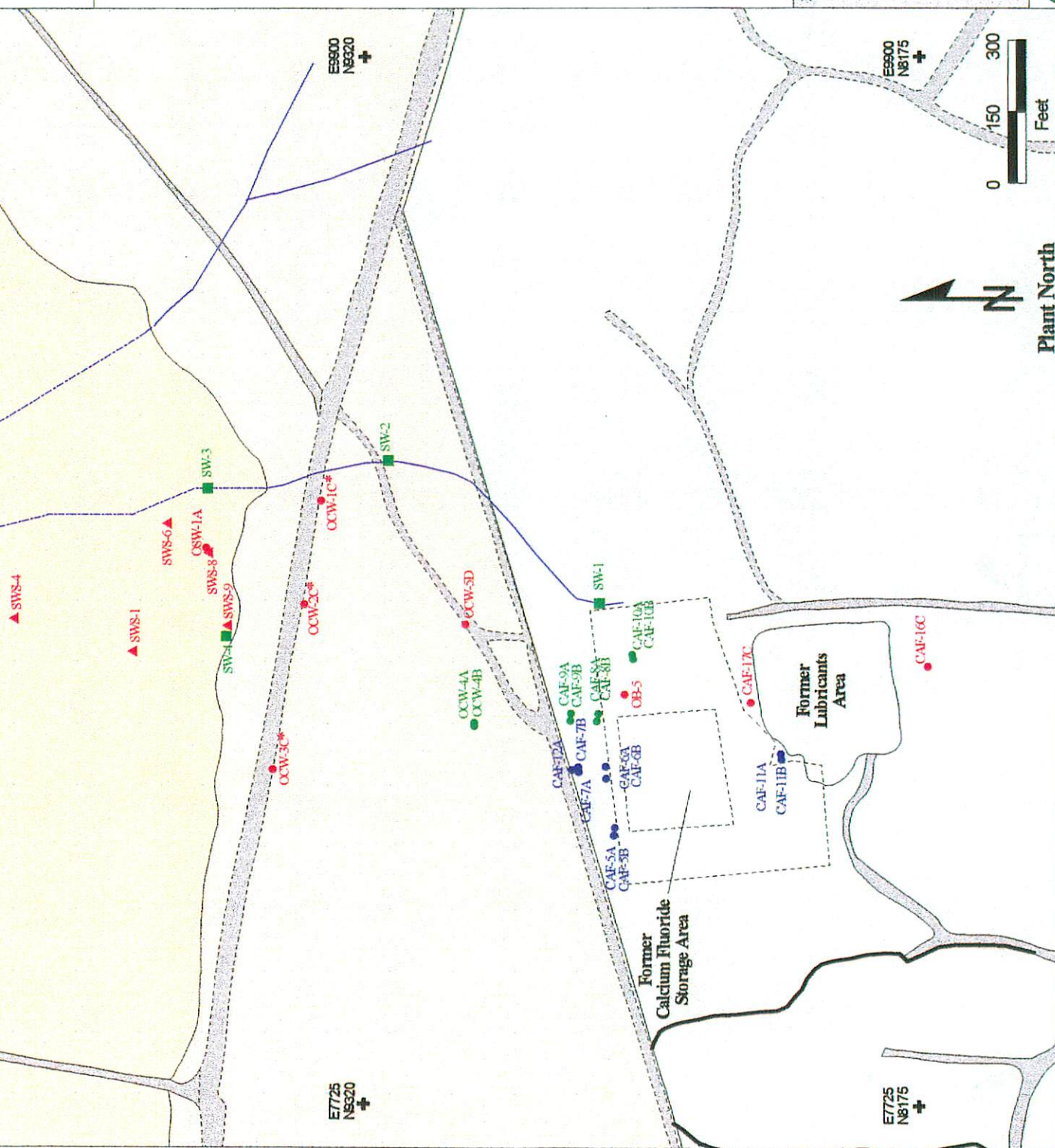
NE Cape Fear River

US 117



Map Preparation Date: 2/18/99

caf_1_26_99.apr



TABLES

**Table 1. Range of Analyte Concentrations
Northwest Site Area Wells and Sampling Points**

Well ID	Analyte:	Fluoride (mg/L)	Total Uranium (mg/L)	²³⁵ U (mg/L)	Gross Alpha (pCi/L)	TCE (ug/L)	cDCE (ug/L)	Vinyl Chloride (ug/L)
	Practical Quantitation Limit:	0.02	0.00015	0.00015	Typically ranges from 1 to 5	0.5	0.5	0.5
Onsite Wells								
CAF-5A	Minimum	ND	ND	ND	ND	ND	ND	ND
	Maximum	0.201	0.00727	ND	9.1	ND	ND	ND
	2 nd Half 1998	0.02	ND	NM	1.6	ND	ND	ND
CAF-5B	Minimum	ND	ND	ND	ND	ND	ND	ND
	Maximum	1.08	0.0146	0.00188	53.35	ND	ND	ND
	2 nd Half 1998	0.1	0.0115	0.000184	28	ND	ND	ND
CAF-6A	Minimum	ND	0.016	0.000341	17	ND	ND	ND
	Maximum	4.85	2.4	0.0102	3173.46	ND	ND	ND
	2 nd Half 1998	1.44	0.0808	0.0017	70	ND	ND	ND
CAF-6B	Minimum	4.24	ND	ND	3	ND	ND	ND
	Maximum	8.03	0.028	0.0031	84.97	ND	ND	ND
	2 nd Half 1998	7.44	0.022	0.000271	30	ND	ND	ND
CAF-7A	Minimum	ND	ND	0.000152	8.7	ND	ND	ND
	Maximum	6.1	0.6723	0.0167	1109.62	ND	ND	ND
	2 nd Half 1998	0.98	0.0169	0.000386	20	ND	ND	ND
CAF-7B	Minimum	4.89	ND	ND	5	ND	ND	ND
	Maximum	8.95	0.0093	ND	67.34	ND	ND	ND
	2 nd Half 1998	8.05	0.00596	ND	21	ND	ND	ND
CAF-8A	Minimum	0.28	ND	ND	ND	ND	ND	ND
	Maximum	1.65	0.00082	ND	6.41	ND	ND	ND
	2 nd Half 1998	1	0.000416	NM	ND	ND	ND	ND
CAF-8B	Minimum	0.11	ND	ND	2.4	ND	ND	ND
	Maximum	12.9	0.00588	0.00019	37.8	1.23	32.0	ND
	2 nd Half 1998	10.2	0.00188	NM	8.2	(0.15)	ND	ND
CAF-9A	Minimum	1.06	ND	ND	ND	ND	ND	ND
	Maximum	4.4	0.006	ND	52.08	ND	0.13	ND
	2 nd Half 1998	1.63	0.000865	NM	3.8	ND	ND	ND
CAF-9B	Minimum	3.39	ND	ND	2.3	ND	ND	ND
	Maximum	4.9	0.008	ND	35.77	0.84	16.0	ND
	2 nd Half 1998	3.68	0.00352	ND	18	ND	ND	ND
CAF-10A	Minimum	ND	ND	ND	ND	ND	ND	ND
	Maximum	2.27	0.006	ND	35.02	ND	ND	ND
	2 nd Half 1998	1.42	0.0014	NM	ND	ND	ND	ND
CAF-10B	Minimum	ND	ND	ND	ND	ND	ND	ND
	Maximum	0.162	0.000757	ND	2.1	ND	ND	ND
	2 nd Half 1998	0.03	0.00071	NM	ND	ND	ND	ND

Table 1 (continued)

Well ID	Analyte:	Fluoride (mg/L)	Total Uranium (mg/L)	²³⁵ U (mg/L)	Gross Alpha (pCi/L)	TCE (ug/L)	cDCE (ug/L)	Vinyl Chloride (ug/L)
	Practical Quantitation Limit:	0.02	0.00015	0.00015	Typically ranges from 1 to 5	0.5	0.5	0.5
Onsite Wells (continued)								
CAF-11A	Minimum	ND	ND	ND	ND	ND	ND	ND
	Maximum	0.114	0.00359	ND	5.78	ND	ND	ND
	2 nd Half 1998	0.06	ND	NM	ND	ND	ND	ND
CAF-11B	Minimum	ND	ND	ND	ND	ND	ND	ND
	Maximum	0.127	0.00407	ND	8.1	ND	ND	ND
	2 nd Half 1998	ND	0.00234	ND	ND	ND	ND	ND
CAF-12A	Minimum	0.687	0.00593	ND	2.9	ND	ND	ND
	Maximum	7.91	0.741	0.0189	1241.63	ND	ND	ND
	2 nd Half 1998	1.74	0.00788	0.000189	11	ND	ND	ND
CAF-16C	Minimum	0.05	0.000151	ND	ND	ND	ND	ND
	Maximum	0.07	0.000752	ND	ND	ND	ND	ND
	2 nd Half 1998	0.05	0.000242	NM	ND	ND	ND	ND
CAF-17C	Minimum	0.02	0.000236	ND	ND	ND	328.0	50.0
	Maximum	0.03	0.00328	ND	ND	0.86	1162	196.0
	2 nd Half 1998	0.02	0.000505	NM	ND	0.86	740.0	50.0
OB-5	Minimum	NM	NM	NM	NM	ND	97.5	ND
	Maximum	NM	NM	NM	NM	ND	761.0	12.0
	2 nd Half 1998	NM	NM	NM	NM	ND	97.5	ND
Offsite Wells								
OCW-1C	Minimum	0.06	ND	ND	ND	ND	ND	ND
	Maximum	0.07	0.00213	ND	ND	ND	ND	ND
	2 nd Half 1998	0.06	0.000285	NM	ND	ND	ND	ND
OCW-2C	Minimum	0.05	0.00078	ND	ND	41.9	348.0	ND
	Maximum	0.09	0.00355	ND	ND	42.3	686.0	1.26
	2 nd Half 1998	0.05	0.000902	NM	ND	42.3	348.0	1.26
OCW-3C	Minimum	0.02	0.0003	NM	ND	ND	ND	ND
	Maximum	0.05	0.00156	NM	2.4	ND	ND	ND
	2 nd Half 1998	0.02	0.000317	NM	ND	ND	ND	ND
OCW-4A	Minimum	ND	ND	NM	ND	ND	ND	ND
	Maximum	0.03	0.00104	NM	ND	ND	ND	ND
	2 nd Half 1998	ND	0.00025	NM	ND	ND	ND	ND
OCW-4B	Minimum	0.03	ND	ND	ND	(0.38)	1.28	ND
	Maximum	0.03	0.00129	ND	3.2	(0.38)	1.28	ND
	2 nd Half 1998	0.03	0.00106	NM	3.2	(0.38)	1.28	ND
OCW-5D	Minimum	0.05	0.00057	ND	ND	ND	(0.26)	ND
	Maximum	0.12	0.00842	ND	18	ND	1.19	ND
	2 nd Half 1998	0.05	0.00287	ND	8.8	ND	(0.26)	ND
OSW-1A	Minimum	0.05	ND	NM	ND	ND	ND	ND
	Maximum	0.06	ND	NM	ND	ND	1.32	ND
	2 nd Half 1998	0.05	ND	NM	ND	ND	1.32	ND

Table 1 (continued)

Well ID	Analyte:	Fluoride (mg/L)	Total Uranium (mg/L)	²³⁵ U (mg/L)	Gross Alpha (pCi/L)	TCE (ug/L)	c DCE (ug/L)	Vinyl Chloride (ug/L)
	Practical Quantitation Limit:	0.02	0.00015	0.00015	Typically ranges from 1 to 5	0.5	0.5	0.5
Offsite Swamp Water Sampling Points								
SWS-1	Minimum	0.02	ND	NM	ND	ND	ND	ND
	Maximum	0.02	0.000517	NM	ND	ND	1.1	ND
	2 nd Half 1998	0.02	0.000517	NM	ND	ND	ND	ND
SWS-4	Minimum	NM	ND	NM	NM	ND	ND	ND
	Maximum	NM	ND	NM	NM	ND	ND	ND
	2 nd Half 1998	NM	NM	NM	NM	NM	NM	NM
SWS-6	Minimum	0.06	0.000253	NM	ND	ND	ND	ND
	Maximum	0.06	0.000448	NM	ND	ND	ND	ND
	2 nd Half 1998	0.06	0.000448	NM	ND	ND	ND	ND
SWS-8	Minimum	0.02	ND	NM	ND	ND	ND	ND
	Maximum	0.05	ND	NM	ND	ND	-0.15	ND
	2 nd Half 1998	0.02	ND	NM	ND	ND	ND	ND
SWS-9	Minimum	ND	0.000832	ND	ND	ND	8.47	ND
	Maximum	ND	0.00491	ND	ND	30.4	562.0	ND
	2 nd Half 1998	ND	0.000832	ND	ND	ND	8.47	ND

VOC concentrations in parentheses indicate estimated concentration of the analyte below the practical quantitation limit.

c DCE = cis-1,2- Dichloroethylene.

ND = Not detected above applicable reporting or detection limit.

NM = Not measured.

TCE = Trichloroethylene.

²³⁵U = Uranium isotope 235. Isotopic abundances are calculated only when the total uranium concentration is at or above the assessment threshold of 0.002 mg/L.

Data prior to 2nd half of 1996 not considered in determining maximum and minimum concentration values for total uranium and ²³⁵U.

Table 2. Monitoring-Well Construction and Pump Details

Well Number	GE Coordinates		Well Diameter (inches)	Top of Casing Elevation		Depth, feet below top of casing				Pump Type	
	North	East		(feet above mean sea level)	(feet above ground level)	Deepest Water Level	Shallowest Water Level	Top of Screen	Bottom of Screen		Pump Intake
Onsite Wells											
CAF-5A	8807.4	8281.2	2	30.99	2.5	15.7	9.0	10.69	20.69	19.19	bladder-T1200
CAF-5B	8805.3	8296.9	2	30.84	2.4	15.9	9.3	22.84	32.84	23.84	bladder-T1200
CAF-6A	8823.4	8400.1	2	29.24	2.4	14.1	7.7	10.39	20.39	18.89	bladder-T1200
CAF-6B	8824.3	8425.5	2	28.86	2.3	22.7	5.5	23.36	33.36	24.36	bladder-T1200
CAF-7A	8880.2	8414.0	2	29.42	2.5	14.5	8.1	9.62	19.62	18.12	bladder-T1200
CAF-7B	8881.0	8424.5	2	29.12	2.4	14.4	8.1	22.82	32.82	23.82	bladder-T1200
CAF-8A	8842.4	8519.6	2	26.62	2.0	11.6	5.6	7.52	17.52	16.02	bladder-T1200
CAF-8B	8839.8	8533.8	2	25.89	2.2	10.9	5.0	17.69	27.69	18.69	bladder-T1200
CAF-9A	8896.6	8520.0	2	27.50	2.4	13.8	6.8	6.60	16.60	15.10	bladder-T1200
CAF-9B	8895.7	8535.6	2	26.88	2.3	12.4	6.5	16.98	26.98	17.98	bladder-T1200
CAF-10A	8768.6	8646.9	2	23.72	2.1	8.4	3.8	5.02	15.02	13.52	bladder-T1200
CAF-10B	8770.2	8656.1	2	24.05	2.5	8.9	4.3	14.75	24.75	15.75	bladder-T1200
CAF-11A	8462.8	8450.8	2	24.96	2.2	8.4	2.8	5.16	15.16	13.66	bladder-T1200
CAF-11B	8461.2	8440.5	2	24.90	2.4	8.9	3.0	18.10	28.10	19.10	bladder-T1200
CAF-12A	8894.2	8417.7	2	29.51	2.5	14.7	8.3	9.51	19.51	18.01	bladder-T1200
CAF-16C	8157.0	8632.0	2	24.72	2.8	6.5	4.7	42.92	52.92	43.92	bladder-T1500
CAF-17C	8526.0	8557.0	2	24.05	3.0	6.6	4.9	37.65	47.65	38.65	bladder-T1500
OB-5	8786.0	8574.0	6	23.68	3.5	10.4	4.9	65.0	83.0	65.0	bladder-T1500
Offsite Wells											
OCW-1C	9408.6	8977.5	2	11.65	-0.3	4.5	3.5	29.45	39.5	30.45	bladder-T1500
OCW-2C	9442.9	8762.3	2	10.39	-0.2	3.3	2.4	29.49	39.5	30.49	bladder-T1500
OCW-3C	9508.4	8419.3	2	8.42	-0.4	2.1	1.6	31.32	41.3	32.32	bladder-T1500
OCW-4A	9095.5	8508.7	2	25.51	0.3	10.6	8.7	10.01	20.0	18.51	bladder-T1200
OCW-4B	9095.8	8515.9	2	25.66	0.6	11.1	9.1	20.26	30.3	21.26	bladder-T1500
OCW-5D	9112.4	8719.3	2	23.90	0.1	11.6	10.1	69.58	79.6	70.58	bladder-T1500
OSW-1A	9645.3	8880.7	1.25	4.76	1.1	0.1	0.1	9.9	15.1	---	peristaltic/bailer

Table 3. Sampling and Analysis Schedule
Quarterly Sampling Event

Laboratory:	Chemical & Environmental Technology, Inc.	Research Triangle Institute ^a	Oxford Laboratory ^a	Teledyne Brown Engineering ^a
Analytes:	VOCs	Total Uranium	Fluoride	Gross Alpha/Beta
Method:	SW-846 8021B	EPA 200.8	SM 4500-F-C	PRO-032-1 ^b
Maximum Holding Time:	14 days	6 months	28 days	6 months
Container:	3 glass vials, 40 mL	1 polyethylene bottle, 250 mL	1 polyethylene bottle, 250 mL	1 polyethylene bottle, 2 L
Preservative:	4 ± 2 °C ^c , HCl, pH < 2	HNO ₃ , pH < 2	4 ± 2 °C ^c	HNO ₃ , pH < 2
Onsite Wells				
CAF-5A	-	✓	✓	✓
CAF-5B	-	✓	✓	✓
CAF-6A	-	✓	✓	✓
CAF-6B	-	✓	✓	✓
CAF-7A	-	✓	✓	✓
CAF-7B	-	✓	✓	✓
CAF-8A	✓	✓	✓	✓
CAF-8B	✓	✓	✓	✓
CAF-9A	✓	✓	✓	✓
CAF-9B	✓	✓	✓	✓
CAF-10A	✓	✓	✓	✓
CAF-10B	✓	✓	✓	✓
CAF-11A	-	✓	✓	✓
CAF-11B	-	✓	✓	✓
CAF-12A	-	✓	✓	✓
CAF-16C	✓	-	-	-
CAF-17C	✓	-	-	-
OB-5	✓	-	-	-
Offsite Wells				
OCW-1C	✓	-	-	-
OCW-2C	✓	-	-	-
OCW-3C	✓	-	-	-
OCW-4A	✓	✓	✓	✓
OCW-4B	✓	✓	✓	✓
OCW-5D	✓	-	-	-
OSW-1A	✓	-	-	-
Offsite Swamp Water Sampling Points				
SWS-1	✓	-	-	-
SWS-4	✓	-	-	-
SWS-6	✓	-	-	-
SWS-8	✓	-	-	-
SWS-9	✓	-	-	-
Offsite Surface Water Sampling Points				
SW-4	✓	-	-	-

Notes

^a Laboratories allowed to receive Special Nuclear Material. Samples received by CET have historically never contained concentrations of uranium above 0.02 mg/L. Samples are screened for total uranium at GE prior to shipment to laboratories.

^b Teledyne Brown Engineering internal method, see QAPP Section 7.2.

^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.

**Table 4. Sampling and Analysis Schedule
Annual Sampling Event**

Laboratory:	Chemical & Environmental Technology, Inc.			Microseeps	Research Triangle Institute ^a	Oxford Laboratory ^a	Teledyne Brown Engineering ^a
Analytes:	VOCs	Alkalinity/ Chloride/ Sulfate	Total Organic Carbon	Methane, Ethane, Ethene	Total Uranium	Fluoride	Gross Alpha/Beta
Method:	SW-846 8021B	SM 2320B/ SM 4500 Cl-C/ SM 4500-SO ₄ -C	SM 5310-C	AM 18.02 ^b	EPA 200.8	SM 4500-F-C	PRO-032-1 ^c
Maximum Holding Time:	14 days	14 days/ 28 days/28 days	28 days	14 days	6 months	28 days	6 months
Container:	3 glass vials, 40 mL	1 polyethylene bottle, 1 L	3 glass vials, 40 mL	2 amber glass vials, 40 mL	1 polyethylene bottle, 250 mL	1 polyethylene bottle, 250 mL	1 polyethylene bottle, 2 L
Preservative:	4 ± 2 °C ^d , HCl, pH < 2	4 ± 2 °C ^d	4 ± 2 °C ^d , H ₂ SO ₄ , pH < 2	4 ± 2 °C ^d	HNO ₃ , pH < 2	4 ± 2 °C ^d	HNO ₃ , pH < 2
Onsite Wells							
CAF-5A	-	-	-	-	✓	✓	✓
CAF-5B	-	-	-	-	✓	✓	✓
CAF-6A	-	-	-	-	✓	✓	✓
CAF-6B	-	-	-	-	✓	✓	✓
CAF-7A	-	-	-	-	✓	✓	✓
CAF-7B	-	-	-	-	✓	✓	✓
CAF-8A	✓	✓	✓	✓	✓	✓	✓
CAF-8B	✓	✓	✓	✓	✓	✓	✓
CAF-9A	✓	✓	✓	✓	✓	✓	✓
CAF-9B	✓	✓	✓	✓	✓	✓	✓
CAF-10A	✓	✓	✓	✓	✓	✓	✓
CAF-10B	✓	✓	✓	✓	✓	✓	✓
CAF-11A	-	-	-	-	✓	✓	✓
CAF-11B	-	-	-	-	✓	✓	✓
CAF-12A	-	-	-	-	✓	✓	✓
CAF-16C	✓	✓	✓	✓	-	-	-
CAF-17C	✓	✓	✓	✓	-	-	-
OB-5	✓	✓	✓	✓	-	-	-
Offsite Wells							
OCW-1C	✓	✓	✓	✓	✓	✓	✓
OCW-2C	✓	✓	✓	✓	✓	✓	✓
OCW-3C	✓	✓	✓	✓	✓	✓	✓
OCW-4A	✓	✓	✓	✓	✓	✓	✓
OCW-4B	✓	✓	✓	✓	✓	✓	✓
OCW-5D	✓	✓	✓	✓	-	-	-
OSW-1A	✓	✓	✓	✓	-	-	-
Offsite Swamp Water Sampling Points							
SWS-1	✓	✓	✓	✓	-	-	-
SWS-4	✓	✓	✓	✓	-	-	-
SWS-6	✓	✓	✓	✓	-	-	-
SWS-8	✓	✓	✓	✓	-	-	-
SWS-9	✓	✓	✓	✓	-	-	-
Offsite Surface Water Sampling Points							
SW-1	✓	-	-	-	✓	✓	-
SW-2	✓	-	-	-	✓	✓	-
SW-3	✓	-	-	-	✓	✓	-
SW-4	✓	-	-	-	✓	✓	-

Notes

- ^a Laboratories allowed to receive Special Nuclear Material. Samples received by CET have historically never contained concentrations of uranium above 0.02 mg/L. Samples are screened for total uranium at GE prior to shipment to laboratories.
- ^b Microseeps internal method, see QAPP Section 7.2.
- ^c Teledyne Brown Engineering internal method, see QAPP Section 7.2.
- ^d 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.

Table 5. Quarterly Sample Collection Plan Summary

Sample Type	Collection Frequency per Quarterly Sampling Event	Planned Number of Analyses per Quarterly Sampling Event
Volatile Organic Compounds		
Primary Sample	1 per location specified on Table 3	22
Duplicate Sample (submitted blind)	1 per quarter	1
Samples Specified for MS/MSD Analyses (<u>not</u> submitted blind)	1 MS/MSD set per 20 primary samples	2
Field Blank (submitted blind)	1 per quarter	1
Trip Blank (<u>not</u> submitted blind)	1 per cooler containing samples for VOC analysis	2
PE Sample (submitted blind)	1 per quarter	1
PE Sample Dilution Water (<u>not</u> submitted blind)	1 per quarter	0 (sample submitted on hold and analyzed only if necessary)
Total Uranium, Fluoride		
Primary Sample	1 per location specified on Table 3	17
Duplicate Sample (submitted blind)	1 per quarter	1
Field Blank (submitted blind)	1 per quarter	1
PE Sample (submitted blind)	1 per quarter	1
Gross Alpha/Beta		
Primary Sample	1 per location specified on Table 3	17

MS/MSD = matrix spike/matrix spike duplicate
PE = performance evaluation
VOC = volatile organic compound

Table 6. Annual Sample Collection Plan Summary

Sample Type	Collection Frequency per Annual Sampling Event	Planned Number of Analyses per Annual Sampling Event
Volatile Organic Compounds		
Primary Sample	1 per location specified on Table 4	25
Duplicate Sample (submitted blind)	1 per annual event	1
Samples Specified for MS/MSD Analyses (<u>not</u> submitted blind)	1 MS/MSD set per 20 primary samples	2
Field Blank (submitted blind)	1 per annual event	1
Trip Blank (<u>not</u> submitted blind)	1 per cooler containing samples for VOC analysis	2
PE Sample (submitted blind)	1 per annual event	1
PE Sample Dilution Water (<u>not</u> submitted blind)	1 per annual event	0 (sample submitted on hold and analyzed only if necessary)
Alkalinity, Chloride, Sulfate, Total Organic Carbon		
Primary Sample	1 per location specified on Table 4	21
Duplicate Sample (submitted blind)	1 per annual event	1
Methane, Ethane, Ethene		
Primary Sample	1 per location specified on Table 4	21
Duplicate Sample (submitted blind)	1 per annual event	1

Table 6 (continued)

Sample Type	Collection Frequency per Annual Sampling Event	Planned Number of Analyses per Annual Sampling Event
Total Uranium, Fluoride		
Primary Sample	1 per location specified on Table 4	23
Duplicate Sample (submitted blind)	1 per annual event	1
Field Blank (submitted blind)	1 per annual event	1
PE Sample (submitted blind)	1 per annual event	1
Gross Alpha/Beta		
Primary Sample	1 per location specified on Table 4	20

MS/MSD = matrix spike/matrix spike duplicate

PE = performance evaluation

VOC = volatile organic compound

**Table 7. Disposition of Purge Water
 Northwest Site Area Wells and Sampling Points**

Sampling Location ID	Disposition of Purge Water		
	Ground Surface	Drum Adjacent to Well	Portable Container for Transfer to Drum Stored Onsite
Onsite Wells			
CAF-5A	✓		
CAF-5B	✓		
CAF-6A		✓	
CAF-6B		✓	
CAF-7A		✓	
CAF-7B		✓	
CAF-8A	✓		
CAF-8B		✓	
CAF-9A		✓	
CAF-9B		✓	
CAF-10A		✓	
CAF-10B	✓		
CAF-11A		✓	
CAF-11B	✓		
CAF-12A		✓	
CAF-16C	✓		
CAF-17C		✓	
OB-5		✓	
Offsite Wells			
OCW-1C	✓		
OCW-2C			✓
OCW-3C	✓		
OCW-4A	✓		
OCW-4B	✓		
OCW-5D			✓
OSW-1A	✓		
Offsite Swamp Water Sampling Points			
SWS-1	✓		
SWS-4	✓		
SWS-6	✓		
SWS-8	✓		
SWS-9			✓

ATTACHMENTS

Example Field Forms

Sample Sequence and Identifier Form
Example Completed Sample Sequence and Identifier Form
Field Instrument Calibration Records
Field Sampling Record
CET Chain-of-Custody Form
Generic RTI Chain-of-Custody Form
Sample Container Label and Custody Seal

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 4 Swamp Pore-Water Sample Collection
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 10 Field Measurement of Water-Sample Ferrous Iron Content
SOP 11 Screening Samples and Packing Sample Coolers for Shipping

Sample Sequence and Identifier Form

Planned Sampling Dates: _____

[illegible]

QC Types

P = primary sample
D = duplicate sample
FB = field blank
PE = performance evaluation sample

b Required Analyses

For single analysis only, enter "✓".
For primary analysis plus matrix spike analysis, or for primary analysis plus matrix spike and matrix spike duplicate analyses, enter "MS" or "MS/MSD", respectively.
Note: Trip blanks and PE sample dilution water are not submitted blind to CET and therefore do not need to be entered on this form.

c. Enter ">0.02" if the previous quarter total U concentration exceeded 0.02 mg/L, and have a sub-sample screened at GE's Chemet Laboratory for total U before the other sample containers are shipped offsite (see SOP 11).

^d Upon sample collection, samples will be maintained in a cooler with sufficient coolant to chill the samples to 4 ± 2 °C until received by the analytical laboratory. While in the laboratory, samples will be stored and maintained at 4 ± 2 °C.

Sample Sequence and Identifier Form
Planned Sampling Dates: January 11 - 15, 1999

			Required Containers, Preservatives, Analyses ^b							
			Laboratory:	Chemical & Environmental Technology, Inc.			Microseeps	RTI	Oxford	Teledyne Brown
			Analytes:	VOCs	Alkalinity/ Chloride/ Sulfate	Total Organic Carbon	Methane, Ethane, Ethene	Total Uranium ^c	Fluoride	Gross Alpha/Beta
			Containers/ Preservatives:	(3) 40 mL glass	(1) 1 L polyethylene	(3) 40 mL glass	(2) 40 mL amber glass	(1) 250 mL polyethylene	(1) 250 mL polyethylene	(1) 2 L polyethylene
Sampling Location ID	COC Number	QC Type ^a	4 ± 2 °C ^d , HCl, pH < 2	4 ± 2 °C ^d	4 ± 2 °C ^d , H ₂ SO ₄ , pH < 2	4 ± 2 °C ^d	HNO ₃ , pH < 2	4 ± 2 °C ^d	HNO ₃ , pH < 2	
SW-2	1041	P	✓				✓	✓		
SW-3	1042	P	✓				✓	✓		
SW-1	1043	P	✓				✓	✓		
CAF-15C	1044	P	✓	✓	✓	✓				
OCW-1C	1045	P	✓	✓	✓	✓	✓	✓	✓	
OCW-3C	1046	P	✓	✓	✓	✓	✓	✓	✓	
SWS-1	1047	P	✓	✓	✓	✓				
SWS-4	1048	P	✓	✓	✓	✓				
SWS-6	1049	P	✓	✓	✓	✓				
SWS-8	1050	P	✓	✓	✓	✓				
CAF-8A	1051	P	✓	✓	✓	✓	✓	✓	✓	
CAF-10B	1052	P	✓	✓	✓	✓	✓	✓	✓	
CAF-9A	1053	P	✓	✓	✓	✓	✓	✓	✓	
CAF-10A	1054	P	✓	✓	✓	✓	✓	✓	✓	
—	1055	PE						✓		
CAF-8B	1056	P	✓	✓	✓	✓	✓	✓	✓	
CAF-9B	1057	P	MS/MSD	✓	✓	✓	✓	✓	✓	
OCW-5D	1058	P	✓	✓	✓	✓				
OSW-1A	1059	P	✓	✓	✓	✓				
OCW-4B	1060	P	✓	✓	✓	✓	✓	✓	✓	
OCW-4A	1061	P	✓	✓	✓	✓	✓	✓	✓	
—	1062	PE	✓							
SWS-9	1063	P	✓	✓	✓	✓				
OB-5	1064	P	✓	✓	✓	✓				
OB-5	1065	D	✓	✓	✓	✓				
OCW-2C	1066	P	MS/MSD	✓	✓	✓	✓	✓	✓	
CAF-17C	1067	P	✓	✓	✓	✓				
CAF-17C	1068	FB	✓							
CAF-5A	1069	P					✓	✓	✓	
CAF-11A	1070	P					✓	✓	✓	
CAF-11B	1071	P					✓	✓	✓	
CAF-7B	1072	P					✓	✓	✓	
CAF-7B	1073	D					✓	✓		
CAF-12A	1074	P					✓	✓	✓	
CAF-5B	1075	P					✓	✓	✓	
—	1076	PE					✓			
CAF-7A	1077	P					✓	✓	✓	
CAF-6B	1078	P					>0.02	✓	✓	
CAF-6A	1079	P					>0.02	✓	✓	
CAF-6A	1080	FB					✓	✓		

^a QC Types

P = primary sample
D = duplicate sample
FB = field blank
PE = performance evaluation sample

^b Required Analyses

For single analysis only, enter "✓".
For primary analysis plus matrix spike analysis, or for primary analysis plus matrix spike and matrix spike duplicate analyses, enter "MS" or "MS/MSD", respectively.
Note: Trip blanks and PE sample dilution water are not submitted blind to CET and therefore do not need to be entered on this form.

^c Enter ">0.02" if the previous quarter total U concentration exceeded 0.02 mg/L, and have a sub-sample screened at GE's Chemet Laboratory for total U before the other sample containers are shipped offsite (see SOP 11).

^d Upon sample collection, samples will be maintained in a cooler with sufficient coolant to chill the samples to 4 ± 2 °C until received by the analytical laboratory. While in the laboratory, samples will be stored and maintained at 4 ± 2 °C.

Field Instrument Calibration and Maintenance Record

[illegible]

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

Purge Method: _____

Actual Purge Volume : _____ L

Purge Start: ____:____ Purge Stop: ____:____

Purge Rate: _____ L/min.

Purge Water Level : _____ ft.**

Purge-Water Appearance _____

** below measuring point (top of casing)

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: _____

CHAIN-OF-CUSTODY

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

Requested Turnaround Time:	<input type="checkbox"/> Normal _____	<input type="checkbox"/> Rush _____	<input type="checkbox"/> Emergency (ASAP)
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[illegible]

- 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

Research Triangle Institute (RTI)	
Project:	6448-018
Sample:	<u>2790</u>
Date/Time:	_____
Analysis:	<u>8021</u> Preservative: HCl

COOLER CUSTODY SEAL

RESEARCH TRIANGLE INSTITUTE

SUBMITTER'S SIGNATURE: _____ DATE SEALED: _____

COOLER DESIGNATION (i.e. A, B, C, D etc.) _____ TIME SEALED: _____

STANDARD OPERATING PROCEDURE 1

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 and cooler thermometer
- 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. Groundwater field parameter meters designated in the FSP (e.g., pH probe, conductivity and temperature meter)
- i. Resealable sample bags
- j. Stopwatch
- k. Deionized water in spray bottle
- l. Additional water-quality meters as specified in the project-specific FSP
- m. Disposable laboratory wipes (e.g., Kimwipes)

- n. Well-construction information (if not previously entered on Field Sampling Record form)
- o. Field Sampling Record forms, project notebook, waterproof-ink pens
- p. Calculator
- q. Electric water-level indicator (see SOP 3)
- r. Purge water collection buckets with lids
- s. Teflon-lined discharge tubing and elbow connectors (typically dedicated to each well and stored in locked well protective casing)
- t. 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 survey mark at top of well casing) with electrical water level indicator (see SOP 3). Record water level on the Field Sampling Record form. Clean water-level probe with deionized 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:

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

where

PV_s = purge volume for shallow well, in liters

SD = screen diameter, in inches

SB = depth to bottom of screen, in feet below top of casing

WD = measured depth to water, in feet below top of casing.

- 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:

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

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 field parameters (pH, specific conductance, temperature, and other 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 deionized 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 collected, 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 no greater than 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

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 and cooler thermometer
- 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. Groundwater field parameter meters designated in the FSP (e.g., pH probe, conductivity and temperature meter)
- h. Resealable sample bags
- i. Stopwatch
- j. Deionized water in spray bottle
- k. Additional water-quality meters as specified in the project-specific FSP
- 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 container buckets with lids
- r. 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 survey mark at top of well casing) with electrical water level indicator (see SOP 3). Record water level on the Field Sampling Record form. Clean water-level probe with deionized 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:

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

where

PV_s = purge volume for shallow well, in liters

SD = screen diameter, in inches

SB = depth to bottom of screen, in feet below top of casing

WD = measured depth to water, in feet below top of casing.

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.

- 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 field parameters (pH, specific conductance, temperature, and other 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 deionized 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 deionized 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

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 deionized 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 deionized water and wipe dry.
- 3.5 Resecure well.

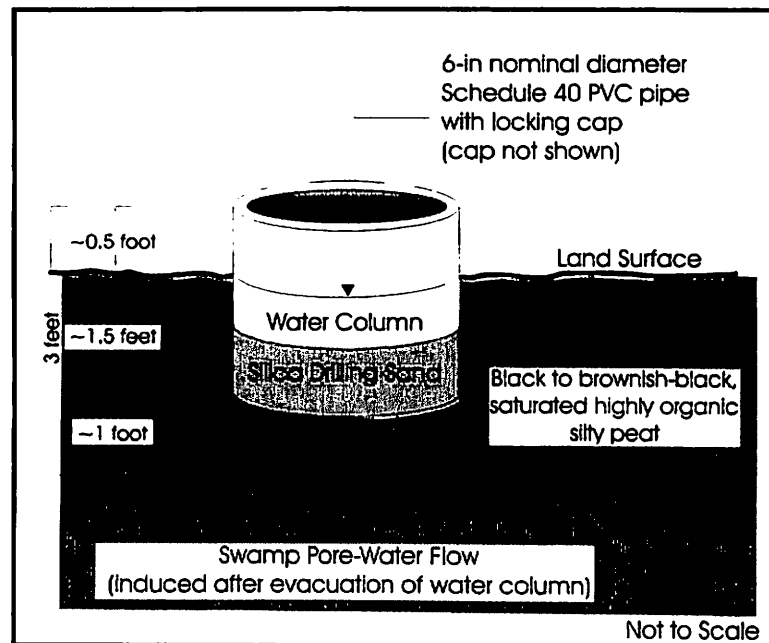
STANDARD OPERATING PROCEDURE 4

Swamp Pore-Water Sample Collection

1.0 SCOPE AND APPLICATION

This standard operating procedure (SOP) describes the protocol that should be used to collect samples of swamp pore-water (water entrained in the pore spaces of saturated surface sediments/soils). These points facilitate the collection of representative samples of groundwater that eventually discharges to the surface in a swampy environment.

Devices installed for swamp pore-water monitoring are 3-foot long sections of 6-inch diameter solid polyvinyl chloride (PVC) pipe with an open bottom. At each location, approximately 1 foot of organic swamp muck was excavated and approximately 2.5 feet of the 3-foot long pipe was pushed into the soft sediments. An approximately 0.5- to 1.0-foot thick layer of filter-pack material (e.g., fine quartz sand of a uniform grain size) was placed in the bottom of the device. The purpose of the filter pack is to retain organic debris and fine sediments, allowing collection of low-turbidity samples. The figure below shows the typical detail of these shallow pore-water monitoring devices.



2.0 MATERIALS

- a. Electric water-level meter
- b. Groundwater field parameter meters designated in the Field Sampling Plan (FSP) (e.g., pH probe, conductivity and temperature meter)
- c. Deionized water in spray rinse bottle
- d. Clean disposable bailer or new 250-mL polyethylene bottle cut in half with a decontaminated blade to serve as "dipper" for purging standing water
- e. Field Sampling Record forms, project notebook, waterproof-ink pens
- f. Disposable nitrile gloves
- g. Pre-preserved and unpreserved sample containers and separate preservatives as specified in the project-specific FSP
- g. Insulated cooler with frozen ice packs and cooler thermometer
- h. Rubber boots
- i. Ground cloth/sheet plastic/trash bags

3.0 PROCEDURES

- 3.1 Spread sheet plastic on ground next to the monitoring device for use as a working surface for equipment and sample containers.
- 3.2 Measure water level from top of PVC casing and record (see SOP 3). As the depth to water is typically a few inches from the top of the 6-inch diameter casing, the depth of water may be measured directly using a measuring tape.
- 3.3 Don nitrile gloves and, using a clean disposable beaker or dipper, carefully remove (i.e., purge) stagnant water from inside PVC casing. Fill dipper slowly to avoid creating a turbid condition. As much of the entire water column as possible should be removed from the casing. Contain or disperse purge water as specified in the FSP. Purged water should not be discarded near the pore-water monitoring device. Note: a peristaltic pump can be used to purge the pore-water sampling devices if preferred (see SOP 2). The water level will recover and groundwater will flow through the filter pack and into the casing.
- 3.4 After the water level has recovered, lower the sample container into the device and allow the water to flow into the bottle. If the bottle is too large to practically use, a clean transfer vessel (e.g., a new polyethylene bottle cut in half) or a peristaltic

pump (see SOP 2) can be used to collect samples to be analyzed for inorganic analytes. For samples to be collected for volatile organic compounds (VOCs), unpreserved 40-mL sample bottles should be inclined slightly and the water allowed to slowly fill the bottle. It will not be possible to fill the VOC container to zero headspace by dipping alone, the VOC container cap should be used to bail small amounts of water into the sample vial for form a positive meniscus and headspace-free samples. Add preservative as specified in the FSP. If pre-preserved sample containers are used, care must be exercised not to release preservative into the sample device.

- 3.5 Place sample containers in a resealable bag and store bagged samples in cooler.
- 3.6 Record sample time on Field Sampling Record form.
- 3.7 Clean up work area and resecure well casing or access port.

STANDARD OPERATING PROCEDURE 5

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 Before the sample is collected, sample bottles not pre-dosed with preservative should be filled three times with water from the stream/pool and discarded downstream/downgradient and away from the collection point. Sample should be collected directly into bottles that are pre-dosed with preservative, and the bottle should not be rinsed before collection. The mouth of the sample container should be held entirely below the water surface if possible, but should not drag the bottom that would cause 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. 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

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 Equipment Calibration 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 4.00, 7.00, and 10.01 (single-use buffer pouches are preferred)
- c. Deionized 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 Equipment Calibration 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 been constantly stored in solution 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 (or after meter has been turned off) 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 4.00, 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 4.00 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 deionized water and shake off excess water.
- 3.2.9 Repeat the steps in 3.2.7 and 3.2.8 for pH 4.00 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 deionized 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 Equipment Calibration 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. Repeat measurement in same sample aliquot. 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

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 $0.01 \mu\text{S/cm}$ (0 to $499.9 \mu\text{S/cm}$) and $1.0 \mu\text{S/cm}$ (499.9 to $4,999 \mu\text{S}$) for conductivity ranges typical of groundwater. The meter has a total operational range of 200 mS/cm ($200,000 \mu\text{S/cm}$). The YSI Model 30 meter has a sliding accuracy of $\pm 0.5\%$ of the full scale. The accuracy at low range ($< 499.9 \mu\text{S/cm}$) is $\pm 2.5 \mu\text{S/cm}$ and then steps down at the next range interval ($> 499.9 \mu\text{S/cm} \leq 4,999 \mu\text{S/cm}$) to $\pm 24.9 \mu\text{S/cm}$.

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. Distilled 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 Equipment Calibration 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 \pm 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 ($^{\circ}$ C) will be flashing. Specific conductance is the conductance of the solution if it were measured at 25 $^{\circ}$ 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 deionized 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 Equipment Calibration 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 distilled/deionized water, shake off excess water, and return cell to storage chamber.

3.2.9 All 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) used 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 Equipment Calibration 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 error 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 distilled/deionized 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 Equipment Calibration 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. 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 glass 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 a 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 Gently stir sample with cell.
- 3.4.10 Record measurement appropriately (e.g., 2,000 $\mu\text{S}/\text{cm} \pm 5\%$). Repeat measurement and record on Field Sampling Record form. If duplicate measurement is not within 5 percent of original measurement, check calibration (Section 3.2).
- 3.4.11 Rinse cell thoroughly with distilled/deionized 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 \pm 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 from 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 10

Field Measurement of Water-Sample Ferrous Iron Content

Hach IR-18C Test Kit

1.0 SCOPE AND APPLICATION

The purpose of this Standard Operating Procedure (SOP) is to delineate protocols for field measurements of ferrous iron in aqueous samples.

Precautions should be taken when performing ferrous iron measurements to avoid inhalation or ingestion of the ferrous iron reagent powder containing phenanthroline which is very toxic and irritating. In addition, because ferrous iron ions are unstable when in contact with oxygen, samples should be analyzed as soon as possible to prevent oxidation of ferrous iron to ferric iron.

Field measurements for ferrous iron in the range of 0.0 to 10.0 mg/L should be conducted using the Hach IR-18C Test Kit. Using the test kit method, the 1,10-phenanthroline indicator in the reagent reacts with ferrous iron in the sample to form an orange color in proportion to the ferrous iron concentration. The iron concentration is visually determined by comparing the color of the water sample with a color comparator wheel.

2.0 MATERIALS

- a. Hach IR-18C Test Kit (including an adequate supply of reagent powder pillows)
- b. Disposable nitrile gloves
- c. Spray bottle with deionized water
- d. Field Sampling Record forms, field notebook, and waterproof-ink pen
- e. Decontaminated beaker
- f. Lidded container for waste water
- g. Disposable laboratory wipers (e.g., Kimwipes)

3.0 PROCEDURE

- 3.1 Set up a work area on a suitable flat surface with plastic sheeting, test kit, beaker, and deionized spray bottle.
- 3.2 Don nitrile gloves and collect water sample in decontaminated beaker.

- 3.3 Fill a clean viewing tube to the 5-mL line with sample water for the sample blank. Place this tube in the top left opening of the color comparator. Fill the clean measuring vial to the 25-mL mark with sample water. Use the provided clippers to snip open the end of one ferrous iron reagent powder pillow and gently tap open the pillow, taking care to avoid inhaling the powder. Add the pillow powder to the measuring vial. Cap the measuring vial and swirl to mix. An orange color will develop in this prepared sample if ferrous iron is present. Allow 3 minutes for full color development. Fill another clean viewing tube to the 5-mL mark with the prepared sample, and place this tube in the top right opening of the color comparator. Insert the color disc into the disc slot, and hold the comparator up to a light source. Rotate the color disc until the color matches in the two viewing openings. Read the mg/L ferrous iron in the scale window.
- 3.4 Record measurement on the Field Sampling Record form.
- 3.5 Dispose of water in viewing tube and beaker in lidded waste container.
- 3.6 Clean beaker, sample viewing tubes, and measuring vial with deionized water spray and dry with laboratory wipes.

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 than 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.

Appendix I

RTI Report No. 6448-018/006/01F

March 31, 1999

**Quality Assurance Project Plan
Monitored Natural Attenuation Corrective Action
for the Northwest Site Area**

General Electric - Wilmington, NC

Prepared for:

General Electric Company
Wilmington, North Carolina

Prepared by:

Caroline J.B. Anderson, Ph.D.
Andrew D. Stahl, P.G., C.P.G.
Jeff W. Reynolds, P.G., P.HG.

Geosciences Department
Center for Environmental Measurements and Quality Assurance




**Quality Assurance Project Plan
Monitored Natural Attenuation Corrective Action
for the Northwest Site Area**

**General Electric Company
Post Office Box 760
Wilmington, North Carolina 28402**

Prepared by: Research Triangle Institute
Geosciences Department
PO Box 12194
Research Triangle Park, NC 27709
(919)541-8758

Plan Approval Signatures:


General Electric-Wilmington Site EHS Manager/Herbert R. Strickler


RTI Project Manager/Jeff W. Reynolds, P.G., P.HG.


Acting RTI Quality Assurance Officer/Andrew D. Stahl, P.G., C.P.G.



Table of Contents

1.0 Introduction	1
2.0 Project Description	2
2.1 Purpose and Objectives	2
2.2 Discussion of Activities	2
2.2.1 Target Analytes	2
2.2.2 Data Use	4
3.0 Project Organization	5
3.1 Role of General Electric	5
3.2 Role of Analytical Laboratories	5
3.2.1 Laboratory Directors	6
3.2.2 Laboratory Quality Assurance Officers	6
3.3 RTI Project Leader	7
3.4 Lead Field Geologist	7
3.5 Field Team Members	8
3.6 Project Quality Assurance Officer	8
4.0 Quality-Control Elements	10
4.1 Quality-Control Procedures	10
4.1.1 Use of Dedicated Sampling Equipment	11
4.1.2 Standard Materials	11
4.1.3 Supplies	12
4.1.4 Holding Time Compliance	12
4.2 Quality-Control Samples	12
4.2.1 Trip Blanks	13
4.2.2 Field Blanks	13
4.2.3 Laboratory Reagent Blanks	14
4.2.4 Matrix Spike/Matrix Spike Duplicate Samples	14
4.2.5 Laboratory Duplicate Samples	15
4.2.6 Field Duplicate Samples	15
4.2.7 Performance Evaluation Samples	16
4.2.8 Other Method-Required Control Samples and Standards	16
5.0 Data Quality Acceptance Criteria	18
5.1 Precision	18
5.1.1 Analytical Precision	18
5.1.2 Total Precision	20
5.2 Accuracy	20

5.2.2 Field Accuracy	21
5.3 Representativeness	21
5.4 Completeness	22
5.5 Comparability	22
5.6 Sensitivity	22
6.0 Field Procedures	24
6.1 Sample Collection and Field Measurements	24
6.2 Sample Containers, Preservation, and Maximum Holding Times	24
6.3 Sample Handling and Storage	25
6.4 Sample Custody	25
7.0 Laboratory Analytical Procedures	27
7.1 Laboratory Analysis of Project-Critical Parameters	27
7.2 Laboratory Analysis of Non-Critical Parameters	28
8.0 Data Documentation And Reporting	30
8.1 Field Documentation	30
8.2 Laboratory Data Reporting	30
9.0 Data Validation	31
9.1 Validation Criteria	31
9.2 Standard Operating Procedures for Data Validation	32
9.3 Data Qualifiers	32
10.0 Performance and System Audits	33
10.1 Description of Audits	33
10.2 Audit Schedule	33
10.3 Reports to Management and Responsibilities	33
11.0 Preventive Maintenance	34
12.0 Corrective Action	35
13.0 References	36

List of Figures

1. Project Organization

List of Tables

1. Target Volatile Organic Compound Analytes
2. Analytical Laboratories, Methods, Containers, Preservatives, and Maximum Holding Times
3. Quality-Control Acceptance Criteria
4. Explanation of Data Validation Qualifiers

List of Acronyms and Abbreviations

APG	Analytical Products Group, Inc.
ASTM	American Society for Testing and Materials
CAP	Corrective Action Plan
CEMQA	Center for Environmental Measurements and Quality Assurance
CET	Chemical & Environmental Technology, Inc.
cis-1,2-DCE	cis-1,2-dichloroethylene
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
ELCD	electrolytic conductivity detector, Hall detector
FSP	Field Sampling Plan
GC	gas chromatograph
GE	General Electric
HCl	hydrochloric acid
HNO ₃	nitric acid
HPS	High Purity Standards, Inc.
ICP-MS	inductively coupled plasma mass spectrometry
LCS	laboratory control sample
LOQ	limit of quantitation
MDL	method detection limit
mg/L	milligrams per liter
µ/L	micrograms per liter

MNA	monitored natural attenuation
MS	matrix spike
MSD	matrix spike duplicate
NIST	National Institute of Standards and Technology
ORP	oxidation/reduction potential
PE	performance evaluation
PID	photoionization detector
PM	project manager
PQL	practical quantitation limit
QA	quality assurance
QAM	Quality Assurance Manual
QAPP	Quality Assurance Project Plan
QC	quality control
%R	percent recovery
RPD	relative percent difference
RTI	Research Triangle Institute
SM	<i>Standard Methods for the Examination of Water and Wastewater</i> (APHA, et al., 1992)
SNM	special nuclear material
SOP	standard operating procedure
SW-846	<i>Test Methods for Evaluating Solid Waste, Physical/Chemical Methods</i> (EPA, 1997a)
T15A NCAC	Title 15A of the North Carolina Administrative Code
TCE	trichloroethylene
TOC	total organic carbon
²³⁵ U	uranium isotope 235
VOA	volatile organic analysis
VOC	volatile organic compound

1.0 Introduction

This Quality Assurance Project Plan (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 data generated during the monitored natural attenuation (MNA) corrective action being undertaken at the northwest site area at the General Electric Company (GE) site in Wilmington, North Carolina. This QAPP is included as Appendix I of a Corrective Action Plan (CAP) and will be the quality-controlling document for activities relating to the collection and analysis of samples which are described in the project Field Sampling Plan (FSP) (Document 6448-018/0005/01F - included in the CAP as Appendix H). 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 *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods*, EPA SW-846 (EPA, 1997a), *Standard Methods for the Examination of Water and Wastewater* (APHA, et al., 1992), and *Contract Laboratory Program National Functional Guidelines for Organic and Inorganic Data Review* (EPA, 1994).

2.0 Project Description

Groundwater contamination identified in the remote northwest area of the GE-Wilmington site consists of volatile organic compounds (VOCs) and inorganic constituents. Groundwater concentrations above North Carolina groundwater standards (T15A NCAC Subchapter 2L Section .0202) have previously been detected for fluoride and the following VOCs: trichloroethylene (TCE) and its degradation products, cis-1,2-dichloroethylene (cis-1,2-DCE), and vinyl chloride. In addition, low levels of uranium exhibiting non-natural isotopic ratios (delineated by the distribution of the isotope ^{235}U) have also been detected in shallow groundwater.

2.1 Purpose and Objectives

As described in the CAP, MNA is the selected remedial alternative for the northwest site area. As implied by the name of the proposed corrective action approach, monitoring is the most important component of this remedial approach. The sampling and analysis activities governed by this QAPP are designed to monitor the fate and transport of the identified contamination. The objective of this monitoring is to verify that natural-attenuation processes are occurring and that these processes are reducing the mass, toxicity, volume, concentration, and/or mobility of the contamination. Natural-attenuation processes include contaminant biodegradation, dispersion, dilution, sorption, volatilization, and chemical or biological stabilization, transformation, or destruction.

2.2 Discussion of Activities

The media to be monitored include groundwater, surface water (streams), swamp pore water, and swamp standing water. Monitoring of these waters will enable evaluation of contaminant fate and transport and verification that downgradient receptors are not being impacted.

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

Project-Critical Parameters
fluoride total and isotopic* uranium cis-1,2-dichloroethylene trichloroethylene vinyl chloride

* Isotopic analyses performed when total uranium concentration is 0.002 mg/L or above.

Non-critical parameters include:

- ▶ Non-critical VOCs (see Table 1 for the full list of VOCs targeted for quarterly analyses),
- ▶ Gross alpha/beta activity (analyzed quarterly on samples also analyzed for uranium and fluoride), and
- ▶ Natural-attenuation indicator parameters listed below.

Non-Critical Natural-attenuation Indicator Parameters
<i>Quarterly Field Measurements</i> <i>performed on water samples collected from each quarterly monitoring location</i> pH temperature specific conductance oxidation/reduction potential (ORP) dissolved oxygen (DO) ferrous iron
<i>Annual Laboratory Measurements</i> <i>performed annually on samples collected at locations routinely (quarterly) sampled for VOC analysis</i> alkalinity chloride sulfate total organic carbon (TOC) methane ethane ethene

As the CAP describes, 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 (RTI Project No. 6448-018) will be used to evaluate the spatial distribution of and temporal trends for VOCs and inorganic contaminants in groundwater in the northwest site area. The data will also be used to demonstrate the effectiveness of the MNA corrective action approach.

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 contractor, Research Triangle Institute (RTI), RTI's subcontracted analytical laboratories, 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

Three analytical laboratories will be responsible for analyzing samples for project-critical parameters. These "primary" laboratories are: (1) Chemical and Environmental Technology, Inc. (CET), of Cary, North Carolina, who will analyze samples quarterly for the list of VOCs shown in Table 1 (includes project-critical and non-critical VOCs), (2) Oxford Laboratory of Wilmington, North Carolina, who will analyze samples quarterly for fluoride, and (3) RTI's Center for Environmental Measurements and Quality Assurance (CEMQA) Laboratory in Research Triangle Park, North Carolina, who will analyze samples quarterly for total and isotopic uranium.

In addition, three analytical laboratories will be responsible for analyzing samples for non-critical parameters. These laboratories are: (1) CET, who will analyze samples annually for alkalinity, chloride, sulfate, and TOC, (2) Microseeps of Pittsburgh, Pennsylvania, who will analyze samples annually for methane, ethane, and ethene, and (3) Teledyne Brown

Engineering, of Westwood, New Jersey, who will analyze quarterly samples for gross alpha/beta activity.

Each of these laboratories has demonstrated acceptable qualifications and experience to perform the respective analytical methods, is certified by the Certification Section of the NC Division of Water Quality (DWQ) Chemistry Laboratory under 15A NCAC 2H .0800 for the utilized method (if such certification is required), and is allowed to receive special nuclear material (SNM) if the laboratory is to receive samples potentially classified as such. Other specific laboratory QA/QC activities not discussed in this QAPP are described in the respective laboratories' Quality Assurance Manuals (QAMs).

3.2.1 Laboratory Directors. The five 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 RTI 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. Jeff Reynolds, 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, Dr. Caroline Anderson, is responsible for keeping the Project Leader informed of the status of project QA/QC compliance and identifying QA/QC problems. 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.

Mr. Andrew Stahl and Ms. Cynthia Salmons will serve as QA technical advisors to Dr. Anderson.

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 (fluoride, uranium, cis-1,2-dichloroethylene [cis-1,2-DCE], trichloroethylene [TCE], vinyl chloride) plus the non-critical VOCs listed in Table 1 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 and gross alpha/beta activity 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 and non-critical VOCs 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 groundwater investigations will be used to evaluate groundwater quality in the northwest site area. Consequently, it is critical that the chemical 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 and trip 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 matrix spike (MS) and MS duplicate (MSD) analyses on groundwater samples collected specifically at the GE-Wilmington site for further evaluation of analytical precision and accuracy;
- Utilizing customized standard solutions that include the project-critical VOCs discussed in Section 2.2.1 and several other analytes detected in groundwater elsewhere at the GE-Wilmington site for analysis of laboratory control samples (LCSs) and performing MS and MSD analyses; and
- Attaining completeness goals.

4.1.1 Use of Dedicated Sampling Equipment. Water samples will be collected using dedicated sampling equipment (e.g., dedicated sampling pumps installed in each well). 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. Bladder pumps will be dedicated to all but one well. The dedicated tubing attached to each pump is lined with Teflon which will not adsorb and desorb contaminants. Groundwater samples from wells not outfitted with a dedicated bladder pump (due to a smaller well diameter) and surface-water and swamp-water samples will be collected using other dedicated or disposable equipment.

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 2. Analysis completion, as used to assess holding times, is defined as the completion of all analytical runs, including dilutions, second-column confirmations, 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 Trip Blanks. The primary purpose of trip blanks is to detect possible additional sources of VOC contamination that could potentially influence contaminant values reported in field samples, both quantitatively and qualitatively. Trip blanks serve as a mechanism of control for sample bottle preparation, blank-water quality, and sample handling.

Each trip blank consists of two VOC sample vials filled in the laboratory with American Society for Testing and Materials (ASTM) Type II reagent-grade water. In order to simulate sample handling conditions, the trip blank travels to the site with the cooler and returns from the site in the cooler with the collected field samples. One trip blank will be included in each cooler transporting samples for VOC analysis. Potential sources of contamination in trip blanks include:

- Laboratory reagent water;
- Sample containers and preservatives;
- Cross-contamination during shipment;
- Ambient air, or contact with analytical instrumentation during preparation and analysis at the laboratory; and
- Laboratory reagents used in analytical procedures.

Handling and the holding time are two other issues that may affect the use and integrity of trip blanks. Trip blanks may be held at the field site for a maximum of one week before sampling begins. During storage, trip blanks will be maintained in a chilled state (approximately 4°C). Expired trip blanks will be returned to the laboratory for disposal. The trip blank holding time begins at the time the oldest sample in the set is collected.

4.2.2 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). CET will provide laboratory-purified water for preparing the field blanks to be analyzed for VOCs. Laboratory-purified water obtained from RTI will be used for preparing the field blanks to be analyzed for fluoride and 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, and then the field blanks are preserved, stored,

transported, and otherwise treated exactly as the field samples. Field blanks will be submitted blind to the laboratory and will be analyzed for the same analytes as the primary samples. One field equipment blank will be collected each sampling event for VOC analysis, and one field equipment blank will be collected each sampling event for analysis of fluoride and uranium. Separate field blanks will be prepared for these two sets of analytes because the former source area for fluoride and uranium is different than the VOC source area, and an effort will be made to collect field blanks at sampling locations near these former source areas.

4.2.3 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). For VOC and fluoride analyses, at least one reagent blank will be analyzed with each analytical batch of 20 or fewer samples. For uranium analyses, at least one reagent blank will be analyzed with each analytical batch of 15 or fewer samples.

4.2.4 Matrix Spike/Matrix Spike Duplicate Samples. MS analyses are performed by the laboratory in order to evaluate the efficiency of the sample analysis procedure. These analyses are 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 VOC and uranium analyses, at least one MS analysis will be performed with each analytical batch of 20 or fewer samples. For fluoride 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 and fluoride analyses are sufficient for the initial analysis and a MS analysis, and the laboratories will select which samples will be subjected to MS analyses (volume requirements for VOC MS analyses are discussed in the next paragraph).

For this project, the VOC MS analyses will be performed by spiking samples with a project-specific standard that contains the project-critical VOCs discussed in Section 2.2.1 and several other analytes detected in groundwater elsewhere at the GE-Wilmington site. Furthermore, to evaluate the precision of the VOC-analysis procedures, MSDs are performed and relative percent differences (RPDs) between the two analyses are calculated. Field personnel will fill nine 40-mL VOA vials with groundwater sample at a frequency of 1 per 20 samples to provide sufficient solution for the MS and MSD analyses in addition to the primary sample analysis because the laboratory requires three filled 40-mL volatile organic analysis (VOA) vials for each individual VOC analysis

4.2.5 Laboratory Duplicate Samples. To evaluate the precision of the fluoride- and uranium-analysis procedures, the laboratories will perform duplicate analyses of samples at a frequency of 1 per 10 and 1 per 20 analyses, respectively, and will calculate 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.

4.2.6 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. One field duplicate will be collected for each sampling event for analysis of fluoride and uranium, and one field duplicate will be collected for each sampling event for analysis of VOCs. 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.

4.2.7 Performance Evaluation Samples. PE samples will be analyzed to evaluate the accuracy of the laboratories' 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 VOC PE samples will be prepared by, and purchased from, Analytical Products Group, Inc. (APG), of Belpre, Ohio. The PE samples will be sent by APG directly to the field site in new certified-clean VOA vials pre-preserved with hydrochloric acid (HCl) that were provided to APG by RTI, who in turn received them from CET. In addition to providing three vials filled with the PE samples, APG fills three additional vials with a sample of the water used to dilute their stock solution to the final PE sample concentration. These samples are returned to RTI field personnel for inclusion in the sample delivery group. The PE sample dilution water is not submitted to the laboratory blind, is initially placed on hold, and is only analyzed if warranted by the PE sample analytical results to evaluate for potential sources of contamination that may have impacted the PE sample.

The uranium and fluoride PE samples will be prepared by, and purchased from, High Purity Standards (HPS) of Charleston, South Carolina. A supply of new certified-clean 250-mL polyethylene bottles is submitted to HPS for them to further clean according to their internal protocol. HPS retains this stock of bottles for use in providing PE samples each quarter to RTI for total uranium and fluoride analyses.

4.2.8 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 LCSs, surrogate standards, internal standards, and calibration check standards. For this project, the VOC LCS to be analyzed with each

analytical batch of 20 or fewer samples will be prepared from a project-specific standard that contains the project-critical VOCs discussed in Section 2.2.1 and several other analytes detected in groundwater elsewhere at the GE-Wilmington site.

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-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 3.

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 analyses of the same sample in the laboratory, and is evaluated by analysis of laboratory QC samples, such as duplicate control samples,

sample duplicates, or MSD samples. If the recoveries of analytes in the specified control samples are comparable within established control limits, then precision is within limits. For analysis of VOCs on this project, laboratory precision will be assessed by calculating the RPD between MS and MSD analyses performed at a frequency of 5 percent of the primary analyses (see Section 4.2.4). For analysis of fluoride and uranium on this project, laboratory precision will be assessed by calculating the RPD between laboratory duplicate analyses performed at a frequency of 10 and 5 percent of the primary analyses, respectively (see Section 4.2.5).

As discussed in Section 4.2.4, the MS analyses will be performed by spiking samples with a project-specific standard that contains the project-critical VOCs discussed in Section 2.2.1 and several other analytes detected in groundwater elsewhere at the GE-Wilmington site. In accordance with EPA SW-846 procedures (EPA, 1997a), laboratory RPD acceptance limits for each MS/MSD analyte will be calculated by CET using the 100 most recent MS/MSD data points generated by CET. As 50 new data points become available, the oldest 50 points are replaced and the acceptance criteria calculations are updated. The CET QA Officer will provide updates of these acceptance limits to the RTI QA Officer as they become available. The following five analytes are included in CET's routine MS/MSD analyses and, therefore, current RPD acceptance limits for these compounds have been calculated: benzene, chlorobenzene, 1,1-dichloroethylene, toluene, and TCE. For the other 12 project-specific MS/MSD analytes, the RPD acceptance criteria initially is set at 20 percent. CET will take appropriate corrective action and, if necessary, reanalyze the analytical batch and repeat the MS/MSD analysis if the RPD for any MS/MSD VOC analyte falls outside of the current acceptance criteria. For uranium and fluoride analyses, the laboratories will take appropriate corrective action and, if necessary, reanalyze the analytical batch and reperform the duplicate analyses if the RPD is greater than 10 percent. If the RPD for these QC analyses still exceeds the established limits described above for VOCs or exceeds 30 percent for uranium and fluoride, 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 4.2.6). 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, LCSs, and surrogate standards, and by performing initial and continuing calibrations of instruments. As discussed in Section 4.2.4, a project-specific standard that contains the project-critical VOCs discussed in Section 2.2.1 and several other analytes detected in groundwater elsewhere at the GE-Wilmington site will be used for the VOC MS and LCS analyses.

Laboratory %R acceptance criteria for VOCs are established by CET for LCS, surrogate standard, and MS analyses in the same fashion as described for MSD RPD acceptance criteria in Section 5.1.1. Oxford Laboratory's acceptance criteria for fluoride 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, reanalyze the analytical batch and reperform 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 reanalyzed.

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 and fluoride analyses is 80 to 120 %R. The %R acceptance criteria for VOC analyses, described above, are utilized except for MS analyses. Although CET calculates separate acceptance criteria for LCS and MS analyses, RTI applies CET's current LCS acceptance criteria to validate analytical reports with respect to both MS and LCS analyses (i.e., although the analytical laboratory cannot be held responsible for problems associated with matrix interferences, these interferences may nevertheless affect whether the data are of suitable quality to meet their intended use). The acceptance criteria for the VOC PE sample analyte is the inter-laboratory 99-percent confidence interval concentration range certified by APG, which is specific to each purchased PE sample. The acceptance criteria for uranium and fluoride PE sample analyses are 80 to 120 %R.

5.2.2 Field Accuracy. Field accuracy will be assessed through the analysis of trip blanks and field blanks. Analysis of blanks will monitor errors associated with the sampling process, field contamination, sample preservation, and sample handling. The acceptance criteria for trip blanks and 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 the NC Department of Environment and Natural Resources (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. CET's practical quantitation limit (PQL) for each EPA method 8021 target analyte is 0.5 microgram per liter ($\mu\text{g/L}$) as required by the Groundwater Section of the DENR DWQ. Also in conformance with DENR policy, CET will report any constituent detected below the PQL but above the constituent's method detection limit (MDL) and will report the estimated concentration for these detections. As is the case with all detections above the PQL, these low-level

detections also are subject to second-column confirmation. The RTI CEMQA Laboratory and Oxford Laboratory limits of quantitation (LOQs) for uranium and fluoride analyses are 0.150 µg/L and 0.1 milligram per liter (mg/L), 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 important 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 2 presents the sample containers, preservation, and maximum holding times for the quarterly and annual samples to be collected for this program. CET provide unused certified-clean containers for collection of the samples that they will be analyzing. As required, these containers have been dosed by the manufacturer with the preservatives shown in Table 2. For the annual analyses of methane, ethane, and ethene, 40-mL amber glass VOA vials will be provided by Microseeps. RTI purchases new certified-clean 250-mL and 2-L polyethylene bottles from scientific equipment vendors (e.g., Cole Parmer or VWR Scientific) for the remaining analyses listed on Table 2. Samples to be analyzed for uranium and gross alpha/gross beta activity must be preserved with nitric acid (HNO_3). RTI purchases certified reagent-grade HNO_3 from a scientific equipment vendor, creates a 50-percent HNO_3 dilution using laboratory-purified water obtained from RTI, and adds the required amount of preservative to the sample bottles in the field right after the sample has been collected as described in the FSP.

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 using waterproof adhesive labels. At a minimum, the label will indicate the sample identification number, the date and time the sample was collected, and the requested analytical method(s). Glass containers will be securely packed in plastic bubble wrap or foam packing. Except for uranium and gross alpha/beta activity samples, which are not to be kept chilled, the containers then 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 Chemistry Laboratory, the samples will be stored and maintained between 0.1 and 4.4 °C while at the laboratory. Uranium and gross alpha/beta activity samples 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 procedure includes packing a small container of water next to the samples being submitted to CET to serve as a "temperature blank". Upon receipt of the samples, CET will measure the temperature of this small container of water and record the temperature on the chain-of-custody (COC) form. 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 times exceedances, missing or improper sample labeling, temperature-blank measurement above 6 °C, 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. CET will be providing project-specific pre-printed COC forms. RTI's generic COC form will be used for the samples being submitted to each of the other laboratories.

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 samples, ice, 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 fluoride analysis 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	Receiving SNM?
Chemical & Environmental Technology, Inc. (CET)/Cary, NC	VOCs	EPA SW-846 method 8021B	Quarterly and Annual	No
	Alkalinity	Standard Methods (SM) 2320B	Annual	
	Chloride	SM 4500 Cl-C	Annual	
	Sulfate	SM 4500-SO ₄ -C	Annual	
	TOC	SM 5310-C	Annual	
Oxford Laboratory/ Wilmington, NC	Fluoride	SM 4500-F--C	Quarterly and Annual	Yes
Research Triangle Institute/RTP, NC	Total Uranium	EPA method 200.8	Quarterly and Annual	Yes
Microseeps/ Pittsburgh, PA	Methane, Ethane, Ethene	AM-18.02 (internal laboratory method)	Annual	No
Teledyne Brown Engineering/ Westwood, NJ	Gross Alpha and Gross Beta	PRO-032-1 (internal laboratory method)	Quarterly and Annual	Yes

7.1 Laboratory Analysis of Project-Critical Parameters

EPA SW-846 method 8021B, in conjunction with EPA SW-846 method 5030B (purge-and-trap extraction for aqueous samples), are the analytical methods to be used for this project for analysis of VOCs. Method 8021B provides for the detection of halogenated and aromatic VOCs using a gas chromatograph (GC) equipped with both a photoionization detector (PID) and an electrolytic conductivity detector (ELCD, or Hall detector). The laboratory will employ a second GC column equipped with these same two types of

detectors to confirm the primary column analytical results. CET's SOP for these analyses are included in their QAM.

Oxford Laboratory will analyze samples for fluoride by method SM 4500-F⁻-C. This method employs a fluoride electrode as an ion-selective sensor. The key element in the fluoride electrode is the laser-type doped lanthanum fluoride crystal across which a potential is established by fluoride solutions of different concentrations.

The RTI CEMQA Laboratory will analyze samples for total uranium by EPA method 200.8. 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 ²³⁴U, ²³⁵U, and ²³⁸U. 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

Quarterly, Teledyne Brown Engineering will analyze samples for gross alpha/beta activity by their internal method PRO-032-01 which utilizes an automatic proportional counter. This procedure is used to measure the overall radioactivity of water samples without identifying the radioactive species present. No chemical separation techniques are involved.

Annually, CET will analyze samples for:

- ▶ alkalinity by titration method SM 2320B,
- ▶ chloride by mercuric nitrate titration method SM 4500-Cl⁻-C,
- ▶ sulfate by gravimetric/ignition-of-residue method SM 4500-SO₄²⁻-C, and
- ▶ TOC by persulfate-ultraviolet oxidation method SM 5310-C.

Quarterly, Microseeps will analyze samples for three light hydrocarbons, methane, ethane, and ethene, by their internal method AM-18.02. This method is based on Henry's Law

which defines the distribution of volatile components between the aqueous phase and the gaseous phase in a closed system--headspace gas is introduced onto a GC column with appropriate detectors for analysis, and the water concentrations are then calculated from the headspace gas concentrations using Henry's Law.

8.0 Data Documentation And Reporting

This section presents reporting requirements relevant to the data produced during project 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, the CET, Oxford Laboratory, and RTI CEMQA Laboratory data reports will include the following data and summary forms:

- Narrative, cross reference, and method references;
- Chain of custody and statement of condition of samples upon receipt;
- Analytical results and sample-specific PQLs and dilution factors;
- Summary of calibration information;
- Surrogate recoveries for each groundwater sample and QC sample analyzed;
- Blank results for each analytical batch;
- LCS recoveries for each analytical batch; and
- MS and MSD 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 and gross alpha/beta activity 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 blanks,
- Field duplicates,
- LCSs,
- MS/MSDs,
- Laboratory duplicate analyses,
- Surrogates,
- PE samples, and
- Compound identification and quantification.

9.2 Standard Operating Procedures for Data Validation

The *EPA Contract Laboratory Program National Functional Guidelines for Organic and Inorganic Data Review* (EPA, 1994) (*National Functional Guidelines*) provide general data-validation guidelines that can be applied to the data. The guidelines have been employed 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 4.

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 as described in their laboratory QAMs. 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.

North Carolina Department of Environment and Natural Resources. 1998. *Groundwater Section Guidelines for the Investigation and Remediation of Soil and Groundwater: Vol I - Sources Other Than Petroleum Underground Storage Tanks*. Division of Water Quality, Groundwater Section.

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

_____, 1997a. *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW-846, Final Update III*, Office of Solid Waste and Emergency Response, U.S. Environmental Protection Agency, Washington, D.C.

_____, 1997b. *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.

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

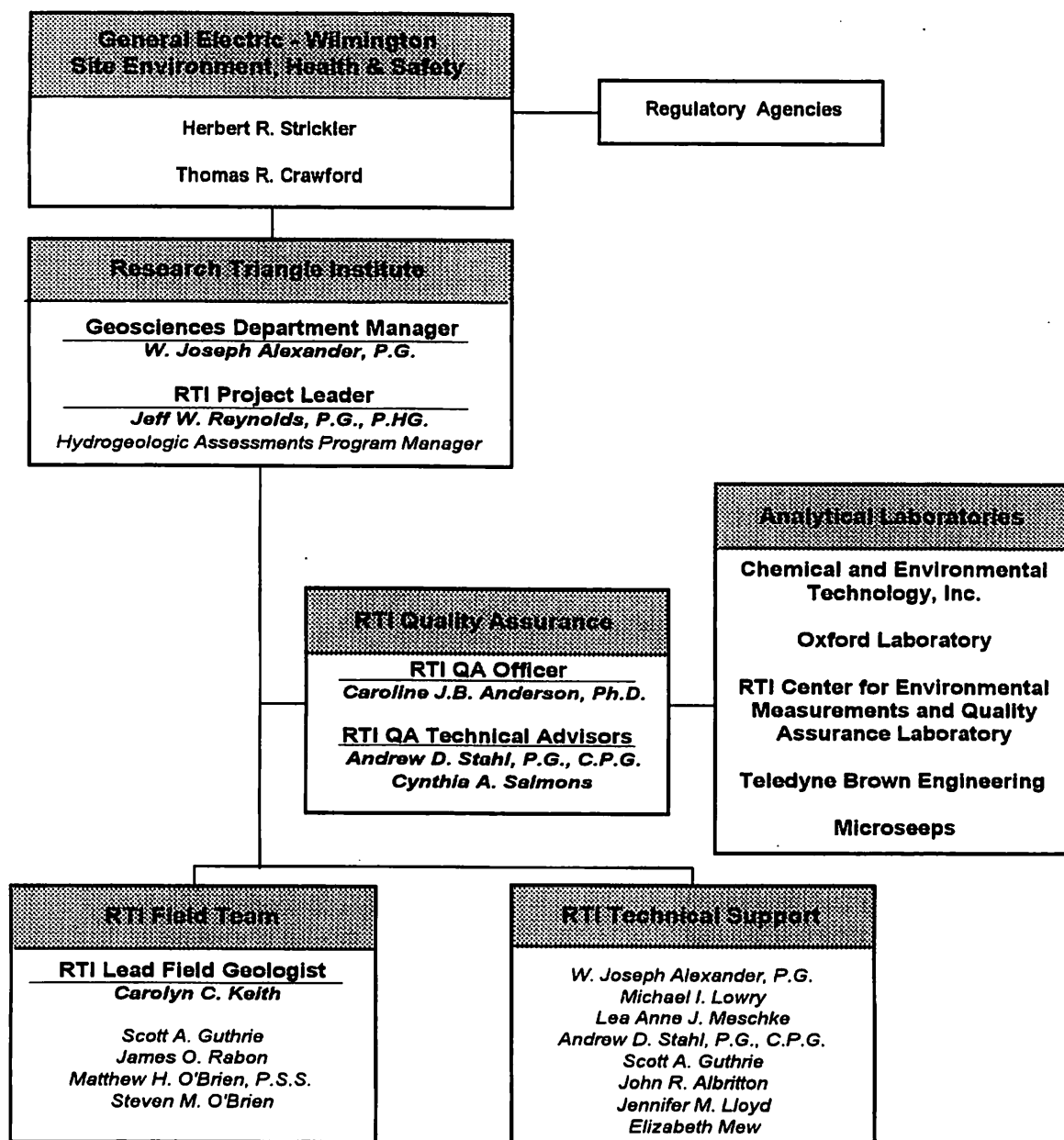


Figure 1. Project Organization

Northwest Site Area Monitored Natural Attenuation Corrective Action
General Electric Company, Wilmington, North Carolina
RTI Project No. 6448-018

Table 1. Target Volatile Organic Compound Analytes

Benzene	1,3-Dichloropropane
Bromobenzene	2,2-Dichloropropane
Bromochloromethane	1,1-Dichloropropene
Bromodichloromethane	cis-1,3-Dichloropropene
Bromoform	trans-1,3-Dichloropropene
Bromomethane	Ethylbenzene
n-Butylbenzene	Hexachlorobutadiene
sec-Butylbenzene	Isopropylbenzene
tert-Butylbenzene	p-Isopropyltoluene
Carbon tetrachloride	Methylene chloride
Chlorobenzene	Naphthalene
Chloroethane	n-Propylbenzene
Chloroform	Styrene
Chloromethane	1,1,1,2-Tetrachloroethane
2-Chlorotoluene	1,1,2,2-Tetrachloroethane
4-Chlorotoluene	Tetrachloroethylene
Dibromochloromethane	Toluene
1,2-Dibromo-3-chloropropane	1,2,3-Trichlorobenzene
1,2-Dibromoethane	1,2,4-Trichlorobenzene
Dibromomethane	1,1,1-Trichloroethane
1,2-Dichlorobenzene	1,1,2-Trichloroethane
1,3-Dichlorobenzene	Trichloroethylene
1,4-Dichlorobenzene	Trichlorofluoromethane
Dichlorodifluoromethane	1,2,4-Trimethylbenzene
1,1-Dichloroethane	1,2,3-Trichloropropane
1,2-Dichloroethane	1,3,5-Trimethylbenzene
1,1-Dichloroethylene	Vinyl chloride
cis-1,2-Dichloroethylene	o-Xylene
trans-1,2-Dichloroethylene	m,p-Xylenes
1,2-Dichloropropane	

Analytes shown as ***bold italics*** text are project-critical parameters.

Table 2. Analytical Laboratories, Methods, Containers, Preservatives and Maximum Holding Times

Laboratory:	Chemical & Environmental Technology, Inc.			Microseeps	Research Triangle Institute ^a	Oxford Laboratory ^a	Teledyne Brown Engineering ^a
Analytes:	VOCs	Alkalinity/ Chloride/Sulfate	Total Organic Carbon	Methane, Ethane, Ethene	Total Uranium	Fluoride	Gross Alpha/Beta
Method:	SW-846 8021B	SM 2320B/ SM 4500-Cl ⁻ -C/ SM 4500-SO ₄ ²⁻ -C	SM 5310-C	AM-18.02 ^b	EPA 200.8	SM 4500-F ⁻ -C	PRO-032-1 ^c
Maximum Holding Time:	14 Days	14days/ 28 days/28 days	28 days	14 days	6 months	28 days	6 months
Container:	3 glass vials, 40 mL	1 polyethylene bottle, 1 L	3 glass vials, 40 mL	2 amber glass vials, 40 mL	1 polyethylene bottle, 250 mL	1 polyethylene bottle, 250 mL	1 polyethylene bottle, 2 L
Preservative:	4 ± 2 °C ^d , HCl, pH<2	4 ± 2 °C ^d	4 ± 2 °C ^d H ₂ SO ₄ , pH<2	4 ± 2 °C ^d	HNO ₃ , pH<2	4 ± 2 °C ^d	HNO ₃ , pH<2

^a Laboratory allowed to receive Special Nuclear Material. Samples to be received by CET will be collected from locations that historically have never contained concentrations of uranium above 0.02 ppm. Samples are screened for total uranium prior to shipment to laboratories.

^b Microseeps internal method, see QAPP Section 7.2.

^c Teledyne Brown Engineering internal methods, see QAPP Section 7.2.

^d 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.

Table 3. Quality-Control Acceptance Criteria

Analyte	Parameter	Frequency	Laboratory QC Acceptance Criteria	Data Validation QC Acceptance Criteria
Fluoride	Method Blank	1 per 20 samples	< detection limit	< detection limit
	Laboratory Control Sample	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	1 per sampling event	—	< detection limit
	Field Duplicate	1 per sampling event	—	≤ 50 RPD
	Performance Evaluation Sample	1 per sampling event	—	80-120 %R
Uranium	Method Blank	1 per 15 samples	< detection limit	< detection limit
	Laboratory Control Sample	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	1 per 20 samples	—	< detection limit
	Field Duplicate	1 per 20 samples	—	≤ 50 RPD
	Performance Evaluation Sample	1 per sampling event	—	80-120 %R
Volatile Organic Compounds	Method Blank	1 per 20 samples	< detection limit	< detection limit
	Laboratory Control Sample	1 per 20 samples	70-130 %R or statistically derived	70-130 %R or statistically derived
	Matrix Spike	1 per 20 samples	70-130 %R or statistically derived	same %R ranges used for laboratory control samples
	Matrix Spike Duplicate	1 per 20 samples	≤ 30 RPD or statistically derived	≤ 30 RPD or statistically derived
	Field Blank	1 per sampling event	—	< reporting limit
	Trip Blank	1 per cooler with VOC samples	—	< reporting limit
	Field Duplicate	1 per sampling event	—	≤ 50 RPD
	Performance Evaluation Sample	1 per sampling event	—	per certificate of analysis

%R = percent recovery
RPD = relative percent difference

Table 4. 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.