NORTH CAROLINA
DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES

APPLICATION FOR PERMIT TO CONSTRUCT AND/OR USE A WELL(S) FOR INJECTION

Class 5I Wells

In Accordance with the provisions of NCAC Title 15A: 02C.0200
Complete application and mail to address on the back page.

TO: DIRECTOR, NORTH CAROLINA DIVISION OF WATER QUALITY
DATE: May 14, 1999

A. PERMIT APPLICANT

Name: Sears Logistics Services
Address: 3333 Beverly Road
City: Hoffman Estates State: IL Zip Code: 60179
County: ______ Telephone: (847)645-5100

B. PROPERTY OWNER (if different from applicant)

Name: W.P. Ballard Company of Greensboro, Inc.
Address: 1775 The Exchange, Suite 320
City: Atlanta State: GA Zip Code: 30339
County: ______ Telephone: (770) 952-1661
*See attached for additional property owner.

C. STATUS OF APPLICANT

Private: ____ Commercial: X Federal: ____ State: ____
County: ____ Municipal: ____ Native American Lands: ____

D. FACILITY (SITE) DATA
(Fill out ONLY if the Status is Federal, State, County, Municipal or Commercial).

Name of Business or Facility: Former Greensboro Distribution Center
Address: 2600 Lawndale Drive
City: Greensboro Zip Code: 27408 County: Guilford
Telephone: (404)364-1400 Contact Person: Ross George

E. INJECTION PROCEDURE

Provide a detailed description of all planned activities relating to the proposed injection facility including but not limited to:
(1) construction plans and materials;
(2) operation procedures; and
(3) a planned injection schedule.

* See Attached

F. DESCRIPTION OF SITE

Provide a brief description of the contamination incident and the incident number assigned by the Division of Water Quality staff in the Department's Regional Office:

See attached supplemental information.

G. HYDROGEOLOGIC DESCRIPTION

Provide a hydrogeologic description, soils description, and cross section of the subsurface to a depth that included the known or projected depth of contamination. The number of borings shall be sufficient to determine the following:

(1) the regional geologic setting;
(2) significant changes in lithology;
(3) the hydraulic conductivity of the saturated zone;
(4) the depth to the mean seasonal high water table; and
(5) a determination of transmissivity and specific yield of the aquifer to be used for injection (showing calculations).

H. MONITORING PROCEDURE

Provide plans for proposed location and construction details of groundwater monitoring well network, including a schedule for sampling and analytical methods. Include any modeling/testing performed to investigate injectant's potential or susceptibility to change (biological, chemical or physical) in the subsurface.

I. WELL USE Will the injection well(s) also be used as the supply well(s) for the following?

(1) The injection operation? YES ____ NO X
(2) Personal consumption? YES ____ NO X

J. CONSTRUCTION DATA (check one)

____ EXISTING WELL being proposed for use as an injection well. Provide the data in (1) through (7) below to the best of your knowledge. Attach a copy of Form GW-1 (Well Construction Record) if available.

X * PROPOSED WELL to be constructed for use as an injection well. Provide the data in (1) through (7) below as PROPOSED construction specifications. Submit Form GW-1 after construction.

*Temporary Geoprobe Points

(1) Well Drilling Contractor's Name: To Be Determined
NC Driller Registration number: To Be Determined

(2) Date to be constructed: 6/99 Number of borings: 200-225
Approximate depth of each boring (feet): 47 ft. To 65 ft. bgs.

(3) Well casing: N/A
Type: Galvanized steel____ Black steel____ Plastic____ Other (specify)__________
Casing depth: From _______to_______ ft. (reference to land surface)
Casing extends above ground _________ inches

(4) Grout: N/A
Grout type: Cement____ Bentonite ____ Other (specify) ____________
Grouted surface and grout depth (reference to land surface):
____ around closed loop piping; from ______ to ______ (feet).
____ around well casing; from _____ to _____ (feet).

(5) Screens N/A
Depth: From _____ to _____ feet below ground surface.

(6) N.C. State Regulations (Title 15A NCAC 2C .0200) require the permittee to make provisions for monitoring wellhead processes. A faucet on both influent (recovered groundwater) and effluent (fluid being injected into the well) lines is generally required.

Will there be a faucet on the influent line? yes_____ no__X___ -N/A
Will there be a faucet on the effluent line? yes__X___ no______

(7) SOURCE WELL CONSTRUCTION INFORMATION (if different from injection well). Attach a copy of Form GW-1 (Well Construction Record). If Form GW-1 is not available, provide the data in part G of this application form to the best of your knowledge.

NOTE: THE WELL DRILLING CONTRACTOR CAN SUPPLY THE DATA FOR EITHER EXISTING OR PROPOSED WELLS IF THIS INFORMATION IS UNAVAILABLE BY OTHER MEANS.

K. OTHER WELL DATA

Provide a tabulation of data on all wells within ¼ mile of the injection well(s), excepting water supply wells serving a single-family residence, which penetrate the proposed injection zone. Such data shall include a description of each well's type, depth, record of abandonment or completion, and additional information the Director may require.

L. PROPOSED OPERATING DATA

(1) Injection rate: Average (daily) __10__gallons per minute (gpm)
(2) Injection volume: Average (daily) __3500__ gallons per day (gpd)
(3) Injection pressure: Average (daily) __150__ pounds/square inch (psi)
(4) Injection temperature: Average (January) __45__ ° F, Average (July) __85__ ° F
(5) Hydraulic capacity of the well: __10 GPM/Point__
(6) Expected lifetime of the injection facility: __N/A__ years -Temporary
(7) Give a description of how the above data will be measured and controlled: ________
__See attached supplemental information__

M. INJECTION-RELATED EQUIPMENT

Attach a diagram showing the detailed plans and specifications of the surface and subsurface construction details of the system.

N. LOCATION OF WELL(S)

Attach a scaled, site-specific map(s) showing the location(s) of the following:

(1) the proposed injection well(s);
(2) all property boundaries;
(3) contour intervals not exceeding two feet;
(4) the direction and distance from the injection well or well system to two nearby, permanent reference points (such as roads, streams, and highway intersections);
(5) all buildings within the property boundary;
(6) any other existing or abandoned wells, including water supply and monitoring wells, within the area of review of the injection well or wells system;
(7) potentiometric surface showing direction of groundwater movement;
(8) the horizontal and vertical extent of the contaminant plume (including isoconcentration lines and plume cross sections);
(9) any existing sources of potential or known groundwater contamination, including waste storage, treatment or disposal systems within the area of review of the injection well or well system; and
(10) all surface water bodies within 1000 feet of the injection well or well system.

O. INJECTION FLUID DATA

(1) Fluid source, if underground, from what depth, formation and type of rock/sediment unit will the fluid be drawn (e.g., granite, limestone, sand, etc.).

Depth: N/A
Formation: N/A
Rock/sediment unit: N/A

(2) Provide the chemical, physical, biological and radiological characteristics of the fluid to be injected.

P. PERMIT LIST

Attach a list of all permits or construction approvals that are related to the site, including but not limited to:

(1) Hazardous Waste Management program permits under RCRA
(2) NC Division of Water Quality Non-Discharge permits
(3) Sewage Treatment and Disposal Permits
(4) Other environmental permits required by state or federal law.

Q. CERTIFICATION

"I hereby certify, under penalty of law, that I have personally examined and am familiar with the information submitted in this document and all attachments thereto and that, based on my inquiry of those individuals immediately responsible for obtaining said information, I believe that the information is true, accurate and complete. I am aware that there are significant penalties, including the possibility of fines and imprisonment, for submitting false information. I agree to construct, operate, maintain, repair, and if applicable, abandon the injection well and all related appurtenances in accordance with the approved specifications and conditions of the Permit."

Thomas R Grandy

(Signature of Well Owner or Authorized Agent)

If authorized agent is acting on behalf of the well owner,
please supply a letter signed by the owner
authorizing the above agent.

R. CONSENT OF PROPERTY OWNER (Owner means any person who holds the fee or other property rights in the well being constructed. A well is real property and its construction on land rests ownership in the landowner in the absence of contrary agreement in writing.)

If the property is owned by someone other than the applicant, the property owner hereby consents to allow the applicant to construct each injection well as outlined in this application and that it shall be the responsibility of the applicant to ensure that the injection well(s) conforms to the Well Construction Standards (Title 15A NCAC 2C .0200)

(Signature Of Property Owner If Different From Applicant)

Please return **two** copies of the completed Application package to:

UIC Program
Groundwater Section
North Carolina DENR-DWQ
P.O. Box 29578
Raleigh, NC 27626-0578

Telephone (919) 715-6165

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(Signature Of Property Owner If Different From Applicant)

GREENSBORO DISTRIBUTION GROUP, LLC, MANAGING MEMBER

Please return two copies of the completed Application package to:

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Groundwater Section
North Carolina DENR-DWQ
P.O. Box 29578
Raleigh, NC 27626-0578

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____
(Signature of Well Owner or Authorized Agent)

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Wiley P Ballard
(Signature Of Property Owner If Different From Applicant)
On behalf of W.P Ballard & Company of Greensboro, Inc.

Please return **two** copies of the completed Application package to:

UIC Program
Groundwater Section
North Carolina DENR-DWQ
P.O. Box 29578
Raleigh, NC 27626-0578

Telephone (919) 715-6165

SUPPLEMENTAL INFORMATION

Part A

No additional information required.

Part B

The information for the second property owner (the former Greensboro Distribution Center facility) is as follows:

Greensboro Distribution Group, LLC
3340 Peachtree Road
Suite 1500
Atlanta, Georgia 30326
(404) 364-1400

Part C

No additional information required.

Part D

No additional information required.

Part E

The objective of this project is to remediate soil and groundwater impacted by a tetrachloroethene release which occurred on the W. P. Ballard Property, and subsequently impacted the downgradient former Sears Greensboro Distribution Center property (now owned by Greensboro Distribution Group LLC). The remedial approach is to apply the technologies of *in situ* chemical oxidation, and high vacuum dual phase (HVDP) extraction and treatment of groundwater and soil vapor utilizing on-site treatment. This approach is based on pilot test data collected in 1997 and 1999, and bench scale tests conducted in 1998 and 1999, coupled with recent experience at similar sites. These technologies will be implemented in a multi-phase approach. The first phase is *in situ* chemical oxidation, and is proposed for implementation by treatment per this application.

In situ chemical oxidation is a technology that has been used at other sites to remediate chlorinated solvents quickly and economically. A recent EPA publication, included in **Attachment A**, describes the technology and some recent applications. IT Corporation has implemented this technology successfully at sites throughout the United States and overseas. Case studies on some of these applications are included in **Attachment B**.

For this site, we are proposing to utilize permanganate as the oxidizing agent. There are many oxidants which are potentially usable, but only some are environmentally acceptable. Permanganate was selected because it is stable, non-hazardous (outside of its oxidizing nature) and easily handled. It is widely used in conventional water treatment. Permanganate reacts well to oxidize PCE, TCE and DCE and the reaction is rapid and complete. As can be seen below:

PCE: $4NaMnO_4 + 3C_2Cl_4 + 4H_2O \rightarrow 4MnO_2 + 6CO_2 + 12Cl^- + 4Na^+ + 8H^+$

TCE: $2NaMnO_4 + 2C_2Cl_3 + 4H_2O \rightarrow 2MnO_2 + 2CO_2 + 3Cl^- + 2Na^+ + H^+$

DCE: $8NaMnO_4 + 3C_2H_2Cl_2 + 4H^+ \rightarrow 8MnO_2 + 6CO_2 + 6Cl^- + 8Na^+ + 4H_2O$

Laboratory (bench scale) treatability tests were performed using site soils and groundwater to confirm the effectiveness of this oxidizer in meeting the remedial objectives for this site. The tests also determined the dosage required to achieve the desired reductions in the adsorbed and dissolved phase chlorinated solvent concentrations. The Laboratory Treatability Study Report is included as **Attachment C**.

The proposed method of delivery of the chemical is by application through temporary Geoprobe points. This method allows for efficient distribution of the oxidizer to the target treatment zones. A pilot test of the application method was conducted at the site on March 25 and 26, 1999 using clean water to confirm the hydraulic properties. The Application Pilot Study Report is included as **Attachment D**.

Based on the laboratory treatability test, pilot application test and the most recent contaminant distribution data from groundwater sampling, the proposed treatment plan was developed and is presented below:

Item (1):

Application of the permanganate solution will be performed in three different zones of contamination. The zones are defined by the levels of chlorinated solvents present within the subsurface, and are shown on attached **Figure 12**. The quantity of permanganate solution to be applied and the spacing of the application points was calculated based on the volume of impacted media present within each zone, dissolved and adsorbed phase contamination levels present and the oxidation potential of natural constituents present within the soil. The following application regime is proposed to utilized:

•Zone I:	15% sodium permanganate solution; application points @ 20 foot centers; 350 gallons per point (average of 25 gallons per 5 foot interval).
•Zone II:	15% sodium permanganate solution; application points @ 40 foot centers; 330 gallons per point (average of 24 gallons per 5 foot interval).
•Zone III:	3% sodium permanganate solution; application points @ 40 foot centers; 350 gallons per point (average of 25 gallons per 5 foot interval).

The application "facility" will consist of two separate operations. The mixing operation will be performed in a pre-established containment area on the former SLS property. The 40% permanganate solution will delivered to the site in either 55-gallon drums or 550-gallon tope tanks. Two 2,500-gallon polyethylene tanks will be used to mix/dilute the 40% solution of sodium permanganate to the required levels. The 40% permanganate solution will be transferred to the polyethylene container using a centrifugal transfer pump and mixed with municipal water to prepare a single 2,000-gallon batch in each 2,500 gallon tank. Individual batches will be prepared daily for use the following day.

For the initial application event, sodium permanganate will be delivered to the site as a 40% solution in a bulk shipment of approximately 70,000 pounds (~20,000 gallons). Currently, 55-gallon drums are the only approved transport method for the solution, a 550-gallon tope tank maybe approved for solution transport prior to the required shipment date, tentatively scheduled for the first week in June 1999. For subsequent events, shipments of smaller quantities will be obtained.

The solution storage and mixing location will be established in stable accessible area. Temporary containment will be employed to prevent the release of the reactive solution. Fencing will also be installed to limit access to staged and mixed materials.

The permanganate solution will be transported from the mixing location to the individual application points using truck mounted 300 - 500 gallon enclosed polyethylene containers. The solution will be applied to the subsurface through temporary Geoprobe points. The Geoprobe points will be advanced to 65 feet bgs, or until bedrock is encountered. Subsequently, the 1.25-inch diameter Geoprobe rods will be manifolded to the permanganate delivery system. A schematic of the proposed manifold and application procedures is attached as **Figure 15**. The permanganate solution will be applied to the subsurface via a Geoprobe subsurface application tool. This tool will be either a two foot slotted screen, or an integral drive tool with an open perforated section located between two wider sections which function as packers during injection. These assemblies will be able to apply the permanganate solution in discrete 2 to 5-foot intervals. A diagram illustrating the application assembly is attached as **Figure 16**.

The solution application will begin at the base of the Geoprobe boring. Once the probe is advanced to 65 feet bgs or the final attainable depth, the Geoprobe rig will disconnect from the boring and the application manifold will be connected. The specified quantity of solution will be introduced into the bottom 5-foot interval with the pressure flow and total quantity documented. Subsequent to the application of the solution, the manifold will be gated off, the pressure relieved and the application assembly point will be raised approximately 5 feet. The application process will be repeated throughout the saturated zone. Application will also be performed in the vadose zone soils in areas with confirmed soil contamination.

Item (3):

The following is the proposed schedule for application of the permanganate solution at the subject site:

Beginning of initial application event (approx. 225 temporary points)	June 7, 1999
End of initial application event	July 30, 1999
Beginning of second application event (approx. 100 temporary points)	June 2000
End of second application event	July 2000

Part F

The subject site is dry cleaning supply facility, located at 2701 Branchwood Drive, approximately 400 feet east of Battleground Avenue in Greensboro, Guilford County, North Carolina. Currently, the site is operated by Phenix Supply Company, who lease the property from W. P. Ballard

Company of Greensboro, Inc. The site location is shown on a portion of the United States Geological Survey 7.5 minute topographic map of Greensboro, North Carolina Quadrangle, included as **Figure 1**.

The subject site was developed in 1957 as a dry cleaning supply and distribution facility, operated by W.P. Ballard Company of Greensboro, Inc. (Ballard). From 1990 to the present, the site has been leased by Phenix Supply Company from Ballard. A petroleum hydrocarbon release was discovered during the performance of underground storage tank (UST) removal activities in September 1991. At the time of the discovery of the release, two 550-gallon USTs, one containing heating oil and one containing gasoline, were removed. The release was reported to have been associated with the former gasoline UST. The NCDENR was notified of the release in September 1991 and was identified as Groundwater Incident Number 6953.

The subsequent investigation revealed the presence of high concentrations of dissolved phase chlorinated ethenes, consisting mainly of tetrachloroethene and it's associated breakdown products. Tetrachloroethene concentrations detected ranged from 11 ug/L to 270,000 ug/L. The detected release is associated with tetrachloroethene distribution activities which have historically been performed on site, and continue to be performed to this day. The site is under the jurisdiction of the Winston-Salem Regional Office of NCDENR (Groundwater Incident Number 6953) with assistance from the Guilford County Health Department.

Part G

Geologic Setting

The Ballard Property is situated in Guilford County, which is located within the Piedmont Physiographic Province of North Carolina. Specifically, the site is located within the Charlotte geologic belt. Per the Geologic Map of North Carolina, the site and surrounding areas are underlain by metamorphosed granitic rock.

Site Geology

Based on data collected during drilling operations, the subsurface stratigraphy consists of unconsolidated mixtures of sand, silt and clay sized particles to depths of between 47 and approximately 65 feet below grade. Unconsolidated materials are saprolitic in nature, resulting from the in situ chemical and physical weathering of the parent bedrock. The unconsolidated material retains relict fractures of the parent material, thereby being saprolitic in nature. Based on observations made during drilling, true, competent bedrock is concluded to exist below depths of 65 feet below grade. Bedrock encountered at shallower depths is likely to be attributed to the local presence of pockets of competent bedrock above true bedrock (undisplaced boulders) due to differential weathering or differences in surface topography. Other than the interface between the unconsolidated overburden and the competent bedrock, significant lithologic changes have not been observed on site. A geologic cross section location map and two geologic cross sections are included as **Figures 5, 6 and 7**, respectively.

Site Hydrogeology

The depth to groundwater varies across the site, and ranges from 6.45 to 24.10 feet below grade. Variations in the depth to groundwater generally correspond with changes in the topography of the site. Wells exhibiting the shallowest depth to groundwater measurements

(MW-13, MW-17, MW-18 and MW-22) appear to be located in cut areas, where excavations were performed to accommodate the former Sears Distribution Center. A water table elevation contour map was prepared using the November 30, 1998 groundwater gauging data, and is included as **Figure 8.**

Between September 10, 1997 and September 18, 1997, pilot test activities were performed by IT Corporation in the surficial aquifer at the site to evaluate the feasibility of remediation options for use at the site. As part of the pilot testing, an aquifer test was performed, in which groundwater was extracted and aquifer response was measured. The aquifer test was performed under several conditions: vacuum enhanced vs. non-vacuum enhanced, variable flow rates, multiple pumping wells, etc. As such, traditional data reduction methods could not be employed to evaluate the data. However, examination of the data does provide useful insight into the subsurface conditions, as well as, the characteristics of the aquifers at the site.

Data reduction for two wells will be discussed here. Well EW-2 is a "shallow well", installed to a total depth of 25 feet below grade. Well EW-3 is a "deep" well, installed to a total depth of 65 feet below grade. Water level recovery data for these wells were input into the Bouwer and Rice formula, using the AQTESOLV data reduction program. Data reduction resulted in the following average horizontal hydraulic conductivity values for the screened intervals of each well:

EW-2: $K_h = 0.60$ ft/day
EW-3: $K_h = 8.11$ ft/day

These values were compared to typical values of horizontal hydraulic conductivity for aquifer materials. It was concluded that these estimated values fall within the typical ranges for sand and silt aquifers. Note that well EW-3 has a higher estimated horizontal hydraulic conductivity. The screened interval for this well was installed near the top of bedrock. The higher hydraulic conductivity in this well is likely attributed to a zone of coarse particles (partially weathered rock) near the top of bedrock.

Examination of drawdown curves from recovery and observation wells during the aquifer test suggests delayed yield effects. Delayed yield would be expected in aquifers with highly stratified sediments, as were found at the site. Stratification of sediments suggests large differences can be expected between the horizontal hydraulic conductivity and the vertical hydraulic conductivity.

The average horizontal hydraulic conductivity was calculated to be 2.20 ft/day for the entire thickness of the surficial aquifer. Since stratified sediments are present, the average vertical hydraulic conductivity of the surficial aquifer is assumed to be 0.5 that of the horizontal hydraulic conductivity. As such, the overall average hydraulic conductivity of the surficial aquifer is estimated to be approximately 1.55 ft/day. The groundwater gradient is estimated to be 0.023 feet/foot across the site. Assuming a porosity of 0.3 and using the average horizontal hydraulic conductivity (2.20 ft/day), the average linear groundwater velocity across the site is 0.17 feet/day. Average linear groundwater velocity is calculated using the following formula:

$V = [\, i\, K_h]/n_e$ where: V = average linear velocity
i = hydraulic gradient
K_h = horizontal hydraulic conductivity
n_e = effective porosity

Transmissivity of the aquifer may be estimated by the following equation:

$T = K_h * b$ where: T = transmissivity
K_h = horizontal hydraulic conductivity
b = aquifer thickness

Using an average K_h of 1.55 feet per day, and an average aquifer thickness of 55 feet (ground surface to top of bedrock), the aquifer transmissivity is estimated to be 85.25 feet squared per day.

Part H

As part of the monitoring plan, the existing groundwater monitoring well network at the site will be utilized. A site map showing the existing monitoring well network is attached as **Figure 6**. Prior to, and one month subsequent to the completion of the initial site-wide application event, groundwater samples will be collected from 39 of the existing monitoring and pilot test wells, including: MW-1 through MW-15, MW-17, MW-18, MW-20 through MW-23, MW-27, MW-28, LMP-1, LMP-2, DW-1 through DW-5, DW-7, DW-8, DW-9, DW-11, DW-12 and DMP-1 through DMP-4. These monitoring wells are located throughout the proposed application area, as well as, along the outer edge of the dissolved phase contaminant plume. Collected groundwater samples will be analyzed for purgeable halocarbons by EPA Method 601, Manganese, Chloride, Potassium, Sodium, total suspended solids and color. In addition, the following field parameters will be measured for each sample: pH, temperature, conductivity, and dissolved oxygen. Based on the results of the initial application event a high vacuum dual phase groundwater and soil vapor recovery and treatment system will be designed and installed. For the first year of operations, groundwater sampling will be performed quarterly, subsequently sampling will be performed on a semi-annual basis.

Bench scale testing was performed to observe the effects of the permanganate application on the residual soils and groundwater, and to monitor the site specific end products of the reaction. The permanganate solution was found to react completely with the chlorinated ethenes and other oxidizable compounds (such as metals or other organics) present in the soils and groundwater. A copy of the Treatability Study Report is included in **Attachment C**.

It is anticipated that a second, more limited treatment event will be performed (June 2000). The number of application points needed for the second event will be based on the results of groundwater monitoring data; however, the application method/process, the permanganate solution, and subsequent groundwater monitoring plan are not expected to change from the initial event.

Part I

Groundwater will not be extracted from the subsurface as part the *in situ* oxidation process, as such there will be no influent line used in the injection process. Water required for mixing/diluting the solution will be acquired from the City of Greensboro Pubic Works Department. Gate valves, pressure gauges and a flowmeter will be installed on the"effluent" or application line to control the quantity and rate of the solution applications. Since groundwater recovery will not be part of the process, there is no "Source Well"; therefore, construction details of such are not applicable.

Part J

The initial application event is scheduled to be performed in June - July 1999 (over a period of approximately 7 weeks). Approximately 225 Geoprobe points will be used to perform the application of the oxidants to the subsurface. Each Geoprobe point will be 1.25 inch in diameter and installed to a depth ranging from 45 and 65 feet below ground surface (depending on depth of refusal). Well casing and screen will not be installed. An illustration of the application tip on the Geoprobe is included as **Figure 16**. Each Geoprobe point will be grouted to the surface with a bentonite/grout slurry (abandoned) after the application has been completed at a particular point.

It is anticipated that the second treatment event will be performed around June 2000. For this event, an estimated 50 to 100 Geoprobe treatment points will be used. This event will be performed in a similar manner as the initial event.

Part K

Attached **Table 1** is a construction summary of the previous permanent monitoring and pilot test wells installed to date. A summary of historic groundwater gauging data is included as **Table 2**. A summary of baseline soil vapor sampling events performed in the source area is included as **Table 3**. A summary of the field screening results for the recent groundwater sampling events performed by IT Corporation of North Carolina, Inc., are included as **Table 4**. A summary of historic laboratory analytical results for shallow and deep groundwater sampling events are included as **Tables 5** and **6**, respectively.

A sensitive receptor survey was performed by IT Corporation of North Carolina personnel in November 1998. No domestic, irrigation or other wells were identified within a 1,500 foot radius of the site. The City of Greensboro Water Resources Department was contacted regarding the use of domestic water in the immediate vicinity of the subject site. Per the Water Resources Department, all residences and businesses located within the city limits must obtain water from the City of Greensboro Water Resources (by city ordinance). Water accounts were also confirmed for all adjacent properties to both the Ballard and former Sears Distribution Center properties. The exception being 2820 Lawndale Avenue, which was verified as being currently unoccupied, so a current water account is not in place. A copy of the correspondence from City of Greensboro Water Resources is included in **Attachment E**.

Part L

The application rate, volume, pressure and temperature, as well as the hydraulic capacity of each Geoprobe point, were estimated based on the results of an application pilot test, performed at the site on March 24-25, 1999. The application rate, at an average pressure of 150 psi, will be approximately 5 gallons per minute per Geoprobe point. Based on the amount of time needed to complete application in a single point, IT anticipates that 5 Geoprobe points can be installed in one day using a single rig. Since IT plans to have two rigs available, a total of 10 Geoprobe points could be installed in one day. Approximately 350 gallons of solution will be applied per point; therefore, the average application volume would be approximately 3,500 gallons per day.

The application temperature is expected to vary due to seasonal and daily variations in ambient air temperature; however, both the initial and subsequent treatment events are scheduled to be performed during the summer months. A process diagram showing the piping and instrumentation manifold from the mixing tank to the Geoprobe tip is also attached. A thermometer, totalizing flow meter, pressure gauge, and gate valves will be used to monitor and control the application process. The application process for each temporary point will be directly monitored/controlled by experienced personnel. Unsupervised applications will not be performed.

Part M

A detailed schematic of the application set-up is included as **Figure 15**. The batch mixing unit will consist of two 2,500-gallon polyethylene containers and a centrifugal pump to transfer the permanganate solution from the transport containers to the mixing vessels.

Part N

The following maps are attached for review:

Figure 1: Site Location Map – Portion of Greensboro Quadrangle USGS Topographic Map
Figure 2: Site Map
Figure 3: Pilot Test Well Location Map
Figure 4: Site Topographic Map
Figure 5: Geologic Cross Section Location Map
Figure 6: Geologic Cross Section A-A'
Figure 7: Geologic Cross Section B-B'
Figure 8: Water Table Elevation Contour Map – 12/98
Figure 9: Surface Water Location Map- Portion of Greensboro Quadrangle USGS Topographic Map
Figure 10: Total VOC Isoconcentration Map for Shallow Wells – 12/98 and 1/99
Figure 11: Total VOC Isoconcentration Map for Deep Wells – 12/98 and 1/99
Figure 12: Total VOC Isoconcentration Map for Shallow Wells Overlain With Proposed Treatment Zones
Figure 13: Temporary Application Point Layout – Zone I
Figure 14: Temporary Application Point Layout – Zones II and III
Figure 15: Application Manifold Schematic
Figure 16: Subsurface Application Schematic

Part O

Part 1: This does not apply; the fluid source is not underground.

Part 2: The MSDS and Carus fact sheet for Sodium Permanganate are included in **Attachment F**. The MSDS contains chemical, physical, biological and radiological characteristics of the fluid to be applied. Sodium permanganate is proposed to be applied as a 15% solution in Zones I and II and as a 3% solution in Zone III.

Part P

As part of the Corrective Action at this site, obtaining the following permits and construction approvals will be necessary:

- Recovery/monitoring well permits
- Corrective Action Plan (CAP) approval from NCDENR – WSRO and Guilford County Department of Health. The CAP proposes in-situ oxidation via potassium permanganate injection followed by the construction and operation of a dual-phase vacuum extraction and treatment system.
- Construction Permits (i.e. building, electrical, fire prevention) from the City of Greensboro – associated with the groundwater extraction and treatment system.
- An air discharge permit (from NCDENR) - associated with the groundwater treatment system.
- NPDES Discharge Permit (issued by NCDENR) for disposal of treated groundwater. A dual phase extraction and treatment system will be designed and installed based on the results of the initial injection event.

Part Q

Sears Logistics Services, Inc. (SLS) is the acting responsible party for the remediation/clean up of this site. SLS was the former property owner of one of the properties associated with this site. A representative of SLS signed the permit application.

Part R

The current owners of the properties associated with the site are W. P. Ballard Company of Greensboro, Inc. and Greensboro Distribution Group, LLC. Representatives from both ownership groups signed the permit application.

TABLES

Table 1

Well Construction Summmary
W.P. Ballard and Downgradient Properties
Greensboro, North Carolina

Well Identification	Casing Diameter	Well Material	Total Depth	Cased Interval	Screened Interval	Top of Casing Elevation	Notes
MW-1	2"	PVC	35'	0-25'	25-35'	881.03	
MW-2	2"	PVC	35'	0-25'	25-35'	882.43	
MW-3	2"	PVC	35'	0-25'	25-35'	883.1	
MW-4	2"	PVC	35'	0-25'	25-35'	882.33	
MW-5	2"	PVC	35'	0-25'	25-35'	883.47	
MW-6	2"	PVC	35'	0-25'	25-35'	884.33	
MW-7	2"	PVC	35'	0-25'	25-35'	882.59	
MW-8	2"	PVC	35'	0-25'	25-35'	883.03	
MW-9	2"	PVC	35'	0-25'	25-35'	880.43	
MW-10	2"	PVC	35'	0-25'	25-35'	882.42	
MW-11	2"	PVC	35'	0-25'	25-35'	874.71	
MW-12	2"	PVC	35'	0-25'	25-35'	862.15	
MW-13	2"	PVC	35'	0-25'	25-35'	863.77	
MW-14	2"	PVC	35'	0-25'	25-35'	884.36	
MW-15	2"	PVC	35'	0-25'	25-35'	872.1	
MW-16	2"	PVC	35'	0-25'	25-35'	NS	Damaged during construction
MW-17	2"	PVC	35'	0-25'	25-35'	861.43	
MW-18	2"	PVC	35'	0-25'	25-35'	862.26	
MW-19	2"	PVC	35'	0-25'	25-35'	NS	Destroyed during construction
MW-20	2"	PVC	35'	0-25'	25-35'	866.15	
MW-21	2"	PVC	35'	0-25'	25-35'	866.12	
MW-22	2"	PVC	35'	0-25'	25-35'	861.83	
MW-23	2"	PVC	35'	0-25'	25-35'	861.15	
MW-24	2"	PVC	35'	0-25'	25-35'	NS	Destroyed during construction
MW-25	2"	PVC	35'	0-25'	25-35'	NS	Destroyed during construction
MW-26	2"	PVC	35'	0-25'	25-35'	NS	Destroyed during construction
MW-27	2"	PVC	35'	0-25'	25-35'	879.8	
MW-28	1"	PVC	35'	0-25'	25-35'	881.23	
LMP-1	2"	PVC	35'	0-25'	25-35'	873.5	
LMP-2	2"	PVC	35'	0-25'	25-35'	871.41	
DW-1	1"	PVC	65'	0-50' / 0-55'	55'-65'	882.31	
DW-2	2"	PVC	65'	0-50' / 0-55'	55'-65'	881.12	
DW-3	2"	PVC	65'	0-50' / 0-55'	55'-65'	882.59	
DW-4	2"	PVC	65'	0-50' / 0-55'	55'-65'	883.69	
DW-5	2"	PVC	63.5'	0-45' / 0-48.5'	48.5-63.5'	872.8	
DW-6	2"	PVC	63.5'	0-45' / 0-48.5'	48.5-63.5'	NS	Destroyed during construction
DW-7	2"	PVC	63.5'	0-45' / 0-48.5'	48.5-63.5'	862.17	
DW-8	2"	PVC	63.5'	0-45' / 0-48.5'	48.5-63.5'	861.44	
DW-9	2"	PVC	53'	0-40' / 0-43'	43-53'	NS	
DW-10	2"	PVC	58'	0-40' / 0-43'	43'-58'	NS	Destroyed during construction
DW-11	2"	PVC	53'	0-40' / 0-43'	43-53'	NS	
DW-12	2"	PVC	47'	0-40'/0-42'	42-47'	845.45	
DMP-1	2"	PVC	65'	0-45'/0-50'	50-60'	870.83	
DMP-2	2"	PVC	60'	0-45'/0-50'	50-60'	872.13	
DMP-3	2"	PVC	57'	0-40'/0-47'	47-57'	862.18	
DMP-4	2"	PVC	64'	0-41'/0-49'	49-64'	862.25	
EW-1	4"	PVC	64	0-49	49-64	882.57	Pilot Test Extraction Well
EW-2	4"	PVC	25	0-5	5-25	882.56	Pilot Test Extraction Well
EW-3	4"	PVC	65	0-50	50-65	882.81	Pilot Test Extraction Well
EW-4	4"	PVC	25	0-5	5-25	882.84	Pilot Test Extraction Well
PT-1S	1"	PVC	25	0-5	5-25	882.69	
PT-2S	1"	PVC	22.2	0-2.2	2.2-22.2	882.95	
PT-3S	1"	PVC	25	0-5	5-25	882.59	
PT-4S	1"	PVC	25	0-5	5-25	882.21	
PT-5S	1"	PVC	25	0-5	5-25	882.97	
PT-1D	2"	PVC	65	0-50	50-65	882.70	
PT-2D	2"	PVC	65	0-50	50-65	882.95	
PT-3D	2"	PVC	65	0-50	50-65	882.66	
PT-4D	2"	PVC	65	0-50	50-65	882.41	
PT-5D	2"	PVC	65	0-50	50-65	882.96	

Table 2

Groundwater Gauging and Water Table Elevation Summary
W.P. Ballard and Downgradient Properties
Greensboro, North Carolina

Well Identification	Date	Top of Casing Elevation	Depth to Water	Water Table Elevation
MW-1	11/30/98	881.03	16.05	864.98
MW-2	11/30/98	882.43	16.70	865.73
MW-3	11/30/98	883.10	17.40	865.70
MW-4	11/30/98	882.33	17.50	864.83
MW-5	11/30/98	883.47	18.70	864.77
MW-6	11/30/98	884.33	18.75	865.58
MW-7	11/30/98	882.59	16.90	865.69
MW-8	11/30/98	883.03	17.66	865.37
MW-9	11/30/98	880.43	17.84	862.59
MW-10	11/30/98	882.42	22.60	859.82
MW-11	11/30/98	874.71	19.03	855.68
MW-12	11/30/98	862.15	11.50	850.65
MW-13	11/30/98	863.77	7.31	856.46
MW-14	11/30/98	884.36	19.78	864.58
MW-15	11/30/98	872.10	16.58	855.52
MW-17	11/30/98	861.43	6.45	854.98
MW-18	11/30/98	862.26	12.15	850.11
MW-20	11/30/98	866.15	22.55	843.60
MW-21	11/30/98	866.12	29.44	836.68
MW-22	11/30/98	861.83	10.80	851.03
MW-23	11/30/98	861.15	24.10	837.05
MW-27	11/30/98	879.80	19.85	859.95
MW-28	11/30/98	881.23	19.40	861.83
LMP-1	01/21/99	873.50	12.83	860.67
LMP-2	01/21/99	871.41	11.52	859.89
DW-1	11/30/98	882.31	17.10	865.21
DW-2	11/30/98	881.12	16.35	864.77
DW-3	11/30/98	882.59	18.30	864.29
DW-4	11/30/98	883.69	18.87	864.82
DW-5	11/30/98	872.80	17.39	855.41
DW-7	11/30/98	862.17	9.91	852.26
DW-8	11/30/98	861.44	5.77	855.67
DW-9	11/30/98	NS	16.35	NS
DW-11	11/30/98	NS	22.23	NS
DW-12	11/30/98	845.45	14.38	831.07
DMP-1	01/21/99	870.83	13.61	857.22
DMP-2	01/21/99	872.13	11.85	860.28
DMP-3	01/21/99	862.18	8.00	854.18
DMP-4	01/21/99	862.25	7.11	855.14

Table 3

Summary of Soil Vapor Monitoring Results
W.P. Ballard and Downgradient Properties
Greensboro, North Carolina

Location	SVMP-1		SVMP-2		SVMP-3		SVMP-4	
Date Compound	1/20/99 (mg/m^3)	1/27/99 (mg/m^3)	1/20/99 (mg/m^3)	1/27/99 (mg/m^3)	1/20/99 (mg/m^3)	1/27/99 (mg/m^3)	1/20/99 (mg/m^3)	1/27/99 (mg/m^3)
Bromodichloromethane	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
Bromoform	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
2-Chloroethylvinylether	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
Dibromochloromethane	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
Dichlorodifluoromethane	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
Trichlorofluoromethane	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
Vinyl Chloride	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
Chloromethane	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
Bromomethane	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
Chloroethane	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
1,1-Dichloroethane	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
t-1,2-Dichloroethene	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
1,2-Dichloropropane	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
1,1,2-Trichloroethane	<0.5	<250	<0.5	<250	**2.2**	<250	<0.5	<250
1,2-Dibromoethane	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
Chlorobenzene	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
c-1,3-Dichloropropene	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
t-1,3-Dichloropropene	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
1,1,2,2-Tetrachloroethane	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
1,2-Dichlorobenzene	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
1,3-Dichlorobenzene	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
1,4-Dichlorobenzene	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
1,2,4-Trichlorobenzene	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
Methylene Chloride	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
Chloroform	<0.5	<250	<0.5	<250	**1.9**	<250	<0.5	<250
Carbon tetrachloride	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
Tetrachloroethene	**5,300**	**8,600**	**7,500**	**57,000**	**8,300**	**13,000**	**5,900**	**6,500**
Trichloroethene	**5.2**	<250	**7.8**	<250	**20**	<250	**24**	<250
1,1,1-Trichloroethane	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
1,2-Dichloroethane	<0.5	<250	<0.5	<250	<0.5	<250	**1.5**	<250
c-1,2-Dichloroethene	<0.5	<250	**1.7**	<250	**4.1**	<250	**5.6**	<250
1,1-Dichloroethene	<0.5	<250	<0.5	<250	**1**	<250	**0.58**	<250
Sum of Detected EPA 601 Compounds	5,305.20	8,600.00	7,509.50	57,000.00	8,329.20	13,000.00	5,931.68	6,500.00
Modified Total VOC Concentration*	5,312.70	12,475.00	7,516.75	60,875.00	8,335.70	16,875.00	5,938.43	10,375.00
Baseline Total VOC Concentration**	8,893.85		34,195.88		12,605.35		8,156.72	

Notes: Soil vapor analysis performed by EPA Method TO3 for the Method 601 compound list.
Detected compounds shown in bold.
* The modified total VOC concentration was determined using the following equation:
TVOC=(Sum of detected compounds)+(Sum of non-detected compound PQLs*0.5)
** The Baseline Total VOC Concentration is the average of the two modified total VOC concentrations detected during the initial baseline sampling events.

Table 3

Summary of Soil Vapor Monitoring Results
W.P. Ballard and Downgradient Properties
Greensboro, North Carolina

Location	SVMP-5		SVMP-6		SVMP-7		SVMP-8	
Date Compound	1/20/99 (mg/m^3)	2/2/99 (mg/m^3)	1/20/99 (mg/m^3)	1/27/99 (mg/m^3)	1/20/99 (mg/m^3)	1/27/99 (mg/m^3)	1/20/99 (mg/m^3)	1/27/99 (mg/m^3)
Bromodichloromethane	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
Bromoform	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
2-Chloroethylvinylether	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
Dibromochloromethane	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
Dichlorodifluoromethane	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
Trichlorofluoromethane	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
Vinyl Chloride	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
Chloromethane	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
Bromomethane	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
Chloroethane	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
1,1-Dichloroethane	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
t-1,2-Dichloroethene	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
1,2-Dichloropropane	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
1,1,2-Trichloroethane	**3.2**	<250	<0.5	<250	**2**	<250	<0.5	<250
1,2-Dibromoethane	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
Chlorobenzene	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
c-1,3-Dichloropropene	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
t-1,3-Dichloropropene	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
1,1,2,2-Tetrachloroethane	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
1,2-Dichlorobenzene	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
1,3-Dichlorobenzene	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
1,4-Dichlorobenzene	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
1,2,4-Trichlorobenzene	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
Methylene Chloride	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
Chloroform	**2.9**	<250	**2.1**	<250	**3**	<250	<0.5	<250
Carbon tetrachloride	<0.5	<250	**0.5**	<250	**0.77**	<250	<0.5	<250
Tetrachloroethene	**8,600**	**48,000**	**8,700**	<250	**12,000**	**35,000**	**6,600**	**5,600**
Trichloroethene	**23**	<250	**22**	**17,000**	**37**	<250	**2**	<250
1,1,1-Trichloroethane	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
1,2-Dichloroethane	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
c-1,2-Dichloroethene	**5.6**	<250	**4.8**	<250	**14**	<250	**0.65**	<250
1,1-Dichloroethene	**1.5**	<250	**1.6**	<250	**2.2**	<250	<0.5	<250
Sum of Detected EPA 601 Compounds	8,636.20	48,000.00	8,731.00	17,000.00	12,058.97	35,000.00	6,603.05	5,600.00
Modified Total VOC Concentration*	8,642.70	51,875.00	8,737.50	20,875.00	12,065.22	38,875.00	6,610.30	9,475.00
Baseline Total VOC Concentration**	30,258.85		14,806.25		25,470.11		8,042.65	

Notes: Soil vapor analysis performed by EPA Method TO3 for the Method 601 compound list.
Detected compounds shown in bold.
* The modified total VOC concentration was determined using the following equation:
TVOC=(Sum of detected compounds)+(Sum of non-detected compound PQLs*0.5)
** The Baseline Total VOC Concentration is the average of the two modified total VOC concentrations detected during the initial baseline sampling events.

Table 3

Summary of Soil Vapor Monitoring Results
W.P. Ballard and Downgradient Properties
Greensboro, North Carolina

Location	SVMP-9		SVMP-10		SVMP-11		SVMP-12	
Date Compound	1/20/99 (mg/m^3)	1/27/99 (mg/m^3)	1/20/99 (mg/m^3)	1/27/99 (mg/m^3)	1/20/99 (mg/m^3)	1/27/99 (mg/m^3)	1/20/99 (mg/m^3)	1/27/99 (mg/m^3)
Bromodichloromethane	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
Bromoform	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
2-Chloroethylvinylether	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
Dibromochloromethane	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
Dichlorodifluoromethane	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
Trichlorofluoromethane	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
Vinyl Chloride	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
Chloromethane	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
Bromomethane	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
Chloroethane	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
1,1-Dichloroethane	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
t-1,2-Dichloroethene	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
1,2-Dichloropropane	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
1,1,2-Trichloroethane	<0.5	<250	<0.5	<250	**1.5**	<250	**4**	<250
1,2-Dibromoethane	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
Chlorobenzene	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
c-1,3-Dichloropropene	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
t-1,3-Dichloropropene	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
1,1,2,2-Tetrachloroethane	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
1,2-Dichlorobenzene	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
1,3-Dichlorobenzene	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
1,4-Dichlorobenzene	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
1,2,4-Trichlorobenzene	<0.1	<250	<0.5	<250	<0.5	<250	<0.5	<250
Methylene Chloride	<0.5	<250	<0.5	<250	<0.5	<250	<0.5	<250
Chloroform	<0.5	<250	<0.5	<250	<0.5	<250	**1.5**	<250
Carbon tetrachloride	<0.5	<250	<0.5	<250	**1.1**	<250	**1.3**	<250
Tetrachloroethene	**6,400**	**5,500**	**5,900**	**11,000**	**11,000**	**55,000**	**12,000**	**43,000**
Trichloroethene	**61**	<250	**200**	<250	**120**	<250	**80**	<250
1,1,1-Trichloroethane	<0.5	<250	<0.5	<250	**2.6**	<250	**1.1**	<250
1,2-Dichloroethane	**1.2**	<250	<0.5	<250	<0.5	<250	<0.5	<250
c-1,2-Dichloroethene	**100**	<250	**620**	<250	**300**	<250	**130**	<250
1,1-Dichloroethene	<0.5	<250	<0.5	<250	<0.5	<250	**5.7**	<250
Sum of Detected EPA 601 Compounds	6,562.20	5,500.00	6,720.00	11,000.00	11,425.20	55,000.00	12,223.60	43,000.00
Modified Total VOC Concentration*	6,569.00	9,375.00	6,727.25	14,875.00	11,431.70	58,875.00	12,229.60	46,875.00
Baseline Total VOC Concentration**	7,972.00		10,801.13		35,153.35		29,552.30	

Notes: Soil vapor analysis performed by EPA Method TO3 for the Method 601 compound list.
Detected compounds shown in bold.
* The modified total VOC concentration was determined using the following equation:
TVOC=(Sum of detected compounds)+(Sum of non-detected compound PQLs*0.5)
** The Baseline Total VOC Concentration is the average of the two modified total VOC concentrations detected during the initial baseline sampling events.

Table 4

Summary of Groundwater Sampling Field Parameters

W.P. Ballard and Downgradient Properties
Greensboro, North Carolina

Well Identification	Date	pH	Specific Conductivity (uS)	Dissolved Oxygen (mg/L)	Temperature (°C)	Oxidation Reduction Potential (mV)
MW-1	12/2/98	5.01	51	2.0	19.0	117
MW-2	12/2/98	5.70	150	3.0	17.7	72
MW-3	12/2/98	4.90	35	4.6	18.0	119
MW-4	12/2/98	5.50	95	2.1	19.0	88
MW-5	12/2/98	5.40	19	5.9	19.0	88
MW-6	12/2/98	5.50	31	4.9	18.0	85
MW-7	12/2/98	5.60	56	2.0	19.1	81
MW-8	12/2/98	4.80	37	1.8	19.8	126
MW-9	12/2/98	5.73	60	4.1	20.0	76
MW-10	12/2/98	5.70	17	5.5	19.0	66
MW-11	12/2/98	6.30	47	4.1	18.6	45
MW-12	12/2/98	5.80	164	3.9	19.0	68
MW-13	1/21/99	7.10	420	NS	15.4	83
MW-14	1/21/99	7.70	280	NS	15.2	70
MW-15	12/2/98	5.60	57	4.0	19.0	78
MW-17	12/2/98	6.10	79	5.8	19.0	26
MW-18	12/2/98	6.01	82	3.6	18.3	60
MW-20	1/21/99	6.30	154	NS	17.6	126
MW-21	12/2/98	6.10	63	5.3	17.0	50
MW-22	12/2/98	6.66	100	5.5	16.1	18
MW-23	12/2/98	6.20	598	1.6	16.9	43
MW-27	12/2/98	4.70	235	2.5	20.0	130
MW-28	12/2/98	4.80	25	2.1	20.0	125
LMP-1	1/21/99	6.80	318	NS	19.3	129
LMP-2	1/21/99	6.70	79	NS	18.7	128
DW-1	12/2/98	6.20	178	1.7	17.4	47
DW-2	12/2/98	5.50	83	4.6	19.0	88
DW-3	12/2/98	5.50	61	5.0	18.0	93
DW-4	12/2/98	5.60	57	4.4	20.0	80
DW-5	12/2/98	6.10	114	3.4	20.0	47
DW-7	12/2/98	6.60	172	3.3	21.0	27
DW-8	12/2/98	6.50	84	4.6	18.6	29
DW-9	12/2/98	7.00	170	0.9	17.9	21
DW-11	12/2/98	8.30	138	4.6	16.4	-84
DW-12	12/2/98	7.34	110	4.3	19.0	-41
DMP-1	1/21/99	5.80	643	NS	18.0	127
DMP-2	1/21/99	7.60	187	NS	17.8	107
DMP-3	1/21/99	7.10	151	NS	16.3	86
DMP-4	1/21/99	7.10	152	NS	15.8	85

Table 5

Summary of Shallow Groundwater Analytical Data

W.P. Ballard and Downgradient Properties
Greensboro, North Carolina

	Sample Location:	MW-1				MW-2				MW-3							MW-4			
	Sample Date:	5/29/92 A	7/22/94 A	07/11/96 A	12/02/98 B	5/29/92 A	7/22/94 A	07/12/96 A	12/02/98 B	5/29/92	6/25/93 A	7/22/94 A	7/10/96 A	07/10/96 B	12/02/98 B	1/21/99 B	5/29/92 A	07/10/96 A	7/10/96 B	12/2/98 B
	Analysis Method:	EPA 601	EPA 601	EPA 601	EPA 601	EPA601	EPA 601	EPA 601	EPA 601	EPA601	EPA601	EPA 601	EPA 601	EPA 601	EPA 601	EPA 601	EPA601	EPA 601	EPA 601	EPA 601
Analyte	NCAC 2L																			
Methylene Chloride (ug/L)	5.0	<1,000	<100	<1,200	<500	**540**	<100	<250	<500	<10,000	<5,000	<1000	<25,000	<25,000	<500	<2,500	<2,000	<12,000	<2,500	<500
Chloroform (ug/L)	0.19	<1,000	<100	<250	<100	<200	<100	<50	<100	<10,000	<5,000	<1000	<5,000	<5,000	<100	<500	<2,000	<2,500	<2,500	<100
Chloromethane (ug/L)	none	<1,000	<100	<250	<100	<200	<100	<50	<100	<10,000	<5,000	<1000	<5,000	<5,000	<100	<500	<2,000	<2,500	<2,500	<100
Carbon Tetrachloride (ug/L)	0.3	<1,000	<100	<250	<100	<200	<100	<50	<100	<10,000	<5,000	<1000	<5,000	<5,000	<100	<500	<2,000	<2,500	<2,500	<100
1,1-Dichloroethane (ug/L)	700	<1,000	<100	<250	<100	<200	<100	<50	<100	<10,000	<5,000	<1000	<5,000	<5,000	<100	<500	<2,000	<2,500	<2,500	<100
1,2-Dichloroethane (ug/L)	38	<1,000	<100	<250	<100	<200	<100	<50	<100	<10,000	<5,000	<1000	<5,000	<5,000	<100	<500	<2,000	<2,500	<2,500	<100
1,1-Dichloroethene (ug/L)	none	<1,000	<100	<250	<100	<200	<100	<50	<100	<10,000	<5,000	**2,100**	<5,000	<5,000	<100	<500	<2,000	<2,500	<2,500	<100
cis-1,2-Dichloroethene (ug/L)	70	NA	NA	NA	<100	NA	NA	NA	<100	NA	NA	NA	NA	NA	**310**	<500	NA	NA	NA	<100
trans-1,2-Dichloroethene (ug/L)	70	NA	NA	NA	<100	NA	NA	NA	<100	NA	NA	NA	NA	NA	<100	<500	NA	NA	NA	<100
1,2-Dichloropropane (ug/L)	0.56	<1,000	<100	<250	<100	<200	<100	<50	<100	<10,000	<5,000	<1000	<5,000	<5,000	<100	<500	<2,000	<2,500	<2,500	<100
Trichloroethene (ug/L)	2.8	<1,000	<100	<250	<100	<200	<100	<50	<100	<10,000	<5,000	<1000	<5,000	<5,000	**210**	<500	<2,000	<2,500	<2,500	<100
Tetrachloroethene (ug/L)	0.7	**33,000**	**8,000**	**18,000**	**12,600**	**11,000**	**6,500**	**4,100**	**5,080**	**270,000**	**250,000**	**110,000**	**200,000**	**200,000**	**152,000**	**94,000**	**55,000**	**39,000**	**38,000**	**17,000**
1,1,1-Trichloroethane (ug/L)	200	<1,000	<100	<250	<100	<200	<100	<50	<100	<10,000	<5,000	<1000	<5,000	<5,000	<100	<500	<2,000	<2,500	<2,500	<100
1,1,2-Trichloroethane (ug/L)	none	<1,000	<100	<250	<100	<200	<100	<50	<100	<10,000	<5,000	<1000	<5,000	<5,000	<100	<500	<2,000	<2,500	<2,500	<100

	Sample Location:	MW-5				MW-6			MW-7				MW-8				
	Sample Date:	5/29/92 A	7/22/94 A	7/22/96 A	12/02/98 B	5/29/92 A	7/11/96A	12/02/98 B	1/9/93 A	7/22/94 A	7/12/96 A	12/02/98 B	1/9/93 A	7/21/94 A	7/11/96 A		12/02/98 B
	Analysis Method:	EPA 601	EPA 601	EPA 601	EPA 601	EPA 601	EPA 601	EPA 601	EPA 601	EPA 601	EPA 601	EPA 601	EPA 601	EPA 601	EPA 601		EPA 601
Analyte	NCAC 2L																
Methylene Chloride (ug/L)	5.0	<200	<100	<500	<5.0	<10	<5	<5.0	**6.8**	<1	<5	<5.0	**7.8**	<1	<5		<5.0
Chloroform (ug/L)	0.19	<200	<100	<100	<1.0	<10	<1	<1.0	<1	**1.4**	<1	<1.0	<1	<1	<1		<1.0
Chloromethane (ug/L)	none	<200	<100	<100	<1.0	<10	<1	<1.0	<1	<1	<1	<1.0	<1	<1	<1		<1.0
Carbon Tetrachloride (ug/L)	0.3	<200	<100	<100	<1.0	<10	<1	<1.0	<1	<1	<1	<1.0	<1	<1	<1		<1.0
1,1-Dichloroethane (ug/L)	700	<200	<100	<100	<1.0	<10	<1	1	12	38	16	2.3	<1	<1	<1		<1.0
1,2-Dichloroethane (ug/L)	38	<200	<100	<100	<1.0	<10	<1	<1.0	<1	<1	<1	<1.0	<1	<1	<1		<1.0
1,1-Dichloroethene (ug/L)	none	<200	<100	<100	**6.9**	**54**	**89**	**203**	<1	**5.9**	**1.8**	<1.0	<1	<1	<1		<1.0
cis-1,2-Dichloroethene (ug/L)	70	NA	NA	NA	1.5	NA	NA	1.9	NA	NA	NA	<1.0	NA	NA	NA		<1.0
trans-1,2-Dichloroethene (ug/L)	70	NA	NA	NA	<1.0	NA	NA	1.6	NA	NA	NA	<1.0	NA	NA	NA		<1.0
1,2-Dichloropropane (ug/L)	0.56	<200	<100	<100	<1.0	<10	<1	<1.0	<1	<1	<1	<1.0	<1	<1	<1		<1.0
Trichloroethene (ug/L)	2.8	<200	<100	<100	1.2	<10	<1	<1.0	<1	<1	<1	<1.0	<1	<1	<1		<1.0
Tetrachloroethene (ug/L)	0.7	**9,500**	**5,100**	**6,300**	**3,200**	**11**	**28**	**66**	**1.4**	**2.4**	**1.3**	<1.0	**4.5**	**3.9**	**2.6**		**4.2**
1,1,1-Trichloroethane (ug/L)	200	<200	<100	<100	<1.0	18	16	19	4.4	6	3.4	<1.0	<1	<1	<1		<1.0
1,1,2-Trichloroethane (ug/L)	none	<200	<100	<100	<1.0	<10	2.8	2.8	<1	<1	<1	<1.0	<1	<1	<1		<1.0

Notes: Compounds detected above the North Carolina 2L Standard are shown in bold.
A - indicates samples collected by Mortensen Engineering, Inc.
B - Indicates samples collected by Fluor Daniel GTI, Inc.
NA denotes compound not analyzed
NS denotes well not sampled
Monitoring wells MW-16, MW-19, MW-24, MW-25 and MW-26 were destroyed during site construction activities.

Table 5

Groundwater Analytical Results for Shallow Groundwater Monitoring Wells

W.P. Ballard and Downgradient Properties
Greensboro, North Carolina

Sample Location:		MW-9					MW-10						MW-11				MW-12			
Sample Date:		1/9/93 A	7/21/94 A	7/9/96 A	7/9/96 B	12/02/98 B	1/9/93 A	6/25/93 A	7/21/94 A	07/10/96 A	7/10/96 B	12/02/98 B	6/25/93 A	7/9/96 A	7/9/96 B	12/02/98 B	6/25/93 A	7/9/96 A	7/9/96 B	12/02/98 B
Analysis Method:		EPA 601	EPA 601	EPA 601	EPA 601	EPA 601	EPA 601	EPA 601	EPA 601	EPA 601	EPA 601	EPA 601	EPA 601	EPA 601	EPA 601	EPA 601	EPA 601	EPA 601	EPA 601	EPA 601
Analyte	NCAC 2L																			
Methylene Chloride (ug/L)	5.0	**9.5**	<1	<5	<1	<5.0	<250	<100	<100	<2,500	<250	<5.0	<1	<5	2.4	<5.0	<1	<25	**44**	<5.0
Chloroform (ug/L)	0.19	<1	<1	<1	<1	<1.0	<250	<100	<100	<500	<250	<1.0	<1	<1	<1	<1.0	<1	<5	<1	<1.0
Chloromethane (ug/L)	none	<1	<1	<1	<1	<1.0	<250	<100	<100	<500	<250	<1.0	<1	<1	<1	<1.0	<1	<5	<1	<1.0
Carbon Tetrachloride (ug/L)	0.3	<1	<1	<1	<1	<1.0	<250	<100	<100	<500	<250	<1.0	<1	<1	<1	<1.0	<1	<5	<1	<1.0
1,1-Dichloroethane (ug/L)	700	<1	<1	<1	<1	<1.0	<250	<100	<100	<500	<250	<1 0	<1	<1	<1	<1.0	<1	<5	<1	<1.0
1,2-Dichloroethane (ug/L)	38	<1	<1	<1	<1	<1.0	<250	<100	<100	<500	<250	<1.0	<1	<1	<1	<1.0	<1	<5	<1	<1.0
1,1-Dichloroethene (ug/L)	none	<1	<1	<1	<1	<1.0	<250	<100	<100	<500	<250	<1.0	<1	<1	<1	<1.0	<1	<5	<1	<1 0
cis-1,2-Dichloroethene (ug/L)	70	NA	NA	NA	NA	<1.0	NA	NA	NA	NA	NA	5.8	NA	NA	NA	<1.0	NA	NA	NA	<1.0
trans-1,2-Dichloroethene (ug/L)	70	NA	NA	NA	NA	<1.0	NA	NA	NA	NA	NA	<1.0	NA	NA	NA	<1.0	NA	NA	NA	<1.0
1,2-Dichloropropane (ug/L)	0.56	<1	<1	<1	<1	<1.0	<250	<100	<100	<500	<250	<1.0	<1	<1	<1	<1.0	<1	<5	**54**	**209**
Trichloroethene (ug/L)	2 8	<1	<1	<1	<1	<1 0	<250	<100	<100	<500	<250	**21**	<1	<1	<1	<1.0	<1	<5	1.2	2.4
Tetrachloroethene (ug/L)	0.7	**14**	**7.7**	**4.3**	**3.8**	**9.1**	**13,000**	**7,200**	**12,000**	**12,000**	**11,000**	**12,000**	<1	<1	<1	<1.0	<1	**110**	**1**	**2.1**
1,1,1-Trichloroethane (ug/L)	200	<1	<1	<1	<1	<1.0	<250	<100	<100	<500	<250	<1.0	<1	<1	<1	<1.0	<1	<5	<1	<1 0
1,1,2-Trichloroethane (ug/L)	none	<1	<1	<1	<1	<1 0	<250	<100	<100	<500	<250	11	<1	<1	<1	<1.0	<1	<5	<1	<1 0

Sample Location		MW-13				MW-14				MW-15			MW-16		MW-17			
Sample Date:		6/25/93 A	7/9/96 A	7/9/96 B	1/21/99 B	6/25/93 A	7/9/96 A	7/9/96 B	1/21/99 B	7/10/96 A	7/10/96 B	12/02/98 B	7/10/96 A	7/10/96 B	7/10/96 A	7/10/96 B	10/07/96 B	12/02/98 B
Analysis Method:		EPA 601	EPA 601	EPA 601	EPA 601	EPA 601	EPA 601	EPA 601	EPA 601	EPA 601	EPA 601	EPA 601	EPA 601	EPA 601	EPA 601	EPA 601	EPA 601	EPA 601
Analyte	NCAC 2L																	
Methylene Chloride (ug/L)	5.0	<1	<5	1.5	<5	<1	<5	<1	<5	<25	<1	<5.0	<5	1.4	<250	<50	<10	<5.0
Chloroform (ug/L)	0.19	<1	<1	<1	<1	<1	<1	<1	<1	**28**	**27**	**24**	<1	<1	<50	<50	**31**	<1.0
Chloromethane (ug/L)	none	<1	<1	<1	<1	<1	<1	<1	<1	<5	<1	<1.0	<1	<1	<50	<50	<10	<1.0
Carbon Tetrachloride (ug/L)	0.3	<1	<1	<1	<1	<1	<1	<1	<1	**29**	**24**	**13**	<1	<1	<50	<50	**140**	**6.4**
1,1-Dichloroethane (ug/L)	700	<1	<1	<1	<1	<1	<1	<1	<1	<5	<1	<1.0	<1	<1	<50	<50	<10	<1.0
1,2-Dichloroethane (ug/L)	38	<1	<1	<1	<1	<1	<1	<1	<1	<5	<1	<1.0	<1	<1	<50	<50	<10	<1.0
1,1-Dichloroethene (ug/L)	none	<1	<1	<1	<1	<1	<1	<1	<1	<5	<1	<1.0	<1	<1	<50	<50	<10	<1.0
cis-1,2-Dichloroethene (ug/L)	70	NA	NA	NA	<1	NA	NA	NA	<1	NA	NA	16	NA	NA	NA	NA	NA	59
trans-1,2-Dichloroethene (ug/L)	70	NA	NA	NA	<1	NA	NA	NA	<1	NA	NA	<1.0	NA	NA	NA	NA	NA	<1.0
1,2-Dichloropropane (ug/L)	0.56	<1	<1	<1	<1	<1	<1	<1	<1	<5	<1	<1.0	<1	<1	<50	<50	<10	<1.0
Trichloroethene (ug/L)	2.8	<1	<1	<1	<1	<1	<1	<1	<1	**130**	**95**	**221**	<1	<1	**780**	**620**	**120**	**490**
Tetrachloroethene (ug/L)	0.7	<1	**1**	<1	<1	<1	<1	<1	<1	**42**	**33**	**39**	<1	<1	**5,200**	**5,200**	**28**	**2,600**
1,1,1-Trichloroethane (ug/L)	200	<1	<1	<1	<1	<1	<1	<1	<1	<5	<1	<1.0	<1	<1	<50	<50	<10	<1.0
1,1,2-Trichloroethane (ug/L)	none	<1	<1	<1	<1	<1	<1	<1	<1	<5	<1	<1.0	<1	<1	<50	<50	<10	<1.0

Notes: Compounds detected above the North Carolina 2L Standard are shown in bold.
A - indicates samples collected by Mortensen Engineering, Inc.
B - indicates samples collected by Fluor Daniel GTI, Inc.
NA denotes compound not analyzed
NS denotes well not sampled
Monitoring wells MW-16, MW-19, MW-24, MW-25 and MW-26 were destroyed during site construction activities.

Table 5

Groundwater Analytical Results for Shallow Groundwater Monitoring Wells

W.P. Ballard and Downgradient Properties
Greensboro, North Carolina

Sample Location:		MW-18			MW-19		MW-20				MW-21			MW-22		
Sample Date:		10/7/96A	10/07/96 B	12/02/98 B	10/7/96 A	10/7/96 B	10/7/96 A	10/7/96 B	12/02/98 B	01/21/99 B	10/7/96 A	10/7/96 B	12/02/98 B	10/7/96 A	10/7/96 B	12/02/98 B
Analysis Method:		EPA 601	EPA 601	EPA 601	EPA 601	EPA601	EPA 601	EPA601	EPA 601	EPA 601	EPA 601	EPA601	EPA 601	EPA 601	EPA601	EPA 601
Analyte	NCAC 2L															
Methylene Chloride (ug/L)	5.0	<250	<100	<5.0	<2.5	<1	<2.5	<1	<5	<5	<2.5	<1	<5.0	<120	<1	<5.0
Chloroform (ug/L)	0.19	<50	<19	<1.0	<0.50	<0.19	<0.50	<0.19	<1	<1	<0.50	<0.19	<1.0	<25	<0.19	<1.0
Chloromethane (ug/L)	none	<50	<200	<1.0	<0.50	<2	<0.50	<2	<1	<1	<0.50	<2	<1.0	<25	<2	<1.0
Carbon Tetrachloride (ug/L)	0.3	<50	<30	<1.0	<0.50	<0.30	<0.50	<0.30	<1	<1	<0.50	<0.30	<1.0	<25	<0.30	<1.0
1,1-Dichloroethane (ug/L)	700	<50	<100	<1.0	<0.50	<1	<0.50	<1	<1	<1	<0.50	<1	<1.0	<25	<1	<1.0
1,2-Dichloroethane (ug/L)	38	<50	<100	<1.0	<0.50	<1	<0.50	<1	<1	<1	<0.50	<1	<1.0	<25	<1	<1.0
1,1-Dichloroethene (ug/L)	none	<50	<100	<1.0	<0.50	<1	<0.50	<1	<1	<1	<0.50	<1	<1.0	<25	<1	<1.0
cis-1,2-Dichloroethene (ug/L)	70	NA	NA	18	NA	NA	NA	NA	<1	<1	NA	NA	1.9	NA	NA	31.4
trans-1,2-Dichloroethene (ug/L)	70	NA	NA	<1.0	NA	NA	NA	NA	<1	<1	NA	NA	<1.0	NA	NA	<1.0
1,2-Dichloropropane (ug/L)	0.56	<50	<20	<1.0	<0.50	<0.20	<0.50	<0.20	<1	<1	<0.50	<0.20	<1.0	<25	**2.8**	<1.0
Trichloroethene (ug/L)	2.8	**440**	**380**	**680**	<0.50	<1	<0.50	<1	<1	<1	**11**	<1	**39**	**62**	**53**	**110**
Tetrachloroethene (ug/L)	0.7	**2,100**	**1,600**	**2,100**	<0.50	<0.70	<0.50	<0.70	<1	<1	**98**	**7.7**	**310**	**1500**	**910**	**1,240**
1,1,1-Trichloroethane (ug/L)	200	<50	<100	<1.0	<0.50	<1	<0.50	<1	<1	<1	<0.50	<1	<1.0	<25	<1	<1.0
1,1,2-Trichloroethane (ug/L)	none	<50	<100	<1.0	<0.50	<1	<0.50	<1	<1	<1	<0.50	<1	<1.0	<25	<1	<1.0

Sample Location:		MW-23			MW-24		MW-25		MW-26		MW-27		MW-28		LMP-1	LMP-2
Sample Date:		10/7/96 A	10/7/96 B	12/02/98 B	10/7/96 A	10/7/96 B	10/7/96 A	10/7/96 B	10/7/96 A	10/7/96 B	8/26/97 B	12/2/98 B	8/26/97 B	12/2/98 B	01/21/99 B	01/21/99 B
Analysis Method:		EPA 601	EPA601	EPA 601	EPA 601	EPA601	EPA 601	EPA601	EPA 601	EPA601	EPA 601	EPA 601	EPA 601	EPA 601	EPA 601	EPA 601
Analyte	NCAC 2L															
Methylene Chloride (ug/L)	5.0	**9.3**	**6.5**	<5.0	<0.05	<1	<2.5	<1	<2.5	<1	<200	<5.0	<200	<5.0	<5.0	<5.0
Chloroform (ug/L)	0.19	**4.7**	**3.8**	<1.0	<0.50	<0.19	<0.50	<0.19	**0.97**	**0.49**	<200	<1.0	<200	<1.0	<1.0	<1.0
Chloromethane (ug/L)	none	<0.50	<2	<1.0	<0.50	<2	<0.50	<2	<0.50	<2	<200	<1.0	<200	<1.0	<1.0	<1.0
Carbon Tetrachloride (ug/L)	0.3	<0.50	<0.30	<1.0	<0.50	<0.30	<0.50	<0.30	<0.50	<0.30	<200	<1.0	<200	<1.0	<1.0	<1.0
1,1-Dichloroethane (ug/L)	700	<0.50	<1	<1.0	<0.50	<1	<0.50	<1	<0.50	<1	<200	<1.0	<200	<1.0	<1.0	<1.0
1,2-Dichloroethane (ug/L)	38	<0.50	<1	<1.0	<0.50	<1	<0.50	<1	<0.50	<1	<200	<1.0	<200	<1.0	<1.0	<1.0
1,1-Dichloroethene (ug/L)	none	<0.50	<1	<1.0	<0.50	<1	<0.50	<1	<0.50	<1	<200	<1.0	<200	<1.0	<1.0	<1.0
cis-1,2-Dichloroethene (ug/L)	70	NA	NA	<1.0	NA	NA	NA	NA	NA	NA	**12,000**	**2,300**	**280**	**1,170**	**47.8**	10
trans-1,2-Dichloroethene (ug/L)	70	NA	NA	<1.0	NA	NA	NA	NA	NA	NA	<200	13	<200	**3**	**1.4**	<1.0
1,2-Dichloropropane (ug/L)	0.56	<0.50	<0.20	<1.0	<0.50	<0.20	<0.50	<0.20	<0.50	<0.20	<200	<1.0	<200	<1.0	**1370**	**238**
Trichloroethene (ug/L)	2.8	<0.50	<1	<1.0	<0.50	<1	<0.50	<1	<0.50	<1	**64,000**	**8,340**	**180**	**800**	<1.0	<1.0
Tetrachloroethene (ug/L)	0.7	<0.50	<0.70	<1.0	<0.50	<0.70	<0.50	<0.70	<0.50	<0.70	<200	<1.0	<200	**70**	**192**	**25.4**
1,1,1-Trichloroethane (ug/L)	200	<0.50	<1	<1.0	<0.50	<1	<0.50	<1	<0.50	<1	<200	<1.0	<200	<1.0	<1.0	<1.0
1,1,2-Trichloroethane (ug/L)	none	<0.50	<1	<1.0	<0.50	<1	<0.50	<1	<0.50	<1	<200	<1.0	<200	<1.0	<1.0	<1.0
															<1.0	<1.0

Notes: Compounds detected above the North Carolina 2L Standard are shown in bold.
A - indicates samples collected by Mortensen Engineering, Inc.
B - indicates samples collected by Fluor Daniel GTI, Inc.
NA denotes compound not analyzed
NS denotes well not sampled
Monitoring wells MW-16, MW-19, MW-24, MW-25 and MW-26 were destroyed during site construction activities.

Table 6

Summary of Deep Groundwater Analytical Data

W.P. Ballard and Downgradient Properties
Greensboro, North Carolina

	Sample Location:	DW-1			DW-2			DW-3				DW-4			DW-5		
	Sample Date:	7/22/94 A	7/12/96 A	12/2/98 B	7/22/94 A	7/11/96 A	12/2/98 B	7/22/94 A	7/10/96 A	7/10/96 B	12/2/98 B	7/22/94 A	7/11/96 A	12/2/98 B	7/15/96 A	7/15/96 B	12/2/98 B
	Analysis Method:	EPA 601	EPA601	EPA 601	EPA 601	EPA 601	EPA 601	EPA 601	EPA 601	EPA 601	EPA 601	EPA 601	EPA 601	EPA 601	EPA 601	EPA 601	EPA 601
Analyte	**NCAC 2L**																
Methylene Chloride (ug/L)	5.0	1.2	**14**	<5.0	<1.0	<12	<5.0	<100	<12,000	<1,000	**50**	<100	<1,200	<5.0	<5	<10	<5.0
Chloroform (ug/L)	0.19	**6.1**	<1.0	<1.0	**3.2**	<2.5	<1.0	<100	<2,500	<1,000	**4**	<100	<250	<1.0	**20**	**31**	**20**
Chloromethane (ug/L)	none	<1.0	<1.0	<1.0	<1.0	<2.5	<1.0	<100	<2,500	<2,000	<1.0	<100	<250	<1.0	<1.0	<10	<1.0
Carbon Tetrachloride (ug/L)	0.3	<1.0	<1.0	<1.0	<1.0	<2.5	<1.0	<100	<2,500	<1,000	<1.0	<100	<250	<1.0	**100**	**140**	**27**
1,1-Dichloroethane (ug/L)	700	<1.0	<1.0	<1.0	<1.0	<2.5	<1.0	<100	<2,500	<1,000	<1.0	<100	<250	<1.0	<1.0	<10	<1.0
1,2-Dichloroethane (ug/L)	38	<1.0	<1.0	<1.0	<1.0	<2.5	<1.0	<100	<2,500	<1,000	<1.0	<100	<250	<1.0	2.7	<10	<1.0
1,1-Dichloroethene (ug/L)	none	**1.6**	**4.6**	<1.0	**23**	<2.5	<1.0	<100	<2,500	<1,000	**3**	<100	<250	<1.0	<1.0	<10	<1.0
cis-1,2-Dichloroethene (ug/L)	70	NA	NA	29.2	NA	NA	<1.0	NA	NA	NA	24.5	NA	NA	**97.7**	NA	NA	14
trans-1,2-Dichloroethene (ug/L)	70	NA	NA	<1.0	NA	NA	<1.0	NA	NA	NA	1.4	NA	NA	<1.0	NA	NA	<1.0
1,2-Dichloropropane (ug/L)	0.56	<1.0	<1.0	<1.0	<1.0	<2.5	<1.0	<100	<2,500	<1,000	<1.0	<100	<250	<1.0	<1.0	<10	<1.0
Trichloroethene (ug/L)	2.8	<1.0	**3**	**52.1**	<1.0	<2.5	1	<100	<2,500	<1,000	**56.1**	<100	<250	**64.4**	**94**	**120**	**78**
Tetrachloroethene (ug/L)	0.7	**31**	**59**	**182**	**55**	**110**	126	**19,000**	**82,000**	**60,000**	**66,000**	**10,000**	**16,000**	**8,600**	**19**	**28**	**54**
1,1,1-Trichloroethane (ug/L)	200	1.4	4.8	3	4.4	5.6	<1.0	<100	<2,500	<1,000	<1.0	<100	<250	<1.0	<1.0	<10	<1.0
1,1,2-Trichloroethane (ug/L)	none	<1.0	<1.0	<1.0	<1.0	<2.5	<1.0	<100	<2,500	<1,000	**21.1**	<100	<250	<1.0	<1.0	<10	<1.0

	Sample Location:	DW-6		DW-7			DW-8			DW-9				
	Sample Date:	7/15/96 A	7/15/96 B	7/15/96 A	7/15/96 B	12/2/98 B	7/15/96 A	7/15/96 B	12/2/98 B	7/15/96 A	7/15/96 B	10/6/96 A	10/6/96 B	12/2/98 B
	Analysis Method:	EPA 601	EPA 601	EPA 601	EPA 601	EPA 601	EPA 601	EPA 601	EPA 601	EPA 601	EPA 601	EPA 601	EPA 601	EPA 601
Analyte	**NCAC 2L**													
Methylene Chloride (ug/L)	5.0	<5	<1.0	<25	<1.0	<5.0	<500	<100	<5.0	<5	<1.0	**5.3**	**6**	<5.0
Chloroform (ug/L)	0.19	**1.5**	**2.6**	<5	**2.9**	<1.0	<100	<100	<1.0	**3.4**	**4.5**	**1.5**	**1.2**	<1.0
Chloromethane (ug/L)	none	<1.0	<2.0	<5	<2.0	<1.0	<100	<200	<1.0	<1.0	<2.0	<0.50	<2.0	<1.0
Carbon Tetrachloride (ug/L)	0.3	<1.0	<1.0	<5	<1.0	<1.0	<100	<100	<1.0	<1.0	<1.0	<0.50	<0.30	<1.0
1,1-Dichloroethane (ug/L)	700	<1.0	<1.0	<5	<1.0	<1.0	<100	<100	<1.0	<1.0	<1.0	<0.50	<1.0	<1.0
1,2-Dichloroethane (ug/L)	38	<1.0	<1.0	<5	<1.0	<1.0	<100	<100	<1.0	<1.0	<1.0	<0.50	<1.0	<1.0
1,1-Dichloroethene (ug/L)	none	<1.0	<1.0	<5	<1.0	<1.0	<100	<100	<1.0	<1.0	<1.0	<0.50	<1.0	<1.0
cis-1,2-Dichloroethene (ug/L)	70	NA	NA	NA	NA	<1.0	NA	NA	**280**	NA	NA	NA	NA	<1.0
trans-1,2-Dichloroethene (ug/L)	70	NA	NA	NA	NA	<1.0	NA	NA	<1.0	NA	NA	NA	NA	<1.0
1,2-Dichloropropane (ug/L)	0.56	<1.0	<1.0	<5	**2.1**	<1.0	<100	<100	<1.0	<1.0	<1.0	<0.50	<0.20	<1.0
Trichloroethene (ug/L)	2.8	<1.0	<1.0	<5	1.0	**10**	**630**	**440**	**380**	<1.0	<1.0	<0.50	<1.0	<1.0
Tetrachloroethene (ug/L)	0.7	**1.1**	**1.6**	**230**	**180**	**205**	**3,700**	**2,600**	**1,620**	<1.0	**3.4**	<0.50	<0.70	<1.0
1,1,1-Trichloroethane (ug/L)	200	<1.0	<1.0	<5	<1.0	<1.0	<100	<100	<1.0	<1.0	<1.0	<0.50	<1.0	<1.0
1,1,2-Trichloroethane (ug/L)	none	<1.0	<1.0	<5	<1.0	<1.0	<100	<100	<1.0	<1.0	<1.0	<0.50	<1.0	<1.0

Notes: Compounds detected above the North Carolina 2L Standard are shown in bold.
A - indicates samples collected by Mortensen Engineering, Inc.
B - indicates samples colected by Fluor Daniel GTI, Inc.
NA denotes compound not analyzed
Deep monitoring wells DW-6 and DW-10 were destroyed during site construction activities.

Table 6

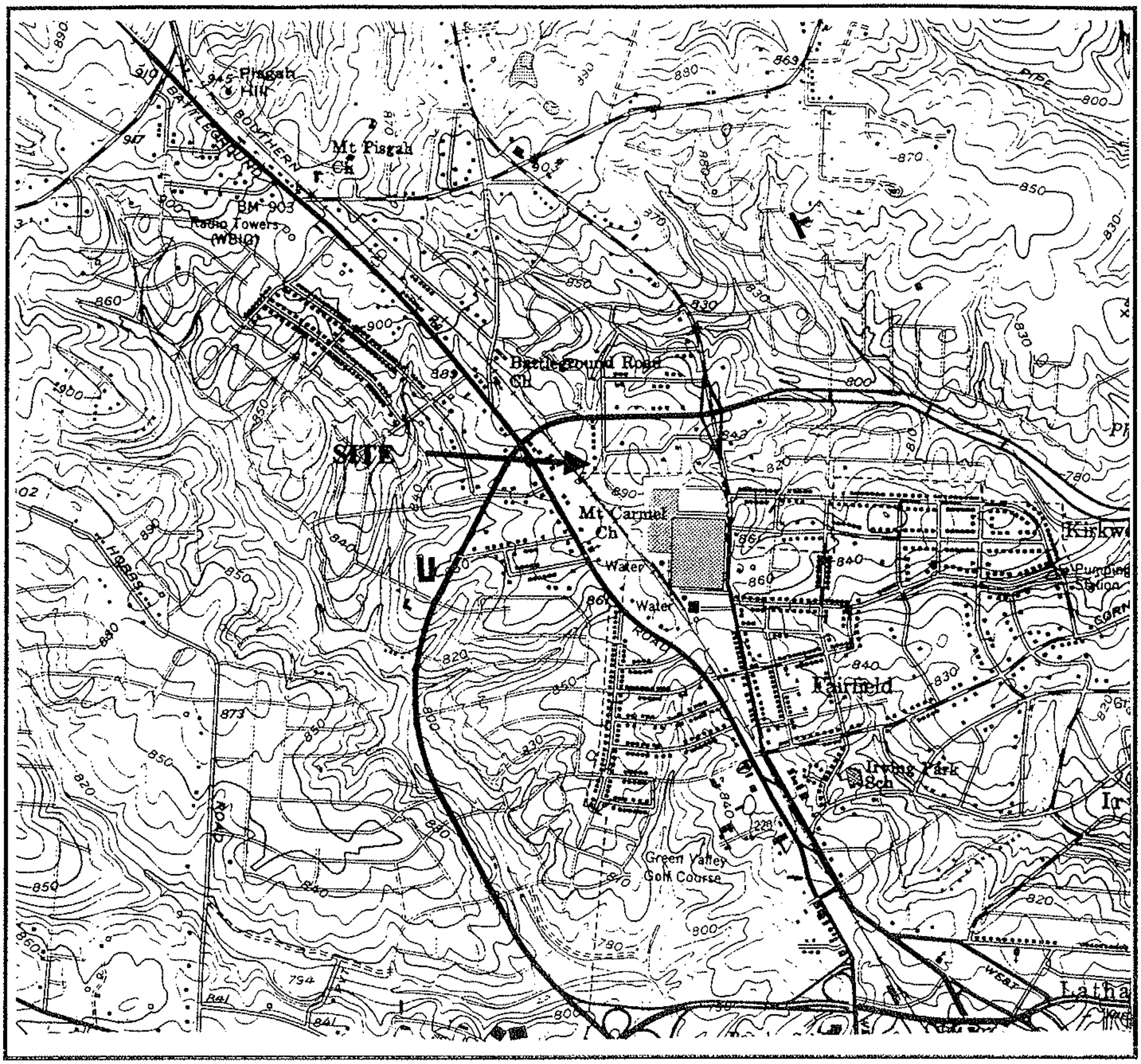
Summary of Deep Groundwater Analytical Data

W.P. Ballard and Downgradient Properties
Greensboro, North Carolina

Sample Location:		DW-10				DW-11			DW-12			DMP-1	DMP-2	DMP-3	DMP-4
Sample Date:		7/15/96 A	7/15/96 B	10/6/96 A	10/6/96 B	10/6/96 A	10/6/96 B	12/2/98 B	10/6/96 A	10/6/96 B	12/2/98 B	1/21/99 B	1/21/99 B	1/21/99 B	1/21/99 B
Analysis Method:		EPA 601	EPA 601	EPA 601	EPA 601	EPA 601	EPA 601	EPA 601	EPA 601	EPA 601	EPA 601	EPA 601	EPA 601	EPA 601	EPA 601
Analyte	**NCAC 2L**														
Methylene Chloride (ug/L)	5.0	<5	<1.0	<2.5	<1.0	<2.5	<1.0	<5.0	<2.5	<1.0	<5.0	<5.0	<5.0	<25.0	<50.0
Chloroform (ug/L)	0.19	<1.0	**3.1**	<0.50	<0.19	**7.1**	**5.4**	<1.0	**4.1**	**4.2**	<1.0	**6.0**	**7.5**	<5.0	<10.0
Chloromethane (ug/L)	none	<1.0	<2.0	<0.50	<2.0	<0.50	<2.0	<1.0	<0.50	<2.0	<1.0	<1.0	<5.0	<5.0	<10.0
Carbon Tetrachloride (ug/L)	0.3	<1.0	<1.0	<0.50	<0.30	<0.50	<0.30	<1.0	<0.50	<0.030	<1.0	<1.0	<5.0	<5.0	<10.0
1,1-Dichloroethane (ug/L)	700	<1.0	<1.0	<0.50	<1.0	<0.50	<1.0	<1.0	<0.50	<1.0	<1.0	<1.0	<5.0	<5.0	<10.0
1,2-Dichloroethane (ug/L)	38	<1.0	<1.0	<0.50	<1.0	<0.50	<1.0	<1.0	<0.50	<1.0	<1.0	<1.0	<5.0	<5.0	<10.0
1,1-Dichloroethene (ug/L)	none	<1.0	<1.0	<0.50	<1.0	<0.50	<1.0	<1.0	<0.50	<1.0	<1.0	<1.0	<5.0	<5.0	<10.0
cis-1,2-Dichloroethene (ug/L)	70	NA	NA	NA	NA	NA	NA	<1.0	NA	NA	<1.0	**1520**	**24.5**	<5.0	**259**
trans-1,2-Dichloroethene (ug/L)	70	NA	NA	NA	NA	NA	NA	<1.0	NA	NA	<1.0	**24.0**	<5.0	<5.0	<10.0
1,2-Dichloropropane (ug/L)	0.56	<1.0	<1.0	<0.50	<0.20	<0.50	<0.20	<1.0	<0.50	<0.20	<1.0	**28.0**	<5.0	<5.0	<10.0
Trichloroethene (ug/L)	2.8	<1.0	<1.0	<0.50	<1.0	<0.50	<1.0	<1.0	<0.50	<1.0	<1.0	<1.0	<5.0	<5.0	<10.0
Tetrachloroethene (ug/L)	0.7	<1.0	**1.9**	<0.50	<0.70	<0.50	<0.70	<1.0	<0.50	<0.70	<1.0	**60.7**	**254**	**580**	**3460**
1,1,1-Trichloroethane (ug/L)	200	<1.0	<1.0	<0.50	<1.0	<0.50	<1.0	<1.0	<0.50	<1.0	<1.0	<1.0	<5.0	<5.0	<10.0
1,1,2-Trichloroethane (ug/L)	none	<1.0	<1.0	<0.50	<1.0	<0.50	<1.0	<1.0	<0.50	<1.0	<1.0	<1.0	<5.0	<5.0	<10.0

Notes: Compounds detected above the North Carolina 2L Standard are shown in bold.
A - indicates samples collected by Mortensen Engineering, Inc.
B - indicates samples colected by Fluor Daniel GTI, Inc.
NA denotes compound not analyzed
Deep monitoring wells DW-6 and DW-10 were destroyed during site construction activities.

FIGURES



SOURCE: U.S.G.S. TOPOGRAPHIC QUADRANGLE
GREENSBORO QUADRANGLE
7.5 MINUTE SERIES
PHOTO REVISED 1963

SCALE 1:24,000

0 2,000 4,000

SCALE FEET

N

IT CORPORATION
A Member of The IT Group

1000 PERIMETER PARK DR.
SUITE I
MORRISVILLE, NC 27560
(919) 467-2227

DESIGNED:

DETAILED: RHW

CHECKED:

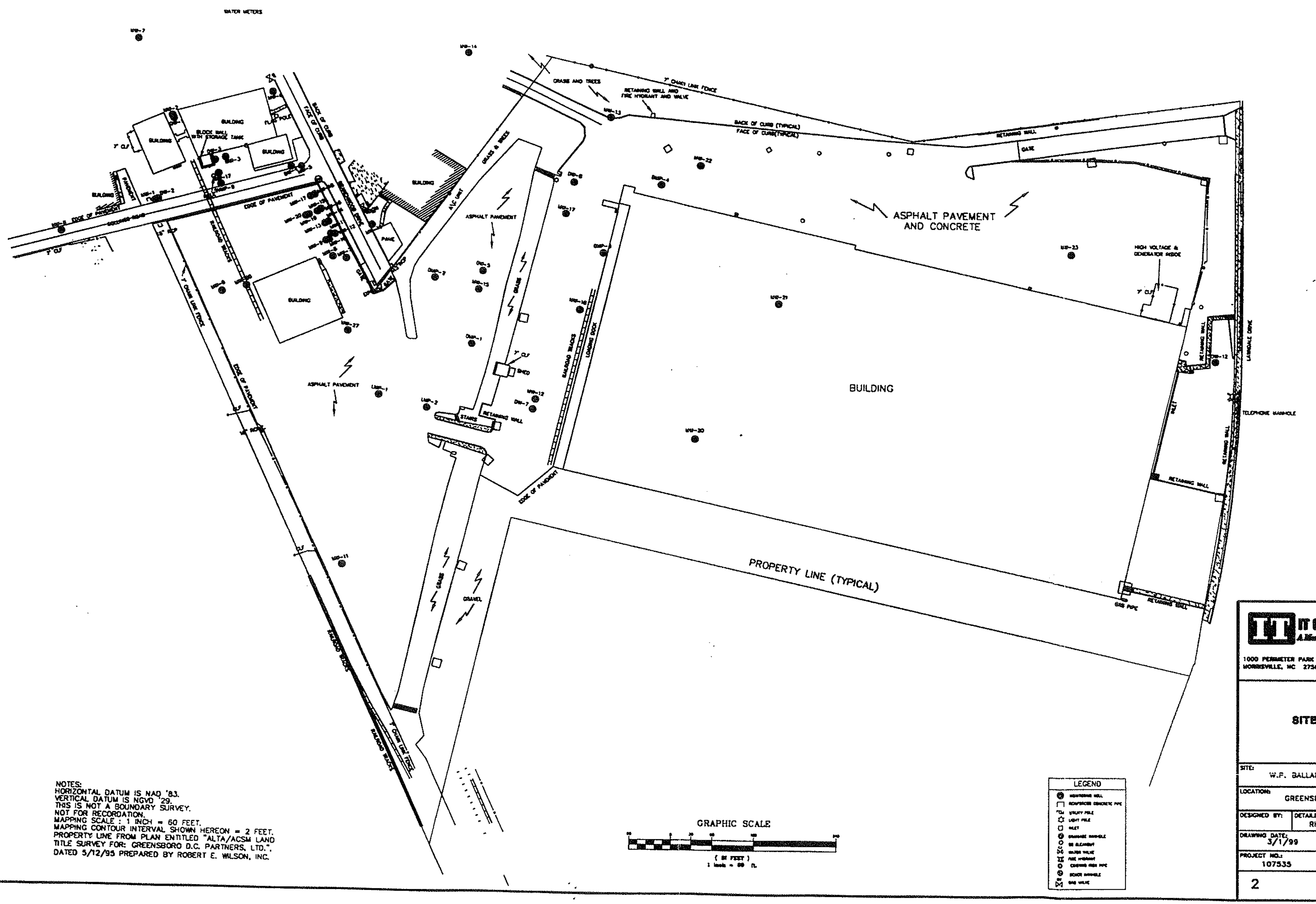
SITE LOCATION MAP
W.P. BALLARD AND DOWNGRADIENT PROPERTIES

SITE: W.P. BALLARD PROPERTY

DRAWING DATE: 3/19/99

LOCATION: GREENSBORO, NC

FIGURE: 1



NOTES:
HORIZONTAL DATUM IS NAD '83.
VERTICAL DATUM IS NGVD '29.
THIS IS NOT A BOUNDARY SURVEY.
NOT FOR RECORDATION.
MAPPING SCALE : 1 INCH = 60 FEET.
MAPPING CONTOUR INTERVAL SHOWN HEREON = 2 FEET.
PROPERTY LINE FROM PLAN ENTITLED "ALTA/ACSM LAND TITLE SURVEY FOR: GREENSBORO D.C. PARTNERS, LTD.", DATED 5/12/95 PREPARED BY ROBERT E. WILSON, INC.

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1000 PERIMETER PARK DR.
MORRISVILLE, NC 27560
(919) 467-2227

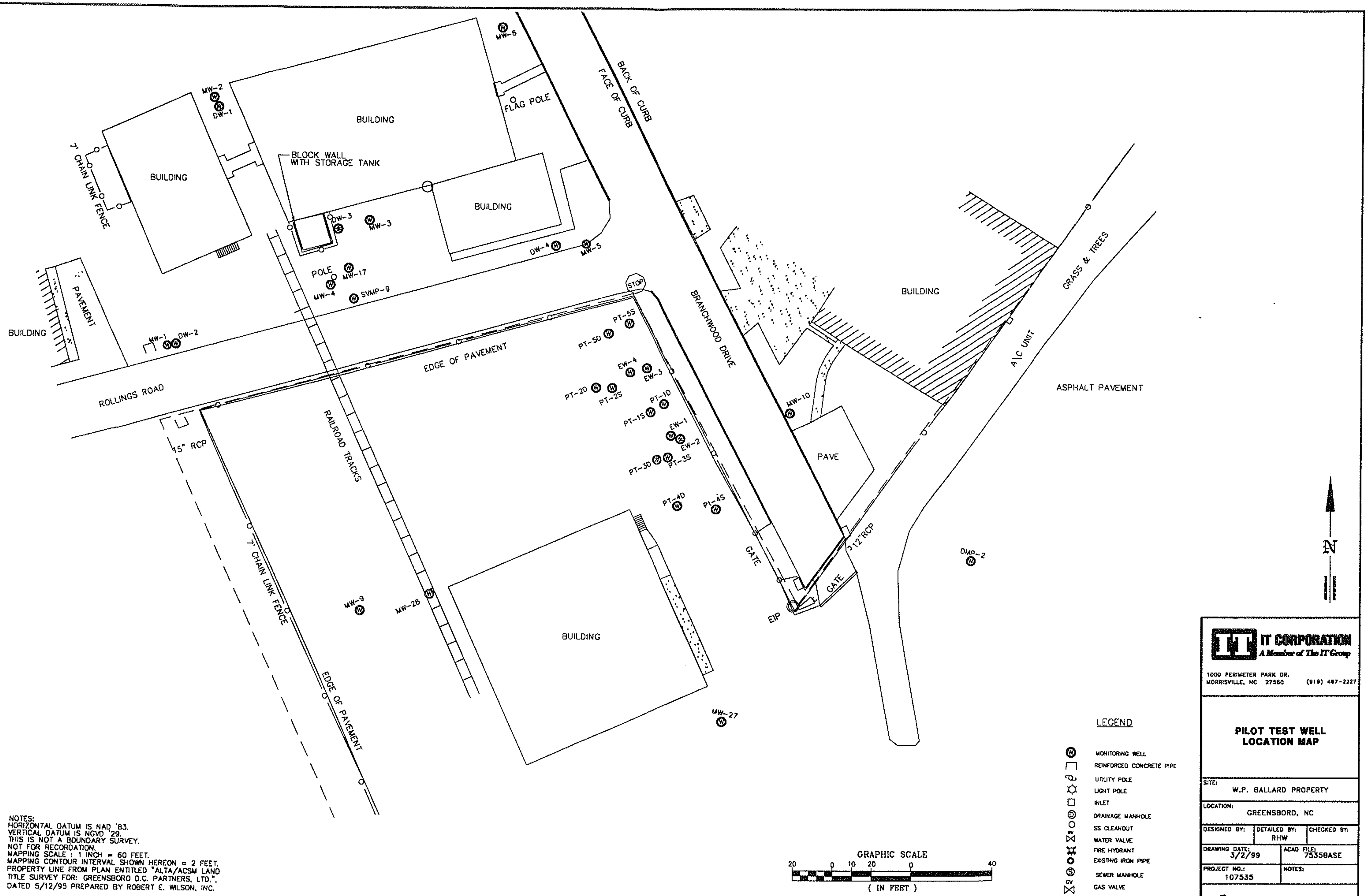
SITE MAP

SITE: W.F. BALLARD PROPERTY
LOCATION: GREENSBORO, NC

DESIGNED BY:	DETAILED BY:	CHECKED BY:
	RHW	

DRAWING DATE:	ACAD FILE:
3/1/99	site2
PROJECT NO.: 107535	NOTES:

2



NOTES:
HORIZONTAL DATUM IS NAD '83.
VERTICAL DATUM IS NGVD '29.
THIS IS NOT A BOUNDARY SURVEY.
NOT FOR RECORDATION.
MAPPING SCALE : 1 INCH = 60 FEET.
MAPPING CONTOUR INTERVAL SHOWN HEREON = 2 FEET.
PROPERTY LINE FROM PLAN ENTITLED "ALTA/ACSM LAND TITLE SURVEY FOR: GREENSBORO D.C. PARTNERS, LTD.", DATED 5/12/95 PREPARED BY ROBERT E. WILSON, INC.

LEGEND

Ⓦ	MONITORING WELL
⊓	REINFORCED CONCRETE PIPE
⚲	UTILITY POLE
☼	LIGHT POLE
□	INLET
Ⓓ	DRAINAGE MANHOLE
○	SS CLEANOUT
⋈	WATER VALVE
⌖	FIRE HYDRANT
●	EXISTING IRON PIPE
Ⓢ	SEWER MANHOLE
GV ⋈	GAS VALVE

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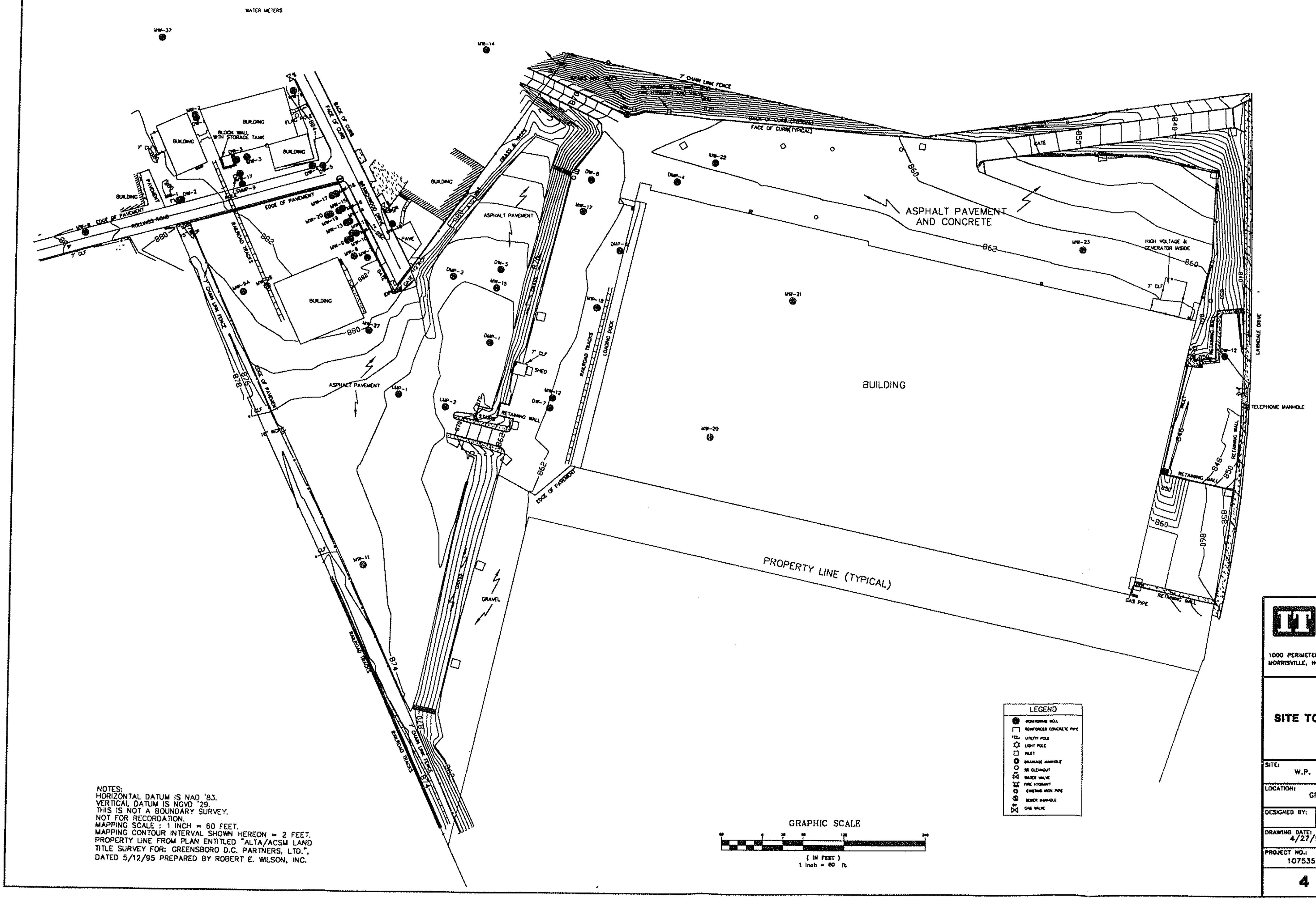
1000 PERIMETER PARK DR.
MORRISVILLE, NC 27560 (919) 467-2227

PILOT TEST WELL LOCATION MAP

SITE: W.P. BALLARD PROPERTY		
LOCATION: GREENSBORO, NC		
DESIGNED BY:	DETAILED BY: RHW	CHECKED BY:
DRAWING DATE: 3/2/99	ACAD FILE: 7535BASE	
PROJECT NO.: 107535	NOTES:	

3



NOTES:
HORIZONTAL DATUM IS NAD '83.
VERTICAL DATUM IS NGVD '29.
THIS IS NOT A BOUNDARY SURVEY.
NOT FOR RECORDATION.
MAPPING SCALE : 1 INCH = 60 FEET.
MAPPING CONTOUR INTERVAL SHOWN HEREON = 2 FEET.
PROPERTY LINE FROM PLAN ENTITLED "ALTA/ACSM LAND TITLE SURVEY FOR: GREENSBORO D.C. PARTNERS, LTD.", DATED 5/12/95 PREPARED BY ROBERT E. WILSON, INC.

IT CORPORATION OF NORTH CAROLINA, INC.
A Member of The IT Group

1000 PERIMETER PARK DR.
MORRISVILLE, NC 27560 (919) 467-2227

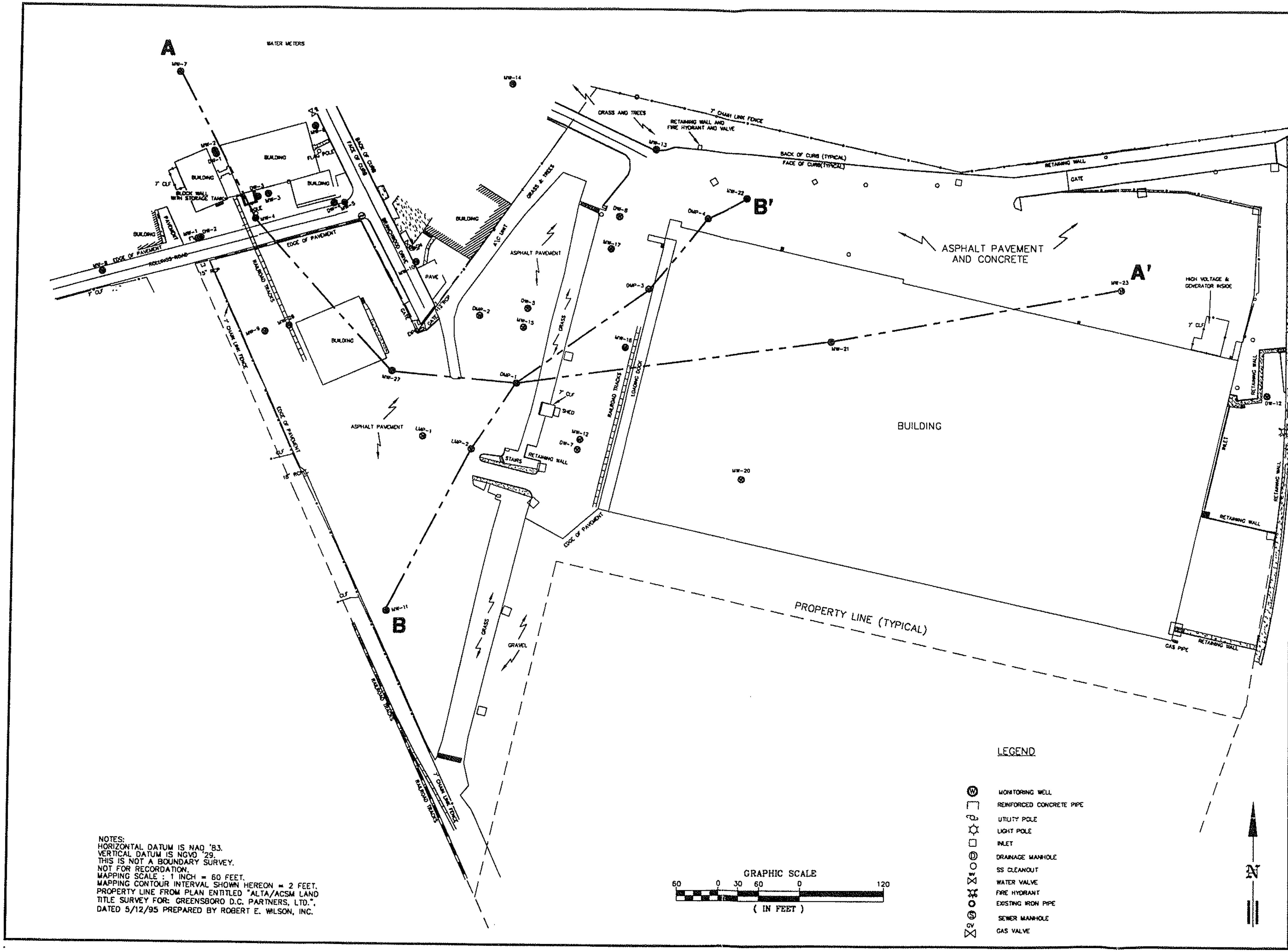
SITE TOPOGRAPHIC MAP

SITE: W.P. BALLARD PROPERTY

LOCATION: GREENSBORO, NC

DESIGNED BY:	DETAILED BY: RHW	CHECKED BY:
DRAWING DATE: 4/27/99	ACAD FILE: 7535TVOCO	
PROJECT NO.: 107535	NOTES:	

4



NOTES:
HORIZONTAL DATUM IS NAD '83.
VERTICAL DATUM IS NGVD '29.
THIS IS NOT A BOUNDARY SURVEY.
NOT FOR RECORDATION.
MAPPING SCALE : 1 INCH = 60 FEET.
MAPPING CONTOUR INTERVAL SHOWN HEREON = 2 FEET.
PROPERTY LINE FROM PLAN ENTITLED "ALTA/ACSM LAND TITLE SURVEY FOR: GREENSBORO D.C. PARTNERS, LTD.", DATED 5/12/95 PREPARED BY ROBERT E. WILSON, INC.

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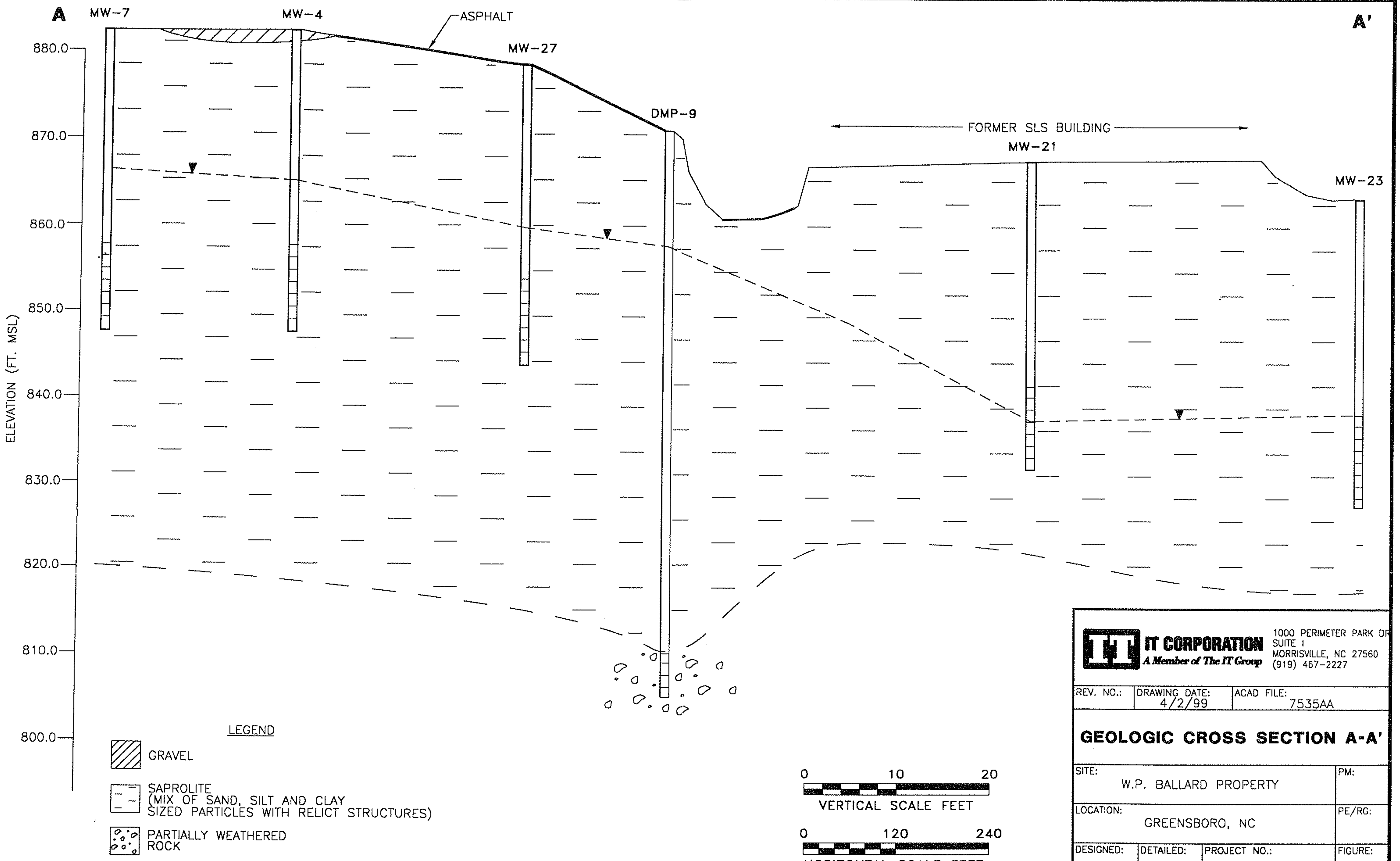
1000 PERIMETER PARK DR.
MORRISVILLE, NC 27560 (919) 467-2227

CROSS SECTION LOCATION MAP

SITE: W.P. BALLARD PROPERTY		
LOCATION: GREENSBORO, NC		
DESIGNED BY:	DETAILED BY: RHW	CHECKED BY:
DRAWING DATE: 4/1/99	ACAD FILE: 7535XLOC	
PROJECT NO.: 107535	NOTES:	

5



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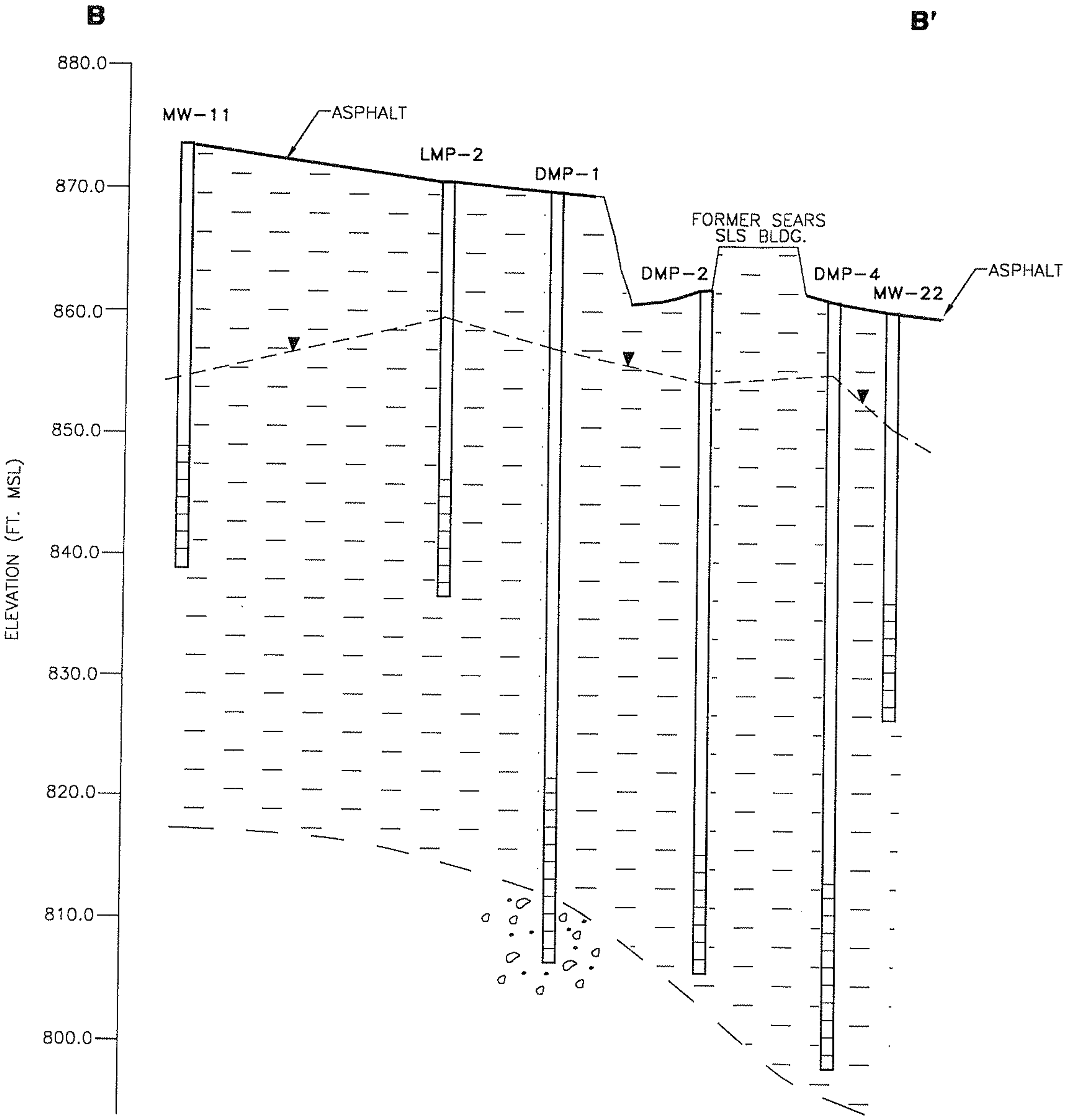
SUITE I
MORRISVILLE, NC 27560
(919) 467-2227

REV. NO.:	DRAWING DATE: 4/2/99	ACAD FILE: 7535AA

GEOLOGIC CROSS SECTION A-A'

SITE: W.P. BALLARD PROPERTY		PM:
LOCATION: GREENSBORO, NC		PE/RG:
DESIGNED:	DETAILED: RHW	PROJECT NO.: 107535	FIGURE: 6



LEGEND

- SAPROLITE (MIX OF SAND, SILT AND CLAY SIZED PARTICLES WITH RELICT STRUCTURES)
- PARTIALLY WEATHERED ROCK

0 10 20
VERTICAL SCALE FEET

0 120 240
HORIZONTAL SCALE FEET

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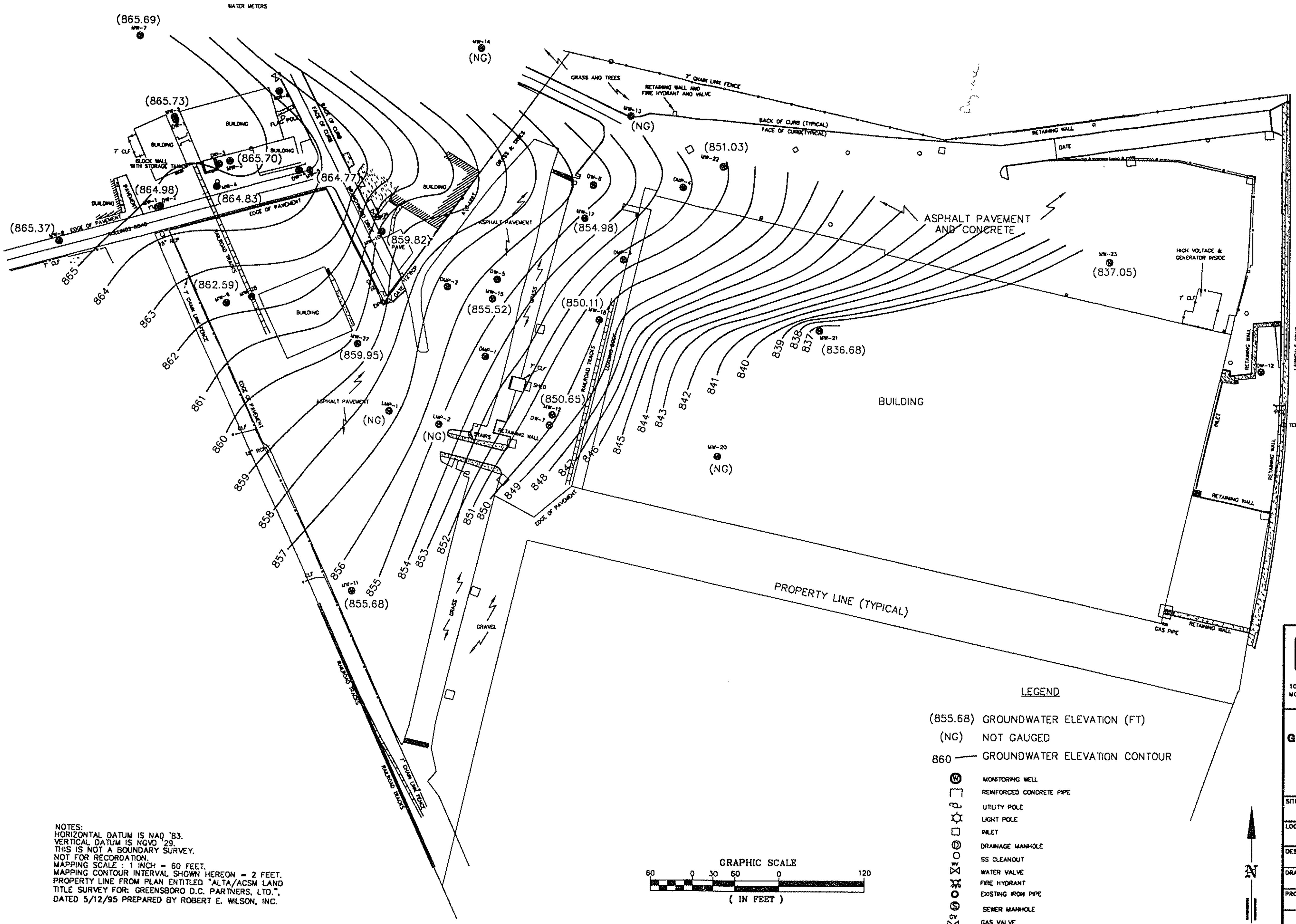
SUITE I
MORRISVILLE, NC 27560
(919) 467-2227

REV. NO.:	DRAWING DATE: 4/2/99	ACAD FILE: 7535BB

GEOLOGIC CROSS SECTION B-B'

SITE: W.P. BALLARD PROPERTY	PM:
LOCATION: GREENSBORO, NC	PE/RG:

DESIGNED:	DETAILED: RHW	PROJECT NO.: 107535	FIGURE: 7



NOTES:
HORIZONTAL DATUM IS NAD '83.
VERTICAL DATUM IS NGVD '29.
THIS IS NOT A BOUNDARY SURVEY.
NOT FOR RECORDATION.
MAPPING SCALE : 1 INCH = 60 FEET.
MAPPING CONTOUR INTERVAL SHOWN HEREON = 2 FEET.
PROPERTY LINE FROM PLAN ENTITLED "ALTA/ACSM LAND TITLE SURVEY FOR: GREENSBORO D.C. PARTNERS, LTD.", DATED 5/12/95 PREPARED BY ROBERT E. WILSON, INC.

LEGEND

(855.68)	GROUNDWATER ELEVATION (FT)
(NG)	NOT GAUGED
860 —	GROUNDWATER ELEVATION CONTOUR
Ⓦ	MONITORING WELL
⊓	REINFORCED CONCRETE PIPE
	UTILITY POLE
☼	LIGHT POLE
□	INLET
Ⓓ	DRAINAGE MANHOLE
○	SS CLEANOUT
WV ⋈	WATER VALVE
	FIRE HYDRANT
●	EXISTING IRON PIPE
Ⓢ	SEWER MANHOLE
GV ⋈	GAS VALVE

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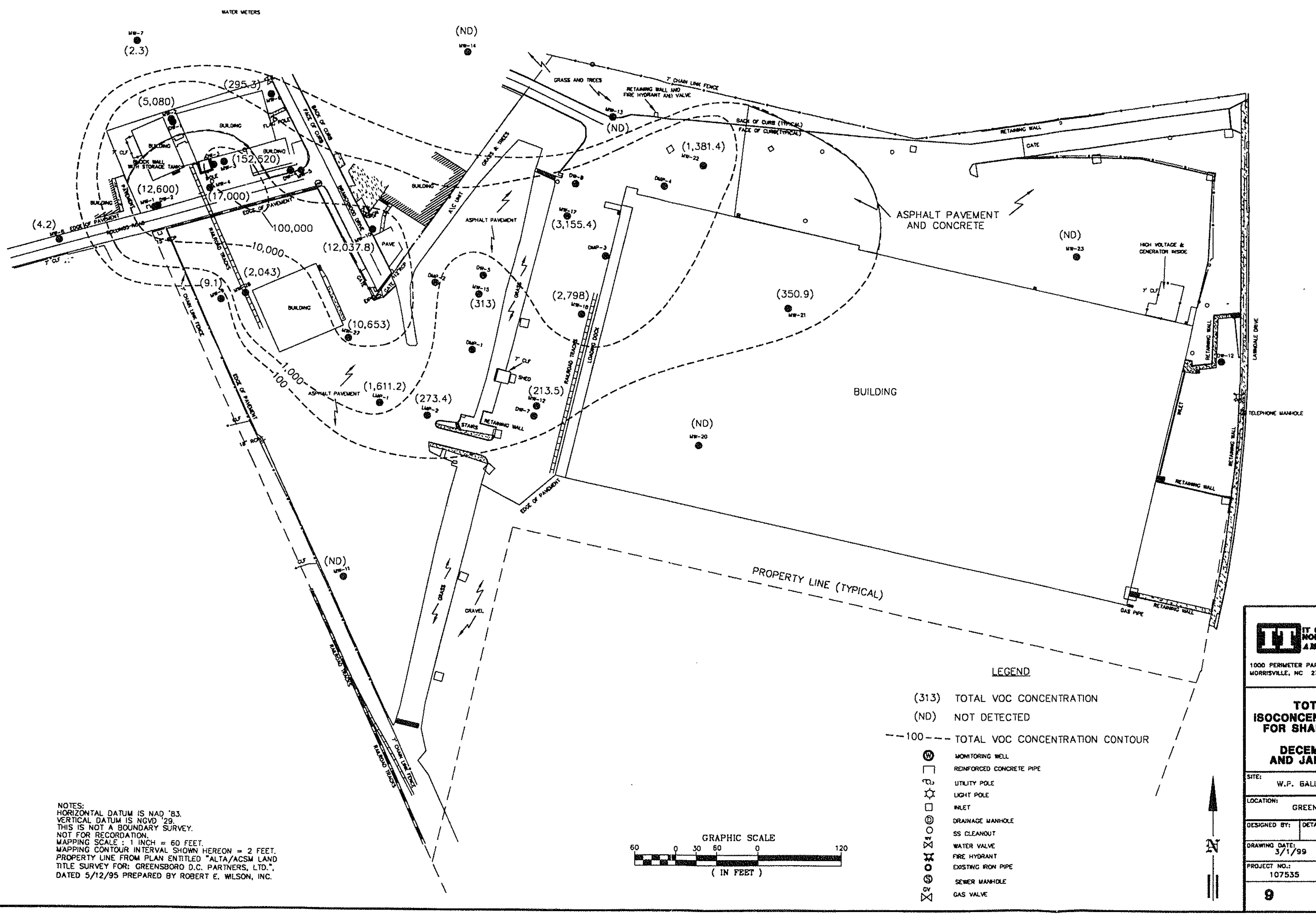
GROUNDWATER ELEVATION CONTOUR MAP

DECEMBER 1998

SITE: W.P. BALLARED PROPERTY
LOCATION: GREENSBORO, NC
DESIGNED BY:
DETAILED BY: RHW
CHECKED BY:
DRAWING DATE: 3/1/99
ACAD FILE: site2
PROJECT NO.: 107535
NOTES:

8



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LEGEND

(313)	TOTAL VOC CONCENTRATION
(ND)	NOT DETECTED
--100---	TOTAL VOC CONCENTRATION CONTOUR
Ⓦ	MONITORING WELL
⊓	REINFORCED CONCRETE PIPE
☌	UTILITY POLE
☼	LIGHT POLE
□	INLET
Ⓓ	DRAINAGE MANHOLE
○	SS CLEANOUT
WV ⋈	WATER VALVE
⌘	FIRE HYDRANT
●	EXISTING IRON PIPE
Ⓢ	SEWER MANHOLE
GV ⋈	GAS VALVE

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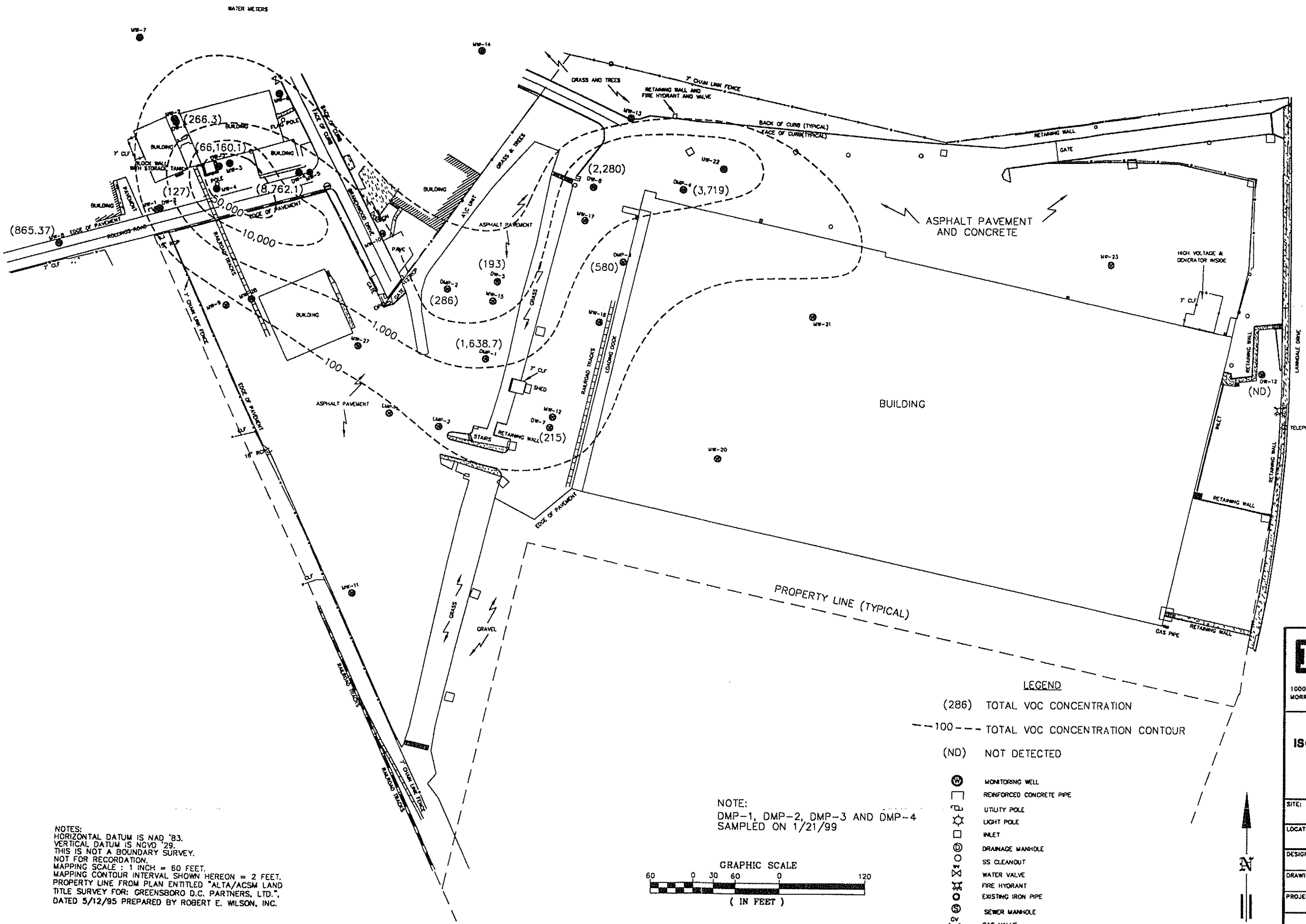
MORRISVILLE, NC 27560 (919) 467-2227

TOTAL VOC ISOCONCENTRATION MAP FOR SHALLOW WELLS

DECEMBER 1998 AND JANUARY 1999

SITE: W.P. GALLARD PROPERTY		
LOCATION: GREENSBORO, NC		
DESIGNED BY:	DETAILED BY: RHW	CHECKED BY:
DRAWING DATE: 3/1/99	ACAD FILE: 7535TVOCS	
PROJECT NO.: 107535	NOTES:	

9



NOTES:
HORIZONTAL DATUM IS NAD '83.
VERTICAL DATUM IS NGVD '29.
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NOTE:
DMP-1, DMP-2, DMP-3 AND DMP-4 SAMPLED ON 1/21/99

GRAPHIC SCALE
60 0 30 60 120
(IN FEET)

LEGEND

(286) TOTAL VOC CONCENTRATION
--100--- TOTAL VOC CONCENTRATION CONTOUR
(ND) NOT DETECTED

Ⓦ MONITORING WELL
REINFORCED CONCRETE PIPE
UTILITY POLE
☼ LIGHT POLE
□ INLET
Ⓓ DRAINAGE MANHOLE
○ SS CLEANOUT
⋈ WATER VALVE
FIRE HYDRANT
● EXISTING IRON PIPE
Ⓢ SEWER MANHOLE
⋈ GAS VALVE

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TOTAL VOC ISOCONCENTRATION MAP FOR DEEP WELLS

DECEMBER 1998 AND JANUARY 1999

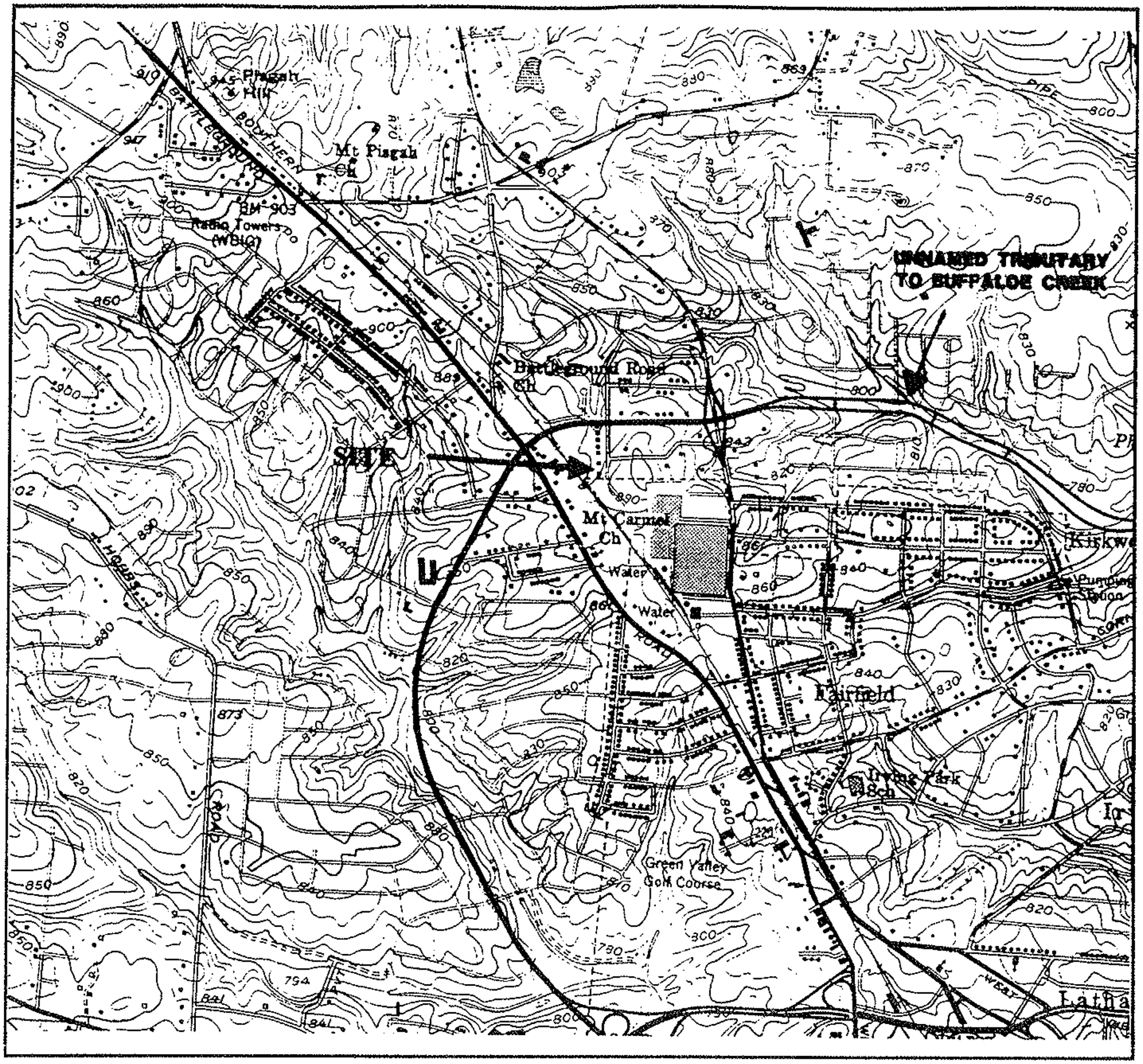
SITE: W.P. BALLARD PROPERTY

LOCATION: GREENSBORO, NC

DESIGNED BY:	DETAILED BY:	CHECKED BY:
	RHW	

DRAWING DATE:	ACAD FILE:
3/1/99	7535TVOCD
PROJECT NO.: 107535	NOTES:

10



SOURCE: U.S.G.S. TOPOGRAPHIC QUADRANGLE
GREENSBORO QUADRANGLE
7.5 MINUTE SERIES
PHOTO REVISED 1963

SCALE 1:24,000

0 2,000 4,000
SCALE FEET

N

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MORRISVILLE, NC 27560
(919) 467-2227

DESIGNED:

DETAILED: RHW

CHECKED:

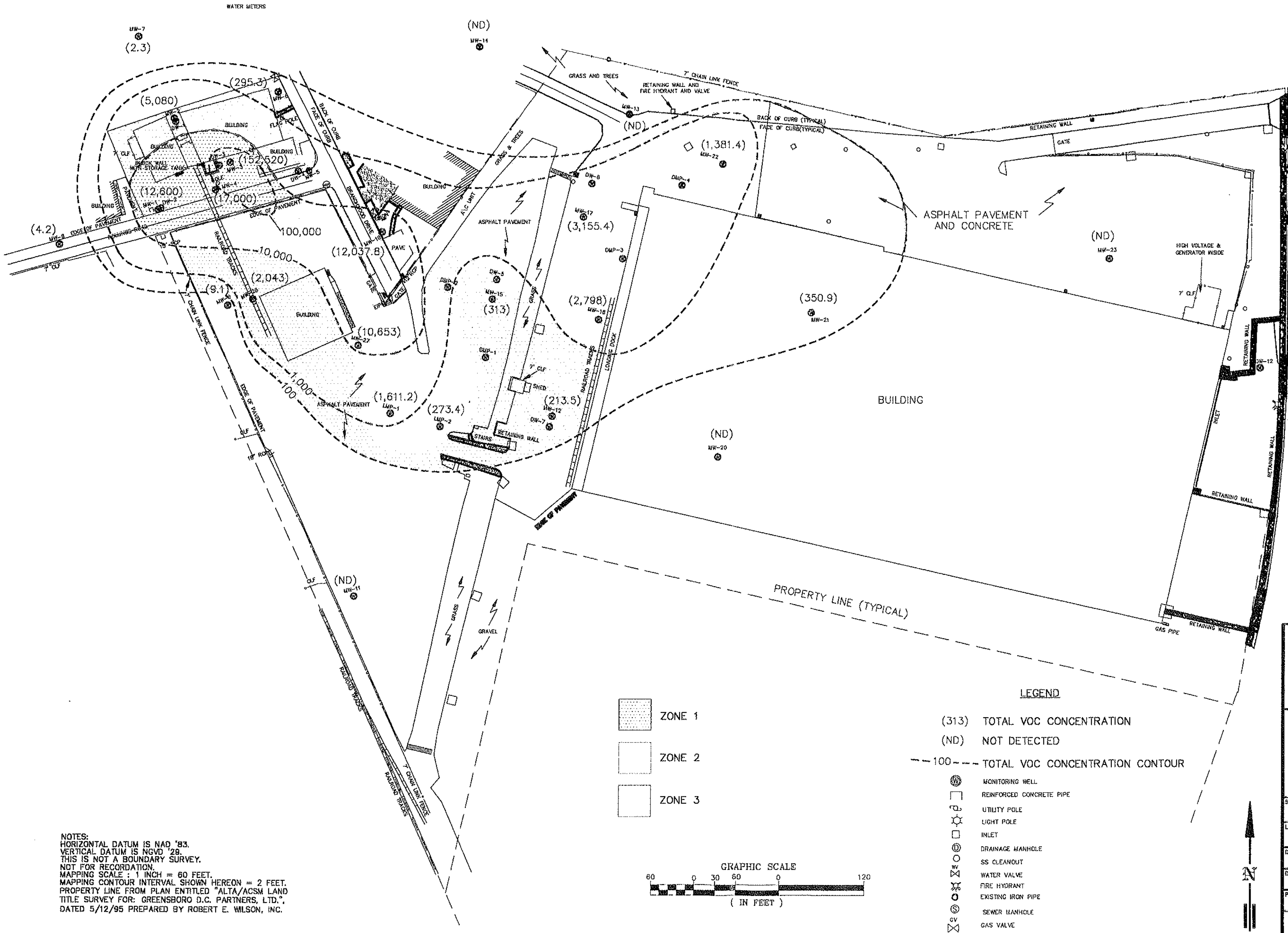
SURFACE WATER LOCATION MAP

SITE: W.P. BALLARD PROPERTY

DRAWING DATE: 4/27/99

LOCATION: GREENSBORO, NC

FIGURE: 11



▨ ZONE 1

ZONE 2

ZONE 3

LEGEND

(313)	TOTAL VOC CONCENTRATION
(ND)	NOT DETECTED
‒ ‒100‒ ‒ ‒	TOTAL VOC CONCENTRATION CONTOUR
⊗	MONITORING WELL
☐	REINFORCED CONCRETE PIPE
	UTILITY POLE
☼	LIGHT POLE
☐	INLET
Ⓓ	DRAINAGE MANHOLE
○	SS CLEANOUT
WV ⋈	WATER VALVE
	FIRE HYDRANT
○	EXISTING IRON PIPE
Ⓢ	SEWER MANHOLE
GV ⋈	GAS VALVE

NOTES:
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TITLE SURVEY FOR: GREENSBORO D.C. PARTNERS, LTD.",
DATED 5/12/95 PREPARED BY ROBERT E. WILSON, INC.

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TOTAL VOC ISOCONCENTRATION MAP FOR SHALLOW WELLS

OVERLAIN WITH TREATMENT ZONE

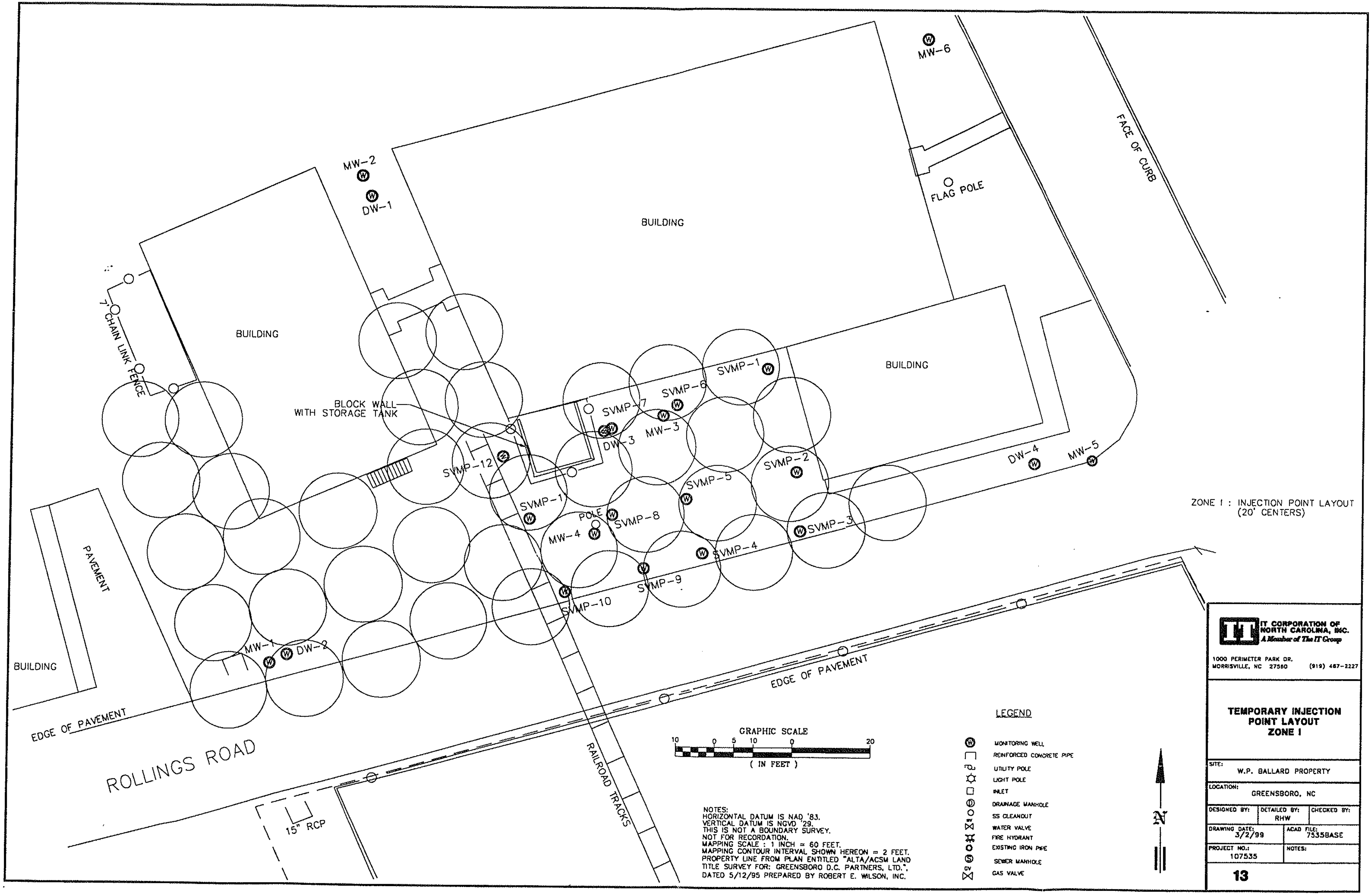
SITE: W.P. BALLARD PROPERTY

LOCATION: GREENSBORO, NC

DESIGNED BY:	DETAILED BY:	CHECKED BY:
	RHW	

DRAWING DATE: 3/1/99	ACAD FILE: 75561VOCS
PROJECT NO.: 107535	NOTES:

12



ZONE I : INJECTION POINT LAYOUT
(20' CENTERS)

GRAPHIC SCALE

10 0 5 10 0 20

(IN FEET)

NOTES:
HORIZONTAL DATUM IS NAD '83.
VERTICAL DATUM IS NGVD '29.
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LEGEND

Ⓦ	MONITORING WELL
⊓	REINFORCED CONCRETE PIPE
	UTILITY POLE
☼	LIGHT POLE
□	INLET
Ⓓ	DRAINAGE MANHOLE
○	SS CLEANOUT
⋈	WATER VALVE
	FIRE HYDRANT
●	EXISTING IRON PIPE
Ⓢ	SEWER MANHOLE
GV ⋈	GAS VALVE

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(919) 467-2227

TEMPORARY INJECTION POINT LAYOUT ZONE I

SITE: W.P. BALLARD PROPERTY

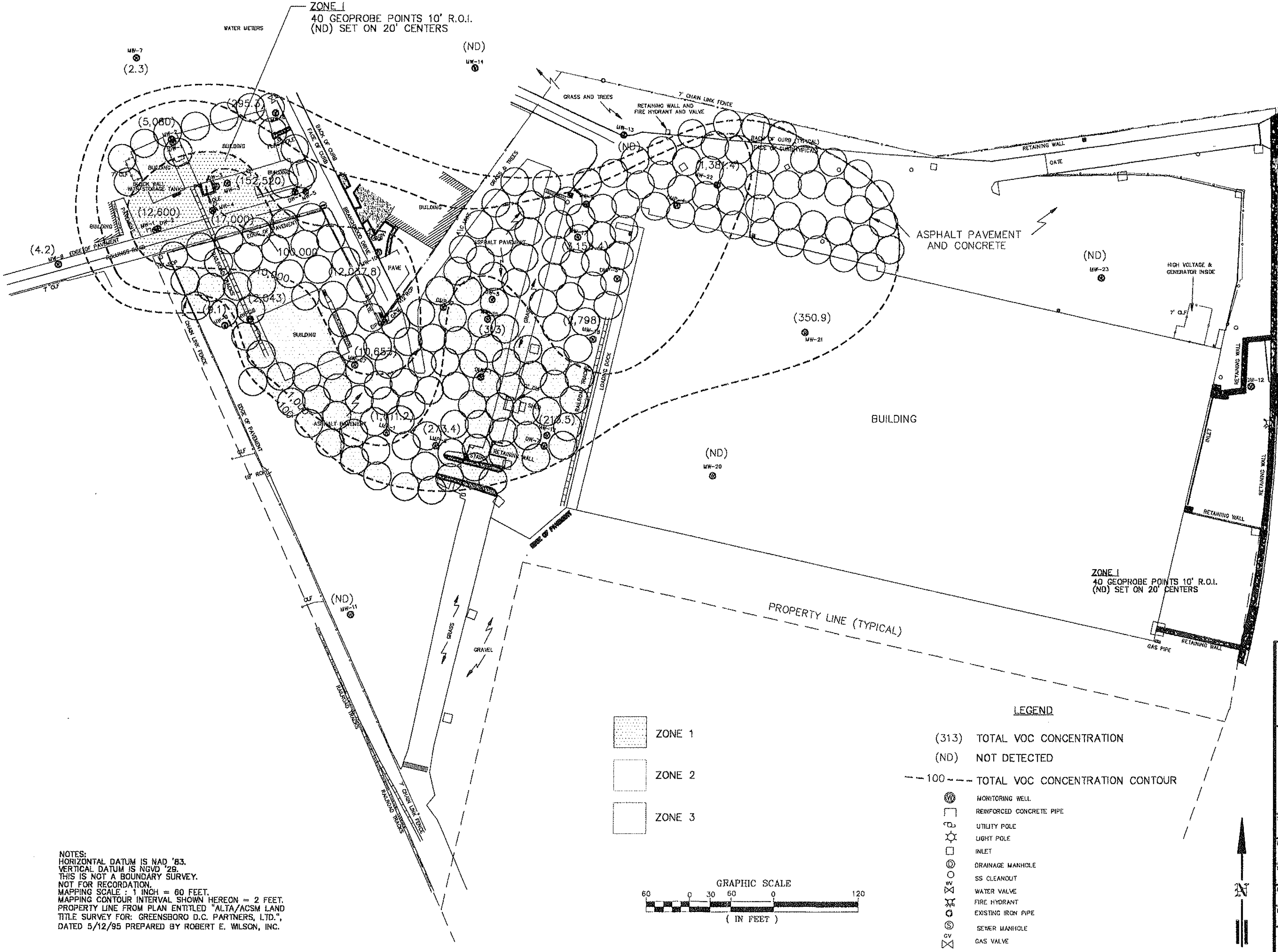
LOCATION: GREENSBORO, NC

DESIGNED BY:
DETAILED BY: RHW
CHECKED BY:

DRAWING DATE: 3/2/99
ACAD FILE: 7535BASE

PROJECT NO.: 107535
NOTES:

13



LEGEND

(313) TOTAL VOC CONCENTRATION
(ND) NOT DETECTED
- - 100 - - - TOTAL VOC CONCENTRATION CONTOUR
MONITORING WELL
REINFORCED CONCRETE PIPE
UTILITY POLE
LIGHT POLE
INLET
DRAINAGE MANHOLE
SS CLEANOUT
WATER VALVE
FIRE HYDRANT
EXISTING IRON PIPE
SEWER MANHOLE
GAS VALVE

NOTES:
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VERTICAL DATUM IS NGVD '29.
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PROPERTY LINE FROM PLAN ENTITLED "ALTA/ACSM LAND
TITLE SURVEY FOR: GREENSBORO D.C. PARTNERS, LTD.",
DATED 5/12/95 PREPARED BY ROBERT E. WILSON, INC.

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NORTH CAROLINA, INC.
A Member of The IT Group

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MORRISVILLE, NC 27560 (919) 467-2227

**TEMPORARY INJECTION
POINT LAYOUT
ZONES II & III**

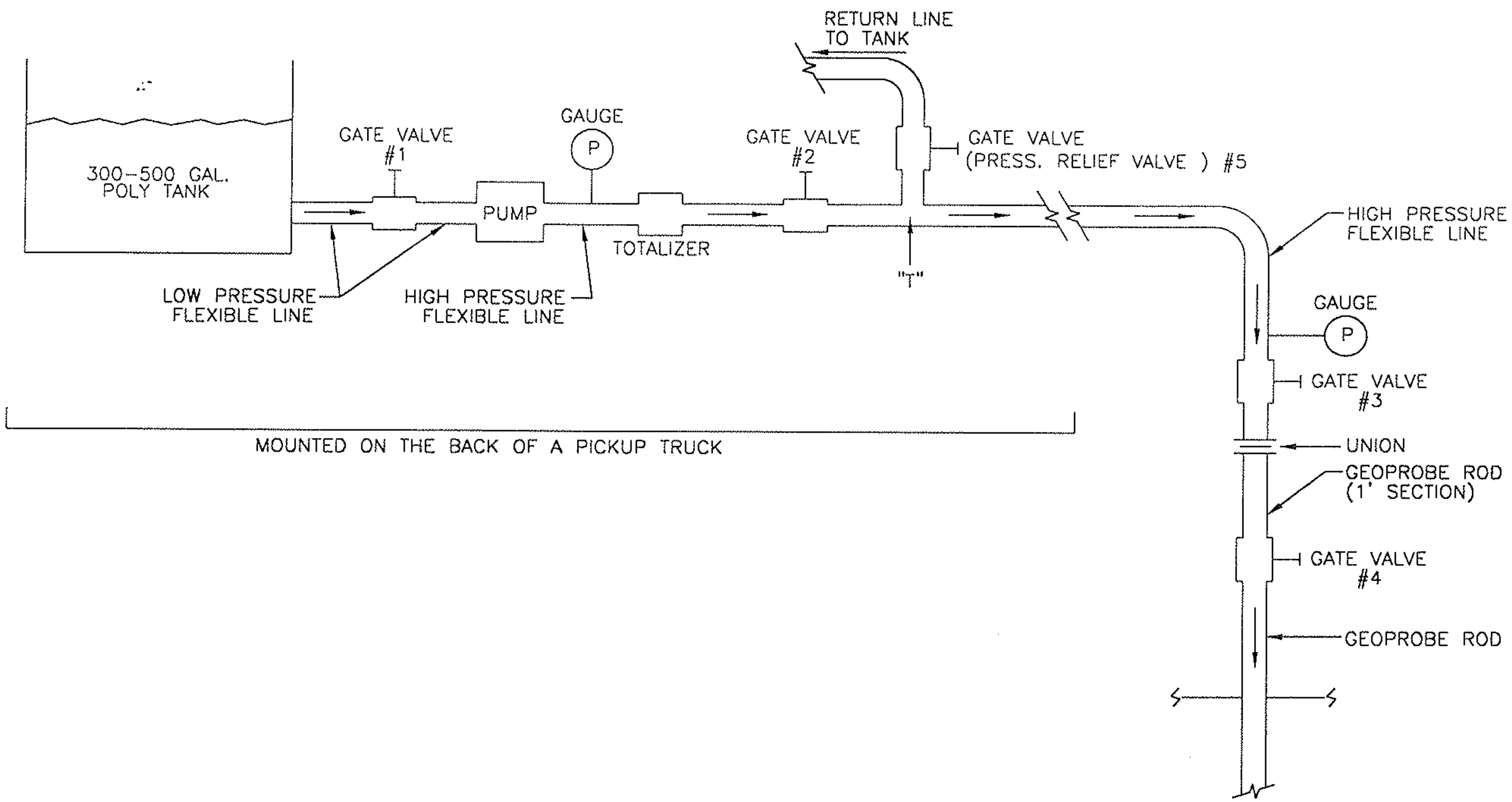
SITE: **W.P. BALLARD PROPERTY**

LOCATION: **GREENSBORO, NC**

DESIGNED BY:	DETAILED BY:	CHECKED BY:
	RHW	

DRAWING DATE:	ACAD FILE:
3/1/99	7535TVOCS
PROJECT NO.: 107535	NOTES:

14



PROCEDURES:
- POLY TANK,PUMP, AND TOTALIZER MOUNTED ON THE BACK OF A PICKUP TRUCK
- 1" GEOPROBE RODS WITH CONCEPTUAL DRIVE POINT
- ADVANCE THE PROBE TO DESIRED DEPTH (~65ft)
- ATTACH NECESSARY EQUIPMENT TO TOP OF RODS
- **A** — OPEN ALL VALVES AND INJECT 24 GALLONS OF WATER (RECORD FLOW RATE AND DELIVERY PRESSURE)
- CLOSE GATE VALVE #2 AND SHUT OFF PUMP
- CLOSE GATE VALVE #4 AND OPEN PRESSURE RELIEF VALVE
- CLOSE GATE VALVE #3 AND DISCONNECT WELL HEAD ASSEMBLY
- RAISE GEOPROBE RODS ONE ROD LENGTH
- RECONNECT WELL HEAD ASSEMBLY
- REPEAT FROM "A" UNTIL REQUIRED QUANTITY HAS BEEN INJECTED

NOT TO SCALE

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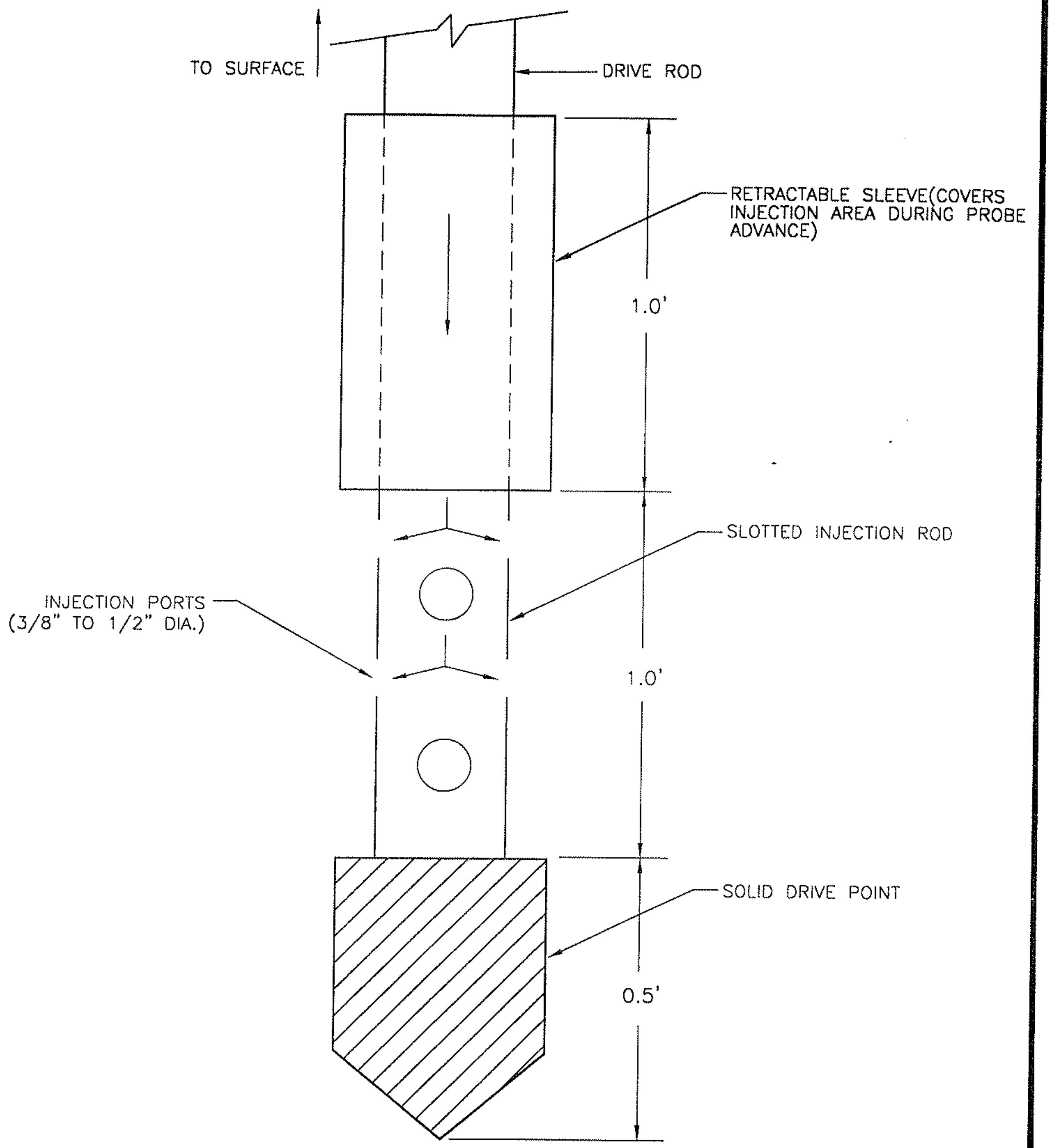
SUITE I
MORRISVILLE, NC 27560
(919) 467-2227

REV. NO.:	DRAWING DATE: 4/27/99	ACAD FILE: 7537PTEST

INJECTION MANIFOLD SCHEMATIC

CLIENT: W.P. BALLARD PROPERTY			PM: KO
LOCATION: GREENSBORO, NC			PE/RG: CB
DESIGNED: BJB	DETAILED: RHW	PROJECT NO.: 107535	FIGURE: **15**



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A Member of The IT Group

1000 PERIMETER PARK DRIVE
SUITE I
MORRISVILLE, NC 27560
(919) 467-2227

DESIGNED:

DETAILED: RHW

CHECKED:

MnO4 SOLUTION INJECTION TIP [CONCEPTUAL DESIGN]

SITE: W.P. BALLARD PROPERTY

DRAWING DATE: 4/5/99

LOCATION: GREENSBORO, NC

FIGURE: **16**

ATTACHMENT A
In Situ Remediation Technology: *In Situ* Chemical Oxidation

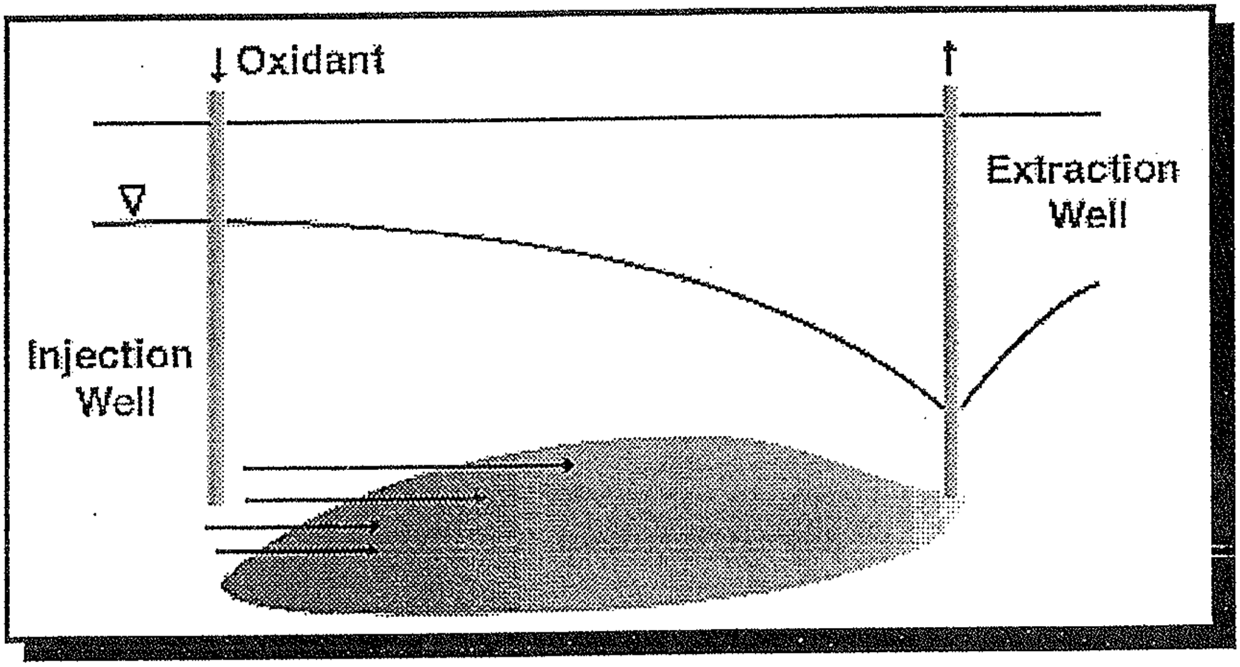
United States
Environmental Protection
Agency

Solid Waste and
Emergency Response
(5102G)

EPA 542-R-98-008
September 1998
http://www.epa.gov/swertio1
http://clu-in.org

In Situ Remediation Technology:

In Situ Chemical Oxidation



EPA 542-R-98-008
September 1998

In Situ Remediation Technology:

In Situ Chemical Oxidation

**U.S. Environmental Protection Agency
Office of Solid Waste and Emergency Response
Technology Innovation Office
Washington, DC 20460**

Notice

This status report was prepared by: Environmental Management Support, Inc., 8601 Georgia Avenue, Suite 500, Silver Spring, MD 20910 under contract 68-W6-0014, work assignment 65, with the U.S. Environmental Protection Agency. Mention of trade names or commercial products does not constitute endorsement or recommendation for use. For more information about this project contact: Dawn Carroll, U.S. Environmental Protection Agency (5102G), Technology Innovation Office, 401 M Street, SW, Washington, DC 20460, 703-603-1234, e-mail: carroll.dawn@epa.gov.

Foreword

Some 80 percent of the hazardous waste sites in the United States have contaminated ground water. Conventionally, the treatment of contaminated ground water has been done by extracting the contaminated water, treating it above ground, and reinjecting or discharging the clean water ("pump-and-treat"). The extracted contaminants must be disposed of separately. It is becoming increasingly apparent that pump-and-treat technologies require considerable investment (between S14-17 million) over a long time (30 years or longer), and may not actually clean up the source of the contamination. Current policies and law stress "permanent" remedies over containment. Consequently, there is considerable interest and effort being expended on alternative, innovative treatment technologies for contaminated ground water.

This report is one in a series that document recent pilot demonstrations and full-scale applications that either treat soil and ground water in place or increase the solubility and mobility of contaminants to improve their removal by other remediation technologies. It is hoped that this information will allow more regular consideration of new, less costly, and more effective technologies to address the problems associated with hazardous waste sites and petroleum contamination. This and other reports are available to the public on line from the Technology Innovation Office website: http://clu-in.org/pubitech.htm.

Surfactant Enhancements
Treatment Walls
Hydrofracturing/Pneumatic Fracturing
Cosolvents
Electrokinetics
Thermal Enhancements
In Situ Chemical Oxidation
Ground-Water Circulation Wells

Contents

Introduction

Purpose and Process

The purpose of this document is to describe completed and ongoing pilot demonstrations and full-scale applications of *in situ* chemical oxidation technologies for the remediation of soil and ground water at waste disposal and spill sites.

Information for this report came from commercial and government databases, such as the Dialog Information Services and the Environmental Protection Agency's (EPA) Vendor Information System for Innovative Treatment Technologies (VISITT). Additional materials were obtained from EPA Regional Offices, Department of Energy staff at the Oak Ridge National Laboratory and Westinghouse Savannah River, Department of Defense site staff, and Battelle Laboratories. Personal interviews and discussions with representatives of EPA and other federal agencies, state environmental quality offices, academic research centers, hazardous waste remediation consulting firms, and technology vendors provided supplementary information.

Technology Needs

In situ chemical oxidation is one of several innovative technologies that show promise in destroying or degrading an extensive variety of hazardous wastes in ground water, sediment, and soil. The oxidants used are readily available, and treatment time is usually measured in months rather than years, making the process economically feasible.

Enrichment with dissolved oxygen has been shown to stimulate *in situ* biological processes, but also is used at at least one site to oxidize arsenic. Potassium permanganate is a stable and easily handled oxidant in both solid and solution form. Hydrogen peroxide can be costly, and because of its volatility requires protective measures. Nevertheless, the shorter process may save on labor and operating costs.

In situ chemical oxidation can be applied in conjunction with other treatments such as pump-and-treat and soil vapor extraction to break down remaining compounds. It is less costly and disruptive then other traditional soil treatments such as excavation and incineration. *In situ* chemical oxidation may be used in applications where the effectiveness of bioremediation is limited by the range of contaminants and/or climate conditions.

Technology Description

In situ chemical oxidation is based on the delivery of chemical oxidants to contaminated media in order to either destroy the contaminants by converting them to innocuous compounds commonly found in nature. The oxidants applied in this process are typically hydrogen peroxide (H_2O_2), potassium permanganate ($KMnO_4$), ozone, or, to a lesser extent, dissolved oxygen (DO).

The most common field applications thus far have been based on Fenton's Reagent whereby hydrogen peroxide is applied with an iron catalyst creating a hydroxyl free radical. This hydroxyl free radical is capable of oxidizing complex organic compounds. Residual hydrogen peroxide decomposes into water and oxygen in the subsurface and any remaining iron precipitates out. This process has a history of application in waste treatment fields.

The volume and chemical composition of individual treatments are based on the contaminant levels and volume, subsurface characteristics, and pre-application laboratory test results. The methods for delivery of the chemical may vary. The oxidant can be injected through a well or injector head directly into the subsurface, mixed with a catalyst and injected, or combined with an extract from the site and then injected and recirculated. In the case of hydrogen peroxide, stabilizers may be needed because of the compound's volatility.

In situ chemical oxidation is being used for ground water, sediment, and soil remediation. It can be applied to a variety of soil types and sizes (silt and clay). It is used to treat volatile organic chemicals (VOCs) including dichloroethene (DCE), trichloroethene (TCE), tetrachloroethene (PCE), and benzene, toluene, ethylbenzene, and xylene (BTEX) as well as semi-volatile organic chemicals (SVOCs) including pesticides, polycyclic aromatic hydrocarbons (PAHs), and polychlorinated biphenyls (PCBs).

Hydrogen Peroxide (H_2O_2)

Anniston Army Depot, Anniston, AL

Installation Date:
1997

Media:
Soil

Contaminants:
TCE

Oxidant:
H_2O_2

Soil Type:
Clay backfill

Points of Contact:
Leslie Ware
Anniston Army Depot (SIOAN-RK)
Directorate of Risk Management
7 Frankford Avenue, Bldg 1
Anniston, AL 36201-4199
Tel: 256-235-7899
Fax: 256-235-7726
E-mail: warel@anad.army.mil

Richard S. Levin, P.G.
QST Environmental Inc.
P.O. Box 1703
Gainesville, FL 32603
Tel: 352-333-3633
Fax: 352-333-6627
E-mail: rslevin@qstmail.com

Full-scale soil remediation using *in situ* chemical oxidation for the removal of dense non-aqueous phase liquids (DNAPLs) such as chlorinated solvents, and hydrocarbons, was begun in 1997 at Anniston Army Depot, Anniston, Alabama.

Site Background

The site consists of three industrial waste lagoons backfilled with clay in 1978. It is approximately 2 acres with over 43,125 yd^3 of contaminated soil containing up to 31% trichloroethene (TCE), dichloroethene (DCE), methylene chloride, and benzene, toluene, ethylbenzene, and xylene (BTEX). TCE accounts for approximately 85% of the 72,000 lbs of volatile organic chemicals. The majority of contaminants were found at depths of 8 ft and greater. The highest concentrations of TCE occur at depths between 8 and 10 ft (maximum 20,100 mg/kg). The water table fluctuates from 25-30 ft below the surface.

Technology Application

Three differently sized injector wells were installed to target three distinct depth intervals. Single shallow injectors screened from 8-14 ft were installed in areas where contamination is shallower than 15 ft, single intermediate injectors were installed where contamination was found from 15-20 ft, and paired shallow and deep injectors screened from 20-26 ft were installed in areas where contamination was found at both deep and shallow depths. In addition, 25 deep ground-water injector wells were used for monitoring, and a vent flow balance system was installed to aid in maintaining an effective radial dispersion of catalyst and H_2O_2. The Geo-Cleanse® patented injection process was employed to deliver H_2O_2 and trace quantities of ferrous sulfate and acid (to control pH) into the contaminated soil. Chemical oxidation of the soil took place over a 120-day period during which 109,000 gallons of 50% H_2O_2 were injected through a total of 255 injectors. Post-treatment sampling began while the full-scale treatment was still in progress. In cases where contaminant concentrations remained above Soil Screening Levels (SSLs), the location was re-treated for polishing treatment.

The total cost to complete this project is estimated to be $5.7M. Project completion originally anticipated for the end of fiscal year 1998 is now contingent upon funding a final $500K and final sampling. Funding for this project was made available in increments. Therefore, the actual expenditures breakdown by cost categories are not available. Project managers estimate that approximately two-thirds of the funds have been allocated for capital costs including chemicals and the injection process and one-third for monitoring and support. Oversight by the Army Corps of Engineers is not included in this funding.

Results

This full-scale treatment was initiated in July 1997. For those areas where sampling and polishing has been completed, results indicate that this process was effective in reducing contaminant concentrations in clays to below SSLs. Soil concentrations of up to 1,760 mg/kg of TCE have been reduced to below detection. Additional polishing treatment may still be warranted depending upon the results of final sampling in the remaining blocks. As noted above, additional funding has been requested to complete this process. Operating data indicate no adverse migration of organics to surrounding soils or ground water.

Site-specific References

Levin, R. S; Wilson, J.; Ware, L.; Findley, J.; and Baehr, J. "Full-Scale Soil Remediation of Chlorinated Solvents in Clay Soils by *In Situ* Chemical Oxidation," Battelle, First International Conference on Remediation of Chlorinated and Recalcitrant Compounds, Monterey, California May 1998

Bryant, J. Daniel and Wilson, J. "Rapid Delivery System Completes Oxidation Picture," *Soil & Groundwater Cleanup,* pp 6-11, August/September 1998

Former Sign Manufacturing Facility, Denver, CO

Installation Date:
1996

Media:
Ground water

Contaminants:
BTEX

A pilot followed by a full-scale treatment of *in situ* chemical oxidation (ISOTEC℠) for remediation of ground water contaminated with benzene, toluene, ethylbenzene, and xylene (BTEX) was conducted at a former sign manufacturing facility in Denver, Colorado, from 1996-1997.

Site Background

The approximate 100 x 100-ft site contained leaking gasoline and fuel oil underground storage tanks. A contaminant plume was found within a thin sandy gravel lens, with a clay layer above and bedrock below. The depth to ground water was 5 ft. Pre-treatment samples indicated BTEX in the ground water at a

Oxidant:
H_2O_2

Soil Type:
Sandy gravel

Point of Contact:
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Englewood, CO 80112
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Fax: 303-843-9094
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maximum concentration of 24,595 µg/L.

Technology Application

The pilot program involved three treatment cycles, with 4 days per cycle. Each cycle involved injection of hydrogen peroxide and chelated iron through each of eight injection points. Full-scale remediation was ordered based on the results of this pilot application. The final application involved one six-day cycle using 14 injection points and 7 injection trenches.

The total cost of this demonstration, including pilot and full-scale programs, was approximately $200K. This included the cost of materials, injections, and sampling. The monitoring wells were pre-existing.

Results

The pilot program began in August 1996, and analyses of post-treatment samples from the full-scale operation were completed in March 1997. BTEX was not detected in the post-treatment samples from nine of the monitoring wells. The total BTEX concentration in the remaining four wells was 89 µg/L. As a result, the state issued an unrestricted "no further action letter" for the site. Based on this action, the property was sold.

Site-specific References

"Remediate Contaminated Property," *Construction Design & Engineering Journal*, March 4-13, 1998, p 2B

Warehousing Facility, Union County, NJ

Installation Date:
1995

Media:
Ground water

Contaminants:
MTBE, BTEX

A pilot test and full-scale treatment of *in situ* chemical oxidation for remediation of ground water contaminated with methyl tert-butyl ether (MTBE) and benzene, toluene, ethylbenzene, and xylene (BTEX) were conducted at a warehouse in Union County, New Jersey, from 1995-1996.

Site Background

The approximately 100 x 80 ft site contained gasoline, waste oil, and fuel oil underground storage tanks that had leaked. The site soils were unsorted and unstratified pebbles, cobbles, and boulders in a matrix of sand, silt, and clay. The depth to ground water was approximately 18 ft. Pre-treatment samples from the well with highest concentrations of contaminants indicated total BTEX levels in excess of 25,000 µg/L and MTBE levels in excess of 6,000 µg/L.

Oxidant:
H_2O_2

Soil Type:
Unsorted rocks in sand

Point of Contact:
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Technology Application

A pilot application was performed using one injection point in the area of highest contamination and one injection point 18 ft away. A single treatment of reagent was completed over a 3-day period. Injections were performed in cycles with catalysts followed by the oxidizer. A site engineered injection apparatus was used to control the flow of hydrogen peroxide (H_2O_2) and the proprietary ISOTEC^{SM} catalyst (iron complex) into the capillary fringe of the vadose zone. Based on the results of this pilot, full-scale remediation was ordered. Six injection points were installed and three treatment cycles were performed over several days within a 3-month period.

The total cost of this demonstration, including pilot and full-scale programs, was approximately $220K. This included chemicals, injections, and sampling. Pre-existing monitoring wells were used for sampling, so installation costs are not included.

Results

The field pilot program began in December 1995, and analyses of post-treatment samples from the full-scale operation were completed in October 1996. Post-treatment samples taken 4 months after the final treatment application indicated that most of the contaminants, including MTBE, were below detection limits. Total BTEX concentrations were less than 25 µg/L in the same well that had registered in excess of 25,000 µg/L in pre-test samples. As a result, the case was closed in November 1996.

Site-specific References

Greenberg, R. S.; Andrews, T.; Kakarla, P.K.C.; and Watts, R.J. "In-Situ Fenton-Like Oxidation of Volatile Organics: Laboratory, Pilot, and Full-Scale Demonstrations," *Remediation*, Spring 1998, pp 29-42

Former News Publisher Facility, Framingham, MA

Installation Date:
1996

Media:
Ground water

Contaminants:
TCA, DCE, VC

Oxidant:
H_2O_2

Soil Type:
Fine-grained silty sand

Point of Contact:
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A pilot and full-scale application of *in situ* chemical oxidation (CleanOX®) for the remediation of 1,1-dichloroethene (DCE), 1,1,1-trichloroethane (TCA), and vinyl chloride (VC) in ground water was performed at a former news publisher facility in Framingham, Massachusetts, in 1996.

Site Background

A dry well discovered during a site assessment contained chlorinated solvents and petroleum hydrocarbons from disposal of ink and degreaser wastes. The site includes a plant, which is approximately 100 x 100 ft, and adjacent land of approximately the same dimensions. The area of cleanup consisted of crushed stone and soil surrounding the former dry well. Soil surrounding the dry well was a fine-grained silty sand. Depth to ground water averages approximately 2½ ft below ground surface. The contaminant plume is approximately 80 x 80 ft. Prior to CleanOX® treatment, remedial actions at the site included disposal of over 6,000 gallons of hazardous liquids and fifteen 55-gallon drums of hazardous sludge. Pre-treatment concentrations of TCA in the two monitoring wells were measured at 40,600 and 4,800 μg/L, and VC concentrations were 440 and 110 μg/L.

Technology Application

The pilot-scale application was conducted to evaluate site-specific geochemistry. Two CleanOX® application points were used over a 3-day period for treatment within the 30 ft diameter dry well area. The application involved a solution of H_2O_2, an iron catalyst, and an acid to control pH. Two 4-in diameter PVC wells and five surrounding monitoring wells were sampled prior to application and resampled 3 weeks after treatment.

The total cost of this application was $45K. This included the chemicals, the application, and the expertise required to apply and report on the treatment. It did not include the cost of monitoring wells.

Results

Samples collected 3 weeks after the treatment indicated that TCA at the two contaminated wells dropped from 40,600 to 440 μg/L and from 4,800 to 2,300 μg/L. Concentrations of VC dropped to levels ranging from below detection to 85 μg/L in nearby wells.

The reduction of chlorinated hydrocarbon contaminants achieved with the CleanOX® application, coupled with the quantity of source contaminants removed during the original remediation tasks, allowed the site owner to successfully close the site with state approval without additional treatment. No specific restrictions on the use of the site were necessary, and the site remains closed.

Site-specific References

Not available.

Active Industrial Facility, Clifton, NJ

Installation Date:
1995

Media:
Ground water

Contaminants:
VOCs, TCA

Oxidant:
H_2O_2

Soil Type:
Fill

Point of Contact:
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A pilot and initial injection for full-scale application of *in situ* chemical oxidation (CleanOX®) for the remediation of trichloroethane (TCA) and other volatile organic compounds (VOCs) in ground water were performed at an active industrial facility in Clifton, New Jersey, from 1995-1996.

Site Background

Releases from an underground storage tank resulted in a ground-water plume. An existing ground-water pump-and-treat system was located outside the building and had operated for five years prior to this application with moderate reduction in contaminant concentrations. The high level of iron-metabolizing bacteria at the site caused frequent operations and maintenance problems for the pump-and-treat system. The aquifer is heterogeneous and highly stratified. Site soils are low in permeability (about 1 millidarcy) and conductivity (about 10^{-5} cm/sec), and the ground water has high organic carbon concentrations. Depth to ground water is approximately 16 ft. Pre-treatment sampling indicated average total VOC concentrations at 44 mg/L. Maximum TCA concentration was measured at 101 mg/L in one monitoring well.

Technology Application

The pilot-scale application, using H_2O_2, an iron catalyst, and an acid for pH balance, was performed at an existing well. The chemicals were applied over a 3-week period. The full-scale application involved the installation of an additional eleven 4-in diameter PVC wells into the fractured bedrock underneath the facility building. The application wells were screened 10 - 30 ft below ground surface. Samples were taken following this application and repeated a couple of months later.

The cost of the pilot and full-scale applications was approximately $235K. This included drilling the wells, applying chemicals, sampling, testing, and engineering oversight.

Results

Average total VOC concentrations dropped from the original 44 mg/L to 15 mg/L. The post-treatment average level is assumed to be skewed since the project uncovered the fracture system containing most of the contaminant. Results of this application indicated a 98% reduction in TCA concentrations in the most contaminated well, from 101 mg/L to 2 mg/L. Another full-scale application probably would be required to achieve MCLs for drinking water. The water standard required for industrial application is 1 mg/L.

Site-specific References

Not available

Westinghouse Savannah River Site, Aiken, SC

Installation Date:
1997

Media:
Ground water, soil

Contaminants:
TCE, PCE

Oxidant:
H_2O_2

Soil Type:
Sand, clay

Point of Contact:
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A field demonstration of *in situ* chemical oxidation to treat dense non-aqueous phase liquids (DNAPLs)—primarily tetrachloroethylene (PCE) and trichloroethene (TCE)—was conducted in 1997 at the Savannah River Site in Aiken, South Carolina.

Site Background

The site selected for this demonstration was a 50 x 50 ft area adjacent to a seepage basin. The treatment zone consisted of 64,000 ft^3 of soil containing approximately 600 lbs of DNAPL. The soils consist of sand and clayey sands. DNAPL is present at approximately 140 ft below ground surface and about 20 ft below the top of the water table. The average ground-water contaminant concentrations in the treatment area were approximately 119 mg/L PCE and 21 mg/L TCE. The soil contained PCE concentrations of 10-150 µg/kg. The highest concentrations were found at approximately 140 ft below ground surface. This area of the Savannah River site was once a fuel and target fabrication facility where uranium, lithium, aluminum, and other materials were processed into fuel elements and targets for use in the nuclear production reactors.

Technology Application

Four injector wells, three monitoring wells, and three vadose zone lysimeters were installed. Holes were drilled to depths of approximately 155 ft, and samples were collected at various levels to determine the soil concentration of TCE and PCE in soil. The treatment zone was approximately 30 ft deep. The Geo-Cleanse® patented injection process was then employed to inject H_2O_2 and a catalyst (ferrous sulfate) over a 6-day period in a circular area with a radius of 27 ft. Injection was conducted in batch mode with one batch injected per day. The volume of the injection varied from 500-1000 gallons per batch. Three days after the last injection, post-test drilling was initiated to verify destruction of DNAPL. In addition, post-test sampling of monitoring wells was conducted weekly for a 3-month period.

The total cost of the demonstration was approximately $511K. This included approximately $60K for site preparation, $151K for pre-test drilling and characterization, $184K for a technology test, $49K for post-test drilling and characterization, $7K for demobilization, and $60K for documentation and project management.

Results

The demonstration, from pre-test characterization of the site through post-test activities, took place between January and July 1997. A comparison of pre- and post-test soil borings indicated a 94% destruction of DNAPL in the treatment zone. The estimated pre-test DNAPL mass was 593 lbs, and the estimated post-test mass was 36 lbs. Total destruction was not achieved and can be attributed to the process not contacting all DNAPL globules in the fine-grained sediments. Average contaminant concentrations in the ground water were reduced to 0.65 mg/L PCE and 0.07 mg/L TCE at the completion of treatment.

Follow-up work was conducted in the summer of 1998 to determine the effects of the chemical reactions on the geochemistry and microbiology of the test zone and surrounding areas.

Site-specific References

Jerome, K.M.; Riha, B.; Looney, B.B. *Final Report for Demonstration of In Situ Oxidation of DNAPL Using the Geo-Cleanse® Technology*, U.S. Department of Energy, Westinghouse Savannah River Company, Aiken, South Carolina, September 1997

Jerome, K.; Looney, B.B.; and Wilson, J. "Field Demonstration of *In Situ* Fenton's Destruction of DNAPLs," Battelle, First International Conference on Remediation of Chlorinated and Recalcitrant Compounds, Monterey, California, May 1998

"Field Demonstration of *In Situ* Fenton's Destruction of DNAPLs," in Wickramanayake, G.B. and Hinchee, R.E. (eds.), *Physical, Chemical, and Thermal Technologies, Remediation of Chlorinated and Recalcitrant Compounds*, Battelle Press, Columbus, Ohio, 1998

Bryant, J. Daniel and Wilson, J. "Rapid Delivery System Completes Oxidation Picture," *Soil & Groundwater Cleanup*, pp 6-11, August/September 1998

Potassium Permanganate ($KMnO_4$)

U.S. Army Cold Regions Research & Engineering Laboratory, Hanover, NH

Installation Date:
1997

Media:
Soil

Contaminants:
TCE

Oxidant:
$KMnO_4$

Soil Type:
Sand, silt

Point of Contact:
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Pilot-scale testing is being performed at the U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) in Hanover, New Hampshire, to evaluate the feasibility of using a 1.5% concentrated solution of potassium permanganate ($KMnO_4$) to promote *in situ* chemical oxidation of trichloroethene (TCE) in low-permeability lenses of silt with clay in the vadose zone. Testing was done at two sites.

Site Background

The presence of TCE is assumed to have resulted from either a leak or an explosion at the facility, which had been used extensively for refrigeration and ice coring. Residual TCE contamination has been identified in unsaturated soils 15-35 ft below the surface. Site soil consists largely of fine sands with some silts, interbedded with veneer-thin stringers of sand and thicker layers of nearly saturated silts and clays. The depth to ground water is approximately 130 ft. Two locations at the site were selected for the pilot tests, representing moderate (approximately 170 mg/kg) and high (maximum 60,000 mg/kg) levels of TCE contamination.

Technology Application

Following pre-test sampling and analysis, a 1.5% $KMnO_4$ solution (15 g/L) was injected to the subsurface via two direct-push wells, one a ¾-in diameter piezometer and the other a 2-in stainless steel screened well, to enable injection at discrete depths from 19.7 to 21 ft. Three samplers were placed near the injection well to collect pore water samples during the treatment process. Approximately 200 gallons of $KMnO_4$ solution was injected in several batches at Site 1 over a 53-day period, while 358 gallons were delivered to Site 2 over a 21-day period.

The cost of this particular pilot has not been itemized. It is part of an overall remediation demonstration program at the site, which is budgeted at $790K for fiscal year 1998.

Results

Pre-treatment sampling began in November 1997, with actual oxidant injection beginning in early 1998. Pre and post-injection monitoring of pore water showed increases of chloride concentrations from 20 to 6,420 mg/L, indicating that

TCE was being oxidized. Analyses of post-injection soil samples also indicated cleanup may have been occurring, but confirmation required additional treatment and sample collection since the samples collected were too small to have been statistically significant. It was determined that significantly larger volumes of $KMnO_4$ solution or higher concentrations of the oxidant would be required to achieve complete cleanup. A second pilot took place in the spring 1998 with a larger volume of the oxidant (1,200 gal/week), and post-treatment samples were collected in June. Preliminary results of these samples indicate the need to inject the oxidant under pressure using smaller boreholes to better contain the oxidant. Actual data are not yet available. CRREL anticipates having two additional larger-scale demonstrations up and running in the fall of 1998. These sites will involve the use of boreholes with packers to inject the $KMnO_4$ under pressure.

Site-specific References

McKay, D.; Hewitt, A.; Reitsma, S.; LaChance, J.; and Baker, R. "*In Situ* Oxidation of Trichloroethylene Using Potassium Permanganate: Part 1. Theory and Design," Battelle, First International Conference on Remediation of Chlorinated and Recalcitrant Compounds, Monterey, CA, May 1998

McKay, D.; Hewitt, A.; Reitsma, S.; LaChance, J.; and Baker, R. "*In Situ* Oxidation of Trichloroethylene Using Potassium Permanganate: Part 2. Pilot Study," Battelle, First International Conference on Remediation of Chlorinated and Recalcitrant Compounds, Monterey, CA, May 1998

Canadian Forces Base Borden, Ontario, Canada

Installation Date:
1996

Media:
Ground water

Contaminants:
TCE, PCE

Oxidant:
$KMnO_4$

A field demonstration of *in situ* chemical oxidation using potassium permanganate ($KMnO_4$) to treat dense non-aqueous phase liquid (DNAPL)—primarily trichloroethene (TCE) and tetrachloroethene (PCE)—was conducted at the Canadian Forces Base Borden in Ontario, Canada, from 1996-1997. It follows two similar but smaller field demonstrations on the base in the early 1990s.

Site Background

The approximately 50 x 50 meter (164 x 164 ft) site is in a 4-meter (13-ft) thick sand aquifer. The sand is highly homogeneous and has hydraulic conductivity of approximately 86 cm/day. The source zone is located 1 m (3.3 ft) below the water table. Typical ground-water velocities at the site are on

2.82ft/day

Soil Type:
sand

Point of Contact:
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the order of 9 cm/day. At the initiation of an oxidant flush in 1996, it was estimated that the source zone contained an average of 1,200 mg/kg TCE and 6,700 mg/kg PCE.

Technology Application

This demonstration used a series of six injection and five oxidant recovery wells. While previous experiments were conducted in sheetpile containment wells, the only form of hydraulic control on the injected oxidant in this demonstration were the wells. The reaction was monitored using a fence of seven bundled mini-piezometers (98 sample points total) perpendicular to ground-water flow and 1 m (3.3 ft) downgradient of the source zone. The DNAPL source zone was flushed with a solution of approximately 8 g/L $KMnO_4$ for almost 500 days.

The total cost of the demonstration is approximately $45K.

Results

The oxidant flush was conducted between May 1996 and September 1997. Preliminary analyses indicate a 99% reduction in peak concentrations for both PCE and TCE; final sampling results are expected in late 1998. The mass flux (mg/day) dissolved contaminants seems to have reduced by four or five orders of magnitude. Further work to confirm these preliminary results, including an estimate of solvent mass currently in the source zone, is continuing.

Site-specific References

Schnarr M.; Truax, C.; Farquhar, G.; Hood, E.; Gonullu, T.; and Stickney, B. "Laboratory and Controlled Field Experiments using Potassium Permanganate to Remediate Trichloroethylene and Perchloroethylene DNAPLs in Porous Media," *Journal of Contaminant Hydrology*, 29(3), p 205-224, 1998.

Hood, E. D.; Thomson, N. R.; and Farquhar, G. J. "*In Situ* Oxidation: An Innovative Treatment Strategy to Remediate Trichloroethylene and Perchloroethylene DNAPLs in Porous Media," Sixth Symposium and Exhibition on Groundwater and Soil Remediation, Montreal, Canada, March 18-21, 1997

Hood, E. D.; Thomson, N. R.; and Farquhar, G. J. "*In Situ* Oxidation: Remediation of a PCE/TCE Residual DNAPL Source," Battelle, First International Conference on Remediation of Chlorinated and Recalcitrant Compounds, Monterey, California, May 1998

Kansas City Plant, Kansas City, MO

Installation Date:
1996

Media:
Ground water, soil

Contaminants:
TCE, DCE

Oxidant:
$KMnO_4$

Soil Type:
Clay

Points of Contact:
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An *in situ* chemical oxidation field demonstration using potassium permanganate ($KMnO_4$) for the remediation of chlorinated solvents was conducted in 1996 at the U.S. Department of Energy (DOE) Kansas City Plant in Kansas City, Missouri. It was part of a larger study in which three technologies—bioaugmentation, chemical oxidation, and mixed-region vapor stripping with calcium oxide—were combined with deep soil mixing.

Site Background

The test site occupied approximately 60 x 140 ft in stiff clay soils just north of a former lagoon. Depth to ground water is approximately 8-10 ft below ground surface. Ground-water samples indicated high concentrations of trichloroethene (TCE), 1,2-dichloroethene (DCE) (over 15,000 μg/L) and chloroethene (over 1,500 μg/L). Previous soil investigations indicated elevated levels of total petroleum hydrocarbons (TPH) ranging up to 6,961 mg/kg, polychlorinated biphenyls (PCBs) as high as 9.8 mg/kg, and concentrations of TCE and 1,2-DCE in soil below the water table as high as 81 mg/kg and 15 mg/kg, respectively.

Technology Application

The field demonstration, testing, and evaluation activities involved a crane-mounted vertical rotating blade system designed to mix the soil using 8-10 ft diameter blades. During the *in situ* mixing process, treatment agents were injected through a vertical, hollow shaft into the soil. Fifteen soil columns, 8 ft in diameter, grouped three to a treatment cell, were treated to depths of approximately 25 to 47 ft. A shallow (25 ft) and a deep (47 ft) cell were used for *in situ* mixing with a 4-5% $KmnO_4$ solution. The cells were treated separately over two 2-day periods in three overlapping test columns. Although soil mixing redistributed the media making it impossible for post-treatment sampling to replicate pre-treatment sampling, post-treatment samples were collected in similar fashions and locations as pre-treatment samples.

The total cost of the demonstration was approximately $1M. This included all pre- and post-testing, permitting, equipment, and labor. Actual cost breakdowns are not available. On a prorated basis, the costs by technology are estimated to be \$128/yd^3 for $KMnO_4$ compared to \$77/yd^3 for bio-augmentation and \$62/yd^3 for vapor stripping.

Results

This demonstration was conducted in July 1996. The goal of the project was to achieve a 70% removal rate of contaminants. Comparing pre- and post-treatment TCE mass values at the two cells treated with $KMnO_4$, one cell indicated an overall removal of 83% of TCE from the unsaturated soil and the other a reduction of 69% from the saturated soil. This compares to a 65% reduction in the unsaturated soil treated by vapor stripping, and a 38% reduction for that treated with bioaugmentation. The results also show that the physical and biological properties of the soil treated with $KMnO_4$ remain essentially intact. Additional sampling was performed in Spring 1998 and analysis is underway.

Site-specific References

U.S. DOE, *Implementation of Deep Soil Mixing at the Kansas City Plant*, Oak Ridge National Laboratory, Grand Junction, CO, February 1997

Cline, S.R.; West, O.R.; Siegrist, R.L.; and Holden, W.L., *Performance of In Situ Chemical Oxidation Field Demonstrations at DOE Sites*, presented at the *In Situ* Remediation of the Geoenvironment Conference, Minneapolis, Minnesota, October 5-8, 1997

Portsmouth Gaseous Diffusion Plant, Piketon, OH

Installation Date:
1997

Media:
Ground water, soil

Contaminants:
TCE

Oxidant:
$KMnO_4$

Soil Type:
Sand, gravel

A full-scale demonstration of *in situ* chemical oxidation through recirculation (ISCOR) to remediate soil and ground water for chlorinated solvents, primarily trichloroethene (TCE), was conducted at the X-701B site of the Portsmouth Gaseous Diffusion Plant in Piketon, Ohio, in 1997.

Site Background

The site was 200 x 90 ft, with four distinct underlying strata: silt and clay (25-30 ft thick), a sand and gravel (2-10 ft thick), shale (10-15 ft thick), and sandstone (47 ft deep). The field test was targeted at treating contamination in the relatively permeable sand and gravel layer, since it has the highest risk for off-site migration. This layer is 5-6 ft thick and approximately 30 ft below ground surface. The layer is contaminated primarily with TCE. Ground water is 12-14 ft below the surface. Pre-treatment testing of soil samples detected an average TCE concentration of 54 mg/kg with a maximum concentration of 302 mg/kg. Ground-water samples revealed concentrations up to 800 mg/L.

Points of Contact:
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Technology Application

This demonstration used a pair of previously installed parallel horizontal wells, 90 ft apart with 200-ft screened sections consisting of 5-inch diameter, high-density polyethylene porous filters. Water for the oxidant injection solution was extracted from the upgradient horizontal well, mixed with crystalline potassium permanganate ($KMnO_4$) in concentrations of 1.5-2.5%, and re-injected into the downgradient horizontal well. Twenty-two boreholes were drilled between the wells and samples were taken at 1-ft intervals from 20-30 ft below ground surface. Three-quarter-inch-diameter PVC wells with 5-ft screens were installed in 14 of the boreholes.

The total cost of the demonstration was $562K. Approximately $56K was allocated for project planning and management, $163K for pre-treatment sampling and mobilization, $163K for operations and maintenance, $101K for post-treatment sampling, $68K for resistivity monitoring, and $11K for support.

Results

This field test was conducted from July-August 1997, and post-treatment characterization was completed in August 1997. Post-treatment characterization showed that ISCOR was effective at reducing TCE in both soil and ground water to non-detectable levels in those areas where the oxidant was able to migrate. Lateral and vertical heterogeneities within the treatment zone impacted the uniform delivery of the oxidant.

Monitoring of the ground water in the area was conducted between October 1997 and June 1998 and analysis continues to date. New field testing at a different location on this facility using sodium permanganate and vertical injection and extraction wells is expected to begin in the summer of 1998. Sodium permanganate was selected because of its considerably higher solubility in aqueous solutions than $KMnO_4$. Its higher solubility allows for the use of alternate modes of delivery such as liquid chemical feed.

Site-specific References

West, O.R.; Cline, S.R.; Holden, W.L.; Gardner, F.G.; Schlosser, B.M.; Thate, J.E.; Pickering, D.A.; and Houk, T.C. *A Full-Scale Demonstration of In Situ Chemical Oxidation Through Recirculation at the X-701B Site,* Oak Ridge National Laboratory, Oak Ridge, Tennessee, December 1997

Cline, S.R.; West, O.R.; Siegrist, R.L.; and Holden, W.L., "Performance of *In Situ* Chemical Oxidation Field Demonstrations at DOE Sites," *In Situ* Remediation of the Geoenvironment Conference, Minneapolis, Minnesota, October 5-8, 1997

West, O.R.; Cline, S.R.; Siegrist, R.L.; Houk, T.C.; Holden, W.L.; Gardner, F.G.; and Schlosser, B.M. "A Field Scale Test of *In Situ* Chemical Oxidation Through Recirculation," International Conference of Decommissioning and Decontamination and on Nuclear and Hazardous Waste Management, American Nuclear Society, Denver, Colorado, September 13-18, 1998

Ozone (O_3)

Former Service Station, Commerce City, CO

Installation Date:
1997

Media:
Ground water, soil

Contaminants:
TPH, BTEX

Oxidant:
Ozone

Soil Type:
Sand-gravel mix

Point of Contact:
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Moiety Associates
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A full-scale application using a combination of an air/ozone (C-Sparge™) system and a vacuum extraction system to remediate soil and ground water contaminated with petroleum hydrocarbons and benzene, toluene, ethylbenzene, and xylene (BTEX) was administered at a former service station site in Commerce City, Colorado, in 1997.

Site Background

The site, which once served as a bulk storage and service station facility, is part of a metal recycling facility. Subsurface material consists of sand and gravel mixtures to approximately 43 ft below ground surface, grading to a blue clay. Ground water is approximately 28 ft below ground surface. A soil and ground-water investigation indicated that total petroleum hydrocarbons (TPH) in the soil ranged from 90-2,380 mg/kg. Total BTEX in soil ranged from 7,800-36,550 µg/kg. TPH in the ground water ranged from free product to 490 mg/L and BTEX ranged from 22-2,260 µg/L. Concentrations of benzene, the contaminant by which the cleanup standard was measured, ranged from below detection limits to 16 µg/L.

Technology Application

The C-Sparge™ process consists of a combination of *in situ* air stripping with encapsulated ozone to oxidize contaminants. Two master panels, each controlling three wells, were installed. Each well consists of an in-ground sparge point that injects pulsating ozone and air into the ground water, an in-well sparge point that injects pulsating water in the well casing under pressure, a water-circulation pump, and a packer. The pressurized system allows the fine bubbles that transport the encapsulated ozone to infuse the formation without fracturing it. Each well was drilled 50 ft deep, and sealed from 10 ft below grade to the ground surface. Sparge-point pressures ranged from 14-20 psi, depending on the distance from the well to the surface equipment. The system was augmented with a large blower pulling 160 ft^3/min at 48-inch-vacuum water column. The entire system ran through 12 complete cycles per day. Each cycle involved all six wells going through the approximately 25 minute/well process of blowing ozone and air into the ground water, blowing water into the casing, and pumping. The blower operated continuously.

The anticipated cost of the demonstration from site investigation through final monitoring is approximately $160K. Of this, $20K was allocated for site investigation, $55K for equipment, $35K for installation, and $15K for sparge wells.

Results

The system started in August 1997. The ground-water wells at the site are monitored quarterly. The March 1998 results showed dissolved TPH at 37 mg/L in the well that contained free product during previous monitoring. No TPH or BTEX was detected in any other monitoring wells, so the remediation system was turned off. Monitoring results in June 1998 indicated levels remaining below the state maximum contaminant levels for drinking water. The state did not require confirmatory soil sampling. Samples will need to be taken for four consecutive quarters following the shutdown of the system in March 1998.

Site-specific References

Not available

Dry Cleaning Facilities, Hutchinson, KS

Installation Date:
1997

Media:
Ground water

Contaminants:
PCE

Oxidant:
Ozone

Soil Type:
Sand, silt, clay

A pilot test using ozone and air injection for remediation of tetrachloroethene (PCE) in ground water was conducted in Hutchinson, Kansas, in 1997. This pilot was part of a test designed to compare and evaluate the cost-effectiveness of three remediation technologies. It involved three similar locations within the city. The technologies included a combination of air sparging with soil vapor extraction (AAS/SVE); in-well stripping (NoVOCs™); and a combination of air and ozone injection with vertical circulation of ground water (C-Sparge™).

Site Background

All three test sites were located near former and existing dry-cleaning facilities within the city limits. Sediments underlying the sites consist of unconsolidated stream and terrace deposits (sand, silt, and clay). The water table is from 14 to 16 ft below ground. Dissolved-phase PCE appeared limited to the top 15 ft of the aquifer with maximum concentrations ranging from 30-600 µg/L.

Technology Application

Each of the 3 test configurations consisted of above-ground remediation hardware in a temporary enclosure or trailer, a

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single or combination remediation well configuration, above- and below-grade piping, and ground-water monitoring wells. The placement of monitoring wells varied for each site to accommodate the technology-specific data collection requirements.

The ozone injection test involved a C-Sparge™ process which combines air stripping with oxidation. The system included a 4-in diameter PVC remediation well installed to 35 ft below grade with a micro-porous sparge point placed 33-35 ft below grade. The wells were screened in the vadose and saturated zones. A self-contained down-hole unit, containing a second sparge point and fluid pump, was then installed in the well. Ground-water information was collected from a cluster of five monitoring wells. The average rate of injection was 3 standard cubic ft per minute. To better understand the effects of ozone, a second identical configuration was installed to inject air only through the sparge points. A cluster of three monitoring wells was used to collect information from this test.

The cost of this field demonstration for all three sites was approximately $195K, of which $52K was for the C-Sparge™ test, $95K was for the NoVOCs™ test, and about $48K for the AAS/SVE test. A cost comparison indicated that the AAS/SVE system was the least expensive to install and the C-Sparge™ the most economical to operate.

Results

Pilot test activities for all sites were conducted over a 5-month period and included monitoring well and system installation, pre-test ground-water sampling, a 6-day system start-up period, on-going data collection and operation and maintenance, and post-test ground-water sampling.

Monitoring wells 10 ft from the remediation well using ozone indicate a 91% reduction in concentration of PCE, from 34 to 3 μg/L. Air-only injections resulted in a 71% reduction, in-well stripping an 87% reduction, and AAS/SVE a 66% reduction.

Site-specific References

Dreiling, D.N.; Henning, L.G.; Jurgens, R.D.; and Ballard, D.L. "Multi-Site Comparison of Chlorinated Solvent Remediation Using Innovative Technology," Battelle, First International Conference on Remediation of Chlorinated and Recalcitrant Compounds, Monterey, California, May 1998

Former Industrial Facility, Sonoma, CA

Installation Date:
1998

Media:
Ground water, soil

Contaminants:
PCP, PAHs

Oxidant:
Ozone

Soil Type:
Sand, clay

Point of Contact:
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A field demonstration of *in situ* chemical oxidation using ozone is underway at a former industrial site in Sonoma, California to remediate the vadose zone and ground water for pentachlorophenol (PCP) and polycyclic aromatic hydrocarbons (PAHs).

Site Background

This site (approximately 300 x 300 ft) was once the location for a wood treating facility, a cooling tower, and a water tank manufacturer. These operations involved the use of PCP and creosote. Contamination extends from shallow soils down to the water table. The geology consists of semi-continuous layers ranging from fine sands to clays, resulting in highly stratified contamination. The application was designed to address contamination in all layers. Initial sampling of 10 locations on the site indicated an average concentration of 1,800 mg/kg of total PAHs and 3,300 mg/kg of PCP.

Technology Application

This demonstration involves at least four multi-level ozone injections (for all the stratigraphic layers) utilizing a variety of instrumentation including soil gas probes, piezometers, lysimeters, monitoring wells, thermocouples, and reflectometry instruments to measure soil moisture content. Soil vapor extraction wells were placed outside the treatment areas to ensure that fugitive ozone emissions were minimized. Ozone was injected through wells in the vadose zone at varying rates up to 10 ft^3/min.

The inclusive cost of this field demonstration, once completed, is anticipated to be approximately $300K (half the cost was for capital equipment and half for operations and maintenance).

Results

This field study was begun in the spring of 1998 and is anticipated to continue for an additional six months. After one month of continuous ozone injection, sampling from the 10 locations averaged 530 mg/kg PAHs and 570 mg/kg PCP. Concentrations of PAHs were reduced 67 - 99.5% and concentrations of PCP were reduced 39 - 98%. Subsurface gaseous ozone concentrations appear to be relatively uniform, decreasing with increasing distance from injection points. Soil gas data suggests that ozone utilization of greater than 90% is achieved. The study calls for additional data to be acquired, soil borings to be advanced after three and six months of treatment, respirometry to be performed to determine the effects of ozonation on microbial activity, and various engineering issues to be investigated.

Site-specific References

Marvin, B.K.; Nelson, C.H.; Clayton, W.; Sullivan, K.M.; and Skladany, G. "*In Situ* Chemical Oxidation of Pentachlorophenol and Polycyclic Aromatic Hydrocarbons: From Laboratory Tests to Field Demonstration," Battelle, First International Conference on Remediation of Chlorinated and Recalcitrant Compounds, Monterey, CA, May 1998

Park Between Commercial and Residential Area, Utrecht, The Netherlands

Installation Date:
1997

Media:
Ground water

Contaminants:
TCE, BTEX

Oxidant:
Ozone

Soil Type:
Fine sand

Point of Contact:
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A pilot test of micro-encapsulated ozone oxidation for remediation of a deep plume of dissolved chlorinated solvents in ground water was conducted in Utrecht, The Netherlands, in 1997. Micro-encapsulated ozone is emplaced in fine bubbles to allow it to penetrate the subsurface.

Site Background

The field test took place in a small park midway on a long plume of chlorinated solvents, primarily trichloroethene (TCE), originating from a commercial building and extending over 800 ft across a predominantly commercial and residential area. The plume lies in a thick fine-sand deposit containing gravel lenses. About one-half of the area of ground water overlying the TCE plume was contaminated with benzene, toluene, ethylbenzene, and xylene (BTEX) from a nearby fuel spill. Borings showed a surface loam to 6 ft deep, ground water at 9 ft deep, fine sand beginning at 19 ft deep, and clay from 124-130 ft deep. Initial sampling at four wells indicated concentrations of halogenated volatile organic compounds (HVOCs) from 1,450-14,500 µg/L and BTEX from 62-95 µg/L. The mean concentrations were 3,000 µg/L HVOCs and 60 µg/L BTEX.

Technology Application

The test involved a C-Sparge™ well consisting of an in-ground sparge point, an in-well sparge point, a packer and a fluid pump, four monitoring wells, of previously installed mini-wells, and a fire well. Mini-wells, commonly used in Europe, are small points installed using cone penetrometer rigs to help determine the position of the plume and function as part of the monitoring system. The C-Sparge™ system consists of a combination of *in situ* air stripping, where the dissolved

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chlorinated solvents are extracted from aqueous solution into small bubbles, and the introduction of encapsulated ozone to oxidize the contaminants. Water and fine bubbles were injected from the lowest screen in the system (75 ft below grade), and return water entered the middle screen (42 ft below grade). The uppermost screen (8 ft below grade) collected the gases from just above the water table to assure vapor control.

The cost of this field demonstration was approximately $35K. This included placing the C-Sparge unit on site, a trailer to house the work area and monitoring equipment, a generator system for the blower unit, drilling, enclosing part of the site, laboratory sampling, and report preparation. It did not include the cost of installing the pre-existing wells.

Results

This field test ran for a 10-day period in April 1997. Its purpose was to determine the rates of contaminant removal. A kinetic analysis of the reaction rates was performed. HVOC concentration for the well with 14,500 µg/L fell to below 1,000 µg/L during the test period. Mean BTEX levels were reduced from 54 to 17 µg/L in the central monitoring wells. Full-scale treatment is expected to bring these concentrations to a level between acceptable commercial and drinking water levels. Negotiations are currently underway to treat the entire plume.

Site-specific References

Kerfoot, W. B.; Schouten, C.J.J.M; and Van Engen-Beukeboom, V.C.M., "Kinetic Analysis of Pilot Test Results of the C-Sparge™ Process," Battelle, First International Conference on Remediation of Chlorinated and Recalcitrant Compounds, Monterey, California, May 1998

Dissolved Oxygen (DO)

Peterson/Puritan, Inc. Superfund Site, Cumberland, RI

Installation Date:
1996

Media:
Ground water

Contaminants:
Arsenic

Oxidant:
DO

Soil Type:
Sand, gravel

Points of Contact:
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An Oxidant Delivery System was installed in 1996 at the Peterson/Puritan, Inc. Superfund Site in Cumberland, Rhode Island, to reduce arsenic concentrations in ground water to less than 50 µg/L.

Site Background

The site continues to support general and specialty chemical manufacturing industries. Historically, high organic-content wastewater at the source area were disposed through subsurface leachfields. The 1993 Record of Decision (ROD) specified that part of the remediation include the construction and installation of an *in situ* chemical oxidation system comprised of an infiltration gallery for delivering oxygenated water to the former leachfield locations and an above-ground oxidant delivery system. Some wells in the remediation area indicated concentrations of arsenic on the order of 1,000 µg/L. These elevated levels of arsenic are, to a degree, the result of reductive dissolution of the metal from native soil. The history of the site indicates that arsenic has also been reported in the wastewater stream going to the leachfield. This oxidant delivery system was constructed and became operational following excavation and removal of leachfield soils from the site.

Technology Application

A 35 x 65 ft infiltration gallery, a membrane-lined excavation, which holds the oxygenated water allowing it to percolate into the subsurface, was installed within the former leachfield at a depth of 14 ft. Monitoring wells were installed within the gallery, and the leachfield excavation was backfilled. Eleven additional micro-wells were installed around the site. A prefabricated treatment building was constructed on site, and the Oxidant Delivery System, composed of a degassing skid, an oxygen dissolution skid, a degassing tank, and an oxygen dissolution tank was assembled in the building. The system was designed to degas, superoxygenate, and inject municipal water (at 8-9 gpm) into the aquifer. The goal of this application is to increase ground-water dissolved oxygen (DO) concentrations to a level greater than 0.5 mg/L causing the arsenic to precipitate and rendering it immobile. It is intended to reduce the concentrations of dissolved arsenic and prevent its

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migration in the ground water. The long-term objective is to return the geochemical balance of the site to its pre-leachfield state, which includes some level of arsenic because it occurs naturally in the native soil.

The total capital cost of the remediation is estimated at $1.4M. This includes $620K for design, $460K for gallery installation and system construction, and $320K for pilot startup. Annual operations and maintenance costs, including sampling, utilities and reporting are estimated to be $175K. Indirect costs, such as project management and oversight, are included in these figures.

Results

The system was installed in 1996, a pilot test was performed in early 1997, and full-scale operations began in April 1997. EPA is assessing the success of this technology on an ongoing basis. Data are being compiled for submission as part of the five-year review, which is due in the 4th quarter of the Year 2000. No data are currently available.

Site-specific References

U.S. EPA, *Remedial Action Report, Peterson/Puritan Superfund Site*, prepared by ENSR Consulting and Engineering, revised edition, March 1998

Li, Z.M.; Comfort, S.D.; and Shea, P.J. "Destruction of 2,4,6-Trinitrotoluene by Fenton Oxidation," *Journal of Environmental Quality*, Vol. 26, No. 2, pp 480-487, March-April 1997.

Li, Z.M.; Peterson, M.M.; Comfort, S.D.; Horst, G.L.; Shea, P.J.; and Oh, B.T. "Remediating TNT-Contaminated Soil by Soil Washing and Fenton Oxidation," *Science of the Total Environment*, Vol. 204, No. 2, pp 107-115, 1997.

Li, Z.M.; Shea, P.J.; and Comfort, S.D. "Fenton Oxidation of 2,4,6-Trinitrotoluene in Contaminated Soil Slurries," *Environmental Engineering Science*, Vol. 14, No. 1, pp 55-66, 1997.

Lloyd, F.M. and Rossi, N.J. "Railyard Back on Track After Quick Remediation," *National Environmental Journal*, Vol. 6, No. 2, p 54, March-April 1996.

Lou, J.C. and Lee, S.S. "Chemical Oxidation of BTX Using Fenton's Reagent," *Hazardous Waste & Hazardous Materials*, Vol. 12, No. 2, pp 185-193, 1995.

Lu, M-C.; Chen, J-N.; and Chang, C-P. "Effect of Inorganic Ions on the Oxidation of Dichlorovos Insecticide with Fenton's Reagent," *Chemosphere*, Vol. 35, No. 10, p 2285, November 1997.

Miller, C.M.; Valentine, R.L.; Roehl, M.E.; and Alvarez, P.J.J. "Chemical and Microbiological Assessment of Pendimenthalin-Contaminated Soil after Treatment with Fenton's Reagent," *Water Research*, Vol. 30, NO. 11, pp 2579-2586, November 1996.

Mohatny, N.R. and Wei, I.W. "Oxidation of 2,4-Dinitrotoluene Using Fenton's Reagent: Reaction Mechanisms and Their Practical Applications," *Hazardous Waste & Hazardous Materials*, Vol. 10, No. 2, pp 171-183, 1993.

Pignatello, J.J. and Baehr, K. "Ferric Complexes as Catalysts for 'Fenton' Degradation of 2,4-D and Metolachlor in Soil," *Journal of Environmental Quality*, Vol. 23, pp 365-370, 1994.

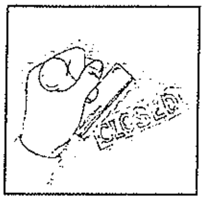
Sedlak, D.L. and Andren, A.W. "Oxidation of Chlorobenzene with Fenton's Reagent," *Environmental Science Technology*, Vol. 25, No. 4, pp 777-782, 1991.

Stanton, P.C. and Watts, R.J. "Process Conditions for the Mineralization of a Biorefractory Polycyclic Aromatic Hydrocarbon in Soils Using Catalyzed Hydrogen Peroxide," 68th Annual Conference and Exposition of the Water Environment Federation, Miami Beach, Florida, October 21-25, 1995.

Stokely, K.E.; Drake, E.N.; Prince, R.C.; and Douglas, G.S. "The Role of Fenton's Reagent in Soil Bioremediation," Fourth International *In Situ* and On-Site Bioremediation Symposium, New Orleans, Louisiana, April 28 - May 1, 1997.

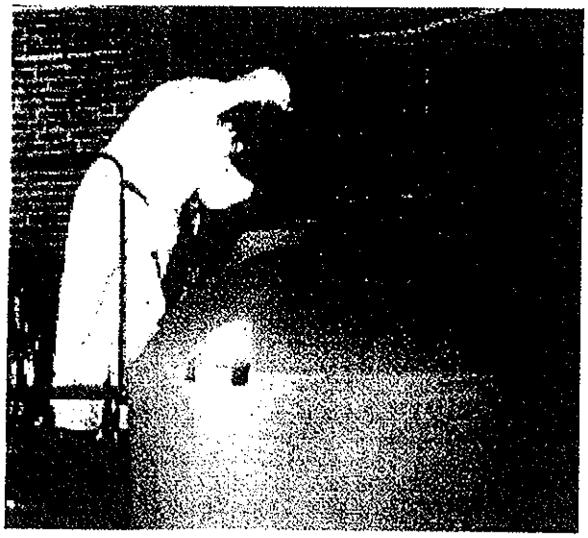
ATTACHMENT B
In Situ Oxidation Case Studies

Chemical Oxidation Using Potassium Permanganate



Fluor Daniel GTI is recognized as a leader in developing and applying advanced remediation technologies. In recent years, we have been at the forefront of introducing new chemical oxidation applications. We are currently one of only four technology experts to use potassium permanganate as an oxidant in environmental applications.

For decades, potassium permanganate has been used in the water and sewage treatment industry to oxidize and precipitate dissolved metals and treat sulfide odors. In 1997, the University of Waterloo published research confirming the chemical's effectiveness in treating impacts to soil and groundwater.



Fluor Daniel GTI scientists apply potassium permanganate to groundwater during a field test of the new chemical oxidation agent.

Based on these findings, Fluor Daniel GTI began its own investigation of potassium permanganate through treatability studies at our Remediation Technology Testing Facility (RTTF). Favorable laboratory results prompted our staff to conduct field–pilot tests at applicable client sites to determine the effectiveness of the chemical in expediting groundwater restoration.

Potassium permanganate oxidizes solvents

Like other oxidants, potassium permanganate is introduced into the subsurface to effect a chemical reaction. This reaction causes target constituents to oxidize and become nonhazardous.

Potassium permanganate has proven effective in remediating chlorinated solvents plumes, such as TCE and PCE, as well as PAHs and BTEX. These constituents can be difficult to treat, because they are mobile in the subsurface and do not naturally biodegrade. For example, TCE plumes have been known to extend for a mile, inhibiting containment and remediation. But by injecting potassium permanganate into existing groundwater pump-and-treat wells or through hydrofracturing techniques, these plumes can be treated in a matter of days.

TCE reduced to non-detect levels in 6 days

To date, Fluor Daniel GTI has successfully conducted potassium permanganate pilot tests at a site in Australia and two US sites. At the Australian site, the pilot test was used to determine the effectiveness for remediating TCE concentrations as high as 8,600 parts per billion. In just 6 days, TCE concentrations were reduced to below detection limits. Due to the success of the pilot test, the project team is installing a full-scale system at the site to expedite cleanup and avert years of groundwater pumping. This approach is contributing to a $7 million cost savings for the client.

Conclusion

As our success applying this approach continues, Fluor Daniel GTI is securing additional contracts for chemical oxidation using potassium permanganate at other chlorinated solvent sites. Several of our current potassium permanganate projects are described in greater detail in the following case histories.

In Situ Remediation of Automotive Manufacturing Site

Project Highlights

- Implementing innovative chemical oxidation and nutrient injection systems to avert operation of traditional pump-and-treat system, saving client estimated $7 million
- Reduced TCE concentrations in groundwater to non-detect levels after 6 days of potassium permanganate field test
- Conducting risk assessments and developing predictive groundwater models to support natural attenuation of residuals

Facility

Automotive components manufacturing site, Australia

Regulatory Involvement

South Australian EPA, South Australian Health Commission, and South Australian Water

Constituents of Interest

Petroleum and chlorinated hydrocarbons

The Problem

A property transfer triggered an environmental site assessment at the manufacturing site, identifying three on-site chlorinated hydrocarbon plumes, each approximately 120 meters in length. Five petroleum hydrocarbon plumes, as well as a number of smaller MEK plumes, also were found co-mingled across the site. On-site impacts also were identified as migrating off-site to surrounding residential areas.

The Solution

Fluor Daniel GTI was contracted to develop a remediation program that would address on-site impacts while preventing further migration to residential properties.

Chemical treatments target additional plumes

Our project team proposed a "hot spot" reduction remedy for chlorinated hydrocarbons, consisting of chemical oxidation. This process involves injecting a chemical reductant, in this case potassium permanganate, into groundwater. Once the chemical comes in contact with the targeted contaminant, it initiates a chemical reaction to oxidize the contaminant and leave only trace concentrations of chlorine, carbon dioxide, or hydrogen.

Fluor Daniel GTI conducted a pilot test of this system to address TCE concentrations as high as 8,600 parts per billion (ppb). Six days after the potassium permanganate addition, TCE concentrations were reduced to below detection limits. We are currently installing a full-scale chemical oxidation system using potassium permanganate. This along with other chemical treatment remedies is expected to expedite closure and avert an estimated $7 million in groundwater pumping costs. Other chemical treatment remedies being explored include nitrate injection and the addition of oxygen-releasing compounds to address petroleum hydrocarbon plumes.

Case History

Field Test Proves Potassium Permanganate Effective

Project Highlights

- Conducted chemical oxidation field test using potassium permanganate addition to evaluate effectiveness in expediting groundwater remediation
- Reduced TCE levels in groundwater from 72 to 99.8 percent in just 21 days

Facility

Former manufacturing facility, Kansas

Regulatory Involvement

EPA Region VII

Constituents of Interest

TCE and PCE

The Problem

Chlorinated solvents from former manufacturing operations impacted portions of a 2,600-acre downtown area earmarked for revitalization. Our client operated two downtown factories for more than 80 years and, as a result, was targeted for cleanup costs.

The Solution

Our client agreed to investigate impacts to several city blocks under a state consent order and hired Fluor Daniel GTI to lead the remedial investigation and feasibility study (RI/FS).

Pilot test nets significant contaminant reductions

During the FS, Fluor Daniel GTI conducted a field test of chemical oxidation. This technology involves introducing a chemical reductant into groundwater for the purpose of initiating a chemical reaction. For this project, we tested the addition of potassium permanganate.

After a one-time addition of potassium permanganate, chlorinated ethene concentrations in the subsurface were reduced from 72 to 99.8 percent in just 21 days. Our project team continues to evaluate these results to determine if a full-scale system is warranted for treating the groundwater contaminant plume.

Testing Potassium Permanganate Addition at Superfund Site

Project Highlights

- Secured ROD amendment for use of alternate soil technology, thermally enhanced SVE augmented by groundwater pump-and-treat
- Achieved soil cleanup levels in 2 years of active remediation— 3 years ahead of project schedule
- Conducted field test of potassium permanganate addition, resulting in reductions of TCE, PCE, and xylene levels by 80 percent

Facility

Former solvent recycling facility, Maine

Regulatory Involvement

Federal Superfund program under EPA Region I

Constituents of Interest

Solvents

The Problem

The site of a former solvent recycling facility is impacted by high concentrations of solvents in tight soils and groundwater, earning it a place on EPA's National Priorities List. The original Record of Decision (ROD) for this site dictated excavation and off-site incineration of impacted soils.

The Solution

To reduce our client's environmental cleanup costs, Fluor Daniel GTI proposed an innovative thermally enhanced soil vapor extraction (SVE) system, augmented by pump-and-treat in a preliminary design report to EPA. This recommendation resulted in a ROD amendment approving the use of this alternate technology, which is expected to reduce cleanup costs by an estimated $4 million and eliminate 20 years of groundwater pumping. This work is being conducted under a lump sum contract with performance guarantees that specify soil and groundwater cleanup within 5 and 7 years, respectively, of system start-up.

Innovative technology expedites soil cleanup

Fluor Daniel GTI designed, installed, and is operating the SVE and pump-and-treat system. The SVE system is enhanced by an innovative hot air injection process for volatilizing difficult-to-treat contaminants, such as DMF. In just 2 years of operation, soil levels were reduced to the established closure goals. This is 3 years ahead of our projected schedule.

Potassium permanganate proven effective

While operating the groundwater pump-and-treat system, our project team evaluated additional technologies that would expedite groundwater cleanup. For example, Fluor Daniel GTI conducted a 3-month field test of a potassium permanganate addition—one of the largest field tests conducted for this technology. Once added to groundwater via a series of 26 pump and vent wells, the chemical remains stable and mobile until coming into contact with double-bonded contaminants, such as TCE, PCE, and xylenes. Upon contact with these contaminants, oxidization occurs leaving only trace concentrations of chlorine, hydrogen, or carbon dioxide. Our field test data confirmed the technology's effectiveness in reducing chlorinated solvent concentrations by more than 80 percent.

Conclusion

Fluor Daniel GTI will present field data to our client and regulators in an attempt to receive approval for the long-term addition of this oxidizing agent to on-

Testing Potassium Permanganate Addition at Superfund Site

site groundwater. If successful in receiving regulatory approval, this chemical addition is expected to expedite groundwater cleanup by a number of years.

ATTACHMENT C
Laboratory Treatability Study Report

IT Corporation of North Carolina, Inc.
A Member of The IT Group

Permanganate Laboratory Treatability Study Report for W.P. Ballard Property, Greensboro, North Carolina

Prepared by:

Richard A. Brown, Ph.D.
Duane Root, Ph.D.
IT Corporation

March 23, 1999

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FIGURES

1.0 Initial Characterization of Site Groundwaters and Soil

Two, 4-liter (L) samples of moderately contaminated groundwater (MW-1 and MW-4), 20 L of highly contaminated groundwater (MW-3), and a 3.5 gallon pail of highly contaminated site soils (SVMP-12) were received at the Technology Applications Laboratory (TAL) in Knoxville, TN, on January 8, 1999. At the TAL, the two moderately contaminated groundwater samples were composited for testing, and three, 40- milliliter (mL) VOA vials were filled with zero headspace with the composited groundwater. The highly contaminated groundwater was sampled in the same manner. Each groundwater was analyzed in singlet for VOCs by EPA Method 601. The highly contaminated groundwater was also analyzed in singlet for BTEX and PAHs. The soils were screened to a uniform size, mixed to apparent homogeneity, and analyzed in singlet for VOCs by EPA Method 8010 as well as for BTEX and PAHs. An analytical turn-around-time of two days was used with the Initial Characterization samples.

All testing stoichiometries were based on the following results of initial sample characterization:

Highly contaminated groundwater	240 mg/L PCE
Moderately contaminated groundwater composite	15.1 mg/L PCE
Soil	75.3 mg/kg PCE

2.0 Chemical Oxidation Treatability Study

While potassium permanganate is expected to effectively treat the chlorinated ethenes present, it will also be consumed by other suitably oxidizable compounds such as metals or other organics present in site soils and groundwater. Soil and groundwater slurries and soil columns were used in these experiments. The chemical oxidation treatability study was conducted in three separate phases as described in the sections below.

2.1 Slurry Permanganate Test

The treatability protocol called for reacting a 50% soil and groundwater (highly contaminated) slurry at three different permanganate concentrations (3, 10, and 15 times PCE stoichiometry). The reaction of permanganate on PCE at each oxidant concentration was monitored by periodic sampling over a 48 hour period. At each sampling point, the reaction mixture was chemically quenched with a stoichiometric amount of ferrous chloride to react with 100% of the permanganate that was added, and the slurry was fractionated into soil and aqueous phases by centrifugation. Representative soil and aqueous samples were then analyzed. **Table 1** presents the basic experimental design.

Each sample point in the experiment was set up in individual 250 mL centrifuge bottles using 220 mL of a 50% (wt soil to total volume) soil/groundwater slurry. An appropriate volume of a stock 5% permanganate solution (as potassium permanganate) was added to each bottle to produce the desired final permanganate concentration. Approximately 30 mL of headspace was left in each bottle to allow for slurry mixing, and all centrifuge bottles were mixed continuously on a shaker table until sampled. At each sampling point, one bottle from each permanganate concentration was sacrificed for analysis. Each bottle was opened and a small sample was withdrawn to test for ORP and unreacted permanganate.

Table 1.

Test Condition	Soil and Water Samples (Time in hours)					
	0	2	4	8	24	48
Control (unquenched)	XX				X	X
Control (quenched)					X	X
Permanganate at 3X Stoichiometry		X	X	X	X	X
Permanganate at 10X Stoichiometry		X	X	X	X	X
Permanganate at 15X Stoichiometry		X	X	X	X	X

The remaining slurry was quenched with a ferrous chloride solution, and the bottles recapped and centrifuged to produce separate soil and aqueous fractions. The aqueous fraction was removed for analysis, and the remaining soil fraction mixed with 110 mLs of methanol. The methanol slurry was mixed and then centrifuged. A methanol aliquot was sent for analysis to represent the concentration of PCE in the soil.

Control samples (no permanganate added) were analyzed in duplicate at T = 0 and in singlet at T = 24 and T = 48 hours.

2.2 Groundwater Oxidation Testing

Two different groundwater samples were individually tested with permanganate.

2.2.1 Moderately Contaminated Groundwater

Moderately contaminated groundwater was tested at a permanganate to PCE stoichiometry of 3:1 using 250 mL VOA bottles with septum caps. The starting concentration was supposed to be ~15 PPM; however, the concentration of PCE in the bottles after set-up was too low (< 1 PPM) to gather meaningful data.

2.2.2 Highly Contaminated Groundwater

The effects of permanganate oxidation on highly contaminated groundwater were monitored during this test. The highly contaminated groundwater was tested at a permanganate to total contaminant stoichiometry of 3:1 using appropriately sized bottles with septum caps. A suitable volume of composited groundwater was placed into each of 12 bottles and the bottles capped. Two of these bottles were analyzed to provide the Time Zero concentrations of PCE in the liquid. Two other bottles received an injection of ferrous chloride quenching solution through the septa at a stoichiometry of 100% of the permanganate to be added. These bottles were analyzed for PCE concentrations to establish whether the quenching solution had any direct impact.

To the remaining eight VOA bottles, an appropriate volume of permanganate solution was added with a syringe to achieve the desired 3:1 stoichiometric ratio. At sampling points of 0.5 hours, 1 hour, 2 hours, and 4 hours, two reactive bottles were each sampled using a syringe to remove solution for ORP and unreacted permanganate testing. The remaining liquid in each bottle then received a 100% stoichiometric amount of quenching solution, based on the original permanganate used, injected by syringe. All control and quenched bottles had their liquid PCE concentrations determined by analysis.

2.3 Soil Column Testing

Four, 2" outer diameter by 18" height glass soil columns were used for this test. Each column was filled to a height of approximately 12 inches with a processed site soil/sand mixture (approximately 1 kilogram of solids per column, estimated at 60:40 by weight of sand:soil). Two "Time Zero" soil samples were taken for analysis when the columns were constructed. A continuously working recirculating water system was employed to keep each column flushed with pore water at a rate of approximately 5 mLs/min. The pore water volume of the columns was determined to be 220 mLs. A volume of 270 mLs (sufficient liquid for recirculation and sampling) was applied to all four columns.

As will be discussed later, the PCE concentration in the columns was too low to be effectively tested. The four columns that were run evidenced significant consumption of permanganate. The columns results are useful in examining the fate of permanganate.

Column #1: This column served as an experimental control. At the beginning of the experiment, one working volume (270 mLs) of distilled water was added to the column. This volume of liquid was recirculated through the column for a period of seven days.

Column #2: This column evaluated permanganate oxidation at a permanganate to PCE stoichiometry of 10:1. At the beginning of the experiment, one working volume of appropriate strength permanganate solution was added to the column. The volume of liquid was recirculated through the column for a period of two days. A small sample of the pore water was collected and analyzed for unreacted permanganate on a daily basis. The water was colorless at the end of the second day (permanganate reacted).

Column #3: This column was a duplicate of Column #2, but was operated for a period of 7 days. The water was colorless at the end of the second day (permanganate reacted).

Column #4: This column evaluated permanganate oxidation at an increased permanganate to PCE stoichiometry of 20:1. At the beginning of the experiment, the working volume of appropriate strength permanganate solution was added to the column. The volume of liquid was recirculated through the column for a period of seven days. A small sample of the pore water was collected and analyzed for unreacted permanganate on a daily basis. The water was colorless at the end of the sixth day (permanganate reacted).

3.0 Results

Four tests were attempted. Two, the slurry test and the highly contaminated groundwater test, were successful. The other two tests, the moderately contaminated groundwater and the column tests were not successful, as the initial PCE levels were too low to provide meaningful data. The column tests, however, provide useful information on the fate of permanganate in the soil at the site. The data for all four tests are included in **Tables 2 to 4**.

3.1 Soil Slurry Test

Figures 1, 2, 3 and **4** depict the oxidation of PCE in the soil slurries. **Figure 1** depicts the results for the water phase; **Figure 2**, the soil phase; and **Figure 3**, the permanganate consumption. **Figure 4** compares the oxidation of PCE and the consumption of permangante. The data for the soil slurry studies is in **Table 2.**

As shown in **Figure 1**, the reaction in the slurry phase takes at least 2-4 hours to see significant reductions in the water phase. This is probably due to the continued desorption of PCE from the soil. Once the soil level is reduced the groundwater concentration is also reduced. The importance of this desorption phenomenum is shown for the 3X sample. Initially the water concentration rises after the addition of the permanganate.

The oxidation of PCE in the soil phase **(Figure 2)** is a little slower than in the water phase. The 3X run shows an initial rapid drop in PCE followed by a more gradual decrease. This may be due to either desorption or due to the consumption of permanganate.

Figure 3 depicts the decrease in permanganate with time. In all studies (3X, 10X, 15X) the permangante concentration in the slurry decreased with time. In the case of the 3X study, the permanganate was 85% gone by 24 hours. By contrast, the 15X study was only 33% gone after 48 hours. The loss of permanganate indicates that it is reacting with materials other that PCE. Most likely, it is reacting with reduced iron in the saprolitic soil. The loss of permanganate seems to impact the oxidation of PCE.

Figure 4 compares the loss of permanganate (% of initial) with the oxidation of PCE (% of Initial). The 3X run shows that permanganate decreases as fast as PCE. Once the permanganate is consumed, PCE oxidation also ceases. It would appear that maintaining a large excess of permanganate is important for maximizing reaction efficiency.

The closure goals for the remedial system are < 100 μg/L VOC and a >90% reduction in VOCs in soil and groundwater. Using this as a criteria of success, the following table shows that the 3 X test did not completely meet the criteria, because the soil reduction was above target.

Table 5

	Control	3 X	10 X	15 X
GW Conc (< 100 PPB)	6,100	920	60	20
% Red Soil (> 90%)	38.1	86.2	97.9	98.3
% Red GW (> 90%)	82.3	97.3	99.8	99.9

Both the 10X and 15X runs were able to meet the closure criteria.

3.2 Groundwater Study

Table 3 and **Figure 5** depict the oxidation of PCE in highly contaminated ground water with a 3X stoichiometry. As can be seen, the reaction is rapid and complete. The PCE is essentially gone after 1 hour. **Figure 6** compares PCE oxidation with the permanganate usage. In contrast to the slurry studies, there is no excess consumption of permanganate after the PCE is oxidized. This indicates that the soil is the cause of the permanganate loss in the slurry study.

3.3 Soil Column Study

The soil columns yielded no meaningful data on PCE oxidation, as the initial PCE concentrations were low (<100 µg/Kg). However, the study did further confirm that the soil actively reacts with permanganate. The results are given in **Table 4** and depicted in **Figure 7**. As can be seen with both the 10X and 20X columns the permanganate is consumed. With the 10X column, it is gone in 1 day. With the 20X column, it is significantly reduced after 1 day and is completely gone in 6 days.

4.0 Conclusion

Potassium permanganate is able to oxidize PCE in soil and groundwater from the W.P. Ballard Greensboro, NC site. Properly applied, permanganate oxidation can achieve the target closure goals of <100 µg/L VOCs and >90% mass removal. However, the permanganate also reacts with the soil matrix, resulting in a loss of permanganate and a decrease in PCE oxidation. As can be seen in the following table, the soil consumes about 1.8 mg of $KMnO_4$ per gram of soil. Permanganate additions below this amount result in complete loss of permanganate and incomplete reaction with PCE. The reaction of permanganate with PCE and the soil are competitive reactions.

Table 6

Experiment	Ratio: mg $KMnO_4$ Added per g Soil used	Ratio: mg $KMnO_4$ consumed per g Soil used	Observation
3X Slurry	1.0	1.0	Permanganate 92% decreased in 48 hours
10X Slurry	3.7	1.8	Permanganate 50% decreased in 48 hours
15X Slurry	5.4	1.8	Permanganate 33% decreased in 48 hours.
10X Column	0.35	0.35	Permanganate completely gone in 2 days
20X Column	0.70	0.70	Permanganate completely gone in 6 days

However, it appears that the PCE reaction is faster. Maximum efficiency for PCE destruction can be obtained by adding excess permanganate to overcome the soil demand. This demand is approximately 5 lb $KMnO_4$ per yd^3 of soil treated. This needs to be added in addition to any stoichiometric requirement based on the PCE concentration present.

Table 2

Soil/Groundwater Slurry Permanganate Tests - Batch Treatment
W.P. Ballard Property & Surrounding Properties

Highly Contaminated Groundwater:
KMnO4:PCE stoichiometry based on groundwater at 240 mg/L and soil at 75.3 mg/kg

Initial KMnO4 Conc. (mg/L):

3x Stoichiometry =	793
10x Stoichiometry =	2548
15x Stoichiometry =	3727

Sample	Stoich. (x)	Time (hr)	PCE Conc.		KMnO4 Conc. (mg/L)	ORP (mV)
			Water (mg/L)	Soil (mg/kg)		
T0 - Control A	0	0	34.5	41.7	0	373
T0 - Control B	0	0	31.0	39.8	0	370
T24 - Control	0	24	10.5	42.4	0	385
T48 - Control	0	48	6.1	25.8	0	372
T24 - Quench Control	0	24	9.88	41.6	0	249
T48 - Quench Control	0	48	6.3	25.0	0	252
T2	3	2	41.7	31.1	530	864
T4	3	4	18.1	16.8	450	883
T8	3	8	9.3	16.2	360	870
T24	3	24	1.43	7.54	120	839
T48	3	48	0.92	5.72	60	813
T2	10	2	14.2	11.4	2470	903
T4	10	4	3.71	6.90	2160	909
T8	10	8	1.01	4.88	2190	905
T24	10	24	0.20	1.5	1730	895
T48	10	48	0.060	0.87	1270	857
T2	15	2	4.90	7.1	3700	915
T4	15	4	2.16	8.85	3320	923
T8	15	8	0.62	3.8	3430	913
T24	15	24	0.080	0.97	3190	913
T48	15	48	<.040	0.71	2480	920

Table 3

Soil/Groundwater Slurry Permanganate Tests - Batch Treatment in Duplicate
W.P. Ballard Property & Surrounding Properties

3:1 Stoichiometry KMnO4:PCE based on groundwater at 240 mg/L

		PCE Conc. (mg/L)		KMnO4 Conc. (mg/L)		ORP (mV)	
Sample	Time (hr)	PCE Conc. (mg/L)	Dup. B	Dup. A	KMnO4, (mg/L)	Dup. A	Dup. B
T0	0	485		900	1500		
T1	0.5	0.38	0.38	1000	1100	969	979
T2	1	0.035	0.53	1100	1200	998	1003
T3	2	0.011	0.015	1200	1200	1009	459
T4	4	0.053	0.017	1100	1200	1012	1009
T0 - Control	4	390	580				
Q4 - Quench Rgt	4	390	440				

Moderately Contaminated Groundwater:
3:1 Stoichiometry KMnO4:PCE based on groundwater target of 15.1 mg/L

		PCE Conc. (mg/L)		KMnO4 Conc. (mg/L)		ORP (mV)	
Sample	Time (hr)	Dup. A	Dup. B	Dup. A	Dup. B	Dup. A	Dup. B
T0	0			60			
T1	0.5	0.43	0.19	80	74	726	736
T2	1	0.49	0.15	79	74	712	720
T3	2	0.57	0.54	75	77	753	725
T4	4	0.54	0.38	52	75	856	723
T0 - Control	4	0.97	1.05				
Q4 - Quench Rgt	4	0.97	0.89				

Table 4
Soil Column Testing
W.P. Ballard Property & Surrounding Properties

Sand:Soil Mixture - 60:40 with pore volume of Highly Contaminated GW (240 mg/L PCE)
Approx. 1 kg solids and 270 mL liquid

			PCE Conc.			
Sample	Stoich. (x)	Time (day)	Water (mg/L)	Soil Dup. A (mg/kg)	Soil Dup. B (mg/kg)	KMnO4 Conc. (mg/L)
T0 - Sand/Soil		0		0.075	0.066	
Control Column:						
Initial Water	0	0				0
1-Day Water	0	1				0.3
2-Day Water	0	2				0.1
3-Day Water	0	3				
4-Day Water	0	4				
5-Day Water	0	5				
6-Day Water	0	6				
7-Day Water/Soil	0	7	0.040	<.020	<.020	
2-Day Column:						
Initial Water	10	0				1300
1-Day Water	10	1				83
2-Day Water/Soil	10	2	0.064	0.029	0.039	0.4
7-Day 10:1 Column:						
Initial Water	10	0				1300
1-Day Water	10	1				78
2-Day Water	10	2				0
3-Day Water	10	3				
4-Day Water	10	4				
5-Day Water	10	5				
6-Day Water	10	6				
7-Day Water/Soil	10	7	0.060	<.020	<.020	
7-Day 20:1 Column:						
Initial Water	20	0				2600
1-Day Water	20	1				700
2-Day Water	20	2				255
3-Day Water	20	3				178
4-Day Water	20	4				89
5-Day Water	20	5				36
6-Day Water	20	6				3.9
7-Day Water/Soil	20	7	<0.04	<.020	<.020	1.5

Figure 1: PCE Oxidation, Soil Slurry Water Phase

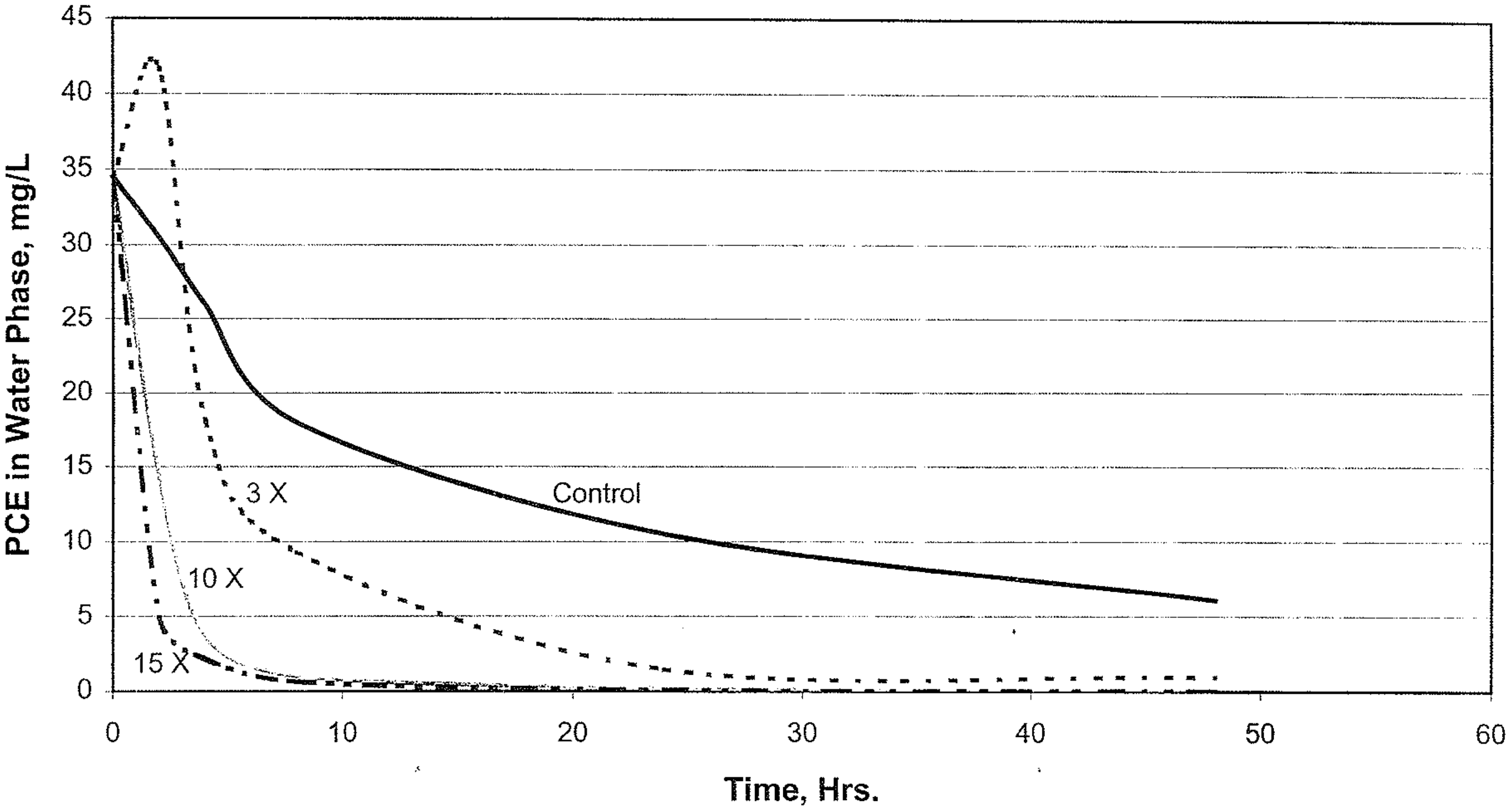


Figure 2: Oxidation of PCE, Soil Slurry
Soil Phase

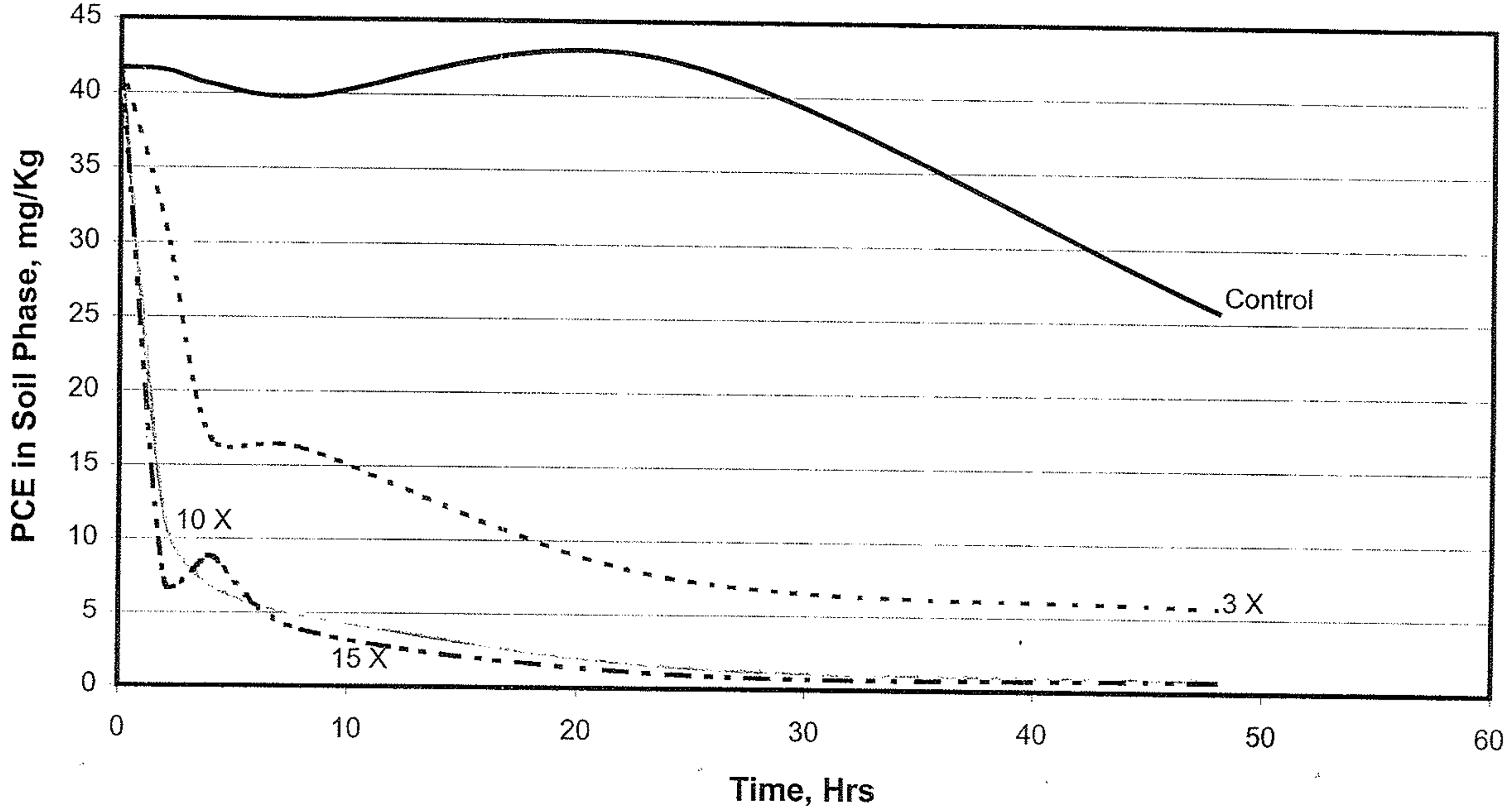


Figure 3: Permanganate Utilization
Soil Slurry

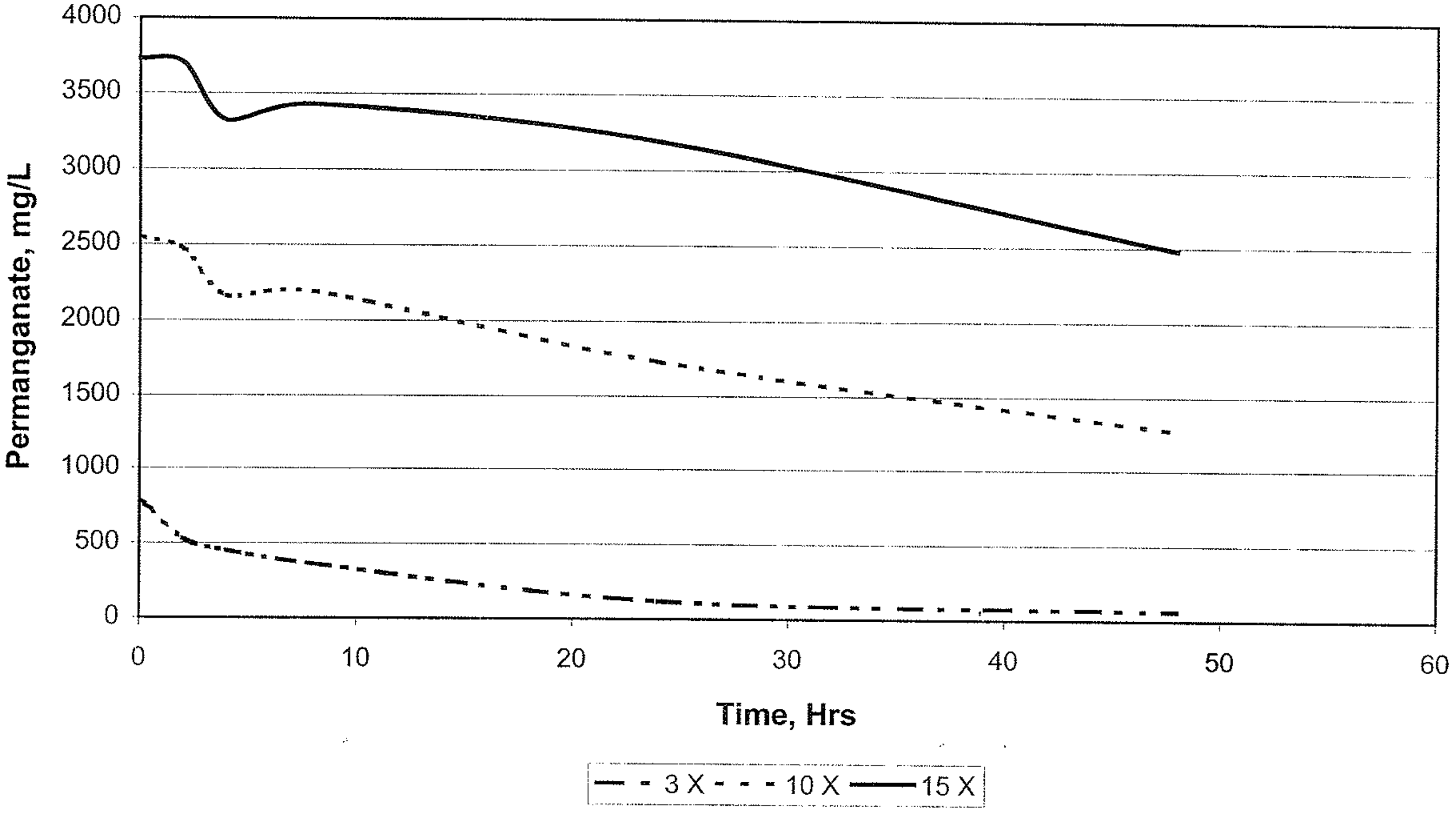


Figure 4: Comparison of Permanganate Consumption and PCE Oxidation: Soil Slurry Study

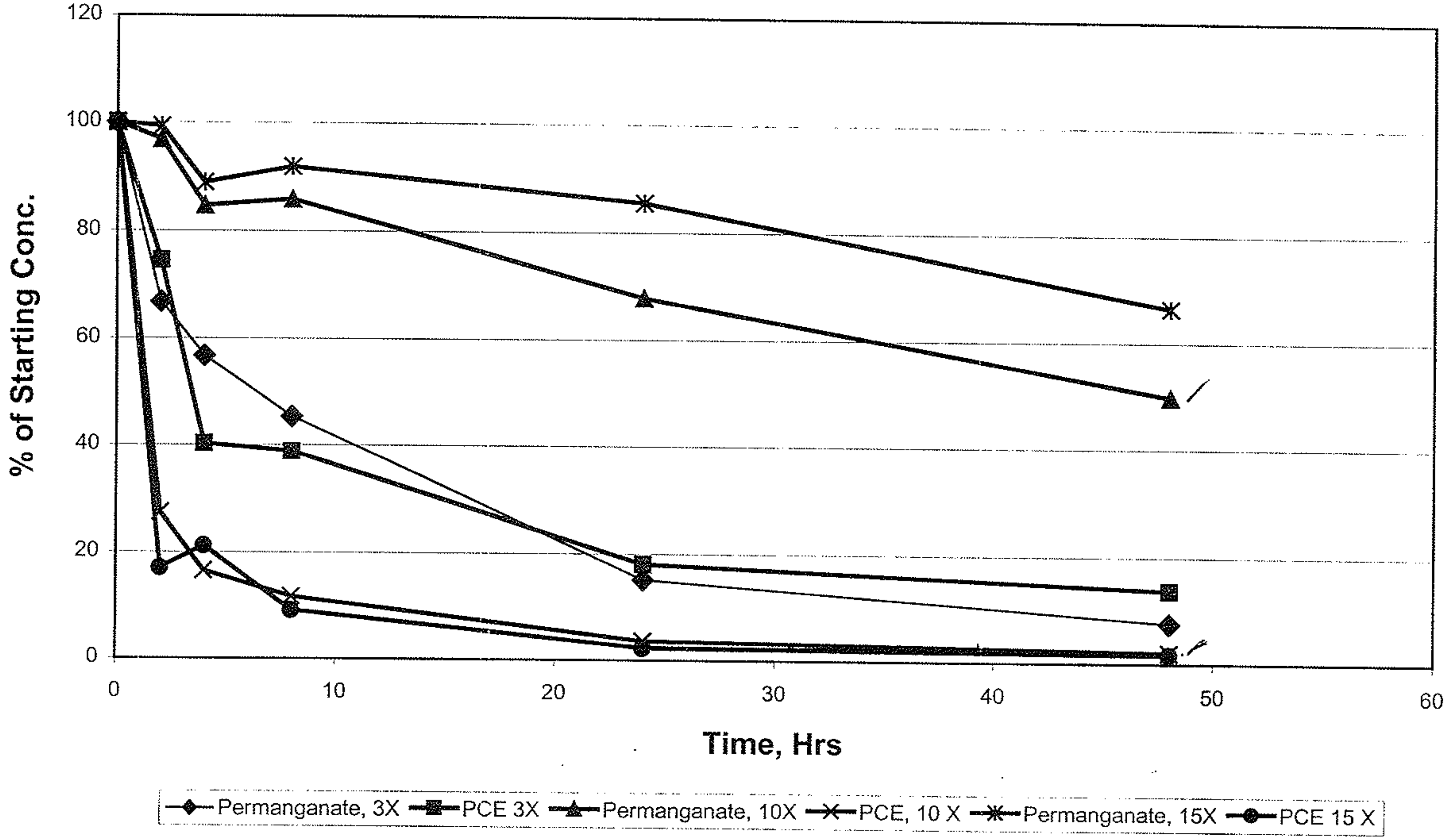


Figure 5: PCE Oxidation
Highly Contaminated Groundwater

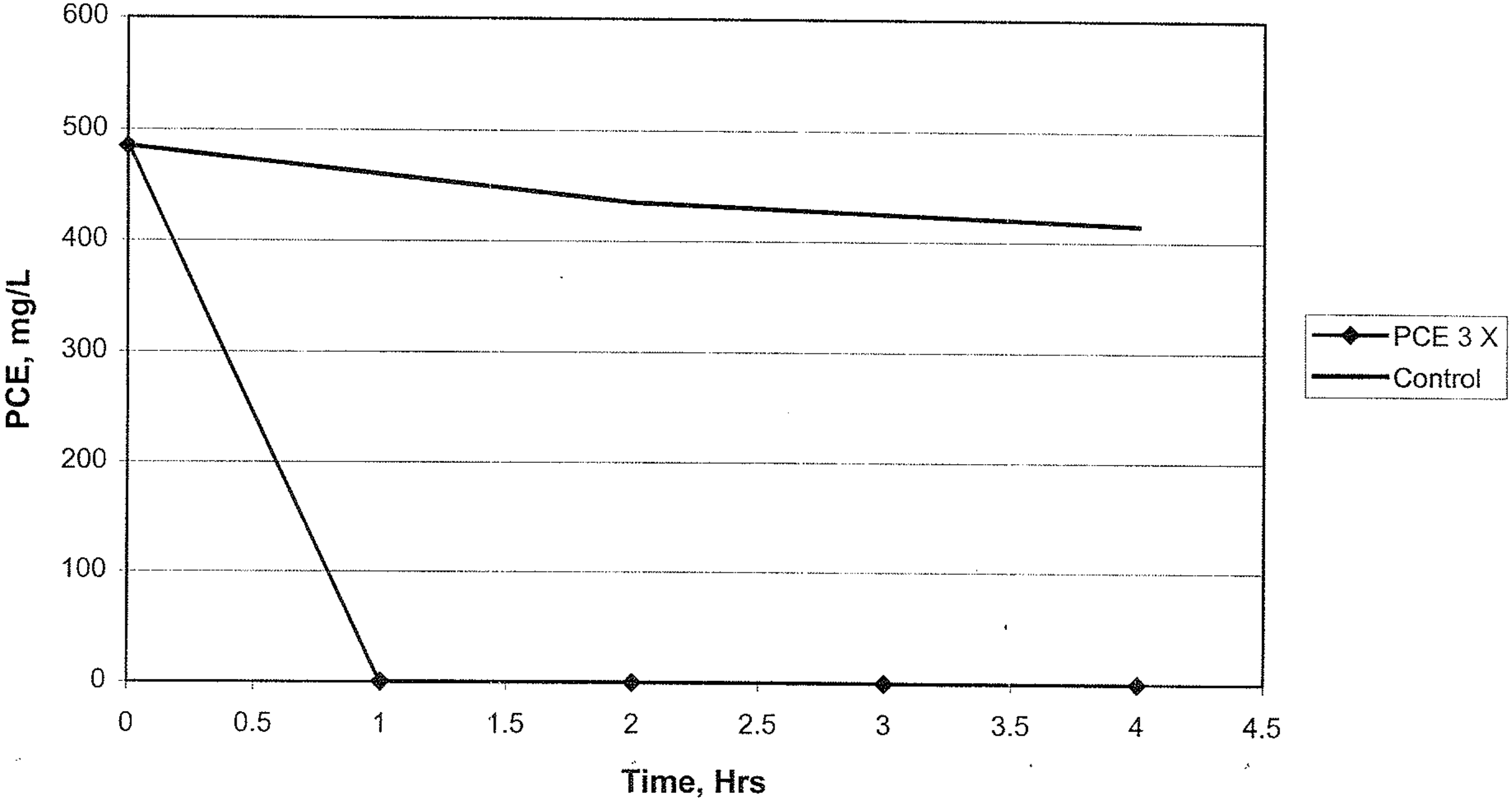


Figure 6: Comparison of PCE Oxidation and Permanganate Consumption

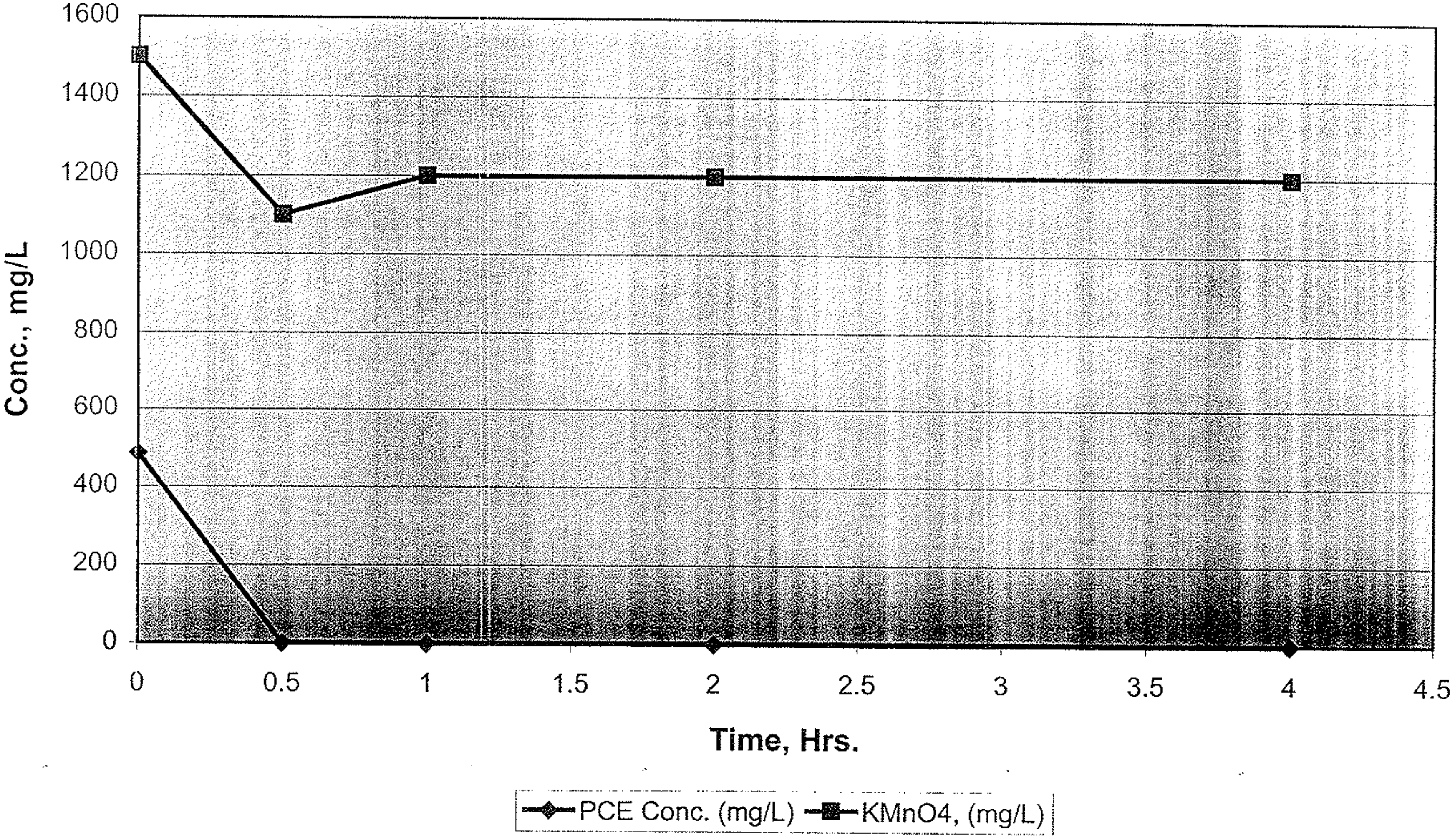
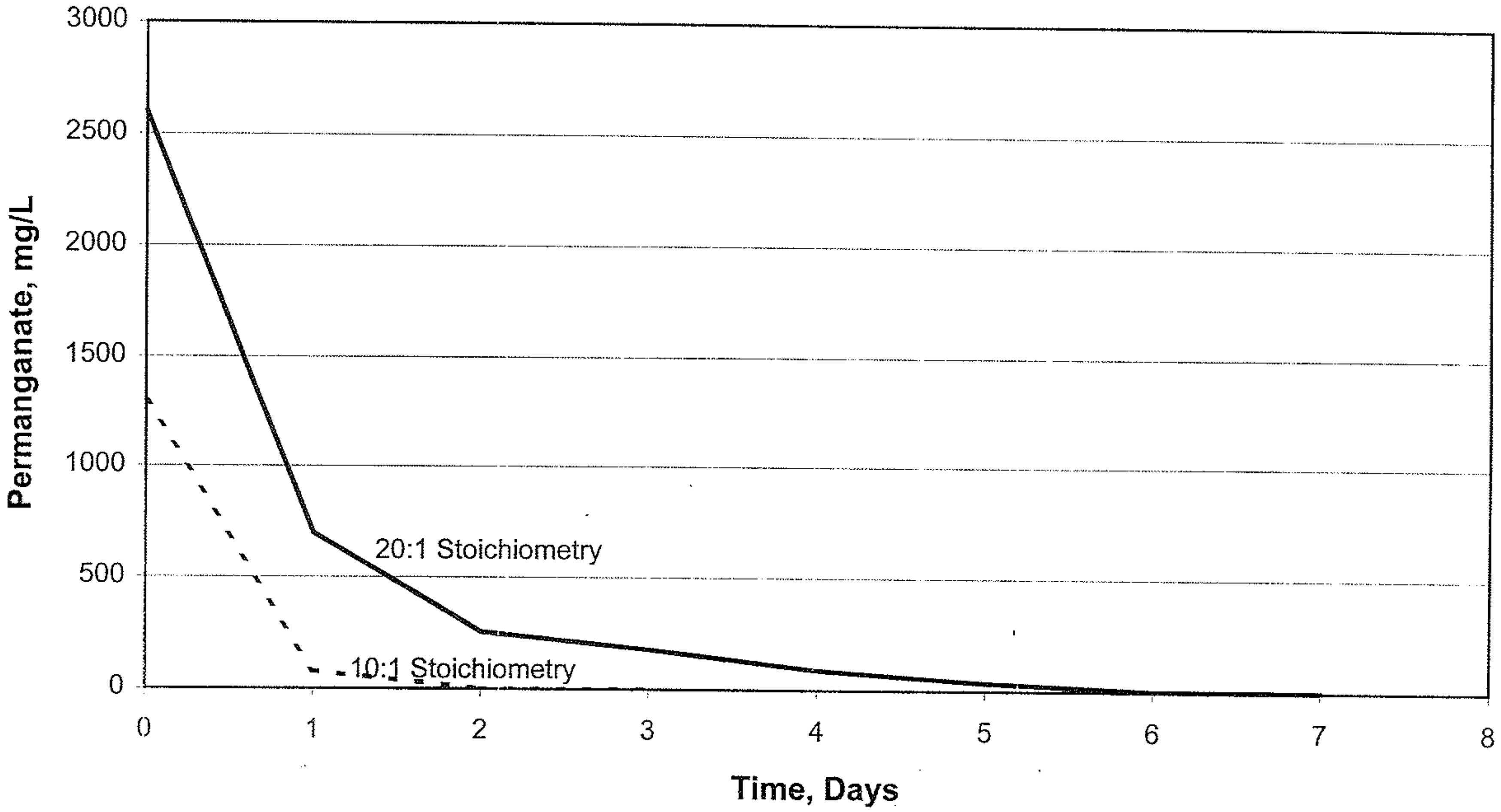


Figure 7: Permanganate Degradation in Soil Soil Columns



ATTACHMENT D
Pilot Geoprobe Application Study Report

Pilot Geoprobe Application Test Report

W.P. Ballard Property
Greensboro, North Carolina

Prepared by:

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April 23, 1999

TABLE OF CONTENTS

Attachments

1.0 Objectives

IT Corporation performed a pilot test to determine the feasibility of applying liquids into the subsurface using a Geoprobe, at the W.P. Ballard Property site. The objectives of the pilot test were three-fold:

1. To determine the maximum depth attainable using the Geoprobe at each boring location, and the total time necessary to probe to the maximum depth (max. overall depth 65 feet) at each location;
2. To determine the flow rates and delivery pressures during liquid application at different application depth intervals; and
3. To determine areas of difficulty with the application process and/or equipment which will allow for improvements prior to the actual application event.

2.0 Planning

In planning the pilot test, three boring locations were selected. One boring location was selected on the existing Phenix Supply site (ITP-1). One boring location was selected adjacent to the former Axton-Cross building (ITP-2). One boring location was selected adjacent to the loading dock on the west end of the former SLS building (ITP-3). Based on data obtained during the installation of soil vent wells on the Ballard property, and data obtained during the installation of previous Geoprobe borings at the site, it was decided that only two application test points would be utilized during the pilot test (ITP-2 and ITP-3). The locations of the Geoprobe points are shown on **Figure 1**.

3.0 Test Execution

The pilot test was conducted on March 25 and 26, 1999. Geologic Exploration was the Geoprobe subcontractor. Geoprobe Systems sent a representative to the site to assist with the application test, and to evaluate the application plan to determine how they will modify their equipment to improve the application process.

The first application test boring was ITP-2, which was located adjacent to the former Axton Cross building. The second application test boring was ITP-3, which was located adjacent to the NW corner of the loading dock on the former Sears building. At boring ITP-2, probe insertion was halted at approximately 64 feet below grade, however, probe refusal was not encountered. The total probe insertion time to depth at this location was approximately 20 minutes. At boring ITP-3, probe insertion was halted at approximately 46 feet below grade, at probe refusal. The total probe insertion time to this depth was approximately 25 minutes. It should be noted, however, that at boring ITP-3, some time was spent attempting to penetrate to depths greater than 46 feet.

To facilitate liquid application, a Geoprobe grout application pump was utilized. This system consists of a 12.5 gallon tank (hopper), and a hydraulically operated positive displacement pump. The grout application pump was connected to 1.25 inch (OD) Geoprobe rods via high pressure hose. The probe rods were connected to a Geoprobe "Zero-Contamination Groundwater Sampler" unit. This unit consists of an expendable drive tip, and a two-foot section of stainless steel, continuous slot screen. The screened interval remains closed until the desired depth is attained. Once the desired depth (64 feet below grade, initially) was attained, the drive rods were retracted 2 feet, which causes the drive tip to separate and the screened interval to be exposed.

Unaltered city water (obtained from Phenix Supply) was the liquid injected. The water was temporarily stored in a clean, polyethylene tank prior to use. Liquid application began at a depth of 64 feet below grade. Upon completion of the each application interval, the drive rods were raised five or 10 feet and the application process was repeated. During application, delivery pressures and liquid flow rates were monitored. These application data are presented on **Tables 1** and **2**. Test data are also graphically represented on **Figures 2** through **9**. Raw test data sheets are included in **Appendix A**. Select photographs taken during the pilot test are included in **Appendix B**.

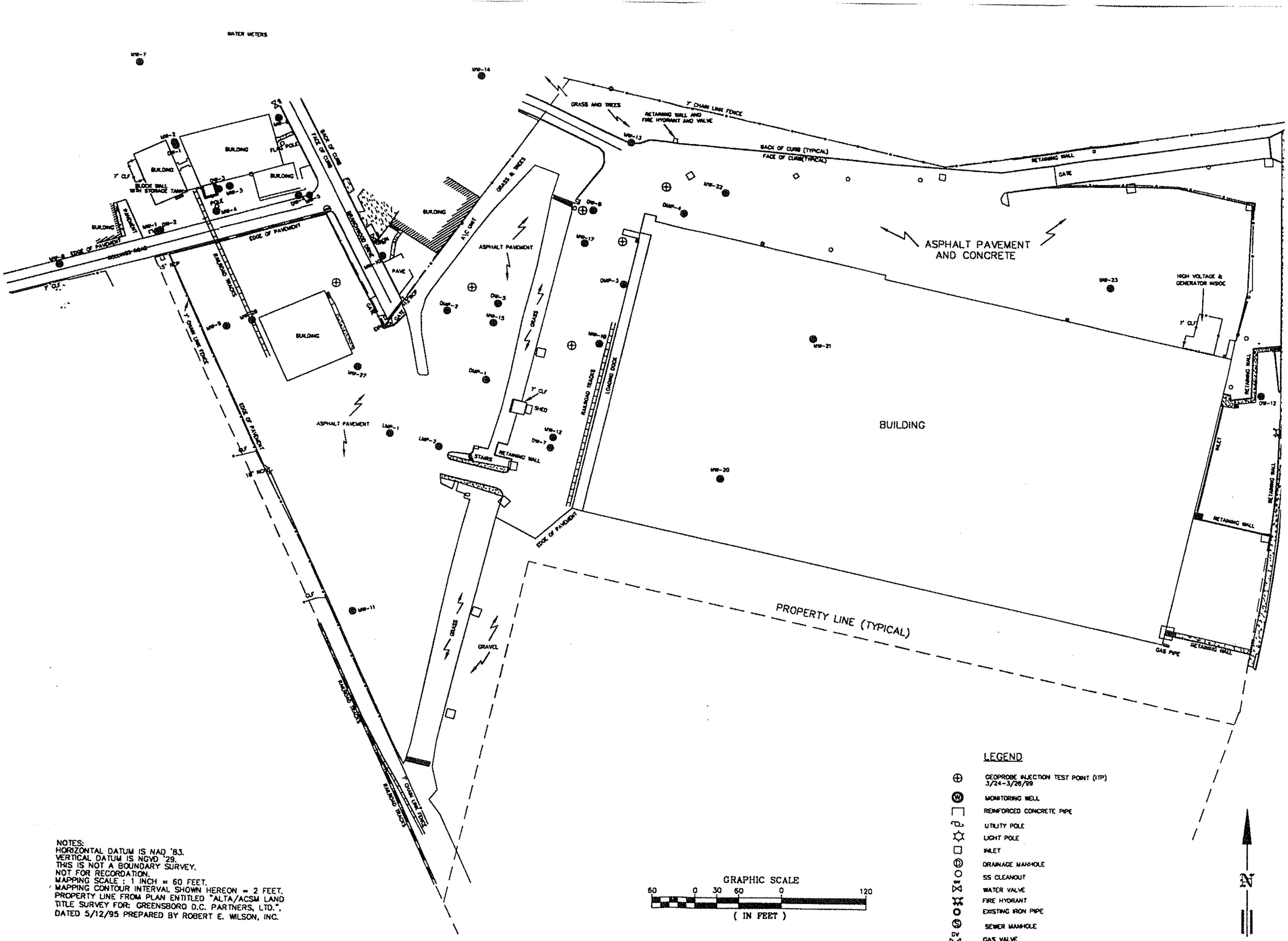
In addition to the application testing, four additional borings were installed at the locations indicated on **Figure 1**. The purpose of these points was to determine the maximum depth attainable using direct push technology at different areas of the site.

4.0 Results and Conclusions

Examination of the data collected during the application test results in the following conclusions:

- The application of a liquid with a viscosity and density similar to that of water can be accomplished a the site using a Geoprobe;
- Fluid application can be attained horizontally into the formation which may serve as to create "microfractures" within the native material during application. These "microfractures" could assist in the distribution of the oxidant within the aquifer unit;
- The average liquid flow rate and average delivery pressures using the Geoprobe grout application system are 1.59 gpm at 140 psi. Higher delivery pressures could result in higher application flow rates;
- The data suggest that the delivery pressures and flow rates are primarily controlled by two factors: 1) The bore and effluent orifice sizes of the application tools and 2) the geologic/hyrdrogeologic characteristics of the native material within the zone of application. The use of application tools with larger bores and larger effluent orifices could result in higher application flow rates at corresponding lower delivery pressures;
- The maximum attainable depth using direct push technology at the site is concluded: 1) To be greater than 65 feet, in the area of Phenix Supply and the Axton Cross Building; 2) Approximately 60 feet in the parking lot area between the Axton Cross Building and the former Sears building; and 3) Approximately 36 to 50 feet in the vicinity of the loading dock of the former Sears building. These depths are assumed to be equivalent to the surface of competent bedrock beneath the site, and seem reasonable based on differences in topographic elevation across the site.

FIGURES



NOTES:
HORIZONTAL DATUM IS NAD '83.
VERTICAL DATUM IS NGVD '29.
THIS IS NOT A BOUNDARY SURVEY.
NOT FOR RECORDATION.
MAPPING SCALE : 1 INCH = 60 FEET.
MAPPING CONTOUR INTERVAL SHOWN HEREON = 2 FEET.
PROPERTY LINE FROM PLAN ENTITLED "ALTA/ACSM LAND TITLE SURVEY FOR: GREENSBORO D.C. PARTNERS, LTD.", DATED 5/12/95 PREPARED BY ROBERT E. WILSON, INC.

Figure 2
Geoprobe Application Test (ITP-2)
Changes in Injection Time with Depth
March 25, 1999

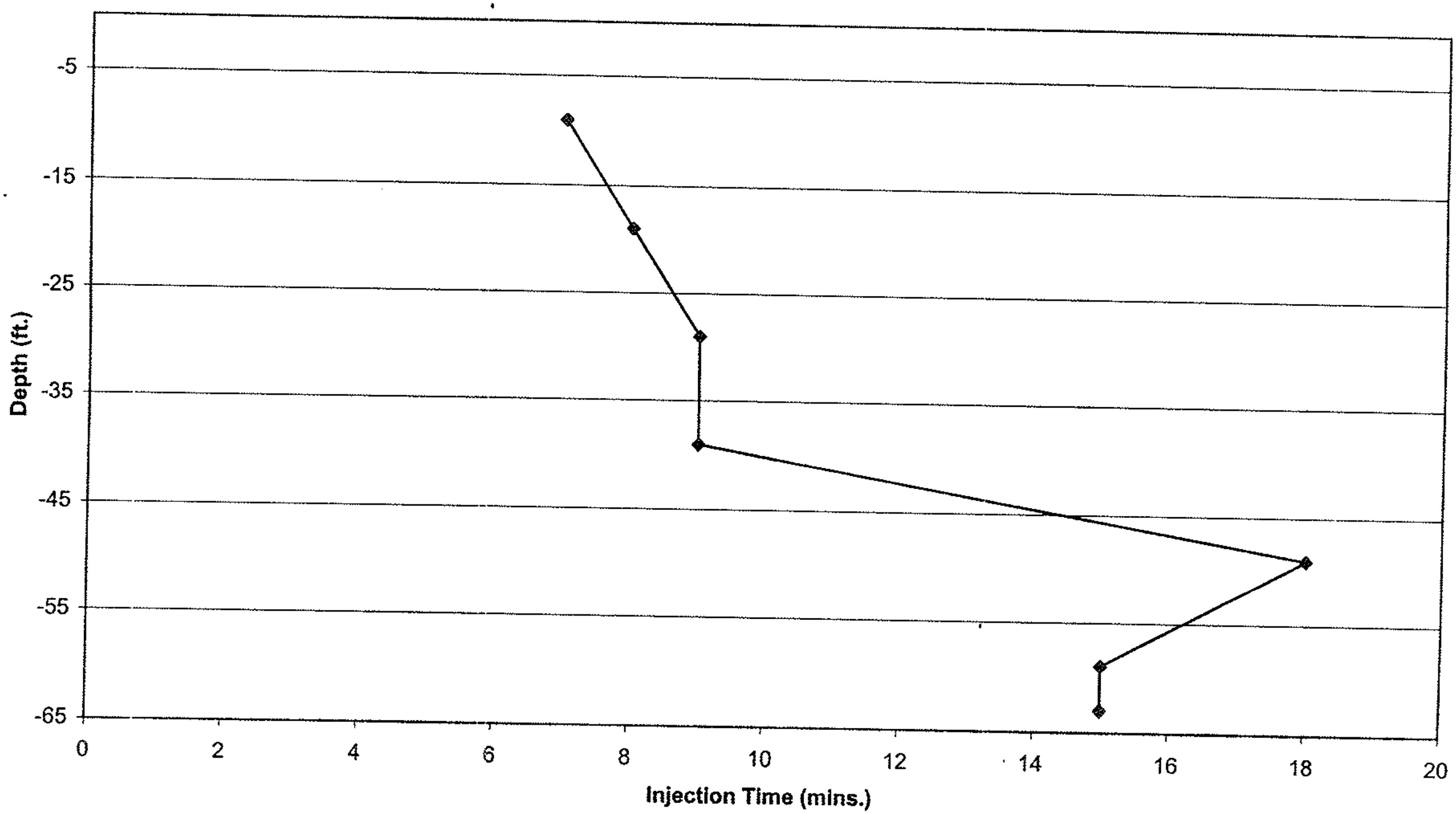


Figure 3
Geoprobe Application Test (ITP-2)
Flow Rate Changes with Depth
March 25, 1999

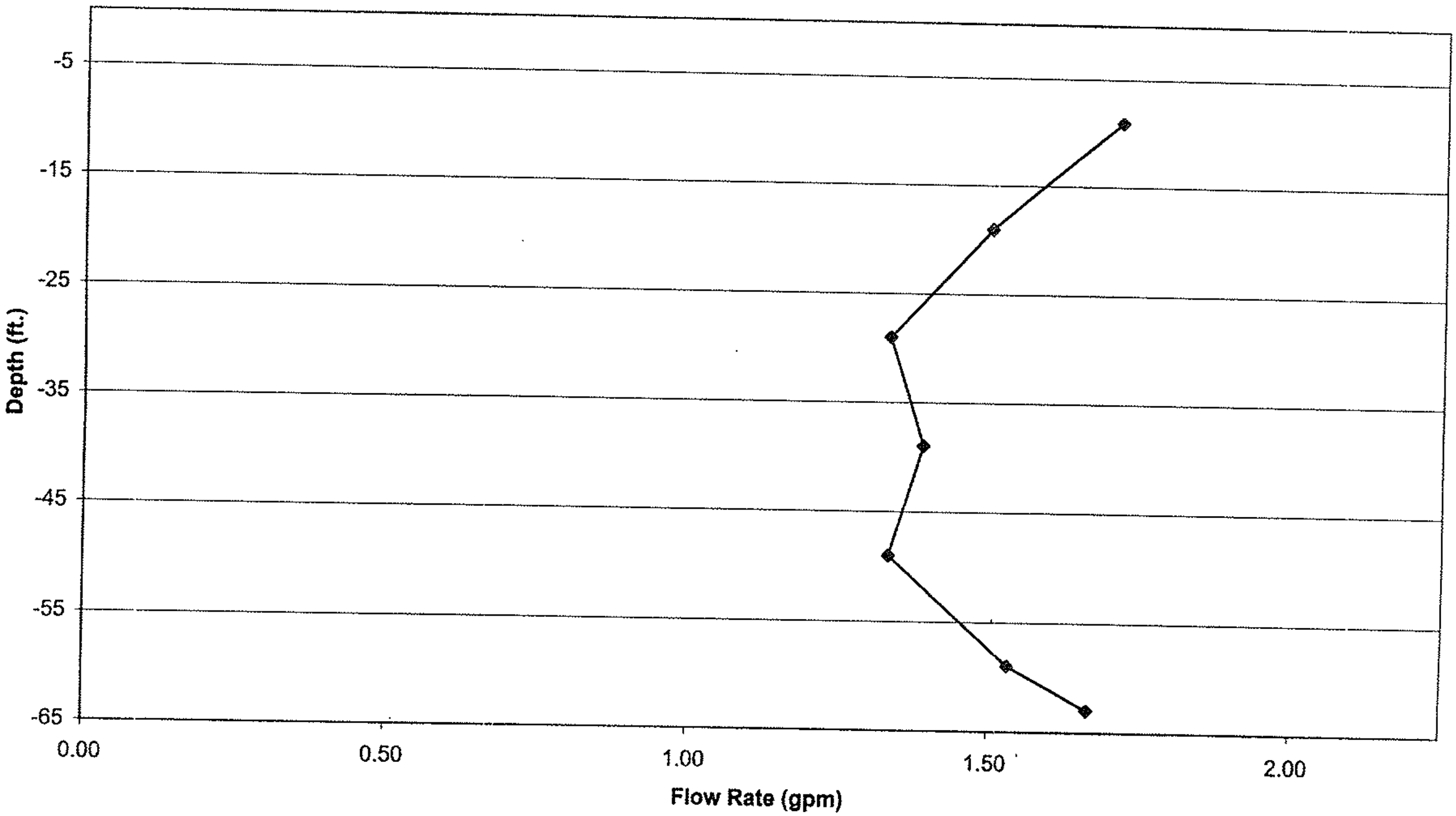


Figure 4
Geoprobe Application Test (ITP-2)
Changes in Delivery Pressure with Depth
March 25, 1999

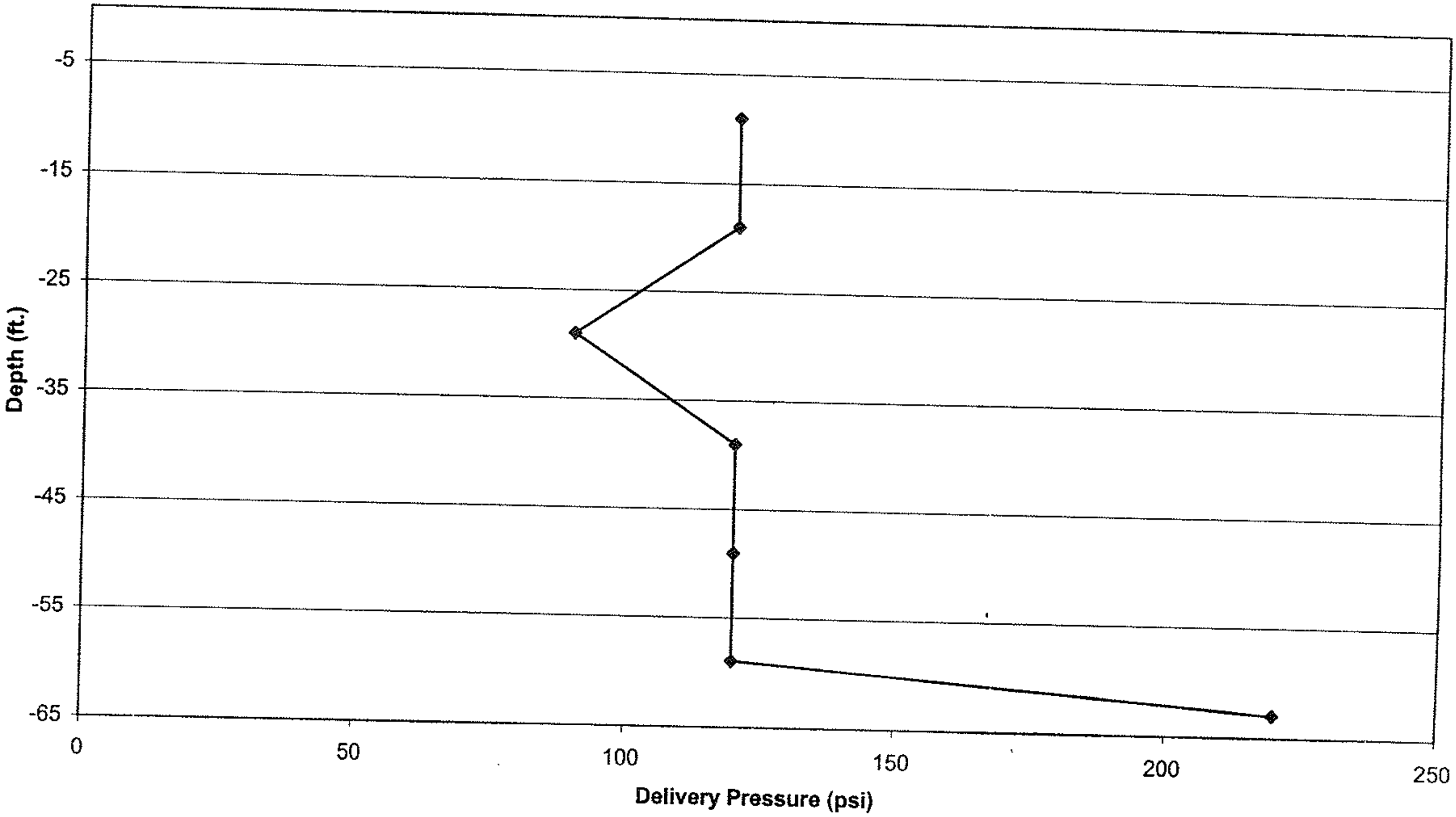


Figure 5
Geoprobe Application Test (ITP-2)
Changes in Back Pressure with Depth
March 25, 1999

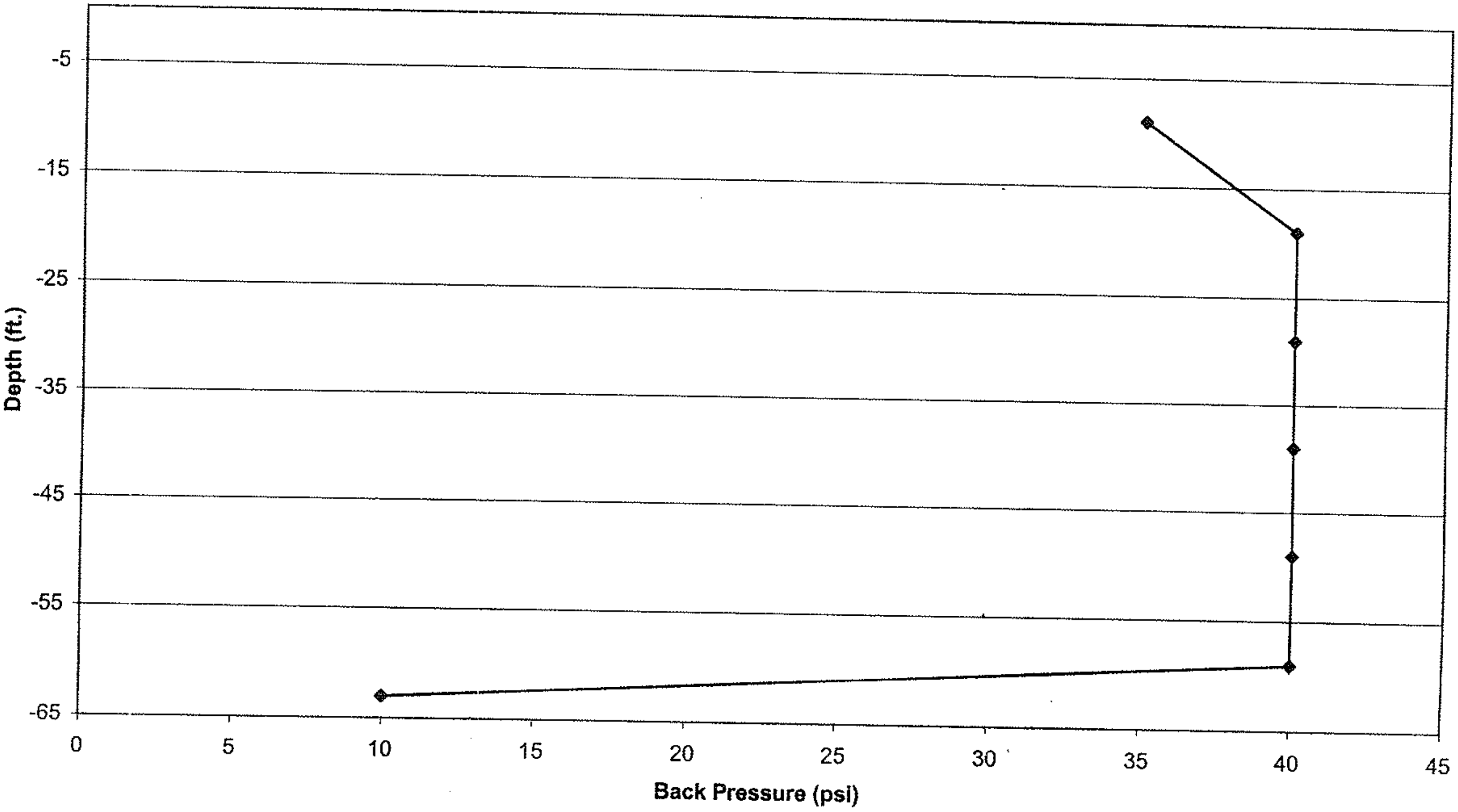


Figure 6
Geoprobe Application Test (ITP-3)
Changes in Injection Time with Depth
March 25, 1999

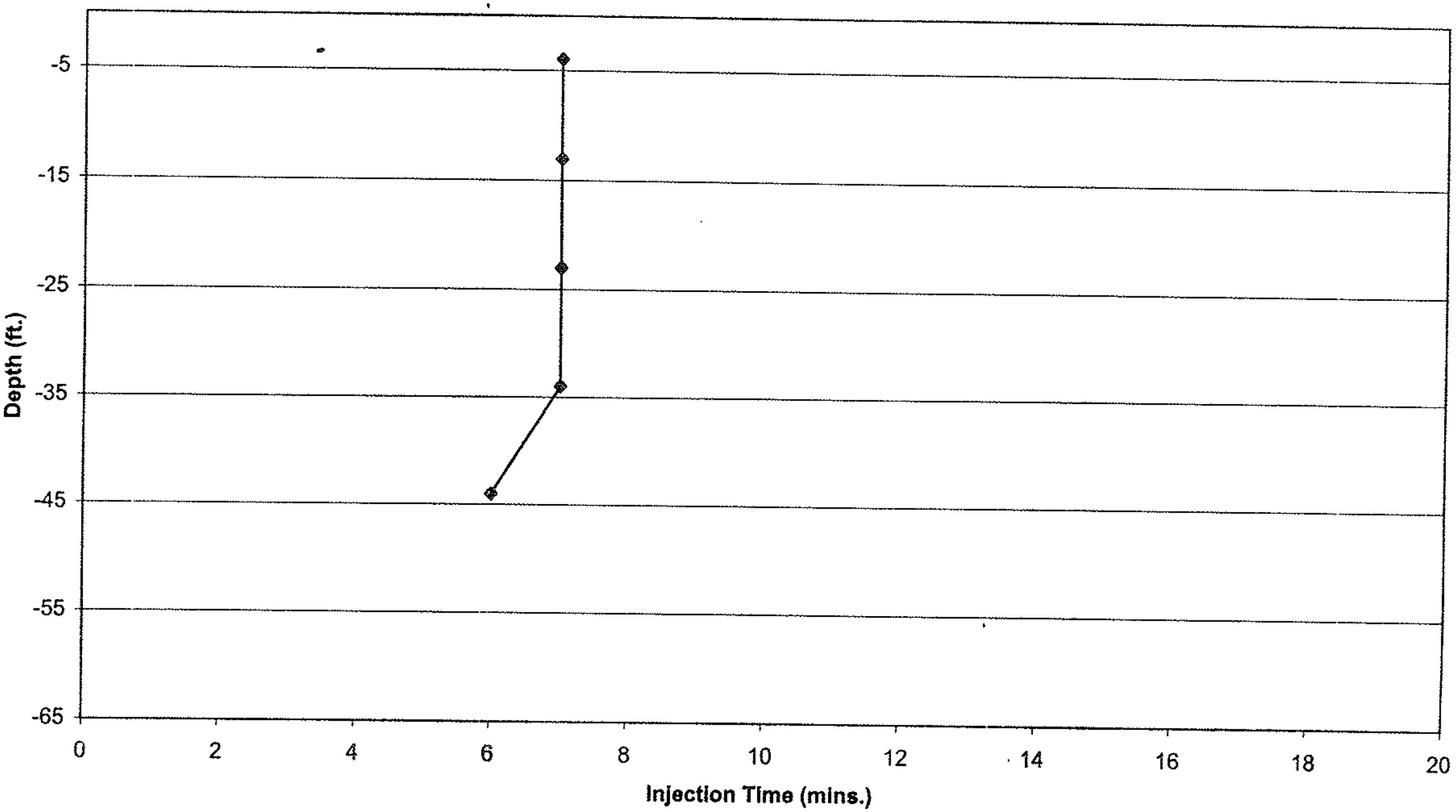


Figure 7
Geoprobe Application Test (ITP-3)
Flow Rate Changes with Depth
March 25, 1999

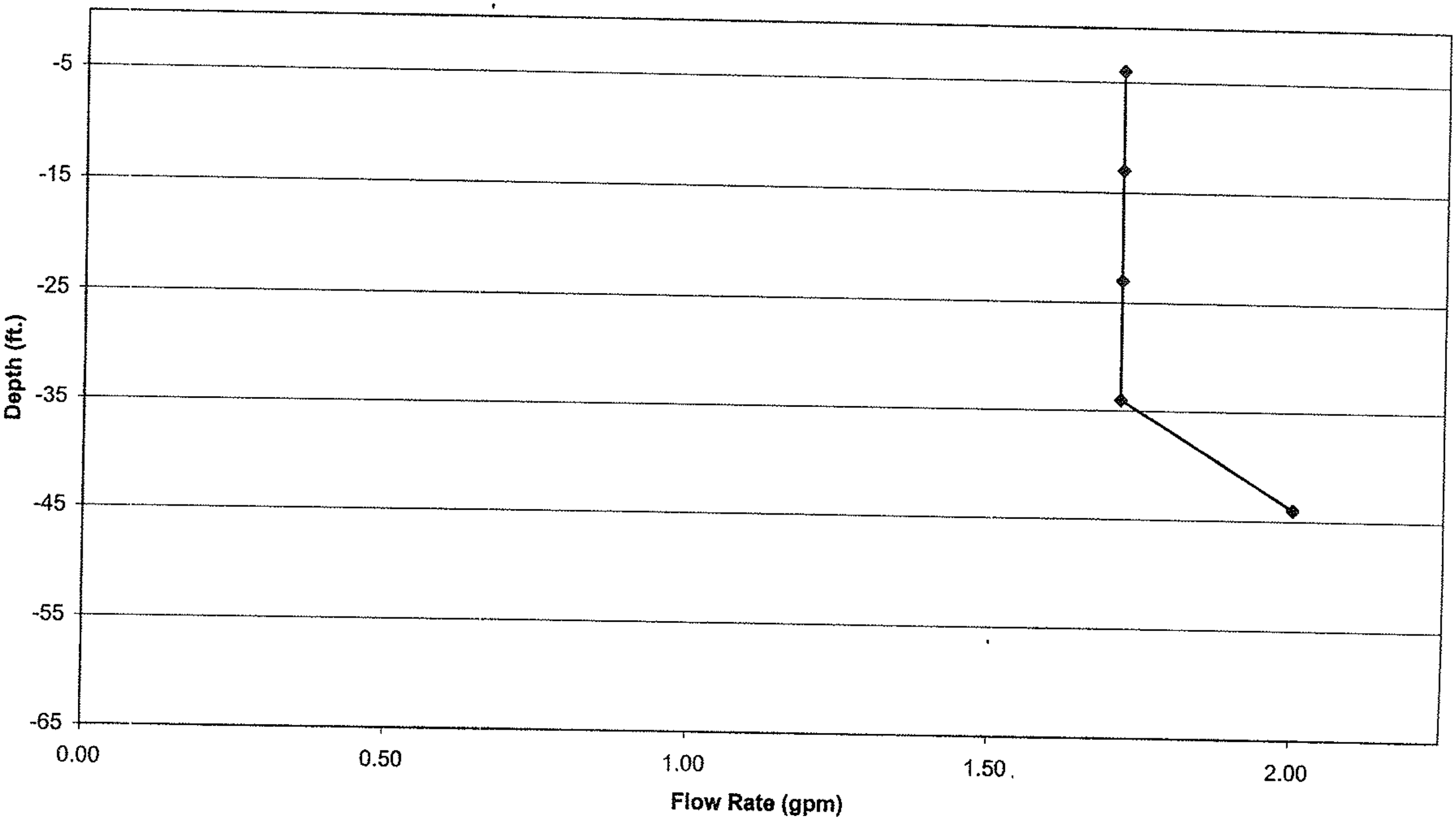


Figure 8
Geoprobe Application Test (ITP-3)
Changes in Delivery Pressure with Depth
March 25, 1999

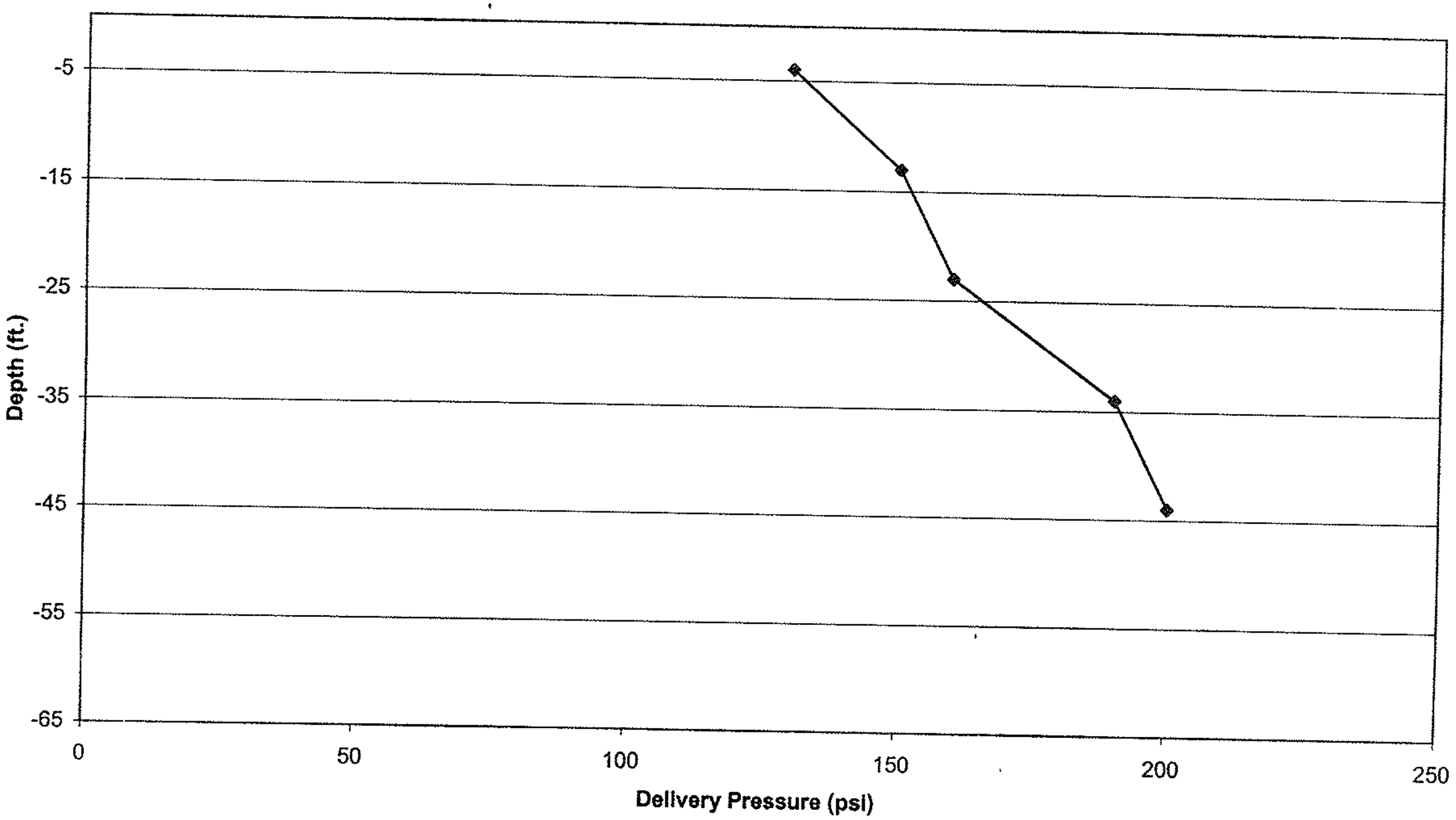
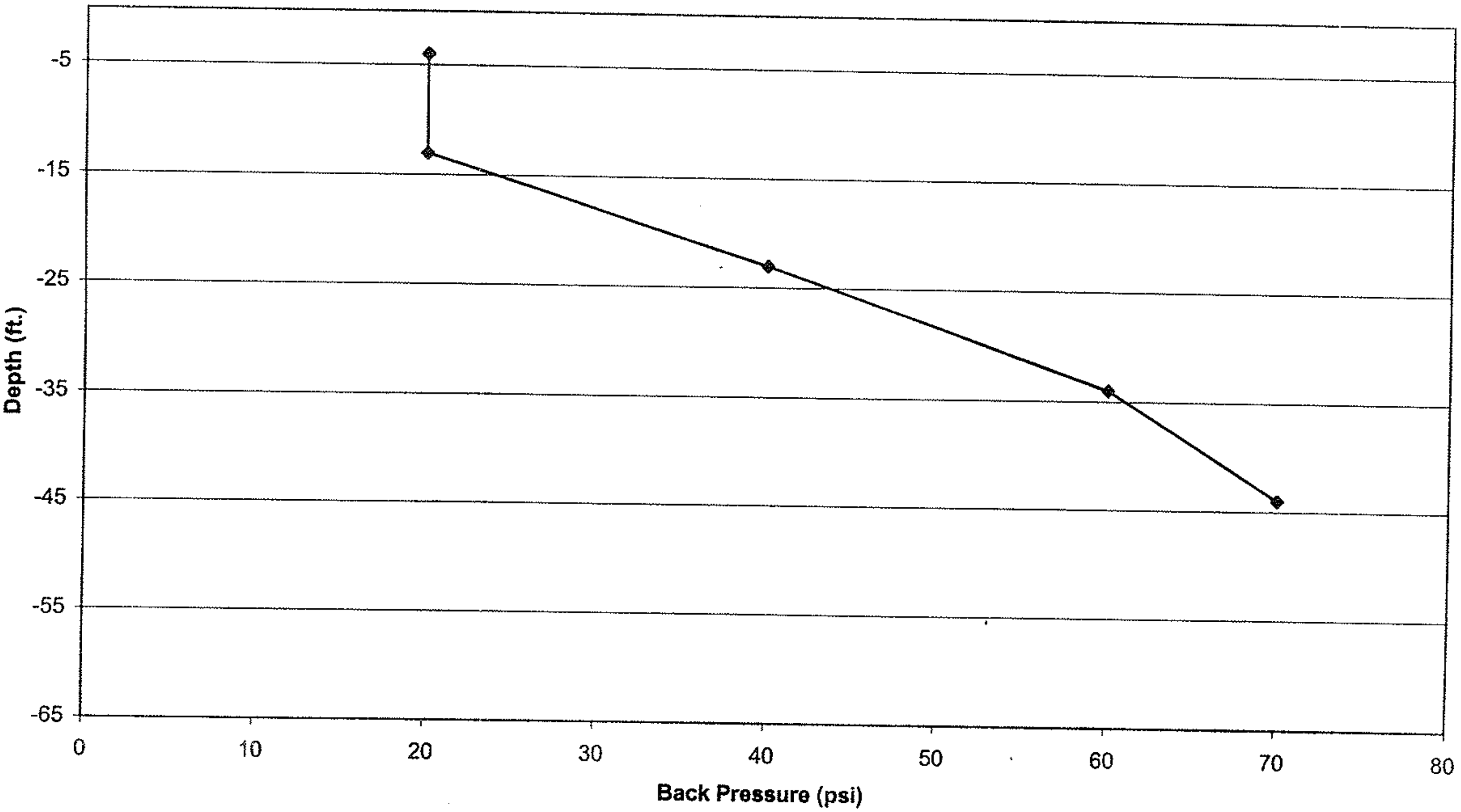


Figure 9
Geoprobe Application Test (ITP-3)
Changes in Back Pressure with Depth
March 25, 1999



TABLES

Table 1

W.P. Ballard Property
Greensboro, North Carolina

Summary of Injection Test Data (ITP-2)
March 25, 1999

Inj. Volume	Start Time	Stop Time	Total Time	Flow Rate	Delivery Pressure	Back Pressure	Depth Interval
12	1247	1254	7	1.71	120	35	-9
12	1236	1244	8	1.50	120	40	-19
12	1223	1232	9	1.33	90	40	-29
12.5	1209	1218	9	1.39	120	40	-39
24	1145	1203	18	1.33	120	40	-49
23	1126	1141	15	1.53	120	40	-59
25	1105	1120	15	1.67	220	10	-63

Table 2

W.P. Ballard Property
Greensboro, North Carolina

Summary of Injection Test Data (ITP-3)
March 25, 1999

Inj. Volume	Start Time	Stop Time	Total Time	Flow Rate	Delivery Pressure	Back Pressure	Depth Interval
12	1525	1532	7	1.71	130	20	-4
12	1513	1520	7	1.71	150	20	-13
12	1500	1507	7	1.71	160	40	-23
12	1449	1456	7	1.71	190	60	-34
12	1436	1442	6	2.00	200	70	-44

APPENDIX A

ITP-2

Geoprobe Injection Pilot Test Data

Site Name: Sears SCS
Location: 650

Technician: Joe B.
Subcontractor Name: Geo Ex / Geoprobe Sys.
Date of Test: 3/24/99

Type of Fluid Injected: Water
Density:
Lighter than water
Same as water X
Heavier than water

Injection Interval	Interval Depth	Gallons Injected	Start Time	Stop Time	Delivery Pressure	Flow Rate	Comments
1	62'-64'	25	11:05	11:20	220/<10	1.6gpm	High del. P initial, then low
2	58-60'	23	11:26	11:41	120/40	1.5	
3	48-50	24	11:45	12:03	120/40	1.3	
4	38-40	12.5	12:09	12:18	120/40	1.38	
5	28-30	12.8	12:23	12:32	90/40	1.33	
6	18-20	12.0	12:36	12:44	128/40	1.50	
7	8-10	12.0	12:47	12:54	120/35	1.71	
8							
9							
10							
11							
12							
13							
14							
15							
16							

push/back

ITP-3

Geoprobe Injection Pilot Test Data

Site Name: SLS Greensboro
Location: ITP-3

Technician: R. Jarosik
Subcontractor Name: Geologic Exploration
Date of Test: 3-24-99

Type of Fluid Injected: water
Density:
Lighter than water ___
Same as water X
Heavier than water ___

Injection Interval	Interval Depth	Gallons Injected	Start Time	Stop Time	Delivery Pressure	Flow Rate	Comments
1	46'	12	1436	1442	200 / 70	2.0	41'-46'
2	36'	12	1449	1456	190/60	1.71	31'-36'
3	26'	12	1500	1507	160/40	1.68	21'-26'
4	16'	12	1313	1520	150/20	1.68	11'-16'
5	6'	12	1525	1532	130/20	1.68	0-6'
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							

APPENDIX B

IT Corporation

Photographic Record

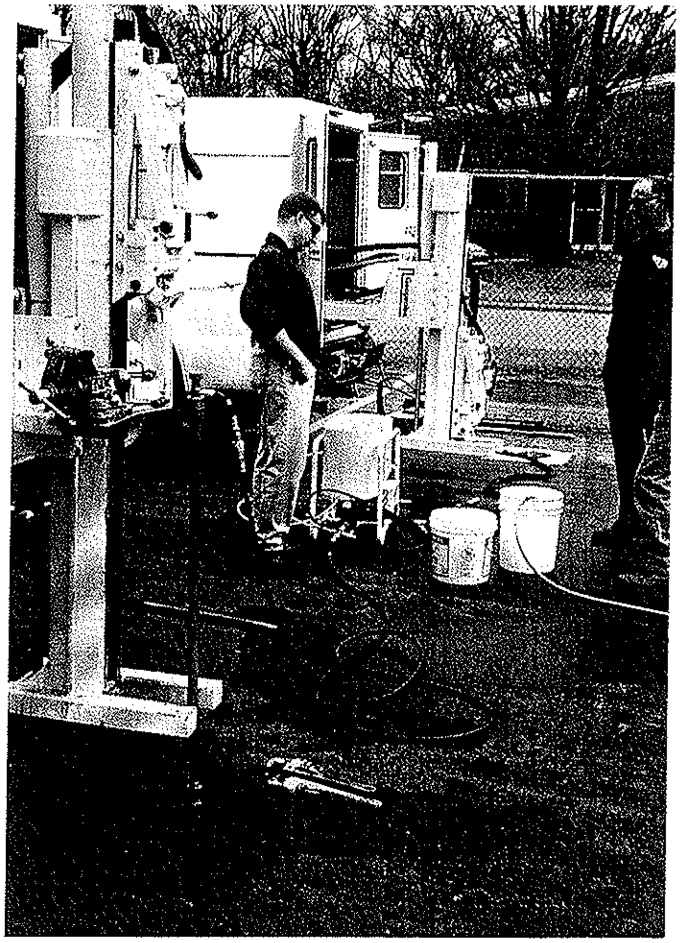
Client:	Sears SLS	**Project Number:**	107535
Site Name:	W.P. Ballard Property	**Site Location:**	Greensboro, NC

Photographer:
K. Ogden

Date:
3/25/99

Direction:
na

Comments:
View of complete Geoprobe application configuration (application point is in the left foreground)

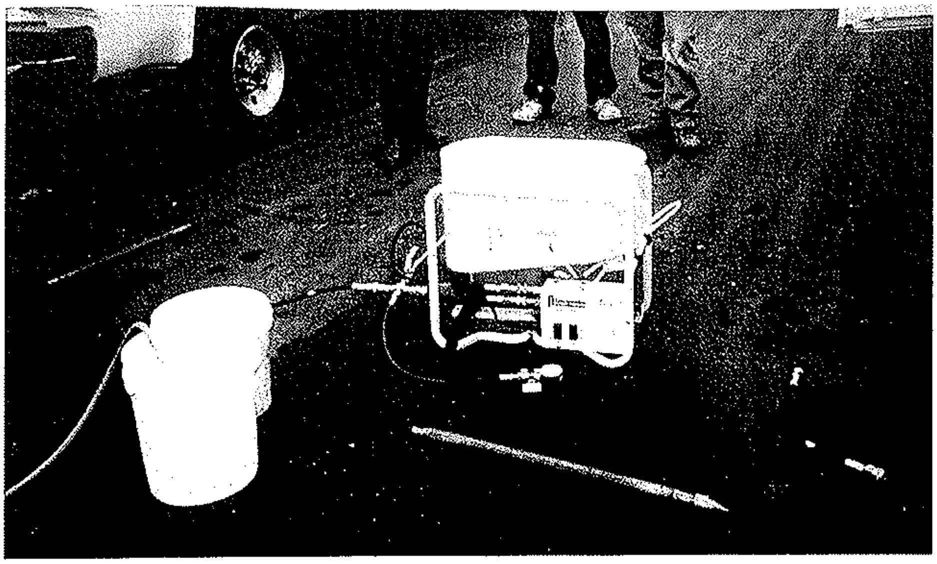


Photographer:
K. Ogden

Date:
3/25/99

Direction:
na

Comments:
View of Geoprobe grout application unit.



IT Corporation
Photographic Record

Client:	Sears SLS	**Project Number:**	107535
Site Name:	W.P. Ballard Property	**Site Location:**	Greensboro, NC

Photographer:

K. Ogden

Date:

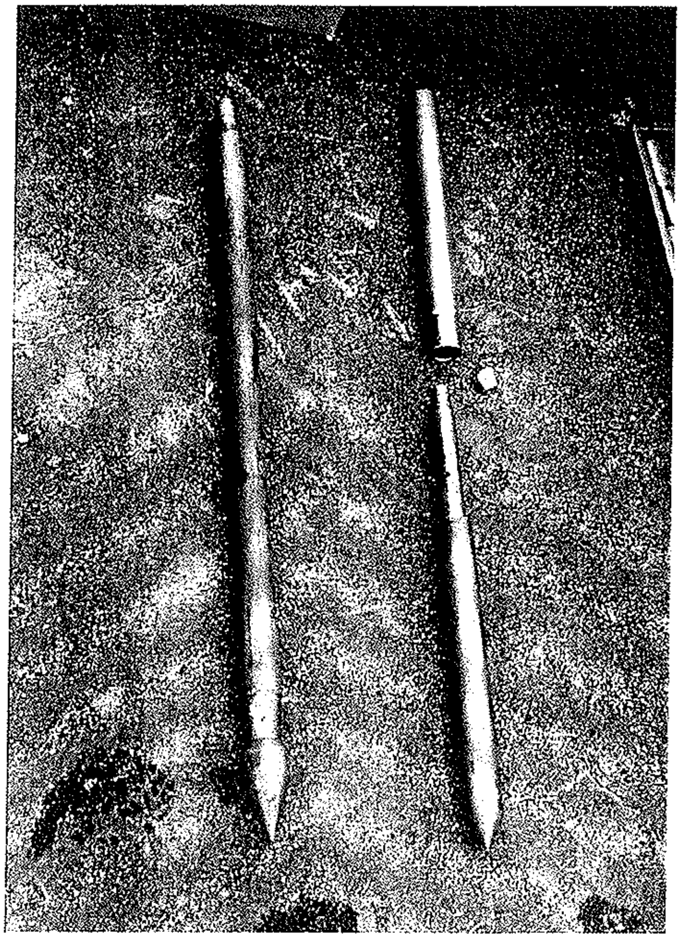
3/25/99

Direction:

na

Comments:

View of Geoprobe subsurface application tools. Unit on right is a new application tool currently under development/modification



Photographer:

Date:

Direction:

Comments:

ATTACHMENT E
Municipal Water Account Confirmation

WATER
Resources
City of Greensboro

ainistration
) 373-2055

tomer Service
) 373-2344

ater Supply
hell Plant
) 373-5855
nsend Plant
336) 375-2230

er Reclamation
h Buffalo Plant
336) 373-5913
Osborne Plant
) 375-2240

onstruction &
intenance
) 373-2033

ater Conservation
) 574-3585

MAR 30 1999

March 29, 1999

Mr. Chris Cuomo
1000 Perimeter Park Dr Suite I
Morrisville, N C 27560

Re: 2701 Branchwood Dr

Dear Mr. Cuomo:

City water and sewer serve the above property. This is inside the City limits.

If you have any questions, call me at 336-373-2055.

Sincerely,

Eleanor Clark

Eleanor Clark
Services Specialist

P. O. Box 3136, Greensboro, NC 27402-3136 • www.ci.greensboro.nc.us • Fax (336) 412-6305 • TDD (336) 373-2376

Michelle Craig

Please indicate whether the following properties utilize water and sewer from the City of Greensboro:

2414 Battleground Avenue, Greensboro, NC	YES ✓	NO
2448 Battleground Avenue, Greensboro, NC	YES ✓	NO
2500 Battleground Avenue, Greensboro, NC	YES ✓	NO
2506 Battleground Avenue, Greensboro, NC	YES ✓	NO
2504 Battleground Avenue, Greensboro, NC	YES ✓	NO
2514 Battleground Avenue, Greensboro, NC	YES ✓	NO
2705 Branchwood Drive, Greensboro, NC	YES ✓	NO
2606 ~~2606A~~ Branchwood Drive, Greensboro, NC	YES ✓	NO
2807 Branchwood Drive, Greensboro, NC	YES ✓	NO
2800 Branchwood Drive, Greensboro, NC	YES ✓	NO
2225 Oak Hill Drive, Greensboro, NC	YES ✓	NO
2223 Oak Hill Drive, Greensboro, NC	YES ✓	NO
2221 Oak Hill Drive, Greensboro, NC	YES ✓	NO
2217 Oak Hill Drive, Greensboro, NC	YES ✓	NO
2213 Oak Hill Drive, Greensboro, NC	YES ✓	NO
2211 Oak Hill Drive, Greensboro, NC	YES ✓	NO
2209 Oak Hill Drive, Greensboro, NC	YES ✓	NO
2207 Oak Hill Drive, Greensboro, NC	YES ✓	NO
2903 Lawndale Drive, Greensboro, NC	YES ✓	NO
2906 Lawndale Drive, Greensboro, NC	YES ✓	NO
2902 Lawndale Drive, Greensboro, NC	YES ✓	NO
2900 Lawndale Drive, Greensboro, NC	YES ✓	NO
2828 Lawndale Drive, Greensboro, NC	YES ✓	NO
2820 Lawndale Drive, Greensboro, NC	YES	NO ✓ SEE TELEPHONE LOG

Completed By: Eleana Clark

Department: Water Resources Adm

Date: 3-31-99

the IT group

The IT Group, Inc.

1000 Perimeter Park Drive, Suite I
Morrisville, NC 27560
Tel: (919) 467-2227
Fax: (919) 467-2299

MICHELLE CRAIG
Site Manager

Made Call (X)
Received Call ( )
Returned Call ( )

Contact:
Name: MR. BEAMAN
Company: BEAMAN REALTY
Phone #: 336-288-9412

Date: 3/31/99
Project Name: SEARS GREENSBORO
Project #:

SUBJECT: WATER SUPPLY AT ADDRESS 2808 LAWNDALE, GREENSBORO, NC

MR. BEAMAN STATED HIS OFFICE (BEAMAN REALTY CO.) USES CITY WATER. THE SUBJECT PROPERTY (2808 LAWNDALE) DOES NOT USE PRIVATE WELL WATER.

BEAMAN REALTY IS AT 2808 LAWNDALE - NO LONGER AT 2820 LAWNDALE

ATTACHMENT F
Sodium Permanganate Information

Section III Health Hazard Data

ROUTES OF EXPOSURE

1. Inhalation
Acute inhalation toxicity data are not available; however, airborne concentrations of sodium permanganate in the form of mist, or spray may cause damage to the respiratory tract.

2. Skin Contact
Sodium permanganate solution is very irritating to the skin.

3. Eye Contact
Sodium permanganate solution is corrosive to the eye on contact. It may cause severe burns that result in damage to the eye.

4. Ingestion
Sodium permanganate solution, if swallowed, may cause severe burns to mucous membranes of the mouth, throat, esophagus, and stomach.

EFFECTS OF OVEREXPOSURE

1. Acute Overexposure
Irritating to body tissue with which it comes in contact.

2. Chronic Overexposure
No known cases of chronic manganese poisoning due to sodium permanganate or other permanganates have been reported. Prolonged exposure, usually over many years, to heavy concentrations of manganese oxides in the form of dust and fumes, may lead to chronic manganese poisoning, chiefly involving the central nervous system.

3. Carcinogenicity
Sodium permanganate solution has not been classified as a carcinogen by OSHA, NTP, IARC.

4. Medical Conditions Generally Aggravated by Exposure
Sodium permanganate will cause further irritation of tissue, open wounds, burns or mucous membranes.

EMERGENCY AND FIRST AID PROCEDURES

1. Eyes
Immediately flush eyes with large amounts of water for at least 15 minutes holding lids apart to ensure flushing of the entire surface. Do not attempt to neutralize chemically. Seek medical attention immediately. Note to physician: Decomposition products are alkaline.

2. Skin
Immediately wash contaminated areas with plenty of water. Remove contaminated clothing and footwear. See SECTION VIII Warning OTHER PROTECTIVE EQUIPMENT. Seek medical attention immediately if irritation develops.

3. Inhalation
Get person out of contaminated area to fresh air. If breathing has stopped, resuscitate and administer oxygen if readily available. Seek medical attention immediately.

4. Ingestion
NEVER give anything by mouth to an unconscious or convulsing person. Give large quantities of water. If available, give several glasses of milk or lemon or orange juice. Seek medical help immediately.

Section IV Hazardous Ingredients

Material or component	CAS No.*	%	Hazard Data	
Sodium Permanganate	10101-50-5	40% min.	PEL** C****	5 mg Mn per cubic meter of air
			TLV-TWA***	0.2 mg Mn per cubic meter of air

* Chemical Abstract Service Number

** OSHA Permissible Exposure Limit, manganese compounds (expressed as Mn) 29CFR1910.1000Z.A1.

*** American Conference of Governmental Industrial Hygienists 1988/1989, for manganese dust and compounds, expressed as Mn, TLV-TWA = The time weighted average concentration for a normal 8-hour workday and a 40-hour workweek, to which nearly all workers may be repeatedly exposed, day after day, without adverse effect.

**** Ceiling Exposure Limit or maximum exposure concentration not to be exceeded under any circumstances.

Section V Physical Data

BOILING POINT, 760 mm Hg	105°
VAPOR PRESSURE (mm Hg)	Not applicable
SOLUBILITY IN WATER % BY SOLUTION	Miscible in all proportions with water
SPECIFIC GRAVITY	1.36g/mL
PERCENT VOLATILE BY VOLUME	60% (as water)
MELTING POINT	Not Applicable
APPEARANCE AND ODOR	Dark purple solution, odorless

Section VI Reactivity Data

STABILITY Under normal conditions, the material is stable.

CONDITIONS TO AVOID Contact with incompatible materials or heat (135°C/275°F)

INCOMPATIBLE MATERIALS Contact with acids, peroxides, and all combustible organic or readily oxidizable materials including inorganic oxidizable materials and metal powders. With hydrochloric acid, chlorine gas is liberated.

HAZARDOUS DECOMPOSITION PRODUCTS When involved in fire, corrosive fumes or smoke may be formed.

CONDITIONS CONTRIBUTING TO HAZARDOUS POLYMERIZATION Material is not known to polymerize.

Section VII Spill or Leak Procedures

STEPS TO BE TAKEN IF MATERIAL IS RELEASED OR SPILLED

Contain spill by collecting the liquid in a pit or holding behind a dam (sand or soil). Dilute to approximately 6% with water, then reduce with sodium thiosulfate, a bisulfite or ferrous salt solution. The bisulfite or ferrous salt may require some dilute sulfuric acid (10% w/w) to promote reduction. Neutralize with sodium carbonate to neutral pH if acid was used. Decant or filter and deposit sludge in an approved landfill. Where permitted, the sludge can be drained into sewer with large quantities of water. To clean contaminated floors, flush with abundant quantities of water into sewer, if permitted by federal, state, and local regulations. If not, collect water and treat as above.

WASTE DISPOSAL

Sodium permanganate is considered a D001 hazardous (ignitable) waste. For disposal of sodium permanganate solutions, follow above procedure and deactivate the permanganate to insoluble manganese dioxide, and dispose of it in a permitted landfill. Contact Carus Chemical Company for additional recommendations.

Section VIII Protective Equipment to Be Used

VENTILATION REQUIREMENTS
Provide sufficient mechanical and/or local exhaust to maintain exposure below levels of overexposure.

RESPIRATORY PROTECTION
In cases where overexposure may exist, the use of NIOSH-MSHA approved dust and mist respirator or an air supplied respirator is advised. Engineering or administrative controls should be implemented to control dust or mist.

EYE
Face shield, goggles, or safety glasses with side shields should be worn.

GLOVES
Rubber or plastic gloves should be worn.

OTHER PROTECTIVE EQUIPMENT
Normal work clothing covering arms and legs, and rubber, or plastic apron should be worn. *Caution:* If clothing becomes contaminated, wash off immediately; spontaneous ignition may occur with cloth or paper.

WORK/HYGIENIC PRACTICES
Wash hands thoroughly with soap and water, after handling sodium permanganate and before eating or smoking.

Section IX Special Precautions and Other Comments

Protect containers from physical damage. Store in a cool, dry area in closed containers or non-combustible floors. Segregate from acids, peroxides, and all combustible, organic, or easily oxidizable materials.

DEPARTMENT OF TRANSPORTATION INFORMATION:

Proper Shipping Name: 49CFR 172.101 .... Permanganates, inorganic, aqueous solution, n.o.s. (contains sodium permanganate)

ID Number: .... UN 3214
Hazard Class: .... Oxidizer 5.1

Chemtrec Telephone Number: 800/424-9300

RCRA: Oxidizers such as sodium permanganate meet the criteria of ignitable waste

Kenneth Krogulski

Kenneth Krogulski

September 1998

CARUS

Responsible Care®
A Public Commitment

Division of Carus Corporation
315 Fifth Street
P.O. Box 599
Peru, IL 61354
Tel (815) 223-1500
Fax (815) 224-6697

[redacted]

LIQUOX™

Sodium Permanganate

CAS No. 10101-50-5

LIQUOX™ sodium permanganate is a liquid oxidant recommended for applications that require a concentrated permanganate solution.

Product Specifications

Assay	40% minimum as $NaMnO_4$
pH	6.0 - 7.0
Specific Gravity	1.36 - 1.39
Solubility in Water	Miscible with water in all proportions.

Chemical/Physical Data

Formula	$NaMnO_4$
Appearance	Dark Purple Solution
Insolubles	100 - 1900 ppm
Potassium	1000 - 2200 ppm
Stability	> 18 Months

Applications

- Printed Circuit Board Desmearing
- Pharmaceutical Synthesis Reactions
- Metal Cleaning Formulations
- Acid Mine Drainage
- Hydrogen Sulfide Odor Control
    - Remote Locations
    - Unheated Locations

Benefits

- Concentrated liquid oxidant is easily stored and handled. Feed equipment is simplified (no need to transfer and dissolve crystalline product).
- Dust problems associated with handling dry oxidants are eliminated.
- High solubility at room temperature. Reactions requiring a concentrated permanganate solution can be conducted without having to raise the temperature.
- Can be used instead of potassium permanganate whenever the potassium ion cannot be tolerated, or if dusting is a critical issue.

Shipping Containers

5 gallon (18.9L) Tight Head HDPE Jerrican
(UN Specification: 3H1) made of High Density Polyethylene (HDPE), weighs 3.5 lb (1.6 kg). Net weight is 57 lb (25.7 kg). Dimensions, 15.33 in. tall, 10.2 in. wide and 11.4 in. long (38.94 cm tall, 25.91 cm by 28.96 cm).

5 gallon (18.9L) Tight Head Steel Drum
(UN Specification: 1A1) made of 12 gauge, mild steel, weighs 5 lb (2.3 kg). Net weight is 57 lb (25.7 kg). The drum is 13.75 in. tall and 11.5 in. in diameter. (34.93 cm tall, 29.21 cm diameter)

55 gallon (208.2L) Closed Head Steel Drum
(UN Specification: 1A1) made of 16 gauge, mild steel, weighs 53.7 lb (24.4 kg). Net weight is 550 lb (249.5 kg). The drum is 34.6 in. tall, outside diameter 23.5 in., inside diameter 22.5 in. (87.9 cm tall, OD 59.7 cm, ID 57.2 cm).

Handling and Storage

Like any potent oxidant, LIQUOX™ sodium permanganate should be handled with care. Protective equipment during handling should include face shields and/or goggles, rubber or plastic gloves, rubber or plastic apron. If clothing becomes spotted, wash off immediately; spontaneous ignition can occur with cloth or paper. **In cases where significant exposure exists, use of the appropriate NIOSH-MSHA dust or mist respirator or an air supplied respirator is advised.**

The product should be stored in a cool, dry area in closed containers. Concrete floors are preferred. Avoid wooden decks. Spillage should be collected and disposed of properly. Contain and dilute spillage to approximately 6% with water and reduce with sodium thiosulfate, a bisulfite, or ferrous salt. The bisulfite or ferrous salt may require dilute sulfuric acid to promote reduction. Neutralize any acid used with sodium bicarbonate. Deposit sludge in an approved landfill or, where permitted, drain into sewer with large quantities of water.

As an oxidant, the product itself is non-combustible, but will accelerate the burning of combustible materials. Therefore, contact with all combustible materials and/or chemicals must be avoided. These include, but are not limited to: wood, cloth, organic chemicals, and charcoal. Avoid contact with acids, peroxides, sulfites, oxalates, and all other oxidizable inorganic chemicals. With hydrochloric acid, chlorine is liberated.

[redacted]

Shipping

LIQUOX™ sodium permanganate is classified as an oxidizer. Sodium permanganate is shipped domestically as Class 70 and has a Harmonized Code for export of 2841.69.0000.

Proper Shipping Name: Permanganates, Inorganic, Aqueous solution, n.o.s. (Contains Sodium Permanganate)

Hazard Class: 5.1

Identification Number: UN 3214

Packaging Group: II

Label Requirements: Oxidizer, 5.1

Special Provisions: T8-Intermodal transportation in IM 101 portable tanks

Package Requirement: 49 CFR Parts 171 to 180 Sections: 173.152, 173.202, 173.242

Quantity Limitations: 1 liter net for passenger aircraft or railcar. 5 liters net for cargo aircraft.

Vessel Stowage: D-material must be stowed "ondeck" on a cargo vessel, but is prohibited on a passenger vessel. Other provisions, stow "separated from" ammonium compounds, hydrogen peroxide, peroxides and superperoxides, cyanide compounds, and powdered metal.

Repackaging

When LIQUOX™ sodium permanganate is repackaged, the packaging, markings, labels, and shipping conditions must meet applicable federal regulations. See Code of Federal Regulations-49, Transportation, parts 171-180, and the Federal Hazardous Materials Transportation Act (HMTA).

Corrosive Properties

LIQUOX™ sodium permanganate is compatible with many metals and synthetic materials. Natural rubbers and fibers are often incompatible. Solution pH and temperature are also important factors. The material selected for use with sodium permanganate must also be compatible with any acid or alkali being used.

In neutral and alkaline solutions, sodium permanganate is **not corrosive** to carbon steel and 316 stainless steel. However, chloride corrosion of metals may be accelerated when an oxidant such as sodium permanganate is present in solution. Plastics such as teflon, polypropylene, HDPE and EDPM are also compatible with sodium permanganate.

Aluminum, zinc, copper, lead, and alloys containing these metals may be slightly affected by sodium permanganate solutions. Actual corrosion or compatibility studies should be made under the conditions in which the permanganate will be used prior to use.

Carus Value Added

LABORATORY SUPPORT

Carus Chemical Company has technical assistance available to its potential and current customers to answer questions or perform laboratory and field testing including:

*Feasibility Studies * Toxicity Evaluations *Treatability Studies *Analytical Services *Field Trials

CARUS CHEMICAL COMPANY

During its more than 80-year history, Carus' ongoing reliance on research and development, as well as its emphasis on technical support and customer service, have enabled the company to become the world leader in permanganate, manganese, oxidation, and catalyst technologies.

CARUS

Responsible Care®
A Public Commitment

Carus Chemical Company
315 Fifth Street
P. O. Box 599
Peru, IL 61354
Tel. (815) 223-1500
Fax (815) 224-6697
Web: www.caruschem.com
E-Mail: salesmkt@caruschem.com

Form #LX1501