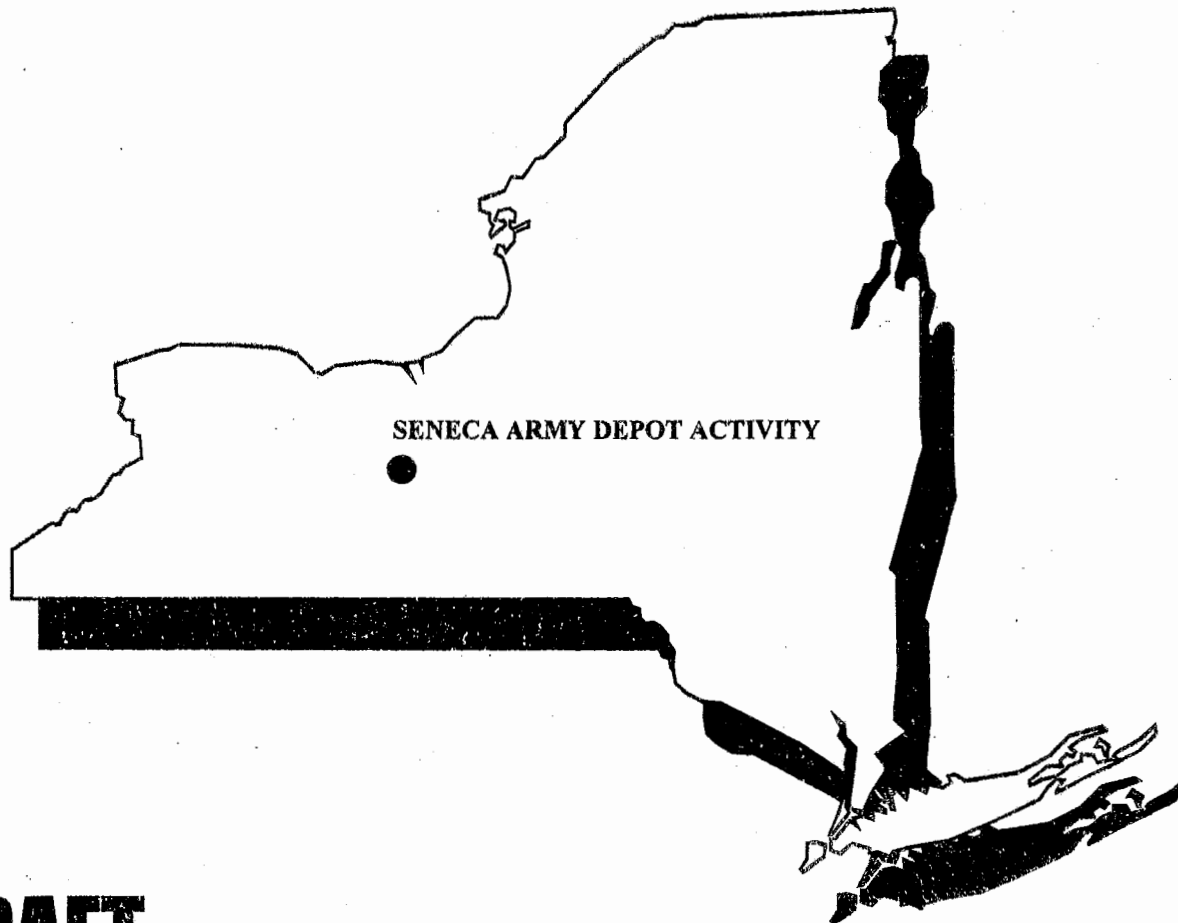
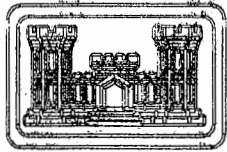


U.S. ARMY ENGINEER DIVISION  
HUNTSVILLE, ALABAMA

00643



**DRAFT**

**FEASIBILITY MEMORANDUM FOR  
GROUND WATER REMEDIATION ALTERNATIVES USING  
ZERO VALENCE IRON CONTINUOUS REACTIVE WALL  
AT THE ASH LANDFILL**

CONTRACT NO. DACA87-92-D-0022  
MODIFICATION 04 TO DELIVERY ORDER NO. 31

AUGUST 2000

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FOR  
GROUNDWATER REMEDIATION ALTERNATIVES USING  
ZERO VALENT IRON REACTIVE WALL  
AT THE ASH LANDFILL**

**SENECA ARMY DEPOT ACTIVITY  
ROMULUS, NEW YORK**

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**August 2000**

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**LIST OF ACRONYMS**

ASTM	American Society of Testing and Materials
AWQS	Ambient Water Quality Standards
Ca	Calcium
cDCE	cis-1,2-dichloroethene
Cl <sup>-</sup>	Chloride ion
CF	cubic feet
CO <sub>3</sub> <sup>2-</sup>	carbonate ion
CY	cubic yards
DeWind	DeWind DeWatering, Inc.
EPA	Environmental Protection Agency
ETI	EnviroMetal Technologies, Inc.
Fe <sup>0</sup>	Zero valent iron
Fe <sup>2+</sup>	Ferrous iron
Fe <sup>3+</sup>	Ferric iron
FFA	Federal Facility Agreement
F&G	Funnel & Gate
FS	Feasibility Study
ft	Feet
H <sup>+</sup>	Hydrogen ion
H <sub>2</sub> O	Water
HRC	Hydrogen Releasing Compound
IRM	Interim Remedial Measure
ITRC	Interstate Technology Regulatory Cooperation
LTTD	Low Temperature Thermal Desorption
mg/L	milligrams per liter
MW	Monitoring Well
NCFL	Non-Combustible Fill Landfill
nM/L	nanomoles per liter
NYSDEC	New York State Department of Environmental Conservation
O&M	Operation and Maintenance
O <sub>2</sub>	Oxygen
OH <sup>-</sup>	Hydroxide ion
OU	Operable Unit
PVC	Polyvinyl chloride
RCI	Chlorinated ethene
RH	End-product of reductive dechlorination (methane, ethane, or ethene)

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RI/FS	Remedial Investigation/Feasibility Study
SEAD	Seneca Army Depot
SEDA	Seneca Army Depot Activity
TAL	Target Analyte List
TCE	Trichloroethene
TCL	Target Compound List
TOC	Total Organic Carbon
VC	Vinyl Chloride
VOC	Volatile Organic Compound
µg/L	Micrograms Per Liter

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Environmental Protection Agency

## 1.0 EXECUTIVE SUMMARY

This report presents the results of an in-situ groundwater remediation technology study involving the use of zero valence iron. Results of a full-scale, year-long demonstration evaluation is provided along with details related to the design, construction and monitoring of this system. Treatment effectiveness and hydraulic performance measurements are provided along with recommendations for future application of this technology. This report is intended to serve as the basis for future decisions regarding the use of the zero valence iron technology as part of a final remedy for groundwater contamination.

This study has been authorized and has been conducted in accordance with the requirements of Delivery Order 0031 of the Parsons Engineering Science (Parsons ES) contract with the US Army Corps of Engineers, Huntsville Center of Engineering Support, Contract Number DACA87-92-D0022. During the project, the Seneca Army Depot Activity (SEDA), US Army Corps of Engineer, Huntsville Center for Engineering Support, the US Army Corps of Engineers, New York District, the US Army Environmental Center, the US Environmental Protection Agency (USEPA) and the New York Department of Environmental Conservation (NYSDEC) provided oversight and valuable suggestions and comments. Guidance for evaluation of this technology was obtained from the Interstate Technology and Regulatory Cooperation (ITRC) Permeable Barriers Subgroup. The methods and the procedures followed for evaluation of this technology was described in the "Workplan for Evaluation of a Permeable Reactive Wall", (Parsons ES, 1998).

The site selected for the study is the Ash Landfill Operable Unit. The Ash Landfill Operable Unit is located within the Seneca Army Depot Activity (SEDA). The SEDA is a 10,587-acre military facility located in Seneca County, Romulus, New York. The facility is located in an uplands area between two of the New York Finger Lakes, Cayuga Lake on the east and Seneca Lake on the west. The depot has been owned by the United States Government and operated by the Department of the Army since 1941. The primary military mission of the depot had been the storage and management of various military items, including munitions. However, since 1995, the SEDA has been undergoing Base Realignment and Closure (BRAC). The military mission at the SEDA will end in July 2000. Environmental closure of sites within the depot will continue beyond the termination of base for military purposes.

Since 1989, the SEDA has been listed on the federal facility list of National Priority List (NPL) of Comprehensive Environmental Restoration, Compensation and Liability Act (CERCLA) sites. Shortly after the NPL listing of the SEDA, the US Army entered into a Federal Facility

Agreement (FFA) with the US Environmental Protection Agency (USEPA) and the New York State Department of Environmental Conservation (NYSDEC). The FFA describes the process to be followed for identification, evaluation and eventual closure of all sites located within the depot. The Ash Landfill Operable Unit has been investigated and evaluated following the requirements of CERCLA. A remedial investigation (RI) and a feasibility study (FS) had been completed at the Ash Landfill Operable Unit prior to the performance of this study.

The Ash Landfill Operable Unit is located along the western boundary of SEDA. The area of the Ash Landfill Operable Unit is approximately 23 acres. The Ash Landfill Operable Unit was a location of solid waste disposal activities for several years. Although specific details of the operation remain unknown, solid waste was stored, incinerated and buried at the Ash Landfill Operable Unit during the years of operation. Ash from the on-site municipal incinerator was cooled and landfilled near the incinerator. The operable unit was named after this landfill but the Ash Landfill Operable Unit includes several other sites adjacent to the landfill. The Ash Landfill Operable Unit is comprised of five Solid Waste Management Unit (SWMU)s including: the Incinerator Cooling Water Pond (SEAD-3), the Ash Landfill (SEAD-6), the Non-Combustible Fill Landfill (NCFL) (SEAD-8), the Refuse Burning Pits (SEAD-14) and the Abandoned Solid Waste Incinerator Building (SEAD-15). The Ash Landfill (SEAD-6) also includes a groundwater plume that emanates from the northern corner of the Ash Landfill.

The Ash Landfill Operable Unit includes a dissolved groundwater plume, which is the focus of this technology evaluation. The source of the plume was leaching of chlorinated solvents from soils adjacent to and within the northern corner of the Ash Landfill. Presumably, this material was residue from degreasing operations within the depot during the 1960s and 1970s. The groundwater plume extends approximately 1,500 feet west and consists primarily of dissolved trichloroethene (TCE) and 1,2-dichloroethene (c1,2-DCE). Vinyl chloride (VC) was detected in a limited number of wells located within the area considered to be the source of the groundwater plume. However, VC was not detected in wells downgradient of the source area. The maximum width of the plume is approximately 650 feet. Vertically, the plume is believed to be restricted to the upper till/weathered shale aquifer and is not present in the deeper competent shale aquifer.

Zero valence iron technology was identified as a cost-effective remedial technology following the assembly and evaluation of remedial alternatives that was conducted as part of the Feasibility Study (FS), (Parsons ES, 1996). In-situ treatment was determined to be a cost-effective alternative compared to other groundwater extraction, treatment and discharge options. The advantages of in-situ treatment include low capital costs, ease of constructability and continual treatment during periods of low water conditions when pumping would be impractical. In

addition, with closure of SEDA, in-situ treatment using a chemical reactant, such as zero valence iron, is preferred over other in-situ technologies, such as air sparging, since a chemical reactant does not require operation and maintenance of a mechanical sparging system. Low operational requirements would reduce the Army's long-term labor commitment to the site, which is consistent with the Army's objective to minimize the Army's long term presence at the depot.

Since the technology is considered innovative, the Army committed to demonstrate the technology because of concerns regarding the effectiveness of the technology. Expected treatment effectiveness, design criteria, susceptibility to fouling, constructability and cost data were identified as key components that supported the decision to conduct the study. This report describes the results of several phases of work including: the design of the in-situ reactive wall, the construction of the reactive wall and the year-long groundwater monitoring program.

The initial phase of work involved the design of the reactive wall. Section 4 provides a description of the design process. The initial aspect of the design involved groundwater modeling of the Ash Landfill Operable Unit. The purpose of this effort was to select an optimal configuration for in-situ groundwater treatment. One option considered was the funnel and gate configuration. The other option involved a continuous, permeable wall. Groundwater mounding was identified as a drawback of the funnel and gate option at the Ash Landfill. Based on the results of the groundwater modeling, it was decided to abandon the funnel and gate configuration and focus the design and the demonstration study on the continuous permeable wall configuration.

The zero valence iron technology has been developed and patented by researchers from the University of Waterloo, Waterloo Canada, (Gilliam and O'Hannesin). Envirometals Inc. (ETI) is the sole license holder of this technology. During the design phase of this study, Parsons ES retained ETI to provide consultation in the design. ETI performed predictive modeling to determine the required residence time from influent groundwater concentrations and expected groundwater velocities in the vicinity of where the reactive wall was to be installed. These parameters were obtained from site data collected during the RI.

It was determined to install the reactive barrier wall near the downgradient portion of the plume, within the boundary of the depot. This location was selected because it would be within the secured boundary of the depot and the concentrations of the plume were thought to be consistent. The expected groundwater concentration of dissolved chlorinated ethenes was approximately 100 µg/L. The expected groundwater velocity was approximately 0.17 feet/day. From this data and the degradation models, ETI recommended a retention time of 1.2 days. Modeling,



performed by ETI indicated that a retention time of 1.2 days would be sufficient to completely degrade TCE and c1,2-DCE to ethene and ethane. A groundwater velocity of 0.17 feet/day would correspond to a required trench width of 0.24 feet (3 inches) using 100% iron.

The installation of the reactive barrier wall was completed in one week in December 1998. This required the coordinated effort of several contractors. Materials testing were performed in the weeks preceding the actual installation. Reactive iron was purchased from Peerless Metal Powders and Abrasive of Detroit Michigan and shipped to the site in 3000-lb sacks. A local supplier of clean sand was selected prior to the reactive barrier wall construction. These materials met the requirements of technical specifications that were prepared for this installation.

The installation of the reactive wall was performed with a continuous trenching excavator. The continuous trenching excavator placed the reactive iron and sand mixture and excavated soil from the trench in one continuous process. This eliminated the need for shoring, increased worker safety and increased the efficiency of the construction process. The width of the trencher was fixed at 14-inches. The backfilled sand and reactive iron material formed the permeable reactive wall. Both the reactive material and the backfill were of a higher hydraulic conductivity than the surrounding soils, which would eliminate the potential for mounding since there should be no additional resistance to flow through the trench. The permeability of the mixed soil and reactive iron, (48% reactive iron/52% sand) was measured at 21.0 feet/day ( $7.4 \times 10^{-3}$  cm/sec) by the falling head method.

To ensure adequate contact, the wall was placed perpendicular to groundwater flow. The length of the reactive wall encompassed the entire width of the plume, which was 650 feet. The wall was installed from approximately 6 inches below the ground surface to the competent bedrock, approximately 7 to 12 feet below ground surface. The wall was 14 inches wide. The depth and length of the reactive wall ensured continuous contact with groundwater, regardless of the fluctuation of groundwater.

A total of eleven (11) monitoring wells were installed within, upgradient and downgradient of the reactive wall. Three (3) clusters of three wells were positioned along the reactive wall to facilitate groundwater sample collection. An additional monitoring well was installed at both ends of the wall. All wells were 2-inch diameter PVC wells except the three (3) monitoring wells within the reactive iron. The wells installed within the reactive iron were 1-inch diameter wells. Well screen lengths varied between 5 and 10 feet, depending upon the thickness of the till. The well screen spanned the entire vertical thickness of the reactive barrier wall.

Following installation of the reactive barrier wall and the eleven monitoring wells, a year-long monitoring program was conducted. Groundwater samples were collected from all eleven monitoring wells and analyzed for volatile organic compounds, metals, pH, specific conductivity, redox potential, dissolved oxygen (DO), ferrous iron (Fe+2), methane, ethane, ethene, dissolved organic carbon (DOC), nitrate/nitrite (NO<sub>3</sub>/NO<sub>2</sub>), alkalinity, sulfate (SO<sub>4</sub>) and chloride (Cl<sup>-</sup>). Four quarterly groundwater sampling events were performed for the eleven wells associated with the reactive barrier wall. The first sampling quarter was April 1999, approximately three months after reactive wall installation. In addition, two complete sampling events were conducted for all monitoring wells.

Slug tests were conducted in each upgradient and downgradient monitoring well following the installation of the reactive wall. The slug tests were conducted in May 1999 to allow for complete consolidation of the reactive iron following the rise in the water table due to spring recharge. Data from the slug testing is present in Appendix B. Since the reactive wall was only 14-inches thick, wells within the reactive iron were not slug tested to avoid influencing the groundwater concentration within the wall. Hydraulic conductivity measurements of the reactive iron and sand mixture had already been tested, prior to installation. In addition to quarterly sampling of wells, water level measurements were made on a monthly basis to observe the potential for mounding due to fouling of the reactive iron.

The results of the slug testing in the upgradient and downgradient locations indicated that the aquifer material in the area surrounding the reactive barrier wall was more conductive than other areas of the site. The range of hydraulic conductivity measurements in the eight (8) upgradient and downgradient wells surrounding the reactive barrier wall was 0.4 feet/day to 55 feet/day, with the average of the measurements being 17.7 feet/day. The range of hydraulic conductivity data, obtained during the RI for the glacial till/weathered shale over the entire site, was 0.088 feet/day to 12.7 feet/day. Twelve (12) hydraulic conductivity measurements were made during the RI. The average hydraulic conductivity for the wells screened in the till/weathered shale material was 0.77 feet/day. This suggested that the velocities through the reactive wall would be faster than expected and the retention time required to achieve complete degradation of the target compounds would not be sufficient, even though the amount of iron installed in the trench was at least twice as much as what was required.

The analytical results from groundwater samples were used to evaluate the effectiveness of the treatment process. Treatment effectiveness was determined by comparison of the upgradient monitoring well data to the analytical data collected from wells located within the reactive wall. Downgradient monitoring well data were not considered as an indicator of the treatment

effectiveness because groundwater at the downgradient location is affected by the dilution of clean water, out of the reactive wall, with residual contaminant concentrations that remain within the aquifer. Eventually flushing of residual concentrations would yield data that would represent effluent reactive wall concentrations but this was not observed during this study. Groundwater concentrations observed at the downgradient location were therefore not used to determine the treatment effectiveness.

There are several indications that the reactive wall is actively degrading chlorinated contaminants. The measured Eh values from within the reactive wall ranged from 90.1 mV to -404.3 mV, which is consistent with reducing conditions. pH measurements ranged from 7.83 to 9.74, which are also indicative that iron is reacting with chlorinated organics. Concentrations of the degradation endpoints, methane, ethene and ethane, were measured in wells within the reactive wall and downgradient monitoring wells. These are all strong indications that the reactive iron technology is operating as expected. The remaining question is how effective is the technology in achieving the required target contaminant levels. This is addressed with a review and evaluation of the analytical groundwater monitoring well data.

Significant reductions in the concentrations of TCE were observed between the upgradient monitoring wells and the reactive wall wells at each monitoring well cluster. The concentration of TCE at each of the three monitoring wells located within the reactive barrier wall was non-detectable for each of the four quarterly rounds of sampling. This data is indicative that the technology is successful in removing TCE to below the target levels. In particular, the monitoring well cluster that included MWT-7 and MWT-8, located in the southernmost portion of the reactive wall, showed the most dramatic reductions. At this cluster, the influent concentration of TCE at MWT-7 in June 1999, was 530  $\mu\text{g/L}$ , whereas the concentration within the trench at MWT-8 was below detectable limits at less than 2  $\mu\text{g/L}$ . This corresponds to a removal efficiency of better than 99.6%. Removal efficiencies of similar degree of removal has been observed during the other three quarterly monitoring events. At the two other monitoring well cluster locations the removal efficiency is less but only because the influent concentration was less.

The removal efficiencies for the breakdown product, cis 1,2-dichloroethene (c1,2-DCE), which is known to be more difficult to degrade than TCE, are less dramatic but do indicate that the technology is effective in removing this contaminant. For example, during the April 1999 monitoring event, the influent concentration of c1,2-DCE at MWT-4, the upgradient monitoring well at the middle monitoring well cluster location, was 49  $\mu\text{g/L}$ , whereas the concentration of c1,2-DCE at MWT-5, the monitoring well within the reactive barrier wall, was below detectable

levels at 0.7 ug/L. This corresponds to a removal of 98.5%. However, during the next monitoring round in June 1999, the upgradient concentration at MWT-4 was 82 ug/L, whereas the concentration of c1,2-DCE at MWT-5 was 20 ug/L. This corresponds to a removal of 75.6%. It is unclear why these removal efficiencies varied.

Several factors are likely contributing to the lower than expected reductions of c1,2-DCE. It is possible that the high influent concentrations of TCE may have produced c1,2-DCE as a breakdown product within the wall. Due to this additional loading, the residence time was not sufficient to account for c1,2-DCE being produced within the wall. Concentrations of TCE entering the trench were approximately 500 ug/L, which was higher than the 260 ug/L design concentration. Additionally, hydraulic conductivities were also variable and appear to be related to the anisotropy of the aquifer. Following the installation of the reactive wall, in-situ hydraulic conductivity measurements were made at the newly installed monitoring wells, upgradient, within the wall and downgradient of the wall. The range of hydraulic conductivity measurements in the wells surrounding the reactive barrier wall was between 0.4 feet/day to 55 feet/day, with the average of the measurements being 17.7 feet/day. The higher values were over ten times higher than any previously measured value at the site.

Probably the most significant factor is the retention time. If the retention time within the reactive wall is less than expected due to higher velocities, then the retention times within the reactive wall will be less than that required by the design. The design residence time was established at 1.25 days. Residence times through the wall were halved to account for the fact that the reactive wall is a mixture of 50% reactive iron and 50% clean sand. The range of equivalent reactive iron wall residence times is 0.09 days to 2.7 days, with the average of the residence times being 1.12 days.

The design velocity was established at 0.17 feet/day. Excluding the instances of reverse flow caused by a change in gradient, the groundwater velocities through the trench ranged from 0.22 feet/day to 6.8 feet/day over the year long study. The average of these measurements is 1.2 feet/day.

The technology appears to be a viable technology, however, future applications at this site will require longer reactive iron residence times in order to meet the targeted groundwater levels.

## 2.0 SITE BACKGROUND

### 2.1 SITE LOCATION

The SEDA is a former military facility, constructed in 1941 that has been undergoing Base Realignment and Closure (BRAC) since 1995. The depot is located approximately 40 miles south of Lake Ontario, near Romulus, New York as shown in **Figure 2-1**. The facility is located in an uplands area, at an elevation of approximately 600 feet Mean Sea Level (MSL), that forms a divide separating two of the New York Finger Lakes, Cayuga Lake on the east and Seneca Lake on the west. Sparsely populated farmland covers most of the surrounding area. New York State Highways 96 and 96A adjoin SEDA on the east and west boundaries, respectively.

The Ash Landfill Operable Unit is situated on an upland area along the western border of the SEDA. The Operable Unit is bounded on the north by Cemetery Road, on the east by the Seneca Army Depot Railroad line, and on the south by open grassland and brush. Beyond the depot's western boundary, on Smith Farm Road and along Route 96A, are farmland and residences. A map identifying the location of the site on the depot is included as **Figure 2-2**. This map also provides the future land areas of the depot that have guided the BRAC closure process. The Ash Landfill Operable Unit is located within the area that has been designated for use as a conservation/recreational area.

A site map of the Ash Landfill Operable Unit, identifying the location of the Solid Waste Management Unit (SWMU)s, is provided as **Figure 2-3**. The Ash Landfill Operable Unit is comprised of five SWMUs including: the Incinerator Cooling Water Pond (SEAD-3), the Ash Landfill (SEAD-6) the Non-Combustible Fill Landfill (NCFL) (SEAD-8), the Refuse Burning Pits (SEAD-14) and the Abandoned Solid Waste Incinerator Building (SEAD-15). SEAD-14 is also known as the Debris Piles. A groundwater plume that emanated from the northern corner of the Ash Landfill area is also provided in **Figure 2-3**. The groundwater plume is shown following completion of a Non-Time Critical Removal Action (NTCRA) that was conducted by the Army in 1994-1995. Remediation of this groundwater plume is the focus of this demonstration study.

### 2.2 SITE GEOLOGY/HYDROGEOLOGY

The site is underlain by a broad north-to-south trending series of rock terraces covered by a mantle of till. As part of the Appalachian Plateau, the region is underlain by a tectonically

undisturbed sequence of Paleozoic rocks consisting of shales, sandstones, conglomerates, limestones and dolostones. At the Ash Landfill site, these rocks (the Ludlowville Formation) are characterized by gray, calcareous shales and mudstones and thin limestones with numerous zones of abundant invertebrate fossils. Locally, the shale is soft, gray, and fissile. Pleistocene age (Late Wisconsin age, 20,000 years bp) till deposits overlie the shales, which have a thin (2 to 3 feet) weathered zone at the top. The till matrix varies locally but generally consists of horizons of unsorted silt, clay, sand, and gravel. The soils at the site contain varying amounts of inorganic clays, inorganic silts, and silty sands. At the Ash Landfill Operable Unit, the thickness of the till generally ranges from 4 to 15 feet. At the location of the continuous reactive wall system, the thickness of the till and weathered shale is approximately 8 to 12 feet.

Groundwater is present in both the shallow till/weathered shale aquifer and in the deeper competent shale aquifer. In both aquifers, the predominant direction of groundwater flow is to the west, toward Seneca Lake.

The hydraulic conductivity of the till and the weathered shale zone ranged between 0.001035 feet/min ( $5.3 \times 10^{-4}$  cm/sec) to 0.00006083 feet/min ( $3.9 \times 10^{-5}$  cm/sec), with the average being 0.000535 feet/min ( $4.6 \times 10^{-4}$  cm/sec). The weathered shale eventually transitions to a competent shale. The hydraulic conductivity of the competent shale ranged between 0.000245 feet/min ( $1.2 \times 10^{-4}$ ) to 0.00000039 feet/min ( $1.9 \times 10^{-7}$  cm/sec), with the average being 0.0000727 ( $3.7 \times 10^{-5}$  cm/sec). These soils are generally considered to be poorly draining.

## 2.3 SITE HISTORY

Since its inception in 1941, SEDA's primary mission had been the receipt, storage, maintenance, and supply of military items.

The SEDA was proposed for the National Priority List (NPL) in July 1989. In August 1990, SEDA was finalized and listed in Group 14 on the Federal Section of the National Priority List (NPL). The EPA, NYSDEC, and the Army entered into an agreement, called the Federal Facility Agreement (FFA), also known as the Interagency Agreement (IAG). This agreement determined that future investigations were to be based on CERCLA guidelines, RCRA was considered to be an Applicable or Relevant and Appropriate Requirement (ARAR) pursuant to Section 121 of CERCLA. In October 1995, SEDA was designated as a facility to be closed under the provisions of the Base Realignment and Closure (BRAC) process.

Prior to the development of the Ash Landfill site, the land in this area was used for farming. From 1941 (the date SEDA was constructed) to 1974, uncontaminated trash was burned in a series of burn pits near the abandoned incinerator building (Building 2207). According to a U.S. Army Environmental Hygiene Agency (USAEHA) Interim Final Report, Groundwater Contamination Survey No. 38-26-0868-88 (July 1987), from 1941 until the late 1950's or early 1960's, the ash from the refuse burning pits was buried in the Ash Landfill (SEAD-6).

The incinerator was built in 1974. Between 1974 and 1979, materials intended for disposal were transported to the incinerator. The incinerator was a multiple chamber, batch-fed 2,000 pound per hour capacity unit which burned rubbish and garbage. The incinerator unit contained an automatic ram-type feeder, a refractory lined furnace with secondary combustion and settling chamber, a reciprocating stoker, a residue conveyor for ash removal, combustion air fans, a wet gas scrubber, an induced draft fan, and a refractory-lined stack (USAEHA, 1975). Nearly all of the approximately 18 tons of refuse generated per week on the depot were incinerated. The source for the refuse was domestic waste from depot activities and family housing. Large items that could not be burned were disposed of at the NCFL (SEAD-8). The NCFL is approximately two acres and is located southeast of the incinerator building (immediately south of the SEDA railroad line). The NCFL was used as a disposal site for non-combustible materials, including construction debris, from 1969 until 1977.

Ashes and other residues from the incinerator were temporarily disposed in an unlined cooling pond immediately north of the incinerator building. The cooling pond consisted of an unlined depression approximately 50 feet in diameter and approximately 6 to 8 feet deep. When the pond filled, the fly ash and residues were removed, transported, and buried in the adjacent ash landfill east of the cooling pond. The refuse was dumped in piles and occasionally spread and compacted. No daily or final cover was applied during operation. The active area of the Ash Landfill extended at least 500 feet north of the incinerator building, near a bend in a dirt road, based on an undated aerial photograph of the incinerator during operation. A fire destroyed the incinerator on May 8, 1979, and the landfill was subsequently closed. The landfill was apparently covered with native soils of various thicknesses but has not been closed with an engineered cover or cap. Other areas on the site were used for a grease pit and burning of debris. The Ash Landfill Operable Unit was initially estimated to encompass an area approximately 130-acres. This larger area was investigated to ensure that no, previously unknown, waste disposal areas were overlooked. Following the remedial investigation the area of the Ash Landfill Operable Unit was refocused to an area of approximately 23 acres.

The first phase of RI fieldwork was completed in January 1992. The RI report was prepared in two phases. The first document provided was the Preliminary Site Characterization Summary Report (PSCR) submitted on April 27, 1992. The PSCR constituted the first four chapters of the RI and was intended to: provide a description of the site conditions, present the Phase 1 data, and identify any data gaps. The PSCR served as the basis for the second phase of data collection. Phase 2 fieldwork was completed in April 1993. The RI report was submitted final on October 3, 1994.

The nature and extent of the constituents of concern at the Ash Landfill were evaluated through the comprehensive RI program. The primary media investigated at the Ash Landfill were soil, surface water and sediment from Kendaia Creek, on-site wetlands, drainage swales, and groundwater. The primary constituents of concern at the Ash Landfill are Volatile Organic Compounds (VOC) (primarily chlorinated and aromatic compounds), semivolatile organics, mainly Polynuclear Aromatic Hydrocarbons (PAHs), and, to a lesser degree, metals. The constituents of concern are believed to have been released to the environment during former activities conducted at the Ash Landfill Operable Unit.

A Non-Time Critical Removal Action (NTCRA), also known as an Interim Removal Measure (IRM), was conducted by the Army between August 1994 and June 1995, under the requirements of the CERCLA, as amended. The NTCRA successfully eliminated continued leaching of VOCs to groundwater associated with this operable unit. The removal action consisted of excavation and thermal treatment of VOC-impacted soils using Low Temperature Thermal Desorption (LTTD). The action thermally treated VOCs and PAHs in soils at two source areas near an area, along a winding access road, near the northwestern edge of the Ash Landfill. Sampling performed during the RI identified elevated concentrations of VOCs and PAHs to be present. This area was named the "Bend in the Road" area.

The treatment of soils involved two distinct source areas at the "Bend in the Road" area. Soil within this area was identified during the RI as the source of groundwater contamination. One of the goals of the IRM was to eliminate the source of groundwater pollution. Approximately 35,000 tons of soil were excavated from the two source areas and heated to 800-900°F in the LTTD system. After the soil was heated and cooled, soil was tested prior to backfilling into the excavation area. Following backfilling and proper grading for drainage control, a vegetative cover was established to prevent erosion. Sampling and analysis of the excavated and treated soil material indicated that these soils were successfully treated and met the VOC clean-up criteria for the project.



The IRM thermal treatment project provided a positive benefit for the long-term remedial action by eliminating continued leaching of VOCs into groundwater and preventing further exposure to humans and wildlife. In the several years that have passed since the IRM, the positive benefits of the IRM have been observed as the concentration of groundwater in this area has decreased over 100 fold.

Treatment of wastewater and monitoring of air dispersion impacts were also performed as part of the NTCRA. Wastewater in the excavation areas (consisting of infiltrating groundwater, precipitation, runoff, and water generated from other project operations) was collected, pumped, and treated by an on-site water treatment system prior to discharge in a nearby field. The treated water met the requirements of the NYSDEC groundwater criteria for a Class GA groundwater. Class GA groundwater means that the groundwater is suitable for use as a source of potable water.

The maximum concentration of TCE in soil at the "Bend in the Road" area, prior to the non-time critical removal action, was 540,000  $\mu\text{g}/\text{Kg}$  or 540 mg/kg. The maximum concentration of trichloroethene in soil following thermal treatment was 46  $\mu\text{g}/\text{kg}$  or 0.046 mg/kg. This is a reduction in concentration of approximately 10,000. Of the 156 valid soil samples collected from the treated soil, excluding duplicates, only this one sample was detected above the Practical Quantitation Limits (PQL) of the analytical method. These samples represent soil from approximately 150 cubic yard piles of soil that had been thermally treated, prior to replacement in the excavation. The typical PQL for trichloroethene in soil was approximately 10  $\mu\text{g}/\text{kg}$ . Following analytical documentation that treatment had been successful, the soil was placed back to the excavation.

Prior to full operation, a prove-out test was performed to document the effectiveness of the proposed thermal treatment technology and evaluate the potential for the treated soil to leach metals. Thermal treatment is not effective in removing metals from soil. A total of 89 post treatment soil samples were collected and analyzed for the 8 Toxicity Characteristics Leaching Procedure (TCLP) metals following treatment. The 8 metals that are included in the TCLP test are: arsenic, barium, cadmium, chromium, lead, mercury, selenium and silver.

The treated soil was tested to evaluate the potential for metals in soil to leach and ensure that the leachable levels did not exceed hazardous waste characteristic levels. The TCLP test is an EPA RCRA test that is used to assess the potential for a waste to leach. It is also used to classify

waste as hazardous. Of the 8 TCLP metals lead was used as an indicator metal. Lead was chosen as the indicator metal due to the toxicity of lead, the potential to leach and the concentrations of lead in soil that were measured during the RI.

The TCLP metal analytical data indicated that the maximum concentration of leachable lead in the soil samples associated with the IRM thermal treatment project was 814 µg/L. The regulatory limit for the RCRA characteristic of toxicity for lead, using the TCLP test, is 5,000 µg/L, therefore no soil tested were found to be a RCRA characteristic hazardous waste. Numerous TCLP sample results for leachable lead in soil were non-detectable. Total concentrations of lead in soil were not measured during the IRM. The concentration of total lead in soil was measured during the RI in the area of the IRM. Total lead in soil measured in the area of the IRM ranged from 4.1 mg/kg to 696 mg/kg. The highest concentration of total lead in soil measured during the RI was 2,890 mg/kg. This sample was obtained from one of the surface debris piles.

The primary VOCs in soils at the Ash Landfill site were cis 1,2-dichloroethene (c1,2-DCE) (maximum=79 mg/kg), trichloroethene (TCE) (maximum=540 mg/kg), and vinyl chloride (VC) (maximum=1.0 mg/kg). The highest concentrations of these compounds were measured in a two-acre area, located in the northwestern corner of the Ash Landfill, near a bend in the access road. The primary aromatic constituents of concern were xylene (maximum=17 mg/kg) and toluene (maximum=5.7 mg/kg). The semivolatiles of principal concern were Polynuclear Aromatic Hydrocarbons (PAH)s. PAHs were measured at concentrations above the NYSDEC Technical and Administrative Guidance Memorandum (TAGM) cleanup guidelines. The metals that were detected at elevated concentrations in soils were copper (maximum=836 mg/kg), lead (maximum=2,890 mg/kg), mercury (maximum=1.2 mg/kg) and zinc (maximum=55,7000 mg/kg). The highest concentrations of metals were detected in the surface soils of the debris piles. The debris piles are small surface features and do not extend into the subsurface. The extent of the aromatics in the horizontal direction was smaller than that for the chlorinated volatile organics (approximately one-half acre). The vertical impacts extended from the land surface to 4 feet below the surface (above the water table).

No volatile or semi-volatile organic compounds were detected in any of the on-site surface waters or Kendaia Creek. Kendaia Creek has been classified by NYSDEC as a Class C stream. The on-site drainage ditches and wetlands have not been classified by NYSDEC. The on-site wetlands and drainage ditches do not contain surface water throughout the entire year

## 2.4 SITE GROUNDWATER IMPACTS

Groundwater at the site is impacted primarily by a plume of chlorinated ethene volatile organic compounds (TCE, c1,2-DCE and VC). The plume extends from an area near the Ash Landfill, westerly, to the boundary of the depot, approximately 1,500 feet away. **Figure 2-3, Figure 2-4 and Figure 2-5** provide a plan view depiction of the plume in 1997, 1999 and 2000. Quarterly monitoring in 1996, 1997 and 1998 detected c1,2-DCE between 0.2 µg/L and 2 µg/L at monitoring well MW-56, which is 225 feet past the depot boundary. The most recent sampling of MW-56 in January 2000 did not detect c1,2-DCE at a concentration of 1 µg/L. The NYSDEC GA groundwater quality standard for c1,2-DCE is 5 µg/L. It is likely that the boundary of the plume extends westward to slightly beyond the depot boundary. Exceedances over the NYSDEC GA groundwater standard, beyond the depot boundary, have not been observed. At the widest point, the plume is approximately 625 feet. The highest concentrations were detected in the area considered to be the source of the contamination. From this area, concentrations of dissolved chlorinated organic compounds in groundwater decrease as the plume migrates with the natural flow of groundwater.

The main source area, located in the northwestern portion of the Ash Landfill, was designated as the "Bend in the Road" area since it was located at the bend in the unpaved access road. Historically, the maximum volatile organics concentration was detected in monitoring well MW-44, located within the area considered to be the source area prior to the soil removal action. In November 1993, the concentrations of TCE, c1,2-DCE and VC were 51,000 µg/L, 130,000 µg/L, and 23,000 µg/L, respectively, for a total chlorinated ethene concentration of 204,000 µg/L in MW-44. This area was eliminated in 1995 through a NTCRA that treated approximately 34,000 CY of soil using LTTD. Prior to the IRM, the maximum detected concentration of total chlorinated ethenes at the site was 132,360 µg/L (at MW-44, which is now MW-44A). After the source removal, which occurred between September 1994 and June 1995, concentrations of chlorinated compounds were reduced significantly, based on a June 1997 sampling event (**Figure 2-3**). For example, prior to the removal action the concentration of total chlorinated ethenes in MW-44 was 204,000 µg/L. In October 1999, the concentration in MW-44A, the replacement well for MW-44, was 1,104 µg/L, a 100-fold decrease in concentration. In January 2000, the concentration of total VOCs in MW-44A was 399 µg/L. Following completion of the NTCRA in June 1997, the concentration of total chlorinated ethenes in the downgradient portion of the plume (i.e., at the proposed location of the reactive wall) ranged between 55 µg/L and 233 µg/L (**Figure 2-3**). The concentrations of chlorinated ethenes in this area remained similar to the

levels observed in 1997. **Figures 2-4 and 2-5** depict the groundwater VOC plume approximately five years after the removal action.

The nearest exposure points for groundwater are the three farmhouse wells, located approximately 1,250 feet from the leading edge of the plume. At least one of the farmhouse wells draws water from the till/weathered shale aquifer and the remaining two wells derive water from the bedrock aquifer. Vertically, the plume is believed to be restricted to the upper till/weathered shale aquifer and is not present in the deeper competent shale aquifer.

Although exceedances of the NYSDEC GA groundwater standards were observed, in at least several wells, during the RI for the metals chromium, lead, nickel, zinc, antimony, barium beryllium and copper, the data appears to be related to the turbidity of the sample. It was noted that wells with high turbidity have high metals concentrations. Subsequent improvements to the sampling techniques provided less turbid samples with a corresponding decrease in the concentration of metals. For example, lead in MW-44, with a turbidity of 100 NTU was measured during the second round of the RI was 147  $\mu\text{g/L}$ , which was above both the EPA criteria of 15  $\mu\text{g/L}$  and the NYSDEC GA standard of 25  $\mu\text{g/L}$ . During the quarterly sampling, conducted following the RI, the concentration of lead in MW-44 was non-detectable at less than 2  $\mu\text{g/L}$ . This same trend was observed for other wells. The turbidity of the quarterly monitoring samples were less than 10 NTU. Furthermore, the locations of the exceedances did not correlate to form a continuous plume, rather the exceedances were randomly distributed and did not related to a source of metal contamination. As a result of this data, concern over exceedances of metals in groundwater were resolved and attributed to turbidity.

Based on recent groundwater chemistry data (October 1999 and January 2000), the overall configuration of the plume is similar to that shown in June 1997 (**Figure 2-4** and **Figure 2-5**, respectively). Concentrations of chlorinated ethenes are generally unchanged in the immediate vicinity of the continuous reactive wall since 1997. And, while the concentrations of chlorinated ethenes remained similar in most locations in the former source area (MW-44A and PT-12A), there was an increase in concentration of total VOCs in the area near PT-18 (up to 10,591  $\mu\text{g/L}$ ) in October 1999 compared to the 1997 results. In January 2000, however, total chlorinated ethenes concentrations had fallen back to levels similar to the 1997 results. This cycle of increase and decrease in chlorinated ethene concentrations is most likely due to seasonal fluctuations in groundwater at the Ash Landfill.

### 3.0 TECHNOLOGY BACKGROUND

Researchers at the University of Waterloo identified the application of and obtained a patent for use of zero valence iron as a viable technology for remediation of contaminated groundwater (Gavaskar, 1997). In 1994, EnviroMetals Technologies, Inc. (ETI) was granted a license to commercially apply the technology. While the patent describes the use of zero valence iron it does not describe or include the groundwater system required to successfully apply the technology at a site. Successful application of this technology requires both groundwater collection and treatment. ETI has been instrumental in performing bench scale and pilot scale studies to obtain vital design parameters and has pursued commercial applications of zero valence iron. These applications have typically involved a combination of engineering consulting firms, contractors and ETI. Through a subcontracting agreement with Parsons, ETI has issued a license to Parsons to apply this technology at the Ash Landfill Operable Unit. ETI, through the terms of this agreement, has provided technical support and oversight during the design, installation and evaluation phases of this project. Several correspondences with ETI are provided in **Appendix D**.

Zero valence iron destroys dissolved chlorinated organic compounds via reductive dechlorination (Matheson and Tratnyek, 1994). During this reaction, zero valence iron, an electron donor, is oxidized to ferrous iron thereby providing two electrons. These two electrons reduce hydrogen ions and chloride cause chloride ions to be released from the organic compound. In the case of TCE and c1,2-DCE, this results in the formation of the alkane compound, ethane, or the formation of the alkene compound, ethene. Additionally water is split, eventually forming hydrogen gas, H<sub>2</sub>, and hydroxide ions, OH<sup>-</sup>. The increase in hydroxide ions causes the pH to increase to alkaline conditions. Thus an increase in pH and hydrogen gas in solution are indications that the iron is active and capable of reducing alkyl halides.

The technology is typically applied in-situ. Successful application this technology requires both adequate collection of capture of the plume and sufficient contact time between the contaminated groundwater and the zero valence iron. Applications of this technology have included various ways to ensure capture and contact time. Capture and treatment with a funnel and gate approach or a continuous permeable reactive wall are two configurations that have been the most widely used. The approach selected for demonstration at this site is the permeable reactive wall.

The technology offers several distinct advantages over other conventional groundwater treatment technologies. In-situ treatment schemes utilize the natural gradients and hydraulic conductivity of the aquifer to drive groundwater through the reactive material. Since the technology is

passive and the destruction is accomplished in-situ there is no need to additional costs associated with construction of an above ground treatment facility. The costs for equipment, such as pumps and piping are also eliminated, in addition to the costs for operation and maintenance of an above ground treatment facility. Costs associated with collecting and treating off-gases from vapor extraction systems or air stripping units are also not a factor.

Another advantage of in-situ treatment, is the elimination of issues associated with permitting effluent discharge points, i.e. surface water bodies, or air.

With this technology, treatment of groundwater remains continuous even during saturated water table conditions that may vary over the year. This advantage was considered significant at this site since the water level elevation data identified a large seasonal change in saturated thickness. During low levels, the ability to effectively remove water from the aquifer with a conventional pumping system is a concern. Such conditions may require groundwater extraction to stop or to be extracted at a low flow rate such that treatment cannot occur continuously. Under such a scenario contaminated groundwater may continue to migrate or may place significant restrictions on the design and operation of an aboveground system. These concerns would be eliminated with a passive in-situ treatment system since an in-situ system would continue to provide treatment under low water table conditions.

Land use is not dramatically affected by such an in-situ treatment system. Thus, use of the area for conservation/recreational land use, which is the current intended future use for this area, would be allowed for an in-situ reactive wall.

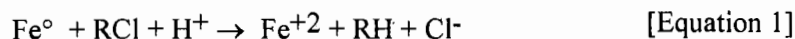
The cost of reactive iron is relatively inexpensive and is a by-product of industrial manufacturing operations. Reactive iron has a large capacity to degrade chlorinated organic contaminants and has been shown to be unaffected by fouling due to inorganic precipitation or premature oxidation. (O'Hannesin and Gillham, 1998, Vogan et. al, 1998 and McMahon et. al, 1999) Although these are limited long-term demonstration studies, the data collected to date has shown that, once operating, the iron in the wall would be effective for a relatively long period of time. Estimates provided by ETI indicate that that iron typically would require replacement after about ten years.

For these reasons the use of zero valence iron as a cost-effective technology for groundwater remediation has been applied at several sites. The technology was selected for demonstration at the Ash Landfill site with the intent of obtaining treatment effectiveness data and other design data that would be then used as the basis for a final remedy at this site.

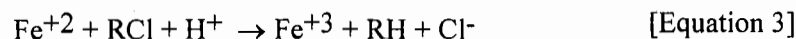
### 3.1 REDUCTIVE DECHLORINATION using ZERO VALENT IRON

Zero valence iron is an effective reactant in destroying dissolved chlorinated organics from groundwater. Chlorinated organics undergo reductive dechlorination in the presence of a proton donor (water) and zero valent iron, which provides electrons. During the process, compounds such as TCE, cDCE, and VC are reduced and iron is oxidized. The end products are methane, ethane, ethene, and chloride. **Figure 3-1** shows the process of reductive dechlorination and **Figure 3-2** shows percent molar conversions of chlorinated compounds during reductive dechlorination.

There are three general pathways leading to the dechlorination of alkyl chlorides, (Matheson and Tratnyek, (1994). The first involves direct reduction of chlorinated solvents that are adsorbed on the metal surface:



The second pathway involves oxidation of  $\text{Fe}^{+2}$  that is an immediate product of corrosion in aqueous systems:



The third pathway involves reduction of alkyl halides from interaction with hydrogen. Hydrogen is produced during iron corrosion, See Equation 2,:



These three pathways, described by Equations 1, 3, and 4, are all contributors to the reductive dechlorination process that is occurring at the Ash Landfill.

Loss of the reactive iron as an effective treatment reactant can under certain conditions. Under aerobic conditions, dissolved oxygen is the preferred reactant during iron corrosion. This results in a rapid reduction reaction with  $\text{O}_2$  instead of water:



Like oxygen, three other chemical constituents, sulfates, nitrates, and phosphates can also serve as oxidants during iron corrosion. Iron corrosion results in a decrease in redox potential, an increase in pH, ferrous iron, and hydrogen. Therefore, to monitor iron corrosion, groundwater was analyzed for redox potential, pH, ferrous iron, and hydrogen.

### 3.2 TECHNOLOGY APPLICATIONS

Several applications of this technology has been documented, Vidic, R.D. and Pohland, F.G., (1996), Gavaskar, Arun et. al, (1997).

One of the first applications of this technology was at the Canadian Forces Base, Borden, Ontario in 1991. This application involved a permeable wall configuration that included the use of sealable sheet pilings, installed to a depth of approximately 33 feet, to allow excavation and backfilling with a mixture of 22% reactive iron and 78% concrete sand. Once backfilling with the reactive mixture was complete, the sheet pilings were removed. The reactive wall was placed perpendicular to groundwater flow and was 5.2 feet wide and 18 feet long. Residence time was estimated at 16 days. Maximum concentrations of TCE and PCE were 250,000 µg/L and 43,000 µg/L, respectively. The system was monitored for a 17-month period. Final results of monitoring showed 99% reductions of TCE and 88% reductions of PCE. Follow-up laboratory studies indicated that a higher percentage of reactive iron would be required to increase the reductions of TCE and PCE.

A continuous reactive wall was installed at the United States Coast Guard (USCG) Center at Elizabeth City, NC in June, 1996. The site is located near the Pasquotank River. The aquifer material is largely fine sand, silt and clay. Higher permeable zones in the surficial aquifer occur at depth of approximately 16 at 22 feet below land surface. The installation was performed using a continuous trenching machine that excavated soil and installed reactive iron at the same time. Installation was completed in 12 hours. The continuous reactive wall was installed with 100% reactive iron. The iron wall was 15 feet long, 24 feet deep and 2 feet wide. The wall was keyed into a layer of low-permeability sandy clay located between 22 and 26 feet below ground surface. Maximum influent contaminant concentrations were 8 mg/L, 12 mg/L 1 mg/L and 0.1 mg/L for chromate, TCE and c1,2-DCE and vinyl chloride, respectively. Monitoring of the reactive wall included an array of 10 compliance monitoring wells and 15 multi-level samplers, located upgradient, downgradient and within the barrier wall. Monitoring data indicates that the majority of the TCE breakdown occurs within the first foot of the barrier with no TCE being detected above the drinking water criteria. Vinyl chloride and less than 2 ug/L. However, TCE



was detected in a downgradient well, suggesting that some TCE had migrated underneath the barrier.

A 1,200-foot long funnel and gate reactive wall was installed at the Denver Federal Center in 1996 (McMahon, P.B. et al, (1999)). Groundwater flows through unconsolidated alluvial sediments and weathered sediment. The mean hydraulic conductivity obtained from slug tests performed on individual wells was 1.64 feet/day. The underlying bedrock consists of a less permeable, unweathered claystone of the Denver Formation. Four gates, each 40 foot wide and 10 foot deep, were installed at various intervals within the 1,200-foot long impermeable barrier, which was comprised of interlocking metal sheet piles that were driven into unweathered bedrock. Each gate contained pea gravel on the upgradient and downgradient ends with reactive iron in the middle. The thickness of the reactive iron varied from 6 feet to 2 feet, depending upon the anticipated groundwater velocity. The maximum concentrations of contaminants entering the gates were 200 µg/L, 15 µg/L, 600 µg/L, 230 µg/L and 18 µg/L for trichloroethane (TCA), 1,1-dichloroethane (DCA), TCE, 1,1-dichloroethene (1,1-DCE) and vinyl chloride (VC), respectively. The only contaminant detected exiting the gates was DCE at a maximum concentration of 15 µg/L. This amount represents about 0.7% of the total contaminant mass that was entering the gates. It was suggested that the presence of DCA within the gates may be a result of the production of DCA in the gates and the relative resistance of DCA to degradation by zero valence iron. Hydraulic monitoring of the reactive wall was performed to evaluate the potential for migration under, around and over the reactive wall. Data suggested that water movement was possible under the reactive wall in only one area near one of the gates. Movement of groundwater around the reactive wall was indicated in one end of the reactive wall. This movement around the reactive wall caused formation of groundwater seeps, which eventually discharged to a nearby stream. However, the amount of leakage did not cause a measurable increase in the concentration of contaminants in the receiving stream flow. Mounding caused by the presence of the impermeable steel sheet pile was identified in all upgradient monitoring wells. A portion of this groundwater was attributed to leakage from a nearby reservoir. Flux calculations performed indicated that approximately 77% of the groundwater moving toward the reactive wall moved through the gates. The rest of the water either accumulate on the upgradient side of the reactive wall or bypassed the reactive wall. Migration of groundwater over the reactive iron in the gates was identified at one location. As a result of the groundwater mounding upgradient of the reactive wall, velocities through the gates were increased. In Gates 2 and 3, the velocities ranged from 0.2 feet/day to 1.3 feet/day. In another gate, Gate 3, the velocities ranged from 0.2 feet/day to 1.5 feet/day. The median groundwater velocity in Gates 2 and 3 were 0.36 feet/day and 0.59 feet/day. The conclusions of the evaluation of this system indicated that while zero valence iron is capable of destroying

chlorinated contaminants, hydraulic movement of contamination around the reactive wall is of greater concern.

The EPA SITE demonstration program conducted a 6-month demonstration study at an industrial facility located in central New York state, EPA/540/R-98/501 (1998). The study involved evaluation of a funnel and gate application of the zero valence iron technology. The site is located in a river valley. Unconsolidated geological deposits consisting of clayey sand and gravel comprise the aquifer materials. These deposits overlie a dense clay confining layer. The top of the confining clay unit is approximately 13 to 16 feet below ground surface. The depth to groundwater ranges from approximately 3 to 7 feet. Following bench-scale and pilot studies, ETI established the required residence time at 56 hours. The system design allowed for a minimum residence time of approximately 72 hours. This was based upon a predicted maximum design groundwater flow of 1 foot per day through the reactive iron. Groundwater velocities assumed a horizontal gradient of 0.002 foot/foot, a hydraulic conductivity of 142 feet per day and a porosity of 0.4 for the reactive iron. The system was constructed in May 1995 by driving sealable-joint sheet piling one foot into the clay aquitard. The sheet piling formed a rectangular box area approximately 12 feet by 6.5 feet. The long portion of the box was placed perpendicular to the groundwater flow direction. Additional 15-foot long sheets were also driven one foot into the clay confining layer on either side of the box to act as the groundwater diversion funnel.

Soil within the box was then excavated to the top of the clay layer and the water within the box was removed. Steel sheet piling was then used to segregate the box into three compartments. Pea gravel was placed within the two end compartments. Each end compartment was approximately 1.75 feet wide. The middle 3-foot wide compartment was backfilled with reactive iron. Pea gravel was used to establish a mixing zone to eliminate short-circuiting caused by the anisotropy of the aquifer. Three monitoring wells were installed within each compartment. Following placement of the monitoring wells and backfilling, the two steel compartment dividers and the two ends of the reactive zone were removed. Groundwater flow through the reactive wall commenced on May 18, 1995.

The influent TCE groundwater concentrations ranged from 32 ug/l to 330 ug/L; for c1,2-DCE the concentrations ranged from 98 ug/L to 550 ug/L; for VC the concentrations ranged from 5 ug/l to 79 ug/L. Traces of 1,1-DCA and t-1,2-DCE have occasionally been detected at levels below 5 ug/L. Analytical samples were collected during the months of June, July, August, October, November and December 1995.

Excluding the June data as unrepresentative due to the dewatering performed during construction, the observed data indicated the treatment system was effective in destroying chlorinated organics. Most of the samples collected from the downgradient wells did not detect chlorinated organics at a detection limit of 1 ug/L. The only exception was for c1,2-DCE that was detected at low levels. Critical chlorinated organic contaminants were below the New York State Department of Environmental Conservation (NYSDEC) target levels for 86 out of 90 measurements. The NYSDEC target criteria for c1,2-DCE were slightly above the target level of 5 ug/L for four measurement, however, the highest measured value was only slightly above the 5 ug/L value at 7.5 ug/L.

A recently published report by Gavaskar, Arun et. al (2000) provides a summary of the status of the of the zero valence iron reactive wall technology. This discussion notes that the confidence in this technology has grown as data from various demonstration studies becomes available. More of the recent applications have been configured as continuous permeable reactive wall rather than as funnel and gate configurations. One reason for this apparent shift is the decrease in cost for reactive iron, which has decreased from approximately \$650/ton to \$300/ton. The benefits of continuous reactive walls included easier design and construction. Groundwater mounding is also lessened with a continuous reactive wall as opposed to the funnel and gate approach. Application of this technology has occurred for a wide variety of site conditions. Groundwater velocities, where this technology has been applied has ranged from 0.0003 ft/day to 2.8 ft/day.

The full-scale applications of this technology have also been helpful in identifying the critical aspects that are essential for success. Hydraulic performance of any reactive wall is essential for adequate system performance. Incomplete plume capture, less than required residence time and aquifer anisotropy are all facets that contribute to these systems not meeting the target goals.

## **4.0 DESIGN AND INSTALLATION OF CONTINUOUS REACTIVE WALL**

### **4.1 INTRODUCTION**

The zero valence iron technology has been developed and patented by researchers from the University of Waterloo, Waterloo Canada, (Gilliam and O'Hannesin). Envirometals Inc. (ETI) is the sole license holder of this technology. During the design phase of this study, Parsons ES retained ETI to provide consultation in the design. Parsons ES provided ETI with a license fee to utilize this technology. The patent involves the use of zero valence iron for groundwater treatment but does not extend to the method by which the reactive iron is contacted with groundwater. However, since attaining sufficient residence time between groundwater and reactive material is an important component for success, ETI was consulted and supported the decision of utilizing a permeable wall configuration.

The design of the zero valence iron reactive wall included a groundwater modeling study of the site prior to conducting the treatability study to determine whether a funnel and gate system or continuous reactive wall would be appropriate for the Ash Landfill site. Parsons ES performed the groundwater study for the site. Calculations of key design parameters including residence time and volume of reactive iron were done by ETI.

### **4.2 GROUNDWATER MODELING**

In-situ reactive treatment walls can achieve contaminant reductions through chemical and/or physical interactions between dissolved pollutants and reactive wall constituents [Vidic and Pohland (1996) and EPA (1995)]. For the treatment to be effective, groundwater must pass through the reactive wall and have a sufficient residence time in the reactive portion of the wall for reductive dechlorination to occur. This is typically accomplished by an efficient wall design configuration using either a funnel and gate configuration or a continuous reaction wall configuration. Groundwater modeling was utilized to evaluate these two in-situ treatment configurations.

The funnel and gate configuration involves diverting groundwater flow through areas where reactive material is placed. As the diverted groundwater migrates through the gate, the appropriate reaction occurs. A funnel and gate configuration has advantages over other configurations because the length of reaction can be controlled by the length of the gate. Maintaining saturated conditions in the zero valence iron during seasons when the groundwater

level is low is easier in a funnel and gate system. In addition, if change-out of the reactive material is required, only the material within the gate would need to be removed, rather than the entire wall. The disadvantage of the funnel and gate configuration includes an increased potential for groundwater mounding, leading to possible breakout of groundwater at the ground surface, and difficulties of construction.

Groundwater monitoring conducted during the RI identified large fluctuations in the elevation of the water table. During the spring, water levels in several wells were measured to be within six inches of the ground surface, whereas, during the late summer and fall, the water table drops by approximately six feet. This change in water levels has been observed over several years of monitoring and appears to be consistent and cyclical. The springtime water level elevations, combined with site soils of moderate to poor hydraulic transmissivity, raised concerns of groundwater mounding with a funnel and gate configuration for effective in-situ treatment of groundwater.

The results of the groundwater modeling confirmed that during high water conditions at the site, groundwater mounding could be sufficient for breakout of the plume to occur at the ground surface or groundwater to move around the confines of the funnel and gate section. This effect could be minimized to less than one foot if four gates, each approximately 40 feet wide, were utilized. However, under worst case conditions, modeling suggested that breakout of contaminated groundwater at the surface was possible. After investigating the design of each system further, a continuous reaction wall was selected for the treatability study for the following reasons:

- A funnel and gate system raises hydraulic concerns. High water table conditions, combined with the low hydraulic conductivity soils at the Ash Landfill, can lead to groundwater mounding. Although the modeling results concluded that the rise in the groundwater table for the funnel and four-gate configuration was within an acceptable margin (using permeable upgradient collection and downgradient discharge zones), use of a continuous reactive wall does not have similar mounding concerns.
- Generally, unsaturated conditions cause iron to oxidize. Based on the experience of ETI, iron within a reactive wall that is subjected to unsaturated conditions shows negligible oxidation and, therefore, does not appear to become ineffective when resaturation occurs. ETI has found little evidence of oxidation of the iron from core samples taken of iron in earlier reactive wall applications where the iron has been subjected to unsaturated conditions. Therefore, the change out of any oxidized iron due to exposure to unsaturated

conditions will be unlikely and the advantage of maintaining saturated conditions by using a funnel and gate system is no longer relevant.

- Design and installation of a continuous reactive wall is simpler and, based on site-specific conditions, may be more cost effective than that of a funnel and gate system.

#### **4.3 LOCATION AND LENGTH OF CONTINUOUS REACTIVE WALL**

The continuous reactive wall was installed near the toe of the plume which is approximately 350 feet downgradient of the source area and adjacent to the SEDA boundary. This location was selected because it would be within the secured boundary of the depot and the concentrations of the plume were thought to be consistent. At the proposed location of the reactive wall, the width of the plume was approximately 550 feet. Therefore, a design length of approximately 650 feet was chosen for the reactive wall, which would provide for a margin of safety along the edges of the plume.

#### **4.4 RESIDENCE TIME AND QUANTITY OF IRON**

ETI performed first order degradation modeling to determine the required residence time from influent groundwater concentrations and expected groundwater velocities in the vicinity of where the reactive wall was to be installed. This model is described in greater detail in **Appendix A**. The groundwater data were obtained from site data collected during the RI.

The reactive wall was designed based on a maximum residence time that was required to treat the concentration of chlorinated ethenes near the downgradient portion of the plume within the boundary of the depot. Prior to installation of the reactive iron wall, the only volatile organics detected in the monitoring wells at this location were TCE, cDCE, and VC. Table A-1 summarizes the maximum concentrations encountered in monitoring wells located near the continuous reactive wall.

ETI's modeling results showed that the concentrations of TCE and 1,2-DCE present near the reactive wall would be reduced to NYSDEC GA Standards if the water remained in contact with iron for 1.25 days. ETI included a safety factor into the residence time to provide enough residence time to reduce chlorinated ethenes with concentrations up to 1,000 µg/L to below NYSDEC GA Standards of 5 µg/L.

Based on the residence time of 1.25 days and a maximum velocity of the groundwater of 60.5 ft/year from the Groundwater Modeling Report at the Ash Landfill Site, (Parsons ES, 1996), the

quantity of iron necessary to treat the water was calculated to be 1,387 cubic feet. A safety factor of 2 was applied to this quantity for a total of 2,774 cubic feet of iron. This quantity of iron was to be mixed with sand having a similar grain size to make up the total volume of the excavated trench. The Technical Specifications required that the iron be evenly distributed over the volume of a 1-foot wide trench to ensure adequate contact between the water and the iron. According to ETI, a minimum of 20% by volume of the trench contents was required to be iron to ensure adequate contact of groundwater and iron. Based on the quantity of iron required for treatment and the dimensions of the reactive wall to be installed at the Ash Landfill, the trench fill material was designed to be comprised of at least 48% iron by volume. (See **Appendix A** for design calculations.)

#### 4.5 INSTALLATION OF THE CONTINUOUS REACTIVE WALL

The reactive wall was installed according to the Technical Specifications presented in the "Treatability Study Work Plan for Zero Valence Iron Continuous Reactive Wall at the Ash Landfill" (Parsons 1998). The notes and data collected during the installation of the reactive wall are included in **Appendix A**.

Materials testing on the reactive iron, sand, and iron/sand mixture were performed in the weeks preceding the actual installation. Reactive iron was purchased from Peerless Metal Powders and Abrasive of Detroit Michigan and shipped to the site in 3000-lb sacks. Mixing of material was performed on-site to avoid the added cost of shipping sand. A local supplier of clean sand was selected prior to the reactive barrier wall construction.

Construction of the continuous reactive wall began on Wednesday, December 9, 1998 and was completed on Monday, December 14, 1998. DeWind DeWatering, Inc. (DeWind) from Holland, Michigan was awarded the contract to construct the wall using a one-pass trenching machine to dig the trench and backfill the iron/sand mixture without an open trench. The trenching machine consisted of a cutting boom resembling a large chain saw and a sand/iron delivery system attached to the cutting boom. This delivery system stabilized the trench side walls during construction to allow placement of the permeable treatment media before the side walls could collapse. The trenching and delivery operation cut a 14-inch wide trench and continuously backfilled the trench with the sand/iron mixture.

Clean sand was supplied to the site and mixed in a cement mixer by a local supplier, DeWitt, Inc. To accommodate the practicality of construction the minimum trench width was 14-inches. To minimize the required volume and cost of reactive iron that would be required to fill this

excavation volume it was determined that a combination of clean sand and reactive iron in a 50/50 ratio, by volume, was sufficient to fill the excavated cavity and ensure that sufficient iron would be present. Since half of the trench would be iron, the equivalent reactive iron thickness was 7-inches, which provided a factor of safety of over 2 since the required iron thickness was determined to be 3-inches. Upon arrival of the clean sand on the site, reactive iron was added in sufficient volume, approximately 5 bags of reactive iron, to achieve a minimum ratio of 50/50 sand and iron, by volume. Mixing of sand and iron was performed for approximately 10 minutes. The mixture of sand and iron was then placed in a temporary stockpile area. Each batch of reactive iron and sand was tested in the field to ensure that the proper ratio of reactive iron and sand had been attained. The reactive iron and sand mixture was then supplied to the trench excavator in order to maintain continuous operation, as needed.

Oversight personnel from DeWind, Parsons ES, and EnviroMetal Technologies, Inc. (ETI) were at the site during the installation.

#### **4.5.1 Pre-construction Submittals**

Prior to the construction of the wall, DeWind arranged for chemical and geotechnical testing of representative samples of the sand fill material and topsoil as required by the Technical Specifications for the project. Both the sand fill material and topsoil were tested for constituents contained in the USEPA target analyte list (TAL) and the target compound list (TCL) to ensure that no additional contamination was added to the reactive wall. A sieve analysis was also performed on the sand.

The analytical results indicated that there were no TAL or TCL impacts in the sand and topsoil materials. The sieve analysis performed on the sand was the sieve analysis of fine and coarse aggregates as per ASTM C136. The sand material was determined to be a well graded, fine to medium grained sand (**Appendix A**).

A permeability test was run on a sample of iron/sand mixture. The results of the permeability test indicated that the sand/iron mixture had a hydraulic conductivity of  $7.4 \times 10^{-3}$  cm/sec, which was within the required limit specified as no less than  $1 \times 10^{-3}$  cm/sec.

#### **4.5.2 Mobilization**

Mobilization for the project began on Tuesday, December 8 1998, with the arrival of DeWind's trenching machine and other equipment. Parsons ES personnel staked the proposed centerline of



the continuous reactive wall and determined that the end of a 6-inch water line crossed the centerline of the wall. Subsequently, the centerline of the wall was moved west of the end of the water line to avoid intercepting the water line during trench installation.

Stationing for the wall began at West Smith Farm Road as Station 0 + 00 and proceeded north to Station 0 + 645. See **Figure 4-1** for a cross sectional view of the reactive wall.

Just prior to the installation of the trench, a drawing of the site was obtained from SEDA which indicated that a building had been located along the depot fence line, beginning approximately 100 feet north of West Smith Farm Road and extending approximately 475 feet north. Foundations were visible at the site. The drawing also indicated that a septic system with a leach field was located along the fence, near the northern end of the wall, beginning approximately 850 feet from the road. **Figure 4-2** shows the location of the building foundation, septic system, and reactive wall.

#### **4.5.3 Test Pits Along Proposed Centerline of Wall**

Prior to construction of the wall, seven test pits were excavated at 100-foot intervals along the proposed centerline of the wall to determine the depth to competent bedrock. The wall depth was measured as depth on grade to the top of bedrock between the test pit locations (where there was a known depth to bedrock) using a laser-guided depth control system. The following is the depth to competent bedrock:

Test Pit	Distance from West Smith Farm Road (feet)	Depth from Ground Surface to Competent Shale (feet)
1	0 + 00	7.5
2	0 + 100	10.9
3	0 + 200	11.2
4	0 + 300	9.0
5	0 + 425	8.1
6	0 + 525	7.0
7	0 + 640	6.5

Bedrock along the centerline of the wall varied from approximately 6 to 11 feet below the ground surface. To ensure that no groundwater flows beneath the wall, the wall was extended several inches into the top of competent bedrock.

Groundwater (less than one foot) was encountered in two test pits at 0 + 300 and 0 + 425. The sidewalls stayed open in all the pits.

Clay pipes and gravel material, which were part of a former leaching field (**Figure 4-2**), were encountered in the test pits at 0 + 425 to 0 + 640.

#### **4.5.4 Trenching**

The trenching machine was set up at the edge of West Smith Farm Road at Station 0 + 00. The depth to the top of the iron/sand mixture was measured and adjusted as necessary with a shovel so that the top of the permeable treatment media was one foot below ground surface. A geotextile was laid out over the top of the iron/sand mixture as the trenching machine proceeded to prevent the backfill from falling directly onto the treatment mixture.

At 100 feet and 175 feet, the trenching machine encountered foundation material. The trenching machine was stopped and the foundation material removed with an excavator. At 300 feet, the excavated material was saturated and began falling on top of the newly installed iron/sand mixture. DeWind removed the soil with the excavator before the geotextile was installed.

The wall was completed by the end of the day on December 11. The actual length of the installed wall at the bottom is 643.1 feet. However, the wall extended slightly beyond the 645-foot design length on the ground level to empty the hopper on the trencher of iron material. Approximately 23 cy of iron/sand mixture was left over for stockpiling. Because the overall wall depth was shallower than the 10-foot depth that was originally estimated in the design, construction was completed a day early.

On December 12, DeWind worked on the surface completion of the wall. At the end of the wall, the elevation of the iron/sand mixture within the wall was adjusted so that it was one foot from the ground surface. Installation of the geotextile was completed and the trench was backfilled. The upper one-foot of the trench was filled with 8 inches of excavated material and 4 inches of top soil. Two soil samples were collected from the excavated material and analyzed for VOCs before the material could be used as backfill. The lab results on the excavated material used to backfill the upper one-foot of the wall are presented in **Appendix A**. The area was graded after backfilling was completed. The surplus excavated material and iron/sand mixture were stockpiled near the Abandoned Incinerator Building. The piles were covered with plastic and anchored with palettes.

#### 4.5.5 Filling

The sand/iron mixture was placed from the top of competent bedrock to one foot below ground surface at a nominal width of approximately 14 inches. The volume of the iron/sand mixture actually placed in the reactive wall was measured to be 5,525 ft<sup>3</sup> (Table 2 of ETI Report in **Appendix D**) This volume was compared to the volume determined during the design based on the dimensions of the trench in order to verify that the trench was being filled completely and that there were no void spaces within the trench. ETI's construction report in **Appendix D** has more discussion about the installation of the zero-valent reactive wall.

Based on the average total depth of 8.8 feet below ground surface, a top depth of 1 foot below ground surface, and an average width of 1.1 feet, the total volume of the excavation was 5,577 ft<sup>3</sup>. This volume was close to the volume of material measured to have been placed in the trench. This suggests that no significant voids were left unfilled at depth and that the dimensions of the trench were as expected.

#### 4.5.6 Iron Ratio

The Technical Specifications for installation of the reactive wall required the following: (1) a minimum of 2,600 CF of iron filings be placed along the entire length of the wall; (2) the iron/sand mixture consist of about 48% by volume iron and the balance a local sand; and (3) the iron and sand be mixed prior to filling such that the iron was distributed uniformly.

A total of 28 cement trucks, each containing 11,500 pounds of sand arrived on site on Thursday and Friday, December 10 and 11. Based on a sand bulk density of 106 lb/ft<sup>3</sup> and an iron bulk density of 150 lb/ft<sup>3</sup>, each truck was loaded on site with five bags of iron filings to produce the required 48% ratio by volume. The iron and sand materials were mixed for 10 minutes then stockpiled on site for use later in the day. These data are also presented in **Appendix A**.

The volumetric ratio of iron to sand was verified by Parsons ES and ETI field engineers to be between 50% and 88%. To verify the ratio, a representative sample was collected from the iron/sand mixture after 10 minutes of mixing and the iron was separated from the sand using a hand-held magnet. The iron was separated two to three times with the magnet to remove most of the sand particles. The volume of the separated iron was determined and compared to the target volumetric percentage to determine if the correct ratio was achieved. In all the tests, the iron volume was greater than the sand volume. This occurred because some sand particles remained in the iron even after three separations and also because of the assumed bulk densities of the two

materials. The iron bulk density of 150 lb/ft<sup>3</sup> used in the calculation is the density of packed iron, however the loose bulk density can be as low as 110 to 125 lb/ft<sup>3</sup>. Therefore, because the amount of iron added was loose material, the volume would be greater.

#### **4.5.7 Moisture Content**

According to the Technical Specifications, samples of the sand fill material were collected and analyzed for moisture content to confirm that moisture content of the sand did not exceed 5 to 7%. If the sand had too high a moisture content, it could cause oxidation of the iron surface, potentially reducing its reactivity. The analysis was conducted by Paratt-Wolfe in Syracuse, NY.

The DeWitt batch plant routinely checked the moisture content on the first load of sand in the morning. It was agreed that if the moisture content was determined to be more than 7%, the batch plant would get drier sand from another source pile.

Two samples were required to be collected each day - one from the first load and one from a load at the end of the day. However, because the moisture content was measured at the batch plant on the first load of each day, one sample from the 10 loads delivered to the site on December 11 was sent for moisture content analysis. On December 12, two sand samples were sent because 20 loads of sand were delivered to the site. Sand was delivered to the site only on December 11 and December 12.

The moisture content of the first load of sand material delivered on December 11 was 3.8% as measured by DeWitt at their batch plant. A sample of sand material from Load #8 on December 11 was collected and analyzed by Paratt-Wolfe. The moisture content of this sample was 5.4%.

The moisture content of the first load of sand delivered on December 12 was 3.5% as measured by DeWitt. The batch plant at DeWitt recalculated the moisture content of the sand delivered at noon (Load #14), which was 3.7%. Samples of sand from Loads #12 and #20 on December 12 were collected and analyzed by Paratt-Wolfe for moisture content analysis. Moisture content for these loads were 4.5% and 4.9%, respectively. See **Appendix B** for moisture content measurement results.

## **4.6                   INSTALLATION OF MONITORING WELLS**

The monitoring plan described below was created based on input from ETI and protocols described in "Regulatory Guidance for Permeable Barriers Design to Remediate Chlorinated

Solvents”, ITRC, 1997. The ITRC guidelines outline the location and installation of the wells, the sampling frequency, and the sampling parameters.

As described in the ITRC guidelines, monitoring wells were installed upgradient, downgradient, and within the reactive wall to monitor the effectiveness of the performance of the reactive iron wall. Two monitoring wells were also installed at each endpoint of the wall to ensure plume capture. The purpose of monitoring upgradient monitoring wells was to determine the upgradient concentration of contaminants and groundwater flow rate. The purpose of collecting downgradient well data was to ensure treatment and determine groundwater flow rate. Data from monitoring wells within the wall was used to determine treatment, groundwater flow rate, and precipitate formation.

A total of 11 monitoring wells were installed between March 30, 1999 and April 1, 1999. Three clusters of monitoring wells were installed with each cluster consisting of three wells: (1) an upgradient well in the till/weathered shale aquifer (MW-T1, MW-T4, and MW-T7); (2) a well point within the reactive iron (MW-T2, MW-T5, and MW-T8); and (3) a downgradient well within the aquifer (MW-T3, MW-T6, and MW-T9). The upgradient and downgradient monitoring wells were located approximately 2.5 feet from the respective edge of the reactive wall. Within the reactive wall, monitoring wells MW-T2, MW-T5, and MW-T8 were located as close as possible to the downgradient reactive material/aquifer interface to provide chemical data that is representative of groundwater exiting through the downgradient side of the wall.

Two additional monitoring wells, MWT-10 and MWT-11, were located at each end of the reactive wall. MWT-11 was located at the centerline of West Smith Farm Road. MWT-10 was located at the northern endpoint and was partially installed within the iron/sand mixture.

The position selected for the clusters of monitoring wells were based upon the known distribution of pollutants within the plume. The first cluster of monitoring wells, MWT-1, MWT-2 and MWT-3, were installed approximately 190 feet from the northern end of the reactive wall. MWT-1 is located approximately 2.5 feet upgradient of the reactive wall. MWT-2 is located within the reactive barrier wall. MWT-3 is located approximately 2.5 feet downgradient of the reactive wall. These wells were positioned to monitor a zone of equivalent groundwater contamination between 10 and 100  $\mu\text{g/L}$ . The second cluster of monitoring wells, MWT-4, MWT-5 and MWT-6, were installed approximately 200 feet south of the first cluster. MWT-4 is located approximately 2.5 feet upgradient of the reactive wall. MWT-5 is located within the reactive barrier wall. MWT-6 is located approximately 2.5 feet downgradient of the reactive wall. These wells were positioned to monitor a zone of equivalent groundwater

contamination at approximately 100 µg/L. The third cluster of monitoring wells, MWT-7, MWT-8 and MWT-9, were installed approximately 200 feet south of the first cluster. These wells were positioned to monitor a zone of highest groundwater contamination, thought to be potentially 100 ug/L. Groundwater monitoring data showed this zone to be approximately 500 ug/L. Prior to collection of these data this zone was not known to exist. MWT-7 is located approximately 2.5 feet upgradient of the reactive wall. MWT-8 is located within the reactive barrier wall. MWT-9 is located approximately 2.5 feet downgradient of the reactive wall.

The monitoring wells and well points within the aquifer were constructed in accordance with the Generic Installation RI/FS Work Plan (Parsons ES, 1995) and the ITRC guidelines. As described in the ITRC guidelines, wells points were constructed within the reactive wall using the direct push method. The direct push method was used to minimize the amount of disturbance of the reactive iron media. At each of the three well points, a core was collected from the reactive media (See **Appendix B** for monitoring well logs).

#### **4.6.1 Procedure for Well Point Installation**

The design of the monitoring wells located within the reactive wall was outlined in the ITRC guidelines. These wells do not incorporate a sand pack or grouting, but are surrounded by the backfilled reactive media. The monitoring wells were constructed with a 1-inch diameter PVC casing.

Because the well points were installed within the reactive wall after its installation, a pipe locator was used to locate the upgradient and downgradient edges of the reactive wall. At the downgradient edge, the Parsons ES field engineer dug down approximately one foot and located the downgradient edge of the geotextile. The hydraulic push system, which was mounted on a small truck, was then positioned over each well point location and the well was advanced to refusal using the hydraulic push system. Well points were located within the reactive iron approximately three inches from the downgradient edge of the wall. Each well was comprised of a 1-inch diameter, five- or ten-foot, pre-packed stainless steel screened section with a polyvinyl chloride (PVC) riser. If necessary, after installation of the well, the void space around the PVC at the surface was backfilled with the iron/sand mixture to bring it to one foot below the ground surface.

#### **4.6.2 Procedure for Monitoring Well Installation**

The monitoring wells were installed in borings (4.25-inch hollow stem augers) drilled with a hollow stem auger rig. The borings were advanced to auger refusal, which for the purposes of this investigation defined the contact between weathered shale and competent shale. Monitoring wells were constructed of 2-inch I.D. Schedule 40 PVC with a wire-wrap well screen slot size of 0.010-inches. Wells were screened from 3 feet above the water table (if space allowed) to the top of competent bedrock. A sand pack was placed by tremie pipe in the annulus and extended a few feet above the well screen. A bentonite seal was placed on the sand pack. In some instances, the bentonite extended to the surface if there was no vertical space available for a cement/bentonite grout. A steel protective casing with a locking cap was installed at the surface and held in place with a 2-foot by 2-foot cement pad. The end of PVC riser was equipped with an expandable well cap. In the instances when bedrock was shallow in depth, i.e., less than 8 feet, modifications were made. The sand pack was extended to 1 foot above the well screen. Bentonite thickness was decreased to a minimum of 0.5 foot, but in most instances was at least 1 foot thick. Following well installation, the elevations of the well protective casing, PVC riser, and ground surface were surveyed.

#### **4.7 SLUG TESTING**

On May 8, 1999 rising head slug tests were conducted in monitoring wells MWT-1, -3, -4, -6, -7, -9, -10, and -11 to determine the hydraulic conductivity of the formation material immediately surrounding the trench. During the tests, Hermit 2000 and Hermit 3000 data loggers were used to record the rise in the water level in each well (**Appendix B**). Slug testing was not originally outlined in the work plan for this treatability study. However, it was decided to conduct these tests after installation of the reactive wall, in particular because of the unexpected subsurface disturbances (i.e., former building foundations and leach field) encountered during the wall installation. Slug tests were conducted in accordance with the Generic Installation Work plan.

## 5.0 QUARTERLY GROUNDWATER MONITORING

Following installation of the reactive barrier wall and the eleven monitoring wells, a year long monitoring program was conducted. Groundwater monitoring that was conducted as part of this treatability study was developed by Parsons using protocols described in "Regulatory Guidance for Permeable Barriers Design to Remediate Chlorinated Solvents"(ITRC, 1997) and, in addition, from input provided by ETI.

### 5.1 ANALYTICAL PARAMETERS AND MONITORING FREQUENCY

The monitoring program for the treatability study included measurements of both the groundwater elevations and chemistry in the wells on the site. The measurement of groundwater elevations was made in the eleven monitoring wells associated with the reactive wall and seven nearby monitoring wells. These measurements helped determine seasonal changes in groundwater flow, and possible damming of the aquifer behind the reactive wall due to reduction in the wall's permeability. These elevations were measured each month from April 1999 to February 2000.

In addition, groundwater chemistry data were collected during four groundwater sampling events at wells MW-T1 through MW-T11: 1) April 1999, 2) June 1999, 3) September 1999, and 4) January 2000. The list of analytes for which the groundwater samples were analyzed, including laboratory methods, frequency of sampling, quality control samples, and field measurements are shown in **Table 5-1**.

Groundwater analysis of VOCs provided information on the reduction of chlorinated compounds due to the presence of the reactive wall. The half lives of TCE and cDCE degradation were calculated by ETI using their software Scientist® for Windows® Ver 2.0 which uses a first order degradation model to predict the half life for certain compounds. To calculate the observed TCE and cDCE half lives, the model used residence times and influent and effluent concentrations measured in the field.

Analyses for chloride, ethene, ethane, and methane were used to assess the by-products of reductive dechlorination. The results of the ferrous iron, redox potential, hydrogen, pH, nitrate, sulfate, and phosphate analyses were used to monitor the extent of iron oxidation. Other indicator parameters were collected during these sampling events to gauge the amount of mineral precipitation occurring in the reactive wall.



## 5.2 SAMPLING PROCEDURES

Sampling the monitoring wells within the reactive wall required special consideration in order to obtain a representative sample that reflected the true conditions within the wall. Typical well purging methods and volume requirements were not used for these wells, since such methods would likely have drawn groundwater from different reactive zones within the reactive wall or even from areas outside of the reactive wall. Thus, groundwater samples were collected such that the volume of groundwater removed was at a rate that did not greatly influence the residence time within the reactive wall. A very low flow purge rate was used and a small volume of groundwater was purged to ensure that the groundwater sampled was from a discrete zone around the well within the reactive iron wall. Low flow purging procedures outlined in the Generic Installation RI/FS Work Plan were used to sample monitoring wells outside the reactive wall. However, for the wells within the reactive iron (MW-T2, -T5, and -T8), a very small diameter polyethylene tubing with a bottom check valve was used and the well was purged until either a) one well volume was removed, or b) field indicator parameters had stabilized, whichever occurred first. Samples were collected as described in the Generic Installation RI/FS Work Plan. When field indicator parameters had not stabilized prior to sample collection, purging of the well (using bailers or polyethylene tubing with bottom check valve) was continued until field indicator parameters had stabilized. Field indicator parameters were recorded to demonstrate that stabilization had occurred.

The order of sampling was as follows: (1) wells within the reactive wall, (2) downgradient wells, and (3) upgradient wells. Wells within the reactive wall were sampled first so that they were not affected by the removal of water from upgradient and downgradient wells.

## 6.0 BARRIER WALL DEMONSTRATION STUDY RESULTS and CONCLUSIONS

The use of zero valence iron as a means to remediate dissolved chlorinated ethene compounds, by reductive dechlorination, in groundwater has been successfully demonstrated under both laboratory conditions and also under field conditions, Gillham, et. al (1994), EPA (1995), and Vidic and Pohland (1996). From these applications, there is sufficient evidence to conclude that this technology is capable of destroying chlorinated ethenes. The treatment effectiveness is related to the application of the technology. Site-specific factors will therefore be significant for the successful application of this technology. The purpose of this study is to collect the data to document treatment effectiveness and identify those sit-specific factors that contributed to the treatment effectiveness. **Section 6.1** presents the groundwater analytical data that was collected to evaluate treatment effectiveness and the other data, such as hydraulic data, that are considered important factors in understanding the technology performance.

Regardless of the application, treatment effectiveness is the ratio of the influent concentration to the effluent concentration. In this instance, the influent concentration is the groundwater concentration entering from the upgradient side of the reactive wall and the effluent concentration is the groundwater concentration leaving the wall from the downgradient side of the reactive wall. Since the downgradient monitoring well is approximately 2.5 feet from the downgradient side of the wall and is affected by residual chlorinated ethene concentrations that were not subject to treatment, the groundwater concentration from within the reactive wall was considered a better representation of the effluent concentration. Residual concentrations from the downgradient side of the reactive wall are expected to decrease over time as treated water from the reactive wall mixes with the downgradient residual pore water.

Hydraulic performance is considered an important parameter to evaluate since treatment performance is closely related to residence time, which is a function of hydraulic behavior. Residence time is critical to ensuring that sufficient treatment has occurred. Residence time is defined as the ratio of the groundwater velocity through the wall to the thickness of the wall. However, because the reactive wall is 50% reactive iron, the equivalent reactive iron residence time is one-half the wall residence time; the equivalent reactive iron residence time is used as a basis of comparison to the design residence time in the following section. Since the reactive barrier wall is a passive system, the movement of groundwater through the wall is determined by the natural flow of groundwater. **Section 6.2** presents data to evaluate the hydraulic behavior of the reactive wall.

## 6.1 ANALYTICAL PERFORMANCE RESULTS and CONCLUSIONS

A goal of this demonstration study is to document the effectiveness of the reactive barrier wall in removing dissolved chlorinated compounds from the Ash Landfill Operable Unit groundwater plume. Analytical data was collected from eleven (11) monitoring wells in and around the reactive wall. These data were collected during four quarterly monitoring events for the purpose of assessing the removal effectiveness.

There are strong indications that the process of reductive dechlorination is occurring in the reactive wall. One indication is the measurement of the endproducts of the degradation process, such as methane, ethane, ethene, and chloride. The concentrations of these compounds were higher in wells in the reactive wall (MWT-2, MWT-5 and MWT-8) than in wells upgradient of the wall (MWT-1, MWT-4, and MWT-7). Additionally, the pH measured in wells upgradient of the wall compared to those obtained within the wall were also consistent with what would be expected from reductive dechlorination process. The pH values within the reactive wall, (MWT-2, MWT-5 and MWT-8), are consistently alkaline, ranging from 7.8 to 9.6 standard units. Further, redox potentials, measured as Eh, are also indicators that reductive conditions are occurring within the reactive wall. The redox potentials upgradient of the wall are positive values ranging between 48 mV to 257 mV. With the exception of the April 1999 sampling event, the redox potentials within the reactive wall are all negative values ranging from -69 mV to -404 mV. This increase in pH and decrease in redox potential are strong indicators that the reduction process is occurring within the wall. **Table 6-1** provides pH and Eh data to highlight this relationship. These data are also provided in **Appendix C**. **Figures 6-1, 6-2, 6-4, 6-5, 6-7, 6-8, 6-10, and 6-11** provide a site view of these data posted next to the locations from where the samples were obtained.

Dissolved hydrogen, a product of iron corrosion that is available for use in the dechlorination process, was also measured at high concentrations, both within the reactive wall and downgradient of the reactive wall. Hydrogen concentrations in monitoring wells downgradient from the iron wall, MWT-3, MWT-6, and MWT-9, ranged from 0.026 µg/L to 0.101 µg/L (**Figures 6-7 and 6-10**). These concentrations are higher than hydrogen concentrations at other part of the Ash Landfill, which range from 0.001 µg/L to 0.052 µg/L (**Table 6-5 and Table 6-6**).

Removal of the target compounds, TCE and c1,2-DCE, were used as the indication of treatment effectiveness. **Table 6-2** presents a summary of the groundwater analytical data collected for

TCE and c1,2-DCE from the four quarterly monitoring events. The northern transect includes monitoring wells MWT-1, MWT-2, and MWT-3, the middle transect includes monitoring wells MWT-4, MWT-5, and MWT-6, and the southern transect includes monitoring wells MWT-7, MWT-8, and MWT-9. Included in this table is an indication of the percent reduction of these two compounds. Percent reduction was calculated as the ratio of the concentration within the reactive wall to the upgradient concentration. Since the monitoring well installed within the reactive wall is not at the most downgradient edge of the wall (but still within the wall), the concentrations obtained from these wells are likely to be higher than the final effluent concentration since additional treatment will occur as the groundwater moves past the monitoring well within the wall. The downgradient concentration (from the well just outside the wall) was not used for this calculation due to the presence of residual contaminated groundwater that will require additional time to be flushed from the aquifer. **Figures 6-1 through 6-12** presents the concentrations of the target compound, TCE, c1,2-DCE, and the degradation endpoint analytes, ethene, ethane and methane. Other components, normally present in groundwater, such as chloride, sulfate, nitrate, phosphate, iron, calcium, pH, alkalinity and total dissolved solids are also presented in these figures. Each of the four monitoring events is provided in a series of three figures. For example, **Figure 6-1, Figure 6-2 and Figure 6-3** present the results from the first quarterly monitoring event performed in April 1999, approximately 4 months following installation of the reactive wall. **Figure 6-4, Figure 6-5 and Figure 6-6** present the results from the second quarterly monitoring event performed in June 1999. **Figure 6-7, Figure 6-8 and Figure 6-9** present the results from the third quarterly monitoring event performed in September 1999. **Figure 6-10, Figure 6-11 and Figure 6-12** present the results from the fourth quarterly monitoring event performed in January 2000. **Appendix C** provides a tabular compilation of the chemical data used to assess the effectiveness of the reactive wall.

Analytical results presented in **Table 6-2** indicate that the reactive wall is effectively reducing TCE. Removal efficiencies range from greater than 50% to greater than 99.8%. The average of these removal efficiencies calculates to greater than 75%. The actual average removal is likely higher than this since this average is affected by several removal efficiencies that are greater than 50% and greater than 66%. These removals are the result of low upgradient TCE concentrations and non-detectable concentrations within the wall. In many instances the TCE concentration within the reactive wall were non-detectable, therefore, the removal efficiencies can only be estimated as being greater than the detectable concentration limit. TCE concentrations in wells upgradient of the reactive wall range from 530 µg/L to 2 µg/L. TCE concentrations in wells

within the reactive wall ranged from non-detectable levels (less than 1 µg/L) to 3 µg/L. TCE was detected in the reactive wall at 1 µg/L only once out of the four quarterly rounds of sampling. In all instances the concentration of TCE within the wall were below the NYSDEC AWQS GA criteria of 5 µg/L. **Figures 6-1, 6-4, 6-7, and 6-10** provide the concentration obtained and the location of these data. TCE and c1,2-DCE concentrations upgradient, within, and downgradient of the reactive wall for each sampling event are shown in **Figure 6-13**; results for the two end wells, MWT-10 and MWT-11 are not shown.

Analytical results for c1,2-DCE concentrations indicate that overall removal efficiencies are similar to those obtained for TCE, however, concentrations of c1,2-DCE within the reactive wall are higher than those for TCE. Excluding the one instance when flow was reversed, i.e. no treatment, but including the two instances when the wall concentration was higher than the upgradient concentration, i.e. zero removal, the removal efficiencies ranged from 0% to 98.5%, with the average removal being 66.3%. The increase in c1,2-DCE within the wall is due to the production of c1,2-DCE as TCE is degraded in the wall, and in some instances the walls inability to further degrade the c1,2-DCE. The concentrations of c1,2-DCE in wells upgradient of the reactive wall range from 6 µg/L to 82 µg/L, whereas, concentrations of c1,2-DCE within the reactive wall ranged from non-detectable at 1 µg/L to 55 µg/L. The concentration of c1,2-DCE within the wall met the NYSDEC AWQS Class GA standard of 5 µg/L for 4 out of the 12 monitoring wells sampled during the four quarters of sampling.

The amount of reduction of c1,2-DCE varied during each sampling event and at each location along the reactive wall. For example, in September 1999, c1,2-DCE concentrations within the wall in the northern and middle transects met the GA standard, while in the southern transect the concentration of c1,2-DCE was just slightly above the standard of 5 µg/L, at a concentration of 7 µg/L (**Figure 6-13**). However, in January 2000, none of the c1,2-DCE concentrations in the wall met NYSDEC Class GA standards; from northern to the southern transect the c1,2-DCE concentrations were 23 µg/L, 7 µg/L, and 55 µg/L, respectively.

From a review of the data presented in **Table 6-1**, these variations in treatment performance appear related to iron residence time within the wall. During the April 1999 sampling event, the upgradient concentration of c1,2-DCE was 49 µg/L and the concentration of c1,2-DCE within the wall at the middle transect was 0.7 µg/L. This corresponds to a removal of 98.5%. The calculated equivalent reactive iron residence time for the middle transect during this event was 1.62 days. The design residence time (in contact with iron) was established at 1.25 days,

therefore, an iron residence time higher than 1.25 days should provide adequate treatment, which in this instance was true. The same relationship is true for the southern transect where the removal efficiency is greater than 95% and the iron residence time is 1.22 days. However, during this same event, the removal efficiencies for the northern transect were only 63% and the iron residence time was 0.36 days, which is below the residence time design requirement of 1.25 days. These data indicates that flow through the wall is variable and therefore treatment efficiencies, which are dependent upon sufficient residence time, will also vary.

During the June 1999 sampling event, the upgradient concentration of c1,2-DCE was 82 µg/L and the concentration of c1,2-DCE within the wall at the middle transect was 20 µg/L. This corresponds to a removal of 75.6%. The calculated iron residence time for the middle transect during this event was 2.03 days. Since the residence time was greater than 1.25 days, adequate treatment should have occurred and the concentration within the wall should be lower than 20 µg/L. It is possible that since the c1,2-DCE influent concentration of 82 µg/L was the highest measured from all of the monitoring events, it caused this slug of c1,2-DCE to surpass the trench capacity as expected from the design criteria. The relationship between percent reduction and residence time holds true for the northern transect where the removal efficiency is 81.3% and the iron residence time is 2.54 days. However, during this same event, the removal efficiencies for the southern transect were only 0% since the concentration within the wall was higher than the upgradient concentration.

During the September 1999 sampling event, the upgradient concentration of c1,2-DCE was 40 µg/L and the concentration of c1,2-DCE within the wall at the middle transect was 5 µg/L, corresponding to a removal of 87.5%. The calculated iron residence time for the middle transect during this event was 2.70 days. Since adequate treatment was attained and sufficient residence time was provided, the wall was operating as expected. However for the southern transect, the upgradient concentration of c1,2-DCE was 25 µg/L and the concentration of c1,2-DCE within the wall at the southern transect was 7 µg/L, corresponding to a removal of 72% with a iron residence time of 0.43 days.

During the January 2000 sampling event, the upgradient concentration of c1,2-DCE was 72 µg/L and the concentration of c1,2-DCE within the wall at the northern transect was 23 µg/L, corresponding to a removal of 68.1%. The calculated residence time for the northern transect during this event was 0.85 days. At this location adequate treatment was not attained and the iron residence time was less than desired. At the middle transect, the upgradient concentration of

c1,2-DCE was 58 µg/L and the concentration of c1,2-DCE within the wall at the middle transect was 7 µg/L, corresponding to a removal of 87.9% with an iron residence time was 1.62 days. Thus, the expected target concentration of 5 µg/L was not attained even though the iron residence time was greater than design iron residence time of 1.25 days. At the southern transect, the concentration within the wall was higher than the upgradient concentration, therefore, the percent removal was considered to be zero.

In summary, the analytical data indicates complete removal of TCE within the reactive wall. Although the removal of c1,2-DCE is observable, concentrations of c1,2DCE remain above the target level of 5 µg/L. Residence times less than the design goal of 1.25 days are the most likely reason for the higher than expected concentrations of c1,2-DCE within the reactive wall. The relationship between residence time and percent removal is a function of the hydraulic behavior of the reactive wall. The following section describes the hydraulic performance of the wall in more detail.

## 6.2 HYDRAULIC PERFORMANCE RESULTS and CONCLUSIONS

Variation in groundwater velocities throughout the length of the reactive wall is a likely reason for the variability of reductions observed during the demonstration study. These variations in groundwater velocities are thought to result from unexpected differences in the hydraulic conductivity of the glacial till/weathered shale, with possible influences from the buried remains of former on-site structures. Hydraulic conductivity in the glacial till/weathered shale were obtained from in-situ slug testing. Similar tests were performed during the RI on several monitoring well throughout the site. Slug testing in the immediate vicinity of the wall indicated that hydraulic conductivities of the aquifer materials were greater than that observed for the undisturbed till/weathered shale during the RI. **Table 6-3** presents the hydraulic conductivities and the associated groundwater velocities that were measured at the reactive wall transects. The slug test data and the analysis of the data are provided in **Appendix B**. Only the upgradient and downgradient monitoring wells were tested due to the effect that the small diameter size of the monitoring wells, within the reactive material, may have on the test. The hydraulic conductivity of the sand/zero valence iron within the trench was obtained from an ex-situ falling head permeability test. This test was conducted prior to installation of the reactive wall. The hydraulic conductivity of the reactive material was determined to be 21 feet/day.

Hydraulic conductivity is considered to be an important parameter to understand the movement of groundwater with a passive treatment scheme such as the reactive wall. Treatment effectiveness is directly related to the groundwater flow velocity and residence time of the groundwater within the reactive wall.

**Equation 6** was used to calculate the velocity of groundwater through the wall.

$$v = \frac{Ki}{n_e} \quad \text{[Equation 6]}$$

where:

$v$  = groundwater velocity (ft/day),

$K$  = ave. hydraulic conductivity, upgradient, within the wall and downgradient (ft/day),

$i$  = hydraulic gradient, change in water elevation over distance between upgradient and downgradient wells, ft/ft, and

$n_e$  = effective porosity, volume of voids over total volume of soil (assumed to be 0.15)  $\text{cm}^3/\text{cm}^3$ .

The results of slug tests performed in all monitoring wells upgradient and downgradient of the reactive wall (within 2.5 feet) indicate that hydraulic conductivity values ranged from 0.4 ft/day to 55 ft/day (**Table 6-3**). Many of these conductivities are considerably greater than the average hydraulic conductivity of the till/weathered shale aquifer, which was determined to be about 1 ft/day (range of 0.1 ft/day to 2 ft/day), based on data in the Remedial Investigation (RI) report (Parsons Engineering Science, 1994) (**Appendix B**). Hydraulic conductivities near the southern section of the wall were 4 ft/day and 7 ft/day in monitoring wells MWT-7 and MWT-9, respectively. Hydraulic conductivities are somewhat higher in downgradient wells in the western portion of the reactive wall (MWT-6 and MWT-9), compared to the upgradient wells (MWT-4 and MWT-7). This could be due to disturbances caused during the excavation of the foundation uncovered on the downgradient side of the wall or to an unusually thick layer of weathered shale. The thick layer of weathered shale is identified in the boring log for MW-29, which is located just upgradient of these locations (**Appendix B**). At the northern section of the iron wall, hydraulic conductivities are unusually high (34 ft/day at MWT-1 and 28 ft/day at MWT-3). This is likely to be due to gravel material at this location, the remains of an old leachfield (**Figure 4-2**).



Because the actual hydraulic conductivities measured in the immediate vicinity of the reactive wall were greater than those used to design the wall, it is likely that localized, high groundwater velocity zones exist near the trench. These high velocity zones have the potential to transmit groundwater through the trench at a rate that exceeds the design residence time. The variability of the hydraulic conductivity along the wall is evident from **Table 6-3**. In the northern portion of the wall, the hydraulic conductivities were 33.8 feet/day and 28.3 feet/day for MWT-1 and MWT-3, respectively. In the middle and southern portion of the reactive wall the hydraulic conductivities were 3.9 feet/day, 8.6 feet/day, 3.8 feet/day and 7.4 feet/day for MWT-4, MWT-6, MWT-7 and MWT-9, respectively. The hydraulic conductivity in MWT-10 was the highest measured at the site, at 55.1 feet/day. At the opposite, southern, end of the reactive wall the hydraulic conductivity was the lowest measured during the demonstration study at 0.39 feet/day. Compared to the hydraulic conductivities obtained during the RI, which ranged from 0.1 feet/day to 2 feet/day, there appears to be a significant difference in the hydraulic properties of the material in the vicinity of the reactive wall. At the southern portion of the wall, the thickness of the till thickens to approximately 12 feet. Monitoring wells MWT-7, MWT-8 and MWT-9 are located within this thick till zone. **Figure 4-1** provide a cross-section view of the till thickness along the reactive wall. The hydraulic conductivities, combined with the thickness of the till in this portion of the wall, appear to be providing a pathway for contaminant transport. This preferred pathway is observable from the plume maps **Figure 2-3**, **Figure 2-4** and **Figure 2-5**, which show a shift towards the southern portion of the reactive wall. This coincides with the area where the glacial till is known to be the thickest.

During the installation of the reactive wall a previously unknown leaching field was uncovered along the northern portion of the reactive wall, which is likely responsible for the high velocities observed in this region of the wall. The leach field appeared to be approximately 4 to 5 feet below the ground surface and consisted of a bed of gravel with drain pipe occasionally observed within the gravel. Following the installation of the wall, historical information was uncovered that identified the presence of a former building foundation in the middle and southern portion of the reactive wall. The building foundation may also have affected the subsurface during excavation of the building foundation. The approximate location of these items and their proximity to the reactive wall are presented on **Figure 4-2**. The increased conductivities would increase the velocity of the impacted groundwater through the wall, and subsequently shorten the residence time required to treat the chlorinated compounds.

At the northern transect of the wall, where the leaching field exists, groundwater elevation and effectiveness of treatment appear related. At times when the groundwater table was high, there was less effective treatment of c1,2-DCE, which may be due to the higher groundwater flow velocities through the former leaching field materials. However, when the water table drops, the impacted groundwater flows through material that is more representative of the natural till material, which has a lower conductivity, which results in an increase in the residence time. During April 1999 and January 2000, when the groundwater elevations were relatively high, effluent c1,2-DCE concentrations were 27 µg/L and 23 µg/L, respectively, but during June 1999 and September 1999 when groundwater elevations were lower, effluent c1,2-DCE concentrations were 6 µg/L and 0.6 µg/L, respectively. Thus, the changes observed in reduction of c1,2-DCE concentrations appear to be due to higher than expected velocities through the reactive wall during times of elevated groundwater when groundwater reaches the level of the leaching field, which is approximately 4 to 5 feet below the ground surface.

Variability in the velocity field around the treatment wall is the most likely cause for the inconsistencies observed in the performance of the treatment wall. These velocity variations are believed to be caused by the presence of man-made subsurface disturbances in the ground that were not known during the treatment wall design. These disturbances include a former building foundation along a portion of the wall (although the depth of the former foundation is not known) and a former leaching field near the northern extent of the wall.

An additional factor to be considered is the greater than expected influent concentrations that were observed in the upgradient monitoring well, MWT-7, of the southern transect. The concentration of TCE and c1,2-DCE were higher than the anticipated design concentration. The reactive wall was designed for maximum TCE and c1,2-DCE concentrations of 260 µg/L and 150 µg/L, respectively. These were the highest TCE and c1,2-DCE concentrations observed historically at the site in the area of the reactive wall. During the demonstration study, the influent TCE concentrations measured in upgradient wells at the northern and middle transects were below the design concentration, however, at the southern transect the influent concentrations were between 430 µg/L and 530 µg/L, which is at least twice as high as expected. Although the influent concentrations of c1,2-DCE ranged from 6 µg/L to 82 µg/L, which are less than the design maximum, the amount of c1,2-DCE produced during the reductive dechlorination of TCE is not accounted for. It is likely that because of the high concentrations of TCE entering the wall there is insufficient time to completely decompose all the TCE and the c1,2-DCE. The trend is consistent with the residence times calculated for the southern transect and the

concentration of c1,2-DCE in the well, MWT-8, located within the wall. For example, during the June 1999, the September 1999 and the January 2000 monitoring events the influent concentration of TCE at MWT-7 were 530 µg/L, 480 µg/L and 480 µg/L, respectively. The concentration of c1,2-DCE in the monitoring well, MWT-8, located within the reactive wall was 42 µg/L, 7 µg/L and 55 µg/L, respectively, which are all above the target concentration of 5 µg/L. The residence times for the southern transect for these three events were 0.66 days, 0.43 days and 0.42 days, which are less than the design residence time of 1.25 days. Therefore, the inability of the reactive wall to achieve the target concentrations is likely due to higher than expected groundwater velocities (caused by the higher hydraulic conductivities of the subsurface materials), which resulted in a less residence time than was expected, and, in addition, to influent concentrations that were higher than expected.

Results of groundwater analyses from wells installed just beyond the ends of the reactive wall indicate that the chlorinated solvents plume at the Ash Landfill site was captured by the reactive wall. TCE and c1,2-DCE concentrations in the wells installed to the north and south of the reactive wall (MWT-10 and MWT-11) were below NYSDEC Class GA standards in all four rounds of groundwater sampling. In most instances, the concentrations within these wells were below detection limits. The only exception was the c1,2-DCE concentration (6 µg/L) found in MWT-10 at the northern end of the wall in April 1999 (**Figures 6-1, 6-4, 6-7 and 6-10**).

The demonstration study assessed the possible decline in the performance of the reactive wall due to precipitation of minerals and eventual loss of porosity in the reactive material. While there is no direct evidence of porosity loss in the wall, there is some associated evidence (groundwater chemistry data) that suggest that mineral precipitation is occurring. The evidence is the alkalinity and calcium data that were measure in the upgradient wells relative to the concentrations measured in wells located within the wall. The concentration of alkalinity and calcium were lower in wells within the wall compared to the concentrations measured immediately upgradient of the wall in the 2<sup>nd</sup>, 3<sup>rd</sup>, and 4<sup>th</sup> rounds of sampling. The loss of alkalinity and calcium is an indication that some precipitation is occurring within the wall. As chlorinated compounds are reduced and iron is oxidized, the pH within the wall increases. At elevated pH levels, bicarbonate ions in solution convert to carbonate ions, which are less soluble. This leads to the precipitation of carbonate minerals, which may explain the decrease in calcium concentrations and alkalinity levels within the wall. The carbonate ions may precipitate as calcite (CaCO<sub>3</sub>) or siderite (FeCO<sub>3</sub>.)

In determining whether there would be a loss in porosity, due to precipitation, within the reactive wall over time, water level measurements were made on a monthly basis to observe the behavior of groundwater in and around the reactive wall. Although the monitoring period was short to observe such effects, if increases of hydraulic head were observed upgradient or within the reactive wall then there may be an indication that precipitation of insoluble carbonate salts could be fouling the wall by decreasing the porosity. Groundwater elevations were made on a monthly basis between April 1999 through February 2000 for the study duration and are presented in **Table 6-3**. The data, plotted in **Figures 6-14** through **Figure 6-23** did not indicate that significant mounding was occurring. In some months, water elevations in upgradient wells were actually lower than in wells within the wall. This is especially true for the north transect of the wall, where in the months of May, August, September, October, and December, the upgradient well (MWT-1) had either a lower or equal water elevation than MWT-2, the well within the reactive wall (**Figures 6-15, 6-18, 6-19, 6-20, and 6-21**).

In addition to the observations made in the field, an estimation was made of the maximum amount of carbonate that could form. For this estimation, it was assumed that groundwater would continue to flow through the reactive wall if its porosity was greater than 15%, which is the estimated effective porosity of the surrounding aquifer. The porosity of the iron/sand mixture in the reactive wall was estimated at approximately 40%. Results of theoretical calculations indicate that the maximum theoretical porosity loss due to carbonate precipitation is 3.5% per year (see Memorandum of March 2, 2000 in **Appendix D**). At this rate, it would take approximately 18 years to reduce the porosity within the reactive wall from 40% to 15%. If the porosity of the wall were to become less than that of the surrounding aquifer, then groundwater would tend to pass around the sides of the reactive wall.

In general, groundwater flows east to west, following the slope of the land. However, the monthly groundwater elevation monitoring suggests that beginning from approximately June 1999 to October 1999, the flow direction shifted to a southeasterly direction. This shift in direction is observable by a review of the groundwater elevation figures (**Figure 6-14** through **Figure 6-23**). This shift is evident in **Figure 6-17** for the month of July 1999. The movement of groundwater appears to move toward the south in this month. The presence of the permeable material within the reactive wall may be increasing this effect. For example, during the July 1999 groundwater elevation measurement, the difference in hydraulic head between the northernmost monitoring well, MWT-10, and the southernmost monitoring well, within the trench, MWT-8, is 3.14 feet, (629.67 – 629.53). The effect is also observable during the June

1999 groundwater elevation and groundwater sampling event, where the difference in hydraulic head between the northernmost monitoring well, MWT-10, and the southernmost monitoring well within the trench, MWT-8, is 2.26 feet (630.98 – 628.72). In some instances, this north-south movement coincides with concentrations that were above the target concentrations. During the June 1999 sampling event, the concentrations of c1,2-DCE in the middle and southern transect wells within the wall were above the target concentration of 5 µg/L. The north-south trend in groundwater movement is noticeable until December 1999, when the difference in hydraulic head between the wells in the trench suggest that the flow is more east-west than north-south.

During the December 1999 monitoring event, the elevation at MWT-10 is 631.71 and the elevation at MWT-2 is 631.73, which is approximately 190 feet away to the south. Therefore, since the difference is only 0.02 feet the movement is most likely to the west rather than along the north-south axis of the reactive wall. The east-west trend in groundwater movement is also consistent during the following month of January 2000, when there is little evidence of a north-south trend. However, the groundwater quality data collected during the January 2000 sampling event does not coincide with what was observed during the June 1999 sampling event when the groundwater movement shifted to a north-south trend. During the January 2000 sampling event, the concentrations of c1,2-DCE in the northern, middle and southern transect wells within the wall were all above the target concentration of 5 µg/L. This shift in groundwater flow direction, although present, does not provide a reason to explain the reactive wall performance data obtained from within the trench. If contaminated groundwater moves down the axis of the wall, as suggested by the groundwater elevation maps, groundwater retention times would be greater than if flow was directly through the wall, thus, such a path would afford more treatment time, since the travel path would be increased rather than decreased.

The movement of groundwater during the summer and fall months shifts unexpectedly to the south along the axis of the reactive wall. During the winter and spring months the shift is less noticeable and flow is as would be expected from the east to the west, following the slope of the land.

The groundwater velocities calculated in the immediate vicinity of the reactive wall are greater than expected. The greater velocities are attributed to higher hydraulic conductivities in the formation materials in which the trench was installed. The high conductivities are possibly due to the combined influences of a former building foundation near the central portion of the trench

and a former leaching field at the north end of the trench. Both of these former structures were not known at the time of the initial trench design.

### 6.3 COMMENTS ON GROUNDWATER SAMPLING AND WALL INSTALLATION WITH REGARD TO REACTIVE WALL PERFORMANCE

The comments provided below are intended to provide explanation for some of the inconsistencies noted in the performance of the reactive iron wall.

Throughout the study, TCE and c1,2-DCE concentrations were higher in wells located downgradient from the reactive wall than in wells located in the wall (**Figures 6-1, 6-4, 6-7, 6-10, and 6-13**). The reactive iron within the wall reduced the level of chlorinated solvents as evidenced by the decrease in chlorinated compound concentrations within the wall. However, chlorinated compound concentrations increased once the groundwater exited the reactive wall as observed in the downgradient well data. This observation is likely due to the presence of residual chlorinated compounds in the aquifer material downgradient of the reactive wall. Over time, as groundwater passes through the wall and enters the downgradient side of the aquifer, TCE and c1,2-DCE that are present within the pore water of the silt and clay particles in the aquifer at the toe of the plume will be reduced as the clean water mixes with the residual groundwater. Additional comments on this phenomenon are provided by ETI, the developer of the in-situ reactive iron wall technology (**Appendix D**).

Another possible cause for the observed inconsistent c1,2-DCE reduction in the reactive wall is that non-representative groundwater samples were collected from within the wall. Non-representative samples could have been collected if: 1) an excessive amount of water was removed from the wells within the reactive wall during purging and sample collection, or 2) if the wells within the reactive wall were not installed vertically.

Neither sampling or well installation methods are believed to have caused non-representative groundwater samples to be collected and the resulting treatment wall inconsistencies observed during the treatability study. First, to evaluate whether or not an excessive amount of water was removed from wells within the reactive wall during purging and sampling, two items were considered, a) the sampling methodology and b) the volume of water removed during each sampling event. Because the residence time of the groundwater in the wall is dependent on the distance it has flowed through the reactive wall, as well as the velocity within the wall, samples

within the reactive wall were collected in such a way as to minimize the amount of purge water and minimize the groundwater flow velocity to the well point. Samples were collected using a very small diameter polyethylene tubing with a bottom check valve. The well was purged until either: a) one well volume was removed, or b) field indicator parameters have stabilized, whichever occurred first. In all cases, one well volume was removed before field indicator parameters had stabilized.

In evaluating the volume of water removed during each sampling event, the amount of purge water and sampling water was calculated. The area around the well from which this water could potentially have been drawn (if drawn uniformly around the well radius) was calculated to determine how far upgradient of the well water may have been collected (**Table 6-4**). The potential distance upgradient that water may have been drawn was compared to the results during the four rounds of groundwater sampling. If a greater amount of water removed from the aquifer during the sampling event corresponded to less reduction of chlorinated compounds within the reactive wall, then it may be possible that water having inadequate residence time was collected from the trench, making the sample non-representative. However, no such relationship was observed. The amount of reduction of chlorinated compounds did not decrease when greater quantities of water were removed during sampling. In addition, if such a relationship existed, one would expect to observe elevated TCE levels within the reactive wall, having been drawn from upgradient. This was not observed.

In addition, samples collected from a monitoring well that is not installed vertically may not be characteristic of conditions within the wall, as noted by ETI in its Memorandum dated March 2, 2000 (**Appendix D**). Groundwater collected from improperly installed monitoring wells might not be representative of treated groundwater because it could have been collected from upgradient regions where it has not had sufficient contact time with the reactive iron. However, if this were the case, one would expect to find elevated levels of TCE within the samples collected from the reactive wall. Groundwater results do not support this explanation. Monitoring wells within the reactive wall were installed using the direct push method as outlined in **Section 4.2**. Since there was not much resistance in the iron/sand media, there is confidence that the monitoring wells within the reactive wall were installed vertically.

Even though extreme care was taken to collect representative groundwater samples during the treatability study, the relatively narrow width of the reactive wall did pose challenges in assuring that absolutely representative samples were collected from the wall. One way to reduce the

uncertainty in the representativeness of the wall samples is to conduct an additional round of groundwater sampling using diffusion samplers, which are a relatively new technology that has recently been demonstrated to be comparable to conventional purge sampling methods. The diffusion method involves the placement of semi-impermeable polyethylene bags filled with distilled water into the monitoring wells. Volatile organic compounds diffuse through the polyethylene, and after being in place for at least 11 days, the samplers equilibrate with the aquifer. This method eliminates the need to remove purge water prior to groundwater sampling. The advantages of diffusion sampling are the elimination of artificial turbidity and mixing of contaminated water with stagnant water caused by high speed sample collection, and the forcing of screened and stagnant water into the aquifer in all directions, including upgradient when a pump is inserted into a monitoring well. An independent evaluation of diffusion samplers is provided in **Appendix D**.

Proper installation methods are required to ensure the optimal performance of the reactive wall. Two aspects of the reactive wall installation that are important to its performance are: a) evenly distributed iron within the reactive wall and b) iron media that extends down to intercept the entire groundwater plume.

Based on the planning and execution during wall installation, we do not believe that improper installation of the reactive wall is a cause for the inconsistent performance observed in the treatability study. Additional information to support this is provided below.

Heterogeneity of the iron and sand mixture within the wall could potentially result in inconsistent performance. Uneven mixing of iron and sand prior to installation could potentially result in sections along the wall with less than adequate quantities of iron. Groundwater flowing through sections of the reactive wall with less than the required volumetric percentage of iron would not have sufficient residence time with the iron to adequately reduce the chlorinated compounds present.

Based on review of the installation records and the in-field testing that was performed on the iron and sand mixture prior to installation, the iron and sand reactive mixture was mixed in proper proportions and for an adequate amount of time to result in uniform mixing. Therefore, it is not believed that regions of low iron content exist along the reactive wall. As indicated in **Section 4**, the volumetric ratio of iron to sand was verified by Parsons ES and ETI field engineers to be between 50% to 88%, equal to or greater than the design ratio of 50%. In addition, samples were



collected from every mixed batch to verify the volumetric ratio of iron and sand. While field tests performed prior to installation showed that the desired ratio of iron and sand was installed in the reactive wall, analysis of core samples from the wall would be a method to confirm that the desired ratio of iron and sand actually exist.

Improper depth of the reactive wall could also result in failure of the reactive wall to capture the entire thickness of the groundwater plume. If the trench in which the iron/sand mixture was placed was not excavated to competent shale, then a portion of the groundwater plume could be flowing beneath the wall. Additionally, if groundwater monitoring points within the trench were screened beneath the iron/sand mixture, untreated groundwater would be collected. For reasons presented below, the depth of installation of the wall is not believed to contribute to its inconsistent performance.

During installation of the iron trench, test pits were dug every 100 feet to determine the depth to the top of the competent shale. Then, the continuous, laser-guided trencher excavated in a straight line between every 100-foot depth measurement, and while it is possible that a small localized dip in the top of competent shale existed between the two test pits, we believe this method was adequate to ensure that the iron and sand mixture was installed all the way to competent shale. Monitoring well point installation logs in the trench indicated that the points were installed to the top of competent shale, which was also the depth to which the reactive wall extended. Also, if the iron was not installed to the depth of the competent shale and untreated groundwater flowing beneath the iron was collected from well points within the wall, one would also expect to find TCE in these samples. However, no TCE was detected in any of the samples collected from within the reactive wall. For these reasons, it is not suspected that improper depth of installation of the wall is a significant cause for the inconsistent performance observed.

#### **6.4 RESULTS OF GROUNDWATER MONITORING AT THE ASH LANDFILL – OCTOBER 1999 AND JANUARY 2000**

During the demonstration study two additional complete rounds of groundwater sampling (October 1999 and January 2000) were also performed that included all existing monitoring wells in addition to the monitoring wells installed to monitor the reactive wall. Results of this additional groundwater sampling are presented in **Figure 2-4** and **Figure 2-5**. The data posted in these two figures are provided in tabular form in **Appendix E**. In general the groundwater plume appears to have remained in a similar configuration to that identified following the

completion of the Interim Remedial Measure (IRM) in June 1996 that thermally treated approximately 34,000 tons of VOC contaminated soil. The concentration of VOCs at MW44a, located within the former source area have remained similar to when the collected in June 1997. In June 1997, the concentration of total VOCs at MW44a was 930 µg/L. In October 1999, the concentration of total VOCs at MW44a was 1,104 µg/L and in January 2000, the concentration of total VOCs was 399 µg/l. A well useful in determining if the groundwater plume is migrating is MW-56, which is located approximately 250 feet beyond the depot boundary. In June 1997, the concentration of total VOCs was 1.6 µg/L. In October 1999, the concentration of total VOCs at MW-56 was non-detectable at 10 µg/L and in January 2000, the concentration of total VOCs was non-detectable at 1 µg/l. Therefore, it appears that the plume has remained as previously shown following the IRM.

The two additional complete rounds of groundwater sampling (October 1999 and January 2000) data were also used in **Section 7** for the following purposes:

- A synoptic round of groundwater conditions had not been obtained since the completion of the IRM. Reductions in groundwater concentrations in and around the former source area were essential for future remedial decisions.
- VOC results (**Appendix E**) were a requirement for future design efforts that could include additional reactive walls. **Section 7.4.2** discusses how residence times based of VOC results of the groundwater monitoring were used in the design of additional reactive walls.
- Indicator parameters and field measurements were collected to understand if natural biodegradation is occurring at the site. Field measurements are listed in **Table 6-5** and **Table 6-6**, for Round 1 (October 1999) and Round 2 (January 2000), respectively. These tables also list optimum conditions for indicator parameters that would be required for biological reductive dechlorination to be an active USEPA (1998).

The results of the two recent rounds of groundwater sampling were also compared to previous groundwater sampling conducted at the Ash Landfill. The following observations were made based on the recent monitoring results:

- There has not been an overall decrease in chlorinated ethene concentrations at the Ash Landfill from 1996 to 1999; only seasonal fluctuations confirming previous conclusions about the site that natural degradation of chlorinated ethenes occurs at a very slow rate.

- Indicators of biological degradation, such as increased concentrations of sulfide, methane or ferrous iron were observed in October 1999 and January 2000. There has been and no corresponding decrease in sulfate and nitrate/nitrite levels from September 1998 (**Appendix E**) to October 1999. This means that other biological activities such as sulfate reduction methane generation and denitrification continue to occur at slow rates.
- Low total organic carbon (TOC) concentrations were observed in September 1998 (**Appendix E**), October 1999, and January 2000. These concentrations were below 20 mg/L, which is the optimum level for biological reductive dechlorination as suggested by USEPA (1998).
- Oxidation-reduction potentials (ORP)s are variable throughout the aquifer. Near the former source area, they were mostly higher than 50 mV, which indicates that reductive dechlorination is not likely to occur according to USEPA (1998), however, at PT-18 in October 1999 ORP was well below this value indicating that reductive chlorination is possible. Farther away from the former source area (at PT-21A and MW-46) there is evidence that reductive dechlorination is possible, as indicated by oxidation-reduction potentials that are lower than 50 mV. Even at these areas, ORPs are still not below the optimum level of -100 mV.
- Hydrogen concentrations are lower in the source area than at other parts of the Ash Landfill. In MW-12A and MW-21A hydrogen concentrations were below detection limit in both rounds of groundwater sampling.

In summary, the conditions within the aquifer do not support natural biodegradation as a significant process in reducing the concentrations of chlorinated ethenes. The lack of a robust environment for natural degradation may be mostly due to a lack of a source of carbon. Addition of a carbon source at the Ash Landfill would possibly be an alternative to enhance biological activity especially at the source area where hydrogen has been detected only at low concentrations or not at all.

## 7.0 FEASIBILITY OF ALTERNATIVES FOR GROUNDWATER REMEDIATION

This section presents focused groundwater treatment alternatives for the Ash Landfill site that use in-situ zero valent iron as the treatment technology. These focused alternatives (or sub-alternatives) are part of Alternative 3a - In-situ Treatment with Zero Valent Iron, which was developed in the Feasibility Study (Parsons ES, 1996). This section also discusses the procedures used for the conceptual design of the proposed zero valent iron wall(s) as well as costs associated with the alternatives. The conceptual design is based on the results of the Treatability Study for the reactive iron wall, and the groundwater flow and transport modeling of different treatment wall configurations, both of which are summarized below.

### 7.1 CONCLUSIONS OF TREATABILITY STUDY

As previously discussed in detail in **Section 6**, the treatability study results demonstrated that the zero valent iron treatment wall at the depot boundary was effective since chlorinated compounds in the reactive wall were reduced. Concentrations of TCE within the wall were degraded to below detection limits and cDCE levels generally decreased. The TCE half-life estimated from the field data, in general, confirmed the design TCE half-life. By-products of reductive dechlorination (i.e., methane, ethane, ethene, and chloride) were also formed. In addition, the chemical data documented that corrosion of iron was taking place as evidenced by the increased pH and decreased redox potential within the reactive wall, and the generation of hydrogen. The treatment wall was effective in capturing the chlorinated ethenes plume as indicated by negligible amounts of TCE and cDCE in wells installed just beyond the ends of the reactive wall. The design life of the existing boundary wall is estimated to be 18 years. During the treatability study, no significant loss in porosity and negligible damming effects were observed within the reactive wall.

Results of the treatability study also indicated that complex hydraulics exist at the existing boundary wall. Groundwater flow through the wall was not uniform, and was greater than expected due to unexpectedly high formation hydraulic conductivities. Half-lives of cDCE that were estimated based on field data were not consistent. Influent concentrations of TCE and cDCE were higher than expected at one part of the wall, although the wall was designed to treat groundwater with these higher concentrations. Therefore, while the overall treatability results proved to be successful, there was some field evidence (e.g., complex hydraulics and

inconsistent half-life for cDCE) that must be considered in the selection of the final design parameters (Section 7.4).

## 7.2 CONCLUSIONS OF GROUNDWATER MODELING TO ASSESS IRON WALL CONFIGURATIONS

Groundwater flow and solute transport modeling was used to evaluate four designs of additional continuous, zero-valent (reactive) iron walls at the Ash Landfill, and to assess the potential impact of the plume on the downgradient Farm House wells. A summary of the modeling results is presented below. The modeling report is provided in **Appendix E**.

The wall designs (scenarios) evaluated in the modeling, all of which supplement the existing iron (boundary) wall that was installed on the site in 1998, were as follows:

1. Scenario 1 – One additional cut-off wall (located at the middle of the plume) installed perpendicular to the direction of groundwater flow;
2. Scenario 2 – Two additional cut-off walls (located at the middle and at the source) installed perpendicular to the direction of groundwater flow;
3. Scenario 3 – V-wall and parallel wall configuration; and
4. Scenario 4 – Multiple parallel walls and single cut-off wall.

Figure 2 of **Appendix E** shows the layout of the walls for each scenario.

The results of the wall design modeling showed that Scenario 2 (three cut-off walls) segmented the total chlorinated ethenes plume and minimized the travel distances needed before it was treated in the walls compared to the other scenarios. The Scenario 2 wall configuration indicated that the plume would be remediated in approximately 15 years (**Appendix E**). Matrix-controlled diffusion was identified as an important factor in evaluating the effectiveness of the scenarios and clean-up times for the plume. Long-term diffusion of chemicals (e.g., TCE, cDCE, and VC) from the aquifer matrix was considered to be a significant factor at the site due to the presence of the till aquifer, which has a relatively high silt and clay content. Therefore, the transport model accounted for multiple flushes of pore water that would be ultimately needed to remove the dissolved chemicals sorbed to the solid phase. Scenario 2 also considered the beneficial affects of the addition of hydrogen (as an electron donor) to the aquifer from chemical reactions in the

iron walls, which would increase the rate of microbial degradation of chlorinated hydrocarbons in the zones between the treatment walls.

The results of the simulation to evaluate the potential for the plume to impact the wells at the Farmhouse showed that a slug of the plume continued to move beyond the boundary reactive iron wall, however, the concentrations within the slug were degraded as they moved farther downgradient of the wall. The simulation showed that a maximum concentration of approximately 0.2 µg/L (total chlorinated ethenes) would reach a point approximately one-half way between the depot boundary and the Farmhouse in approximately 25 years. At the Farmhouse, the results indicated that the maximum concentration would be approximately two orders of magnitude less than this (~0.008 µg/L) in about 40 years (**Appendix E**).

### **7.3 SUMMARY OF FOCUSED GROUNDWATER TREATMENT ALTERNATIVES AT THE ASH LANDFILL**

The focused groundwater treatment alternatives for the Ash Landfill were developed based on results of the treatability study (**Section 7.1**) and the groundwater modeling (**Section 7.2**). These alternatives, which fall under Alternative 3a in the FS, address the impacts upgradient of the boundary reactive wall as well as the impacts downgradient of the boundary wall. These alternatives are summarized in **Table 7-1**.

**Alternative 1:** One reactive wall (compliance wall) downgradient of the existing boundary wall and natural attenuation of aquifer upgradient of boundary reactive wall. [This is a base case that assumes a non-aggressive approach to remediate portions of the plume upgradient of the existing boundary iron wall].

**Alternative 2:** One reactive wall (compliance wall) downgradient of existing boundary wall and two reactive walls (source wall and middle wall) upgradient of the boundary wall. Carbon addition upgradient of the source wall. [This is an aggressive approach that uses results of the modeling (Scenario 2) to design the most effective reactive iron wall configuration to remediate the plume].

## 7.4 DESIGN OF CONTINUOUS REACTIVE WALLS

For the design of the reactive walls that are part of Alternatives 1 and 2, the following procedure was used:

1. Determine the residence time - Recommended residence time is determined for the wall based on degradation half-life and concentration of influent chlorinated ethenes at the proposed location of the wall using ETI's software Scientist® for Windows® Ver. 2.0. Recommended residence time is the time chlorinated ethenes have to spend in a treatment zone made up of 100% iron until their concentrations reduce to within acceptable levels (5 µg/L for TCE and cDCE and 2 µg/L for VC).
2. Calculate treatment wall thickness - Using the recommended residence time and the maximum expected groundwater velocity, the recommended thickness of the wall is calculated using the following equation:

$$h = SF \times v_{\max} \times t_{\text{rec}} \times \frac{1 \text{ day}}{24 \text{ hour}} \quad [\text{Equation 7}]$$

where

$h$  = recommended wall thickness, ft

$SF$  = safety factor,  $SF = 2$

$t_{\text{rec}}$  = recommended residence time, hours

3. Determine length of wall - Length of the wall is determined based on the dimensions of the plume at the proposed location of the wall.
4. Determine design life - Design life is determined based on the rate of precipitation of minerals and consumption of iron. Time to treat the majority of the plume is determined based on the groundwater modeling study. Determination of design life of the wall and treatment time of groundwater are important in the evaluation of operation and maintenance cost of a proposed reactive wall.

In order to follow the above design procedure, the following design parameters of groundwater treatment systems have to be accurately determined:

1. Half-life of chlorinated ethenes,
2. Concentrations of influent chlorinated ethenes and residence time,
3. Groundwater velocity,
4. Length of wall,
5. Design life (based on rate of precipitation of minerals and consumption of iron), and
6. Time to treat the chlorinated ethenes plume.

#### **7.4.1 Half-life of Chlorinated Ethenes**

For the design of additional reactive walls, TCE was assigned a degradation half-life of three hours, and cDCE and VC both were assigned degradation half-lives of six hours. These are the empirical values developed by ETI. The TCE half-life of three hours was supported by field data gathered during the Treatability Study at the Ash Landfill. However, cDCE half-life values calculated based on field data were varied (4 hours to 42 hours), and the higher values were not considered to be representative, possibly due to inconsistencies in the hydraulic conductivities and groundwater flow near the wall. The six-hour half-life for cDCE degradation was estimated by ETI. This estimate is based on several bench scale column tests involving reaction of chlorinated ethenes with 100% zero valent iron; the maximum value of their column test, 2.4 hours, multiplied by a safety factor of 2.5, is 6 hours (See memorandum of March 20, 2000 and memorandum of March 24, 2000 in **Appendix D**). There was no bench scale column test conducted specifically for the Ash Landfill site. However, a bench scale test was conducted for a former industrial facility located in upstate New York. This site had characteristics and chemical constituents similar to that of the Ash Landfill. Results of this test indicated that the half-life of cDCE is 1.5 to 4 hours. cDCE half-lives estimated based on field residence times and VOC concentrations at the industrial site ranged from 3 to 5 hours (Vogan et al. 1999). Therefore, the 6-hour half-life for cDCE was considered to be a reasonable estimate (**Appendix D**.)

#### **7.4.2 Concentrations of Influent Chlorinated Ethenes and Residence Time**

For the determination of residence times necessary to reduce TCE and cDCE to below concentrations of 5 µg/L, and to reduce VC to concentration below 2 µg/L, the concentrations of influent contaminants had to be determined first. ETI provided the degradation data for these influent concentrations. After plotting degradation data (**Appendix F**), maximum residence times were selected for each system. **Table F-1** includes these maximum residence times. The



reasoning to support the representative of influent concentrations selected for each proposed reactive wall is discussed below.

**Middle wall:** To calculate the recommended residence time in the proposed middle wall (**Figure 7-2**), it was conservatively assumed that the maximum influent concentration would be similar to the concentration measured in MWT-7 (TCE - 530 µg/L, cDCE - 32 µg/L, and VC - 15.5 µg/L), which is about 500 ft away from the proposed location of the wall. The reason these influent concentrations were chosen is because concentrations in wells at the proposed location of this reactive wall (PT-22 and PT-20) are much lower than those measured in a downgradient location (MWT-7). For example, in PT-22 TCE and cDCE concentrations are 74 µg/L and 88 µg/L, respectively and in PT-20 TCE and cDCE concentrations are 36 µg/L and 28 µg/L, respectively. Thus, use of the higher concentrations ensures that the wall will accommodate higher than anticipated influent concentrations. Using the MWT-7 data, the recommended residence time used for the design of the source wall was 33 hours.

**Source wall:** To calculate the recommended residence time in the proposed source wall (**Figure 7-2**), it was assumed that the maximum influent concentration at this location would be as high as the concentration at the source of the plume. The three monitoring wells that are close to the source are PT-12A, MW-44A and PT-18A. Based on ETI's degradation model, it takes the most time to degrade chlorinated ethenes in PT-18A, 59 hours. Therefore, influent concentrations at PT-18A (TCE - 9,100 µg/L, cDCE - 1,100 µg/L, and VC - 270 µg/L) were used for the design of this wall. Using the PT-18A data, the recommended residence time used for the design of the source wall was 59 hours.

**Compliance wall:** The compliance wall (see either **Figure 7-1** or **Figure 7-2**) has to be designed based on maximum chlorinated ethene concentrations that are expected to exit the boundary reactive wall, and considering the fact that, over time, TCE and cDCE downgradient of the boundary wall will eventually migrate to the compliance wall. The maximum effluent cDCE concentration measured throughout the Treatability Study was of 55 µg/L, at MWT-8 in January 2000. (There was no TCE and VC at concentrations above detection limit in monitoring wells within the wall throughout the Treatability Study.) For the determination of required residence time, 55 µg/L was assumed to be the influent cDCE concentration. TCE and VC concentrations in groundwater flowing into the new wall are assumed to be below the detection limit since they were not detected in the effluent of the reactive wall in any of the four rounds of sampling. The residence time using the influent cDCE concentration of 55 µg/L is 21 hours. The wall is

designed with a factor of safety of 2, and therefore it has a maximum residence time of  $2 \times 21$  hours, which is 42 hours. This time is enough to treat even TCE and cDCE downgradient of the boundary wall. The highest chlorinated ethenes concentrations downgradient (TCE -  $52 \mu\text{g/L}$ , Cdce -  $150 \mu\text{g/L}$ , and VC -  $4 \mu\text{g/L}$ ) were measured in MWT-9 in June 1999. The time to treat these concentrations to within acceptable levels is 31 hours which is less than the maximum capacity of the wall.

#### **7.4.3 Groundwater Velocity**

For the design of the existing boundary wall, the expected groundwater velocity was estimated using the average of hydraulic conductivities measured at the Ash Landfill 1.03 ft/day (Parsons, 1994). For the design of additional reactive walls upgradient of the boundary wall (middle wall and source wall) a more conservative approach was used. For these walls the maximum expected velocity was calculated using the maximum hydraulic conductivity measured at the Ash Landfill, 2.21 ft/day (Parsons, 1994). For the design of the compliance wall, the highest groundwater velocity that was measured along the reactive wall in the Treatability Study, excluding the velocities measured at the former leachfield, was used. The maximum expected velocities that were used for the design of the three proposed reactive walls are shown in **Table G-1**.

Prior to installation of middle and source reactive walls, two monitoring wells will be installed in the area immediately upgradient of each of the proposed walls. At the compliance wall three wells be installed. Results of slug tests at these wells and other nearby monitoring wells will be used to confirm the hydraulic conductivity of the aquifer in the proposed wall locations and, if necessary, these data will be used to make final revisions to the design (such as thickness of wall, or location of wall).

#### **7.4.4 Length of Proposed Reactive Walls**

The length of the boundary reactive wall was determined so that it would extend 100 ft beyond the  $100 \mu\text{g/L}$  total chlorinated ethene contour line. Results of the treatability study at the Ash Landfill indicated that the plume was captured to its full extent. Therefore, for the lengths of the proposed reactive walls, a 100 ft clearance beyond the  $100 \mu\text{g/L}$  total chlorinated ethene contour line was used to determine the total length of the wall. **Table G-3** has the dimensions of the proposed reactive walls.

#### **7.4.5 Design Life (based on rate of precipitation of minerals and consumption of iron)**

The design life of the reactive walls is affected by porosity loss and iron consumption. The former affects the ability of the wall to transmit impacted groundwater, and the latter affects the ability of the wall to chemically treat the chlorinated organics dissolved in groundwater.

The design life of the existing boundary wall, 18 years, was calculated based on maximum porosity loss estimation (**Section 6.1**). For the additional reactive walls the same design life was assumed. This is a conservative assumption due to the fact that:

- Porosity loss is highly dependent on calcium content of groundwater and groundwater velocity. Since the amount of calcium reduction in the proposed walls is not known, it was assumed that the reduction in calcium in the proposed walls will be the same as the maximum reduction in calcium in the boundary reactive wall, 144.5 mg/L.
- A portion of the existing boundary reactive wall was placed in a highly conductive area of the site (influence from former leaching field) and, it is assumed that the conductivity of the area where the proposed walls are to be installed will be lower. Therefore, the amount of mineral precipitation would be lower in these walls, which would result in an extended design life.

Consumption of iron is another mechanism affecting the ability of the reactive wall to degrade chlorinated ethenes. However, design life of the wall was not significantly affected by consumption of iron. Consumption of iron can be due to corrosion in an aqueous system, VOC degradation, or aerobic reaction with dissolved oxygen. Iron consumption was evaluated for all of the proposed walls by ETI (memorandum of April 20, 2000, in **Appendix D**) and the results show that iron is consumed after 642 years, 695 years, and 756 years for the proposed source wall, middle wall and compliance wall, respectively. At this rate, after 18 years only 3 % of the iron is used up in the source wall and the middle wall, and only 2 % of the iron is used up in the compliance wall. Therefore, consumption of iron has only a minor influence on the design life of the reactive walls.

Since porosity loss controls the design life of the reactive wall, agitation of the iron in the wall, which combat porosity loss through mineral precipitation, will be performed every 10 years to maintain consistent performance. This method is recommended by ETI (memorandum of April 20, 2000 in **Appendix D**).

#### **7.4.6 Time to Treat the Chlorinated Ethenes Plume**

One of the goals of the conceptual design is to develop an alternative that will remediate the plume of dissolved chlorinated ethenes at the site in less than 30 years. This goal is based on previous comments by EPA, which indicated a preference that the selected alternative meet this goal.

#### **7.4.7 Application of Vegetable Oil to Enhance Biodegradation of Chlorinated Ethenes**

Natural attenuation was evaluated at the Ash Landfill as part of the Feasibility Study. Due to long treatment times, it was not chosen to be the preferred remedial alternative. One reason for this long treatment time is that the aquifer lacks a source of carbon that fosters anaerobic biological reactions. Carbon sources (anthropogenic or natural organic matter) are necessary, because they release hydrogen as they degrade. In turn, hydrogen is consumed by microorganisms that use nitrate, Fe(III), sulfate, or CO<sub>2</sub> as terminal electron acceptors. Chlorinated ethenes can also function as electron acceptors, in reductive dechlorination, and they compete with the terminal electron accepting processes noted above. Therefore, it is necessary for hydrogen to be present at sites contaminated by chlorinated ethenes for biodegradation to take place. At sites where carbon sources are low, the following can be done to enhance biodegradation:

- A hydrogen releasing compound (HRC) can be applied. At the Ash Landfill, an HRC can be the zero valent iron reactive wall. Corrosion of iron in the reactive walls can generate hydrogen.
- A carbon source such as vegetable oil can be added to the aquifer.

The use of vegetable oil to enhance degradation of chlorinated ethenes has recently proven to be effective. The application of vegetable oil was recently tested at DDHU, an army installation at Ogden, UT (Parsons, 2000). The groundwater at the DDHU site was impacted mostly by dissolved TCE. Vegetable oil was added to the aquifer and the groundwater was monitored over a 63-day period. Some of the pertinent results from the pilot test conducted by Parsons are as follows:

- At the injection well TCE concentration decreased from 624 µg/L to 4 µg/L in 22 days.

- Downgradient from the injection well, TCE concentrations have generally decreased and cDCE and VC concentrations increased proving that reductive dechlorination was taking place.
- The reaction zone (zone where vegetable oil is present) radius of influence was 7 feet after 22 days, and influences from the reaction zone were apparent at least 10 ft downgradient from the injection point.
- The amount of vegetable oil required for a 10-ft diameter radius of influence in the aquifer would be sufficient for a relatively long period of time, approximately 50 years.

## 7.5 FOCUSED GROUNDWATER REMEDIATION ALTERNATIVES

Below are two groundwater remediation alternatives for the Ash Landfill Site. The first (Alternative 1) is a base case that includes a less aggressive approach that focuses on preventing off-site migration of the plume of chlorinated ethenes, and the second (Alternative 2), which also prevents off-site migration, provides an aggressive approach to address upgradient areas of the dissolved chlorinated ethene plume.

### 7.5.1 Alternative 1: One Reactive Wall Downgradient of Existing Boundary Wall and Natural Attenuation of Plume Upgradient of Boundary Wall

Alternative 1 uses a total of two reactive walls and it serves as a base alternative (**Table 7-1**). This alternative uses the existing reactive wall at the depot boundary and a second wall to be installed downgradient of the boundary wall. The second wall provides further support in degrading the plume and, through the implementation of a monitoring program, ensures that no VOC's will impact the downgradient wells at the Farmhouse. In detail, the alternative involves the following:

- Use of the existing boundary reactive iron wall (50% iron).
- Installation of a compliance continuous reactive wall made up of 100% iron on the west side of the railroad line, about 100 ft downgradient from the existing boundary wall (**Figure 7-1**). The wall would be 645 ft long, 8 ft deep, and 2.1ft thick.
- Installation of seven monitoring wells (MW-61, MW-62, MW-63, MW-64, MW-65, MW-66, and MWT-12) to determine exact location of compliance wall and to monitor groundwater beyond the SEDA boundary (**Figure 7-1**). Results of slug tests and VOCs

analyses in selected monitoring wells near the proposed location of compliance wall will be used in the selection of final location for the compliance wall (**Table 7-2**).

- In the first year, groundwater in wells around the compliance wall and in the compliance wall (total of five) will be sampled twice and analyzed for VOC's in order to document that wall is working properly (**Table 7-2**.)
- Every year, eight wells near the compliance wall and in off-site locations will be sampled and tested for VOC's. The purpose of this monitoring is to monitor the performance of the compliance wall and the possible off-site migration of the chlorinated ethenes plume. The off-site sampling includes the sentry well, trigger well, and compliance well. The sentry well is MW-56, and its purpose is as a warning signal that will indicate the movement of the plume. The trigger well, MW-65, will be located halfway between the Farmhouse wells and MW-56, the sentry well. The trigger well is a location where, if concentrations of chemicals of interest are exceeded, immediate action will be taken to protect the source of water at the Farmhouse (e.g., connection to the town water line and/or supply of drinking water). The compliance well, MW-66, will be located on the Farmhouse property and this location defines the point at which the concentrations of constituents in groundwater must meet the New York GA Standards (**Table 7-2**).
- Every year groundwater elevations throughout the entire site will be measured (a total of 67). These measurements will indicate groundwater flow directions on the site and any mounding of groundwater near the walls (**Table 7-2**).
- Every five years, 60 selected wells at the Ash Landfill will be sampled and tested for VOC's to document the changes in plume concentrations and extent of the plume. For wells in and around the two reactive walls, groundwater will also be analyzed for inorganic parameters such as sulfate, alkalinity, nitrate, total dissolved solids, phosphate, chloride, calcium, magnesium, potassium, sodium, iron, manganese, and pH as well as methane, ethane and ethene. Wells in the reactive walls will also be analyzed for hydrogen. The inorganic parameters will be used to assess performance of the reactive walls and to assess the degree of fouling of the iron (**Table 7-2**).
- Maintenance of the boundary and compliance walls will involve agitation of the iron/aquifer interface with overlapping 1-foot augers. This agitation would be done once every 10 years.

According to results obtained from the groundwater and solute transport modeling, it is estimated that it would take approximately 60 years to remediate the plume of chlorinated organics dissolved in the groundwater at the Ash Landfill site. Under this alternative, the existing boundary reactive iron wall and the compliance reactive wall would, through in-situ

treatment, prevent further downgradient migration of the plume. Upgradient portions of the plume would be treated mostly by natural attenuation, however, these portions of the plume are expected to eventually reach the boundary iron wall where they will be treated.

### **7.5.2 Alternative 2: One Reactive Wall Downgradient of Boundary Wall and Two Reactive Walls Upgradient of the Boundary Wall with Carbon Addition**

Alternative 2 uses a total of four reactive walls (**Table 7-1**). This groundwater treatment alternative involves the following:

- Use of the existing boundary reactive iron wall (50% iron).
- Installation of a middle reactive wall and source reactive wall, both made up of 100 % iron, upgradient of the existing boundary wall. The middle wall, would be installed about 300 feet east of the boundary wall and it would have a thickness of 1.2 ft, a depth of 9 ft, and a length of 700 ft. The source wall would be installed closer to the former source area of the plume, 600 feet east of the boundary wall. This wall would be 2.1 ft thick, about 11 ft deep and 700 ft long (**Figure 7-2**).
- Installation of a compliance reactive wall made up of 100% iron located about 100 ft downgradient from the existing boundary wall, on the west side of the railroad tracks (**Figure 7-2**). The wall would be 2.1 ft thick, about 8 ft deep, and 645 ft long.
- Installation of 13 monitoring wells (MWT-12 to MWT-18, and MW-61 to MW-66) (**Figure 7-2**). Slug tests at selected monitoring wells will determine exact locations of proposed reactive walls (**Table 7-3**). MW-65 and MW-66 are the trigger and compliance wells, respectively. VOC results in monitoring wells nearby proposed location of compliance wall will also aid in the selection of final location for the compliance wall.
- Vegetable oil will be applied to the portion of the plume that is upgradient of the source wall. The vegetable oil is to act as a source of carbon for microbial degradation. Degradation of oil will produce hydrogen, which is necessary for microorganisms that reduce chlorinated ethenes. The oil will be introduced directly into the aquifer using a series of 20-foot long trenches (**Figure 7-2**). The oil's effect on the aquifer microorganisms is expected to last 50 years, therefore the oil will only have to be applied once. This will complement the hydrogen addition to the aquifer that is expected from chemical reactions in the downgradient iron walls. Together, the hydrogen addition from these sources is expected to help degrade the chlorinated organics in areas outside the iron treatment walls faster than they would ordinarily be degraded in the absence of increased hydrogen.

- In the first year, groundwater in wells around newly installed walls (compliance wall, source wall, middle wall) will be sampled twice and analyzed for VOC's in order to document that the wall is working properly (**Table 7-3**).
- Every year, eight wells will be sampled and tested for VOC's. The purpose of this monitoring is to monitor the performance of the compliance wall and the possible off-site migration of the chlorinated ethenes plume. The off-site sampling includes the sentry well, trigger well, and compliance well. The sentry well is MW-56, and its purpose is as a warning signal that will indicate the movement of the plume. The trigger well, MW-65, will be located halfway between the Farm House wells and MW-56, the sentry well. The trigger well is a location where, if concentrations of chemicals of interest are exceeded, immediate action will be taken to protect the source of water at the Farmhouse (e.g., connection to the town water line and/or supply of drinking water). The compliance well, MW-66, will be located on the Farm House property and this location defines the point at which the concentrations of constituents in groundwater must meet the New York GA Standards (**Table 7-3**).
- Every year groundwater elevations throughout the entire site will be measured (a total of 73). These measurements will indicate groundwater flow directions on the site and any mounding of groundwater near the walls (**Table 7-3**).
- Every five years, 66 selected wells at the Ash Landfill will be sampled and tested for VOC's to document the changes in plume concentrations and extent of the plume. For wells in and around the four reactive walls, groundwater analysis will include analysis for inorganic parameters such as sulfate, alkalinity, nitrate, total dissolved solids, phosphate, chloride, calcium, magnesium, potassium, sodium, iron, manganese, and pH as well as methane, ethane and ethene. Wells in the reactive wall will be analyzed for hydrogen as well. These activities will be done in order to assess performance of the reactive walls and to assess the degree of fouling of the iron (**Table 7-3**).
- Maintenance of the boundary, compliance, middle and source walls involves agitation of the iron/aquifer interface with overlapping 1-foot augers. This agitation would be done once every 10 years.

According to the results of the groundwater and solute transport modeling, the plume of chlorinated ethenes will be remediated in approximately 15 years using the four reactive iron walls with carbon addition in the upper portion of the plume.



## 7.6 COSTS OF FOCUSED GROUNDWATER TREATMENT ALTERNATIVES

Costs of both of the focused groundwater treatment alternatives for the Ash Landfill were developed and evaluated. The total present worth costs for the alternatives are estimated as follows:

Alternative 1: \$ 1,564,200

Alternative 2: \$ 2,705,300

The unit costs that were used in the estimates were based on the following source documents (which are included in **Appendix G**):

- Costs provided by Peerless Metal Powders and Abrasive prior to installation of border reactive wall. These costs include cost of iron filings including packaging and shipment to the site.
- Costs provided by Diverse Solutions on April 14, 2000. This includes the cost of excavation and installation of reactive walls using the continuous trencher, and mobilization/demobilization, backfilling, and revegetation.
- Cost associated with maintenance of reactive walls is \$7/ft<sup>2</sup>. This cost was developed by ETI in their April 20 Memorandum (**Appendix D**).

The following assumptions were used in the evaluation of costs associated with treatment of groundwater at the Ash Landfill:

- contingency (20%),
- engineering/oversight (20%), and
- interest (10%)

These percentages were also used in the cost estimates for the Feasibility Study.

Cost calculations are developed in **Tables G-4** and **G-6**. Detailed costs of both treatment alternatives are provided in **Table G-7** and are summarized in **Table 7-4**.

## 7.7 SELECTED ALTERNATIVE

Based on the analysis conducted in this focused feasibility memorandum report, Alternative 2, a sub-alternative under Alternative 3a in the FS, is the preferred alternative to remediate the plume of dissolved chlorinated organics at the Ash Landfill site. This alternative uses four reactive iron walls and vegetable oil addition (**Figure 7-2**). The components of the alternative are as follows:

1. Compliance wall (proposed),
2. Boundary wall (existing),
3. Middle wall (proposed),
4. Source wall (proposed),
5. Hydrogen addition to the aquifer through chemical reactions in the iron walls and through addition and degradation of vegetable oil (a carbon source) in the upgradient portion of the plume.

The treatability study results indicated that the in-situ reactive iron wall technology was effective in treating groundwater that contains dissolved concentrations of chlorinated organics at the Ash Landfill. The conceptual design for the proposed reactive iron walls carefully considers the parameters that were shown to be integral to the effectiveness of the walls (e.g., hydraulic conductivity of the aquifer, influent concentrations, residence time in the wall, % iron in wall). In addition, this analysis incorporated the benefits of hydrogen addition to the aquifer, both through chemical reactions in the iron walls and through degradation of vegetable oil (a carbon source) introduced in trenches, which is expected to increase the rate of degradation of chlorinated ethenes in the zones between the walls. Together, the reactive iron walls and beneficial affects from hydrogen addition are expected to remediate the plume of chlorinated organics in approximately 15 years.

The monitoring plan under Alternative 2 is designed to provide the necessary data to locate the position of the compliance wall, and to evaluate the effectiveness and longevity of the walls. The plan also provides for periodic sampling to assess the progress in the remediation of the plume on-site. A sentry well, trigger well, and compliance well, will be used to ensure that the drinking water at downgradient receptors at the Farmhouse are not impacted by dissolved chlorinated organics.

Table 5-1  
 Sampling Plan for Ash Landfill Groundwater Treatability Study Using Zero Valence Iron Continuous Reactive Wall  
 Ash Landfill Feasibility Memorandum  
 Seneca Army Depot Activity

	Well ID:	MW-T1	MW-T2	MW-T3	MW-T4	MW-T5	MW-T6	MW-T7	MW-T8	MW-T9	MW-T10	MW-T11	QA/QC (2)	Total		
Analysis	Method No	Number of Samples Collected During First Year (1)														
<b>Volatiles and Degradation Products</b>																
VOCs	NYSDEC OLC	4	4	4	4	4	4	4	4	4	4	4	4	20	rb,tb,dup, MS/MSD	64
Methane	EPA Method RSKSOP- 175	4	4	4	4	4	4	4	4	4	4	4	4	12	rb,tb,dup	56
Ethane		4	4	4	4	4	4	4	4	4	4	4	4	12	rb,tb,dup	56
Ethene		4	4	4	4	4	4	4	4	4	4	4	4	12	rb,tb,dup	56
<b>Inorganic Parameters</b>																
Sulfate	EPA 300.0	4	4	4	4	4	4	4	4	4	4	4	4	4	dup	48
Alkalinity	EPA 310.1	4	4	4	4	4	4	4	4	4	4	4	4	4	dup	48
Nitrate	EPA 300.0	4	4	4	4	4	4	4	4	4	4	4	4	4	dup	48
TDS	EPA 160.2	4	4	4	4	4	4	4	4	4	4	4	4	4	dup	48
Phosphate	EPA 365.2	4	4	4	4	4	4	4	4	4	4	4	4	4	dup	48
Chloride	EPA 300.0	4	4	4	4	4	4	4	4	4	4	4	4	4	dup	48
Calcium	EPA 200.7	4	4	4	4	4	4	4	4	4	4	4	4	4	dup	48
Magnesium	EPA 200.7	4	4	4	4	4	4	4	4	4	4	4	4	4	dup	48
Potassium	EPA 200.7	4	4	4	4	4	4	4	4	4	4	4	4	4	dup	48
Sodium	EPA 200.7	4	4	4	4	4	4	4	4	4	4	4	4	4	dup	48
Iron	EPA 200.7	4	4	4	4	4	4	4	4	4	4	4	4	4	dup	48
Manganese	EPA 200.7	4	4	4	4	4	4	4	4	4	4	4	4	4	dup	48
pH	EPA 9040	4	4	4	4	4	4	4	4	4	4	4	4	4	dup	48
Hydrogen	Chapelle, 1997			2			2			2						6

Note 1:

Samples were collected initially after well installation, three months after well installation, six months after installation and nine months after well installation.

Note 2:

One set of QA/QC samples were collected during each sampling event.

rb-rinse blank, tb - trip blank, dup - duplicate, MS - matrix spike, MSD - matrix spike duplicate

Note 3:

pH, conductivity, temperature, turbidity, redox potential, dissolved oxygen, ferrous iron, and water level were also measured in field.

Note 4:

Water level measurements were conducted monthly from the eleven wells listed above as well as in PT-24, MW-29, MW-28, MW-27, MW-53, PT-17, and MW-30.

Table 6-1  
 pH and Redox Potential of Groundwater Flowing Into and Out of Reactive Wall  
 Ash Landfill Feasibility Memorandum  
 Seneca Army Depot Activity

**pH and Redox Potential of Groundwater Flowing Into Reactive Wall**

Time of Sampling	North Transect		Middle Transect		South Transect	
	pH at MW-T1	Eh at MW-T1 mV	Ph at MW-T4	Eh at MW-T4 mV	pH at MW-T7	Eh at MW-T7 mV
April 1999	7.19	207.7	7.16	267.6	7.17	297.1
June 1999	7.19	48	7.14	96.3	7.06	69.1
September 1999	7.27	116	7.46	131.7	7.18	113.8
January 2000	7.27	87.4	7.15	97	7.12	85

**pH and Redox Potential of Groundwater Flowing out of Reactive Wall**

Time of Sampling	North Transect		Middle Transect		South Transect	
	pH at MW-T2	Eh at MW-T2 mV	Ph at MW-T5	Eh at MW-T5 mV	pH at MW-T8	Eh at MW-T8 mV
April 1999	7.83	90.1	9.14	0	9.74	20
June 1999	9.1	-274	9.5	-314	9.22	-362
September 1999	9.15	-256	9.56	-328	9.4	-404.3
January 2000	8.07	-90	9.35	-193.7	9.55	-69.2

Table 6-2  
Zero Valent Iron Reactive Wall Treatment Effectiveness for TCE and cDCE (1)  
Ash Landfill Feasibility Memorandum  
Seneca Army Depot Activity

Monitoring Well	Velocity thru Wall (ft/day) (2)	Residence Time in Wall (days) (3)	Reactive Iron Residence Time (days) (4)	TCE (µg/L)				c1,2-DCE (µg/L)			
				Upgradient	Within Wall	Downgradient	% Reduction (5)	Upgradient	Within Wall	Downgradient	% Reduction (5)
<b>April 26-28, 1999</b>											
Northern Transect				MWT-1	MWT-2	MWT-3		MWT-1	MWT-2	MWT-3	
	1.66	0.72	0.36	23	1	1 J	95.7	73	27	27	63
Middle Transect				MWT-4	MWT-5	MWT-6		MWT-4	MWT-5	MWT-6	
	0.37	3.24	1.62	2 J	1 U	1 U	>50	49	0.7 J	3	98.5
Southern Transect				MWT-7	MWT-8	MWT-9		MWT-7	MWT-8	MWT-9	
	0.49	2.45	1.22	430	1 U	43	>99.8	20 J	1 U	32	>95
<b>June 29, 1999</b>											
Northern Transect				MWT-1	MWT-2	MWT-3		MWT-1	MWT-2	MWT-3	
	0.24	5.07	2.54	8	1 U	0.8 J	>87.5	32	6	10	81.3
Middle Transect				MWT-4	MWT-5	MWT-6		MWT-4	MWT-5	MWT-6	
	0.30	4.05	2.03	2	1 U	1 U	>50	82	20	17	75.6
Southern Transect				MWT-7	MWT-8	MWT-9		MWT-7	MWT-8	MWT-9	
	0.91	1.32	0.66	530 J	2 U	52	>99.6	32	42	150	0
<b>September 28-29, 1999</b>											
Northern Transect				MWT-1	MWT-2	MWT-3		MWT-1	MWT-2	MWT-3	
	-0.72	NA(6)	NA(6)	2 U	1 U	1 U	NA(6)	6	0.6 J	2	NA(6)
Middle Transect				MWT-4	MWT-5	MWT-6		MWT-4	MWT-5	MWT-6	
	0.22	5.40	2.70	3 U	1 U	1 U	>66.7	40	5	11	87.5
Southern Transect				MWT-7	MWT-8	MWT-9		MWT-7	MWT-8	MWT-9	
	1.40	0.86	0.43	480	1 U	56	>99.8	25	7	38	72
<b>January 4-5, 2000</b>											
Northern Transect				MWT-1	MWT-2	MWT-3		MWT-1	MWT-2	MWT-3	
	0.71	1.69	0.85	18	2 U	2 J	>88.9	72	23	48	68.1
Middle Transect				MWT-4	MWT-5	MWT-6		MWT-4	MWT-5	MWT-6	
	0.37	3.24	1.62	3 U	1 U	2 J	>66.7	58	7	10	87.9
Southern Transect				MWT-7	MWT-8	MWT-9		MWT-7	MWT-8	MWT-9	
	1.43	0.84	0.42	480	3 U	32	>99.4	22	55	44	0

Ave. % >75.3%

Ave. % >66.3%

**Notes**

- (1) TCE and DCE concentrations are based on Treatability Study groundwater results. See Appendix D for raw chemical data.
- (2) Velocity =  $Ki/n_e$ , where: K is Distance Weighted Hydraulic Conductivity of each Transect (See Table 6-3 for Velocity)  
i = Hydraulic Gradient (ratio of elevation difference between upgradient and downgradient wells to distance) and  $n_e$  = effective porosity (assumed to be 0.2)
- (3) Residence Time is Distance (width of iron wall) over Velocity. Distance is from Upgradient Side of Wall to Well (assumed to be 1.2 feet).
- (4) Reactive Iron Residence Time is one-half Residence Time in Wall since Half of the Wall is Reactive Iron.
- (5) % Reductions =  $1 - (\text{Ratio of Upgradient Concentration to Concentration within Wall})$ .
- (6) Not Applicable since a negative velocity implies flow is reversed, therefore, removal efficiencies are not calculated.

Table 6-3  
 Monthly Groundwater Elevation Measurements, Groundwater Velocities and Residence Times Measurements  
 Ash landfill Feasibility Memorandum  
 Seneca Army Depot Activity

Monitoring Well ID	Monitoring Well Location	Hydraulic Conductivity <sup>(1)</sup> (ft/day)	Elevation at Top of Riser (MSL)	April 28, 1999		May 28, 1999		June 28, 1999	
				Depth from Top of Riser (ft)	Elevation of Water Level (ft)	Depth from Top of Riser (ft)	Elevation of Water Level (ft)	Depth from Top of Riser (ft)	Elevation of Water Level (ft)
MWT-1	Upgradient	33.8	637.24	4.99	632.25	5.50	631.74	6.37	630.87
MWT-2	Within Wall	21	637.19	5.00	632.19	5.42	631.77	6.35	630.84
MWT-3	Downgradient	28.3	637.31	5.13	632.18	5.40	631.91	6.45	630.86
Hydraulic Gradient through Wall (ft/ft) <sub>(2)</sub>					0.011		-0.027		0.002
Groundwater Velocity through Wall (ft/day) <sub>(3)</sub>					1.66		-4.02		0.24
Residence Time in Wall (day) <sub>(4)(5)</sub>					0.72		-0.30		5.07
Equivalent Reactive Iron Residence Time (day) <sub>(6)</sub>					0.36		-0.15		2.54
MWT-4	Upgradient	3.9	637.68	5.46	632.22	6.40	631.28	8.20	629.48
MWT-5	Within Wall	21	637.72	5.55	632.17	6.54	631.18	8.25	629.47
MWT-6	Downgradient	8.6	637.59	5.42	632.17	6.39	631.20	8.15	629.44
Hydraulic Gradient through Wall (ft/ft) <sub>(2)</sub>					0.008		0.019		0.006
Groundwater Velocity through Wall (ft/day) <sub>(3)</sub>					0.37		0.59		0.30
Residence Time in Wall (day) <sub>(4)(5)</sub>					3.24		2.03		4.05
Equivalent Reactive Iron Residence Time (day) <sub>(6)</sub>					1.62		1.01		2.03
MWT-7	Upgradient	3.8	638.34	6.10	632.24	7.25	631.09	9.58	628.76
MWT-8	Within Wall	21	638.4	6.17	632.23	7.37	631.03	9.68	628.72
MWT-9	Downgradient	7.4	638.08	5.91	632.17	7.97	630.11	9.45	628.63
Hydraulic Gradient through Wall (ft/ft) <sub>(2)</sub>					0.011		0.158		0.021
Groundwater Velocity through Wall (ft/day) <sub>(3)</sub>					0.49		6.84		0.91
Residence Time in Wall (day) <sub>(4)(5)</sub>					2.46		0.18		1.32
Equivalent Reactive Iron Residence Time (day) <sub>(6)</sub>					1.23		0.09		0.66
MWT-10	Northernmost Wall End	55.1	636.07	6.86	629.21	4.25	631.82	5.09	630.98
MWT-11	Southernmost Wall End	0.39	635.9	2.41	633.49	4.45	631.45	7.30	628.60
PT-24	Mid-Wall, Downgradient	NA	636.4	4.56	631.84	5.19	631.21	6.54	629.86
MW-29	Upgradient, Mid-Cluster	NA	637.31	5.76	631.55	6.79	630.52	8.80	628.51
MW-28	Upgradient, North-Cluste	NA	637.21	4.56	632.65	5.59	631.62	6.85	630.36
MW-27	Upgradient, North-Cluste	NA	639.32	4.95	634.37	6.58	632.74	7.61	631.71
MW-53	Upgradient, Mid-Cluster	NA	639.41	5.87	633.54	7.65	631.76	9.70	629.71
PT-17	Upgradient, South-Cluste	NA	640.14	4.54	635.60	7.44	632.70	9.58	630.56
MW-30	Upgradient, Southern End	NA	640.32	5.02	635.30	8.60	631.72	dry	dry
<b>Notes:</b>									
(1) Hydraulic Conductivity of Glacial Till/Weathered Shale from In-situ Slug Tests, Hydraulic Conductivity of Iron/Sand from Falling Head Permeability Test									
(2) Distance is the Length Between the Upgradient and Downgradient Well, 6.2 ft.									
(3) $V = Ki/n_e$ ; where: K = Ave. Hydraulic Conductivity, I = Hydraulic Gradient and $n_e$ = effective porosity, (assumed to be 0.15)									
(4) Residence Time is the Ratio of Velocity to Trench Width, 1.2 ft.									
(5) Negative Residence Times indicate Reverse Flow.									
(6) Equivalent Reactive Iron Residence Time is one-half the Wall Residence Time because the wall is 50% reactive iron.									

Table 6-3  
 Monthly Groundwater Elevation Measurements, Groundwater Velocities and Residence Times Measurements  
 Ash Landfill Feasibility Memorandum  
 Seneca Army Depot Activity

Monitoring Well ID	Monitoring Well Location	Hydraulic Conductivity <sup>(1)</sup> (ft/day)	Elevation at Top of Riser (MSL)	July 29, 1999		August 30, 1999		September 27, 1999	
				Depth from Top of Riser (ft)	Elevation of Water Level (ft)	Depth from Top of Riser (ft)	Elevation of Water Level (ft)	Depth from Top of Riser (ft)	Elevation of Water Level (ft)
MWT-1	Upgradient	33.8	637.24	8.06	629.18	9.05	628.19	7.92	629.32
MWT-2	Within Wall	21	637.19	8.06	629.13	9.00	628.19	7.90	629.29
MWT-3	Downgradient	28.3	637.31	8.16	629.15	9.14	628.17	7.92	629.39
Hydraulic Gradient through Wall (ft/ft) <sup>(2)</sup>					0.005		0.003		-0.011
Groundwater Velocity through Wall (ft/day) <sup>(3)</sup>					0.71		0.47		-1.66
Residence Time in Wall (day) <sup>(4)(5)</sup>					1.69		2.54		-0.72
Equivalent Reactive Iron Residence Time (day) <sup>(6)</sup>					0.85		1.27		-0.36
MWT-4	Upgradient	3.9	637.68	10.29	627.39	11.25	626.43	9.96	627.72
MWT-5	Within Wall	21	637.72	10.34	627.38	11.36	626.36	10.00	627.72
MWT-6	Downgradient	8.6	637.59	10.24	627.35	11.21	626.38	9.90	627.69
Hydraulic Gradient through Wall (ft/ft) <sup>(2)</sup>					0.006		0.008		0.005
Groundwater Velocity through Wall (ft/day) <sup>(3)</sup>					0.30		0.37		0.22
Residence Time in Wall (day) <sup>(4)(5)</sup>					4.05		3.24		-5.40
Equivalent Reactive Iron Residence Time (day) <sup>(6)</sup>					2.03		1.62		2.70
MWT-7	Upgradient	3.8	638.34	11.77	626.57	12.70	625.64	10.64	627.70
MWT-8	Within Wall	21	638.4	11.87	626.53	dry	dry	10.78	627.62
MWT-9	Downgradient	7.4	638.08	11.65	626.43	12.60	625.48	10.58	627.50
Hydraulic Gradient through Wall (ft/ft) <sup>(2)</sup>					0.023		0.026		0.032
Groundwater Velocity through Wall (ft/day) <sup>(3)</sup>					0.98		1.12		1.40
Residence Time in Wall (day) <sup>(4)(5)</sup>					1.23		1.08		0.86
Equivalent Reactive Iron Residence Time (day) <sup>(6)</sup>					0.61		0.54		0.43
MWT-10	Northernmost Wall End	55.1	636.07	6.40	629.67	7.55	628.52	6.50	629.57
MWT-11	Southernmost Wall End	0.39	635.9	8.55	627.35	8.95	626.95	7.14	628.76
PT-24	Mid-Wall, Downgradient	NA	636.4	8.31	628.09	8.20	628.20	8.04	628.36
MW-29	Upgradient, Mid-Cluster	NA	637.31	dry	dry	dry	dry	dry	dry
MW-28	Upgradient, North-Cluste	NA	637.21	8.30	628.91	9.05	628.16	7.92	629.29
MW-27	Upgradient, North-Cluste	NA	639.32	8.43	630.89	8.70	630.62	7.14	632.18
MW-53	Upgradient, Mid-Cluster	NA	639.41	dry	dry	10.00	629.41	9.88	629.53
PT-17	Upgradient, South-Cluste	NA	640.14	dry	dry	11.00	629.14	9.10	631.04
MW-30	Upgradient, Southern End	NA	640.32	dry	dry	dry	dry	dry	dry
<b>Notes:</b>									
(1) Hydraulic Conductivity of Glacial Till/Weathered Shale from In-situ Slug Tests, Hydraulic Conductivity of Iron/Sand from Falling Head Permeability Test.									
(2) Distance is the Length Between the Upgradient and Downgradient Well, 6.2 ft.									
(3) $V = KI/n_e$ ; where: K = Ave. Hydraulic Conductivity, I = Hydraulic Gradient and $n_e$ = effective porosity, (assumed to be 0.15)									
(4) Residence Time is the Ratio of Velocity to Trench Width, 1.2 ft.									
(5) Negative Residence Times indicate Reverse Flow.									
(6) Equivalent Reactive Iron Residence Time is one-half the Wall Residence Time because the wall is 50% reactive iron.									

Table 6-3  
 Monthly Groundwater Elevation Measurements, Groundwater Velocities and Residence Times Measurements  
 Ash landfill Feasibility Memorandum  
 Seneca Army Depot Activity

Monitoring Well ID	Monitoring Well Location	Hydraulic Conductivity <sup>(1)</sup> (ft/day)	Elevation at Top of Riser (MSL)	October 29, 1999		December 2, 1999		January 3, 2000	
				Depth from Top of Riser (ft)	Elevation of Water Level (ft)	Depth from Top of Riser (ft)	Elevation of Water Level (ft)	Depth from Top of Riser (ft)	Elevation of Water Level (ft)
MWT-1	Upgradient	33.8	637.24	6.26	630.98	5.53	631.71	5.26	631.98
MWT-2	Within Wall	21	637.19	6.26	630.93	5.46	631.73	5.22	631.97
MWT-3	Downgradient	28.3	637.31	6.37	630.94	5.59	631.72	5.36	631.95
Hydraulic Gradient through Wall (ft/ft) <sup>(2)</sup>					0.006		-0.002		0.005
Groundwater Velocity through Wall (ft/day) <sup>(3)</sup>					0.95		-0.24		0.71
Residence Time in Wall (day) <sup>(4)(5)</sup>					1.27		-5.07		1.69
Equivalent Reactive Iron Residence Time (day) <sup>(6)</sup>					0.63		-2.54		0.85
MWT-4	Upgradient	3.9	637.68	7.57	630.11	6.45	631.23	6.06	631.62
MWT-5	Within Wall	21	637.72	7.66	630.06	6.53	631.19	6.1	631.62
MWT-6	Downgradient	8.6	637.59	7.52	630.07	6.41	631.18	6.02	631.57
Hydraulic Gradient through Wall (ft/ft) <sup>(2)</sup>					0.006		0.008		0.008
Groundwater Velocity through Wall (ft/day) <sup>(3)</sup>					0.30		0.37		0.37
Residence Time in Wall (day) <sup>(4)(5)</sup>					4.05		3.24		3.24
Equivalent Reactive Iron Residence Time (day) <sup>(6)</sup>					2.03		1.62		1.62
MWT-7	Upgradient	3.8	638.34	8.44	629.90	7.13	631.21	6.66	631.68
MWT-8	Within Wall	21	638.4	8.54	629.86	7.22	631.18	6.74	631.66
MWT-9	Downgradient	7.4	638.08	8.25	629.83	6.95	631.13	6.52	631.56
Hydraulic Gradient through Wall (ft/ft) <sup>(2)</sup>					0.011		0.013		0.019
Groundwater Velocity through Wall (ft/day) <sup>(3)</sup>					0.49		0.56		0.84
Residence Time in Wall (day) <sup>(4)(5)</sup>					2.46		2.15		1.43
Equivalent Reactive Iron Residence Time (day) <sup>(6)</sup>					1.23		1.08		0.72
MWT-10	Northernmost Wall End	55.1	636.07	5.25	630.82	4.36	631.71	4.14	631.93
MWT-11	Southernmost Wall End	0.39	635.9	5.52	630.38	4.15	631.75	3.22	632.68
PT-24	Mid-Wall, Downgradient	NA	636.4	6.10	630.30	5.04	631.36	4.8	631.60
MW-29	Upgradient, Mid-Cluster	NA	637.31	8.00	629.31	6.79	630.52	6.34	630.97
MW-28	Upgradient, North-Cluste	NA	637.21	6.34	630.87	5.5	631.71	5.16	632.05
MW-27	Upgradient, North-Cluste	NA	639.32	6.60	632.72	5.21	634.11	5.46	633.86
MW-53	Upgradient, Mid-Cluster	NA	639.41	8.71	630.70	7.61	631.80	6.7	632.71
PT-17	Upgradient, South-Cluste	NA	640.14	8.05	632.09	5.14	635.00	5.08	635.06
MW-30	Upgradient, Southern End	NA	640.32	9.57	630.75	7.27	633.05	6.78	633.54
<b>Notes:</b>									
(1) Hydraulic Conductivity of Glacial Till/Weathered Shale from In-situ Slug Tests. Hydraulic Conductivity of Iron/Sand from Falling Head Permeability Test.									
(2) Distance is the Length Between the Upgradient and Downgradient Well, 6.2 ft.									
(3) $V = K/n_e$ , where: K = Ave. Hydraulic Conductivity, l = Hydraulic Gradient and $n_e$ = effective porosity, (assumed to be 0.15)									
(4) Residence Time is the Ratio of Velocity to Tranch Width, 1.2 ft.									
(5) Negative Residence Times indicate Reverse Flow.									
(6) Equivalent Reactive Iron Residence Time is one-half the Wall Residence Time because the wall is 50% reactive iron.									



Table 6-3  
 Monthly Groundwater Elevation Measurements, Groundwater Velocities and Residence Times Measurements  
 Ash landfill Feasibility Memorandum  
 Seneca Army Depot Activity

Monitoring Well ID	Monitoring Well Location	Hydraulic Conductivity <sup>(1)</sup> (ft/day)	Elevation at Top of Riser (MSL)	February 29, 2000		April 17, 2000	
				Depth from Top of Riser (ft)	Elevation of Water Level (ft)	Depth from Top of Riser (ft)	Elevation of Water Level (ft)
MWT-1	Upgradient	33.8	637.24	3.94	633.30	4.69	632.55
MWT-2	Within Wall	21	637.19	4.11	633.08	4.93	632.26
MWT-3	Downgradient	28.3	637.31	4.22	633.09	5.04	632.27
Hydraulic Gradient through Wall (ft/ft) <sup>(2)</sup>				0.034		0.045	
Groundwater Velocity through Wall (ft/day) <sup>(3)</sup>				4.97		6.63	
Residence Time in Wall (day) <sup>(4,5)</sup>				0.24		0.18	
Equivalent Reactive Iron Residence Time (day) <sup>(6)</sup>				0.12		0.09	
MWT-4	Upgradient	3.9	637.68	4.77	632.91	5.07	632.61
MWT-5	Within Wall	21	637.72	4.85	632.87	5.16	632.56
MWT-6	Downgradient	8.6	637.59	4.74	632.85	5.05	632.54
Hydraulic Gradient through Wall (ft/ft) <sup>(2)</sup>				0.010		0.011	
Groundwater Velocity through Wall (ft/day) <sup>(3)</sup>				0.44		0.52	
Residence Time in Wall (day) <sup>(4,5)</sup>				2.70		2.32	
Equivalent Reactive Iron Residence Time (day) <sup>(6)</sup>				1.35		1.16	
MWT-7	Upgradient	3.8	638.34	5.19	633.15	5.54	632.80
MWT-8	Within Wall	21	638.4	5.31	633.09	5.65	632.75
MWT-9	Downgradient	7.4	638.08	5.05	633.03	5.38	632.70
Hydraulic Gradient through Wall (ft/ft) <sup>(2)</sup>				0.019		0.016	
Groundwater Velocity through Wall (ft/day) <sup>(3)</sup>				0.84		0.70	
Residence Time in Wall (day) <sup>(4,5)</sup>				1.43		1.72	
Equivalent Reactive Iron Residence Time (day) <sup>(6)</sup>				0.72		0.86	
MWT-10	Northernmost Wall End	55.1	636.07	2.95	633.12	3.74	632.33
MWT-11	Southernmost Wall End	0.39	635.9	1.6	634.30	2.36	633.54
PT-24	Mid-Wall, Downgradient	NA	636.4	3.91	632.49	4.41	631.99
MW-29	Upgradient, Mid-Cluster	NA	637.31	4.96	632.35	5.21	632.10
MW-28	Upgradient, North-Cluste	NA	637.21	3.61	633.60	4.44	632.77
MW-27	Upgradient, North-Cluste	NA	639.32	3.82	635.50	5.11	634.21
MW-53	Upgradient, Mid-Cluster	NA	639.41	5.1	634.31	5.72	633.69
PT-17	Upgradient, South-Cluste	NA	640.14	4.02	636.12	4.59	635.55
MW-30	Upgradient, Southern End	NA	640.32	4.1	636.22	5.55	634.77
<b>Notes:</b>							
(1) Hydraulic Conductivity of Glacial Till/Weathered Shale from In-situ Slug Tests, Hydraulic Conductivity of Iron/Sand from Falling Head Permeability Test.							
(2) Distance is the Length Between the Upgradient and Downgradient Well, 6.2 ft.							
(3) $V = KI/n_e$ ; where: K = Ave. Hydraulic Conductivity, I = Hydraulic Gradient and $n_e$ = effective porosity, (assumed to be 0.15)							
(4) Residence Time is the Ratio of Velocity to Trench Width, 1.2 ft.							
(5) Negative Residence Times indicate Reverse Flow.							
(6) Equivalent Reactive Iron Residence Time is one-half the Wall Residence Time because the wall is 50% reactive iron.							

Table 6-4  
 Calculation of Radius of Influence of Monitoring Wells within Reactive Wall  
 Ash Landfill Feasibility Memorandum  
 Seneca Army Depot Activity

Monitoring Well	Vw Vol of water (gal)	Vw Vol of water (L)	Va Aquifer vol holding Vw (L)	Va ft <sup>3</sup>	r1 well radius inches	r1 feet	r2 radius of water in aquifer inches	r2 feet	h height of water column ft
<i>Apr-99</i>									
MW-T2	0.06	0.24	0.60	0.02	0.5	0.04	0.63	0.05	6.90
MW-T5	0.26	1.00	2.50	0.09	0.5	0.04	0.94	0.08	6.47
MW-T8	0.26	1.00	2.50	0.09	0.5	0.04	0.94	0.08	6.42
<i>Jun-99</i>									
MW-T2	0.33	1.26	3.15	0.11	0.5	0.04	1.34	0.11	3.33
MW-T5	0.38	1.44	3.60	0.13	1.5	0.13	1.96	0.16	3.65
MW-T8	0.60	2.27	5.68	0.20	2.5	0.21	2.80	0.23	5.85
<i>Sep-99</i>									
MW-T2	1.00	3.79	9.46	0.33	0.5	0.04	2.96	0.25	1.80
MW-T5	1.00	3.79	9.46	0.33	1.5	0.13	3.09	0.26	2.10
MW-T8	1.50	5.68	14.19	0.50	2.5	0.21	4.20	0.35	2.02
<i>Jan-00</i>									
MW-T2	0.20	0.76	1.89	0.07	0.5	0.04	0.95	0.08	4.72
MW-T5	0.22	0.83	2.08	0.07	0.5	0.04	0.88	0.07	6.50
MW-T8	0.22	0.83	2.08	0.07	0.5	0.04	0.88	0.07	6.54

Notes:

- 1) Assume effective porosity,  $n_e$ , for the iron/sand media to be 0.4
- 2)  $V_a = V_w / n_e$
- 3)  $V_a = \pi \cdot h (r_2^2 - r_1^2)$

Table 6-5  
 Round 1 Groundwater Monitoring-October 1999 Indicator Parameters and Field Measurements  
 Ash Landfill Feasibility Memorandum  
 Seneca Army Depot Activity

Well ID	Location	DO (mg/l)	Temp (deg. C)	Spec. Cond. (umhos/cm)	pH (units)	ORP (mV)	Turbidity (ntu)	Fe+2 (mg/l)	Sulfide (mg/l)	Methane (ug/l)	Ethane (ug/l)
	Optimum:	<0.5 mg/L	>20C, accelerated		5<pH<9	<50 possible, <-100 likely		>1 mg/L	>1 mg/L	>500 ug/L	
	Comments:									daughter product	daughter product
PT-10	East of impact area	NA	12.09	799	7.14	79.8	0.90	0.06	0.000	8.9	0.02
PT-11	South of West Smith Farm Road	NA	13.78	870	7.38	70.0	<50	0.02	ND	1.4	0.01
PT-12A	Plume	1.20	15.39	1652	6.73	92.5	2.25	0.00	0.012	4.2	0.36
PT-15	South of West Smith Farm Road	5.90	12.58	578	7.39	60.5	25.00	NA	NA	3.0	0.01
PT-16	North of impact area	NA	15.22	555	6.93	103.2	1.00	0.00	NA	0.2	ND
PT-16Dup	North of impact area	NA	NA	NA	NA	NA	NA	0.00	NA	0.2	ND
PT-17	Plume	4.45	14.78	617	6.98	-5.0	1.00	0.00	0.022	ND	0.03
PT-18	Plume	0.92	14.84	1340	6.70	-57.0	2.20	0.13	0.037	515.0	0.98
PT-19	South of West Smith Farm Road	NA	13.89	1234	6.62	-90.0	7.00	9.48	NA	1208.2	0.07
PT-20	Plume	1.91	15.20	855	6.78	130.0	0.50	0.01	0.008	ND	ND
PT-20Dup	Plume	NA	NA	NA	NA	NA	NA	0.02	0.008	ND	ND
PT-21A	Plume	0.94	13.06	1252	7.14	-4.0	2.09	0.58	0.016	7.7	0.43
PT-22	Plume	3.92	13.03	1452	6.92	105.0	4.82	0.00	0.080	ND	0.20
PT-23	North of impact area	NA	16.16	603	7.14	80.1	10.00	0.06	NA	4.8	ND
PT-24	Plume	1.78	15.00	625	7.08	124.0	0.95	0.01	NA	ND	0.02
PT-25	South of West Smith Farm Road	6.77	15.03	417	6.92	117.3	1.80	0.00	NA	ND	ND
PT-26	Off of SEDA property	2.05	12.30	667	7.46	0.7	5.80	0.08	0.021	29.6	0.02
MW-27	North of impact area	8.90	14.24	559	7.41	44.8	100.00	0.01	0.013	393.0	ND
MW-28	Plume	4.32	14.58	618	6.99	111.0	1.25	0.00	0.018	ND	ND
MW-29	Plume	6.12	14.97	931	6.96	113.0	4.85	0.00	0.042	ND	ND
MW-30	South of West Smith Farm Road	6.84	13.55	652	6.97	131.0	0.75	0.00	0.011	ND	ND
MW-31	South of West Smith Farm Road	NA	15.74	569	7.07	106.6	3.00	0.06	0.000	ND	ND
MW-32	Plume	1.83	12.99	662	6.96	-20.5	2.50	0.17	0.016	6.6	ND
MW-33	South of West Smith Farm Road	6.07	15.80	567	7.00	94.0	3.00	0.00	NA	ND	0.01
MW-34	Off of Ash Landfill site	0.94	14.98	509	7.47	49.7	5.40	0.07	NA	3.1	ND
MW-35D	Off of SEDA property	0.63	11.37	541	8.43	2.8	1.50	0.00	0.028	6.3	0.03
MW-36	Off of SEDA property	1.20	13.70	734	7.17	77.1	2.20	0.00	0.013	ND	ND

Table 6-5  
 Round 1 Groundwater Monitoring-October 1999 Indicator Parameters and Field Measurements  
 Ash Landfill Feasibility Memorandum  
 Seneca Army Depot Activity

Well ID	Location	DO (mg/l)	Temp (deg. C)	Spec. Cond. (umhos/cm)	pH (units)	ORP (mV)	Turbidity (ntu)	Fe+2 (mg/l)	Sulfide (mg/l)	Methane (ug/l)	Ethane (ug/l)
	Optimum:	<0.5 mg/L	>20C, accelerated		5<pH<9	<50 possible, <-100 likely		>1 mg/L	>1 mg/L	>500 ug/L	
	Comments:									daughter product	daughter product
MW-36Dup	Off of SEDA property	NA	NA	NA	NA	NA	NA	NA	NA	ND	ND
MW-37	North of impact area	NA	16.52	569	7.09	93.1	7.36	0.00	NA	ND	ND
MW-38D	North of impact area	NA	13.52	550	7.02	25.1	1.35	0.12	NA	1.5	0.04
MW-39	NE of impact area	NA	15.07	546	7.17	84.9	0.58	0.01	NA	ND	ND
MW-40	East of impact area	NA	15.54	603	7.23	94.6	2.00	0.07	NA	ND	ND
MW-41D	Upgradient of Ash Landfill site	NA	11.62	773	7.01	108.0	1.50	0.00	0.060	2.9	0.06
MW-42D	Upgradient of Ash Landfill site	0.78	11.39	547	7.40	78.8	0.90	0.00	0.014	1.0	0.05
MW-43	East of impact area	8.95	13.38	585	7.10	115.8	2.10	0.00	0.016	ND	ND
MW-44A	Plume	0.30	12.95	1401	7.09	112.2	1.11	0.03	0.021	0.6	0.85
MW-45	Plume	7.73	13.77	542	7.18	108.0	1.45	0.00	0.018	ND	ND
MW-46	Plume	NA	15.45	771	6.95	-113.2	1.50	0.77	NA	130.9	0.16
MW-47	Off of SEDA property	4.88	14.07	621	7.13	85.7	2.88	0.09	0.010	ND	ND
MW-48	Plume	NA	15.82	585	7.11	73.0	1.20	0.03	NA	ND	ND
MW-49D	Plume	NA	12.65	656	7.23	-6.2	2.10	0.22	NA	1.1	0.01
MW-50D	Plume	NA	12.41	519	7.56	-63.4	2.60	0.09	NA	4.4	0.01
MW-51D	Off of SEDA property	0.70	12.28	595	7.30	26.6	1.58	0.92	0.009	3.7	0.02
MW-52D	Off of SEDA property	0.67	11.65	482	8.65	-14.5	90.70	0.04	0.290	8.6	0.01
MW-53	Plume	4.47	14.25	926	6.89	108.0	0.46	0.00	0.010	ND	ND
MW-54D	Plume	0.34	12.47	664	7.22	57.4	0.47	0.03	0.008	2.9	0.01
MW-55D	Plume	0.43	13.32	525	9.02	-15.0	27.00	0.02	0.141	10.4	ND
MW-56	250 ft West of boundary of SEDA	3.28	13.30	669	7.00	112.0	0.50	0.01	0.012	ND	ND
MW-57D	Off of SEDA property	0.26	11.45	590	9.12	-32.1	20.80	0.00	0.017	7.9	0.02
MW-58D	Off of SEDA property	0.15	11.17	610	9.12	-110.0	138.00	0.00	0.500	10.9	ND
MW-59	South of West Smith Farm Road	NA	14.95	1286	6.89	82.9	0.60	0.01	NA	18.5	ND
MW-60	South of West Smith Farm Road	NA	14.65	768	7.11	-40.0	1.00	0.01	NA	ND	ND

ND = Not Detected  
 NA = Not Available

Table 6-5  
 Round 1 Groundwater Monitoring-October 1999 Indicator Parameters and Field Measurements  
 Ash Landfill Feasibility Memorandum  
 Seneca Army Depot Activity

Well ID	Location	Ethene (ug/l)	TOC (mg/l)	Nitrate/Nitrite (mg/l)	Tot. Alkalinity (mg/l CaCO <sub>3</sub> )	Sulfate (mg/l)	Chloride (mg/l)	Hardness (CaCO <sub>3</sub> )	Hydrogen (nM/l)	Hydrogen (ug/l)
	Optimum:		>20 mg/L	<1 mg/L	>2 x background	<20 mg/L	>2 x background		>1 nM	
	Comments:	daughter product					daughter product			
PT-10	East of impact area	0.03	4.1	0.01	340	24.4	58.2	350	0.8	1.613E-03
PT-11	South of West Smith Farm Road	ND	8.3	0.50	220	65.1	83.8	328	ND	NA
PT-12A	Plume	0.26	4.9	0.10	396	508.0	91.2	935	ND	NA
PT-15	South of West Smith Farm Road	ND	2.2	0.12	NA	NA	NA	NA	ND	NA
PT-16	North of impact area	ND	2.7	0.12	264	33.0	8.8	300	1.2	2.419E-03
PT-16Dup	North of impact area	ND	2.7	0.11	262	34.0	8.9	296	ND	NA
PT-17	Plume	ND	4.3	0.09	250	88.8	10.4	280	0.8	0.002
PT-18	Plume	4.47	8.5	0.08	516	210.0	23.7	660	2.8	0.006
PT-19	South of West Smith Farm Road	0.08	116.0	<0.01	500	<5	63.7	656	0.9	0.002
PT-20	Plume	ND	4.5	0.21	310	185.0	12.7	412	0.8	0.002
PT-20Dup	Plume	ND	NA	NA	NA	NA	NA	425	ND	NA
PT-21A	Plume	ND	3.1	0.19	302	265.0	116.0	740	6.1	0.012
PT-22	Plume	ND	4.3	0.24	310	339.0	86.7	680	ND	NA
PT-23	North of impact area	0.01	2.3	0.03	280	37.7	9.2	310	ND	NA
PT-24	Plume	ND	3.6	0.94	226	80.3	13.7	308	0.8	0.002
PT-25	South of West Smith Farm Road	ND	2.4	0.66	184	31.3	9.6	204	0.8	0.002
PT-26	Off of SEDA property	ND	2.2	0.10	270	51.4	42.3	164	ND	NA
MW-27	North of impact area	ND	3.3	1.00	256	122.0	10.5	240	ND	NA
MW-28	Plume	ND	2.6	0.02	272	55.7	10.1	370	ND	NA
MW-29	Plume	ND	2.9	0.58	324	143.0	31.0	590	0.6	0.001
MW-30	South of West Smith Farm Road	ND	4.2	0.17	290	58.8	14.0	308	1.3	0.003
MW-31	South of West Smith Farm Road	ND	3.4	0.55	268	28.9	9.4	256	26.0	0.052
MW-32	Plume	ND	3.7	0.74	300	53.1	11.9	302	8.1	0.016
MW-33	South of West Smith Farm Road	ND	2.9	1.40	228	50.2	16.9	292	0.7	0.001
MW-34	Off of Ash Landfill site	ND	2.2	0.05	264	31.1	4.4	160	13.8	0.028
MW-35D	Off of SEDA property	0.07	2.0	0.04	232	34.9	19.0	100	1.4	0.003
MW-36	Off of SEDA property	ND	4.2	0.81	298	59.9	20.2	340	1.3	0.003

Table 6-5  
 Round 1 Groundwater Monitoring-October 1999 Indicator Parameters and Field Measurements  
 Ash Landfill Feasibility Memorandum  
 Seneca Army Depot Activity

Well ID	Location	Ethene (ug/l)	TOC (mg/l) >20 mg/L	Nitrate/Nitrite (mg/l) <1 mg/L	Tot. Alkalinity (mg/l CaCO3) >2 x background	Sulfate (mg/l) <20 mg/L	Chloride (mg/l) >2 x background	Hardness (CaCO3)	Hydrogen (nM/l) >1 nM	Hydrogen (ug/l)
	Comments:	daughter product					daughter product			
MW-36Dup	Off of SEDA property	ND	NA	NA	NA	NA	NA	346	ND	NA
MW-37	North of impact area	0.07	3.2	0.17	272	35.1	7.7	300	0.8	1.613E-03
MW-38D	North of impact area	ND	2.5	0.01	248	31.2	12.2	280	1.2	2.419E-03
MW-39	NE of impact area	ND	3.5	0.11	244	34.2	10.3	278	2.0	4.032E-03
MW-40	East of impact area	ND	2.9	0.33	248	85.0	6.3	294	0.8	0.002
MW-41D	Upgradient of Ash Landfill site	0.02	7.5	0.08	340	76.6	8.1	348	1.0	2.016E-03
MW-42D	Upgradient of Ash Landfill site	0.02	2.5	0.09	272	27.7	3.8	300	ND	NA
MW-43	East of impact area	ND	4.0	0.03	264	69.0	11.2	330	ND	NA
MW-44A	Plume	4.72	7.9	NA	NA	NA	NA	710	ND	NA
MW-45	Plume	ND	2.8	0.02	240	40.1	11.5	270	4.2	0.008
MW-46	Plume	0.05	5.2	0.12	316	77.1	18.1	404	ND	NA
MW-47	Off of SEDA property	ND	2.8	2.20	238	69.8	19.2	288	9.3	1.875E-02
MW-48	Plume	ND	3.2	0.18	260	60.1	10.8	304	1.0	0.002
MW-49D	Plume	0.01	2.7	0.02	276	66.6	18.5	340	1.2	0.002
MW-50D	Plume	0.02	2.6	0.04	240	28.7	12.5	228	1.6	0.003
MW-51D	Off of SEDA property	0.02	2.5	1.30	242	61.4	15.9	242	0.8	0.002
MW-52D	Off of SEDA property	0.06	1.7	0.11	208	39.9	2.2	<2	5.3	0.011
MW-53	Plume	ND	2.9	0.35	314	161.0	32.5	500	0.6	0.001
MW-54D	Plume	ND	1.9	0.03	240	67.3	51.0	298	4.2	0.008
MW-55D	Plume	0.02	2.2	0.23	252	33.5	1.8	10	1.6	0.003
MW-56	250 ft West of boundary of SEDA	ND	2.9	1.80	200	112.0	28.8	308	4.7	0.009
MW-57D	Off of SEDA property	0.05	1.9	0.03	258	50.8	4.9	10	3.4	0.007
MW-58D	Off of SEDA property	0.02	2.0	0.02	276	53.1	2.4	20	1.9	0.004
MW-59	South of West Smith Farm Road	ND	3.9	0.02	284	88.2	47.4	364	2.1	4.233E-03
MW-60	South of West Smith Farm Road	ND	8.1	0.05	516	230.0	27.6	688	0.9	1.814E-03

ND = Not Detected  
 NA = Not Available

Table 6-6  
 Round 2 Groundwater Monitoring-January 2000 Indicator Parameters and Field Measurements  
 Ash Landfill Feasibility Memorandum  
 Seneca Army Depot Activity

Well ID	Location	DO (mg/l)	Temp (deg.C)	Spec. Cond. (umhos/cm)	pH	ORP (mV)	Turbidity (ntu)	Fe+2 (mg/l)	Sulfide (mg/l)	Methane (ug/l)
	Optimum:	<0.5 mg/L	>20C, accelerated		5<pH<9	<50 poss, <-100 likely		>1 mg/L	>1 mg/L	>500 ug/L
	Comments:									daughter product
PT-10	East of impact area	1.6	9.43	765	7.28	71.3	1.3	0.10	0.011	7.5
PT-11	South of West Smith Farm Road	8.04	8.36	968	7.42	78.0	50.5	0.00	0.110	1.8
PT-12A	Plume	1.55	5	1462	7	53.0	1.1	0.06	0.014	4.4
PT-15	South of West Smith Farm Road	9.32	10.24	512	7.58	86.5	5.91	0.13	ND	1.0
PT-16	North of impact area	3.8	7.27	500	7.07	119.0	1.25	0.00	0.000	ND
PT-16Dup	North of impact area	NA	NA	NA	NA	NA	NA	NA	NA	ND
PT-17	Plume	3.19	7.93	629	7.01	108.0	0.54	0.01	0.021	ND
PT-18	Plume	3.4	6.65	1544	6.82	108.0	3.25	0.02	0.014	0.6
PT-19	South of West Smith Farm Road	0.4	6.96	726	6.96	-144.0	1.5	0.65	0.028	1247.3
PT-20	Plume	1.22	7.29	893	6.98	92.3	1.5	0.02	0.000	ND
PT-21A	Plume	1.41	6.52	1112	7.24	0.0	0.57	0.35	0.019	6.5
PT-22	Plume	4.11	6	1175	6.9	148.5	0.87	ND	ND	ND
PT-23	North of impact area	7.27	7.36	504	7.27	104.0	7.6	0.18	0.030	ND
PT-24	Plume	0.29	7.57	517	7.62	68.5	3.6	0.06	0.009	2880.2
PT-25	South of West Smith Farm Road	9.62	8.32	391	7.04	138.7	1.2	0.01	0.009	ND
PT-26	Off of SEDA property	7.43	8.26	697	7.23	92.5	10	0.11	ND	0.8
MW-27	North of impact area	9.57	6.83	547	7.40	87.8	8.95	0.11	0.030	12.0
MW-28	Plume	5.2	7.14	607	7.12	98.0	7.2	0.13	0.024	0.4
MW-29	Plume	7.31	7.37	828	7.03	102.9	4	0.12	0.033	0.2
MW-30	South of West Smith Farm Road	8.67	7.01	569	7.10	144.9	2.2	0.04	0.030	ND
MW-30Dup	South of West Smith Farm Road	NA	NA	NA	NA	NA	NA	0.04	NA	ND
MW-31	South of West Smith Farm Road	10.51	8.14	464	7.18	133.0	8.8	0.26	0.075	ND
MW-32	Plume	4.45	7.11	630	7.05	131.0	9.56	0.09	0.042	ND
MW-33	South of West Smith Farm Road	7.5	7.51	553	6.97	137.0	3.2	0.02	0.019	ND
MW-34	Off of Ash Landfill site	1.49	9.25	533	7.39	111.0	8.9	0.06	0.030	0.3
MW-35D	Off of SEDA property	4.18	8.78	483	8.40	25.2	6.5	0.04	0.010	3.5

Table 6-6  
 Round 2 Groundwater Monitoring-January 2000 Indicator Parameters and Field Measurements  
 Ash Landfill Feasibility Memorandum  
 Seneca Army Depot Activity

Well ID	Location	DO (mg/l)	Temp (deg.C)	Spec. Cond. (umhos/cm)	pH	ORP (mV)	Turbidity (ntu)	Fe+2 (mg/l)	Sulfide (mg/l)	Methane (ug/l)
	Optimum:	<0.5 mg/L	>20C, accelerated		5<pH<9	<50 poss, <-100 likely		>1 mg/L	>1 mg/L	>500 ug/L
	Comments:									daughter product
MW-36	Off of SEDA property	1.51	8.44	633	7.16	32.3	1.95	0.03	0.005	ND
MW-37	North of impact area	6.43	7.63	496	7.05	148.0	3.1	0.00	0.000	ND
MW-38D	North of impact area	2.9	9.75	515	7.34	76.8	7.5	0.00	0.008	0.6
MW-39	NE of impact area	3.4	7.64	554	7.18	116.5	0.95	0.03	0.010	0.6
MW-40	East pf impact area, ND	6.49	7.99	576	7.38	80.3	1.5	0.01	0.009	0.5
MW-41D	Upgradient of Ash Landfill site	0.77	7.15	734	7.23	125.0	2.45	0.00	0.010	3.0
MW-42D	Upgradient of Ash Landfill site	1.26	9.41	536	7.21	35.1	1.97	0.17	0.080	8.2
MW-43	East impact area	5.38	5.24	657	7.28	107.0	0.65	0.01	0.009	0.6
MW-44A	Plume	0.83	5.57	2242	7.25	66.5	3.5	0.08	0.016	6.2
MW-45	Plume	4.13	6.10	549	7.29	53.0	4.5	0.01	NA	0.5
MW-46	Plume	1.03	7.19	758	7.10	-71.1	6.36	0.09	0.040	6.1
MW-47	Off of SEDA property	NA	NA	NA	NA	NA	NA	NA	NA	ND
MW-48	Plume	2.25	7.26	538	7.23	12.0	4.5	0.06	0.018	ND
MW-49D	Plume	1.58	8.63	552	7.27	40.8	10	0.05	0.000	3.7
MW-50D	Plume	1.07	8.04	460	7.56	-46.0	6.1	0.13	0.012	8.2
MW-51D	Off of SEDA property	1.24	9.82	544	7.40	69.9	1.23	NA	NA	0.6
MW-52D	Off of SEDA property	5.2	6.59	439	8.74	31.5	85.2	0.15	NA	4.4
MW-53	Plume	5.37	7.46	752	6.94	149.0	6.18	0.01	0.011	ND
MW-53Dup	Plume	NA	NA	NA	NA	NA	NA	NA	NA	ND
MW-54D	Plume	0.43	7.47	618	7.39	0.0	3	0.04	0.058	2.7
MW-55D	Plume	1.43	7.24	464	9.02	-24.0	47.9	0.10	NA	9.1
MW-56	250 ft West of boundary of SEDA	2.07	4.35	535	7.13	85.3	152	NA	NA	ND
MW-57D	Off of SEDA property	0.83	10.36	535	9.12	-79.8	36.2	0.23	0.094	7.5
MW-58D	Off of SEDA property	0.59	9.89	554	9.24	-96.0	214	NA	NA	11.0
MW-59	South of West Smith Farm Road	2.07	6.21	1164	6.95	79.2	5	0.11	0.025	0.5
MW-60	South of West Smith Farm Road	0.7	6.80	665	7.13	13.6	1.5	NA	NA	1.3

ND = Not Detected  
 NA = Not Available



Table 6-6  
 Round 2 Groundwater Monitoring-January 2000 Indicator Parameters and Field Measurements  
 Ash Landfill Feasibility Memorandum  
 Seneca Army Depot Activity

Well ID	Location	Ethane (ug/l)	Ethene (ug/l)	TOC (mg/l)	Nitrate/Nitrite (mg/l)	Tot. Alkalinity (mg/l CaCO3)	Sulfate (mg/l)	Chloride (mg/l)	Hardness (CaCO3)	Hydrogen (nM/l)	Hydrogen (ug/l)
	Optimum:			>20 mg/L	<1 mg/L	>2 x background	<20 mg/L	>2 x background		>1 nM	
	Comments:	daughter product	daughter product					daughter product			
PT-10	East of impact area	0.03	0.03	NA	NA	NA	NA	NA	NA	0.5	1.008E-03
PT-11	South of West Smith Farm Road	ND	ND	NA	NA	NA	NA	NA	NA	ND	NA
PT-12A	Plume	0.34	0.21	2.7	0.02	356	506.0	92.0	708	ND	NA
PT-15	South of West Smith Farm Road	0.03	ND	1.3	0.11	230	48.9	8.0	265	ND	NA
PT-16	North of impact area	ND	ND	1.3	<0.01	248	129.0	9.0	285	0.8	1.613E-03
PT-16Dup	North of impact area	ND	ND	NA	NA	NA	NA	NA	NA	ND	ND
PT-17	Plume	0.03	ND	2.6	0.02	290	144.0	10.0	308	2.3	0.005
PT-18	Plume	ND	0.02	6.9	0.03	520	570.0	27.0	935	7.7	0.016
PT-19	South of West Smith Farm Road	ND	ND	NA	NA	NA	NA	NA	NA	0.7	0.001
PT-20	Plume	0.01	ND	2.6	0.03	302	261.0	20.0	480	8.2	0.017
PT-21A	Plume	2.39	ND	2.2	0.02	268	238.0	117.0	510	ND	NA
PT-22	Plume	0.01	ND	2.1	0.06	302	333.0	49.0	602	5.4	0.011
PT-23	North of impact area	ND	ND	1.3	0.01	240	161.0	9.0	288	1.4	0.003
PT-24	Plume	1.56	0.45	2	<0.01	84	159	28	252	5.2	0.010
PT-25	South of West Smith Farm Road	ND	ND	NA	NA	NA	NA	NA	NA	4.2	0.008
PT-26	Off of SEDA property	ND	ND	1.0	0.19	310	80.5	12.0	352	4.4	0.009
MW-27	North of impact area	ND	ND	1.6	0.10	246	45.6	9.0	252	ND	NA
MW-28	Plume	0.01	ND	2.2	0.07	278	74.2	11.0	348	4.9	0.010
MW-29	Plume	ND	ND	2.3	0.03	312	143.0	24.0	436	3.4	0.007
MW-30	South of West Smith Farm Road	ND	ND	NA	NA	NA	NA	NA	NA	4.4	0.009
MW-30Dup	South of West Smith Farm Road	ND	ND	NA	NA	NA	NA	NA	NA	ND	NA
MW-31	South of West Smith Farm Road	ND	ND	NA	NA	NA	NA	NA	NA	4.7	0.009
MW-32	Plume	ND	ND	NA	NA	NA	NA	NA	NA	3.5	0.007
MW-33	South of West Smith Farm Road	0.02	ND	NA	NA	NA	NA	NA	NA	3.8	0.008
MW-34	Off of Ash Landfill site	ND	ND	NA	NA	NA	NA	NA	NA	9.4	0.019
MW-35D	Off of SEDA property	0.03	0.07	1.2	0.26	252	32.8	12.0	60	1.6	0.003

Table 6-6  
 Round 2 Groundwater Monitoring-January 2000 Indicator Parameters and Field Measurements  
 Ash Landfill Feasibility Memorandum  
 Seneca Army Depot Activity

Well ID	Location	Ethane (ug/l)	Ethene (ug/l)	TOC (mg/l)	Nitrate/Nitrite (mg/l)	Tot. Alkalinity (mg/l CaCO3)	Sulfate (mg/l)	Chloride (mg/l)	Hardness (CaCO3)	Hydrogen (nM/l)	Hydrogen (ug/l)
	Optimum:			>20 mg/L	<1 mg/L	>2 x background	<20 mg/L	>2 x background		>1 nM	
	Comments:	daughter product	daughter product					daughter product			
MW-36	Off of SEDA property	ND	ND	2.4	0.44	256	63.5	16.0	300	0.9	0.002
MW-37	North of impact area	ND	ND	1.1	0.10	248	151.0	6.0	280	0.9	0.002
MW-38D	North of impact area	0.02	ND	1.3	0.04	256	135.0	11.0	278	1.1	0.002
MW-39	NE of impact area	ND	ND	NA	NA	NA	NA	NA	NA	0.7	0.001
MW-40	East pf impact area, ND	ND	ND	NA	NA	NA	NA	NA	NA	0.8	0.002
MW-41D	Upgradient of Ash Landfill site	0.03	ND	NA	NA	NA	NA	NA	NA	1.2	0.002
MW-42D	Upgradient of Ash Landfill site	0.03	0.02	NA	NA	NA	NA	NA	NA	ND	NA
MW-43	East impact area	ND	ND	NA	NA	NA	NA	NA	NA	0.7	0.001
MW-44A	Plume	0.26	1.27	6.1	0.06	290	693.0	252.0	1090	ND	NA
MW-45	Plume	ND	ND	NA	NA	NA	NA	NA	NA	3.1	0.006
MW-46	Plume	0.09	ND	NA	NA	NA	NA	NA	NA	1.3	0.003
MW-47	Off of SEDA property	ND	ND	NA	NA	NA	NA	NA	NA	ND	NA
MW-48	Plume	ND	ND	NA	NA	NA	NA	NA	NA	0.6	0.001
MW-49D	Plume	0.02	0.04	1.5	0.24	246	50.5	21.0	326	6.7	0.014
MW-50D	Plume	0.01	0.03	0.6	0.10	222	31.1	13.0	225	1.5	0.003
MW-51D	Off of SEDA property	0.01	ND	1.2	2.80	224	57.8	19.0	250	8.8	0.018
MW-52D	Off of SEDA property	0.02	0.11	0.7	0.24	200	47.1	2.0	23	ND	NA
MW-53	Plume	0.01	ND	2.3	0.14	282	130.0	24.0	370	3.2	0.006
MW-53Dup	Plume	ND	ND	NA	NA	NA	NA	NA	NA	ND	NA
MW-54D	Plume	0.01	ND	0.7	0.08	238	57.1	42.0	292	4.9	0.010
MW-55D	Plume	0.02	0.08	1.3	0.15	240	32.9	2.0	11	2.8	0.006
MW-56	250 ft West of boundary of SEDA	0.02	ND	2.3	1.89	190	88.9	23.0	305	1.1	0.002
MW-57D	Off of SEDA property	0.02	0.02	<0.5	0.12	252	43.8	6.0	11	2.3	0.005
MW-58D	Off of SEDA property	0.02	0.02	<0.5	0.04	266	55.0	4.0	20	4.8	0.010
MW-59	South of West Smith Farm Road	ND	ND	NA	NA	NA	NA	NA	NA	4.3	8.668E-03
MW-60	South of West Smith Farm Road	ND	ND	NA	NA	NA	NA	NA	NA	1.2	2.419E-03

ND = Not Detected  
 NA = Not Available

Table 7-1  
 Summary of Sub-Alternatives of Alternative 3a  
 Ash Landfill Feasibility Memorandum  
 Seneca Army Depot Activity

	Alternative 1	Alternative 2
<b>Description</b>	One Reactive Wall Downgradient of Existing Boundary Wall and Natural Attenuation of Plume Upgradient of Boundary Wall	One Reactive Wall Downgradient of Boundary Wall and Two Reactive Walls Upgradient of the Boundary Wall with Vegetable Oil Addition Upgradient of Source Wall
<b>Total Number of Treatment Walls</b>	2	4
<b>Wall Descriptions</b>	<p>1 Boundary wall (existing) <i>(1.2' thick, 6-8' deep, 645' long, 50% iron)</i></p> <p>2 Compliance wall 100 ft west of boundary wall <i>(2.1' thick, 8' deep, 645' long, 100% iron)</i></p> <p>3</p> <p>4</p>	<p>Boundary wall (existing) <i>(1.2' thick, 6-8' deep, 645' long, 50% iron)</i></p> <p>Compliance wall 100 ft west of boundary wall <i>(2.1' thick, 8' deep, 645' long, 100% iron)</i></p> <p>Middle wall just east of West Patrol Road <i>(1' thick, 9' deep, 700' long, 100% iron)</i></p> <p>Source wall about 600 ft east of boundary wall <i>(2' thick, 11' deep, 700' long, 100% iron)</i></p>
<b>Additional Treatment</b>	None	Application of vegetable oil as a carbon source for microbes in the zone upgradient of source wall - yields hydrogen (electron donor) for reductive dechlorination
<b>New Monitoring Wells</b>	7	13
<b>Monitoring Program</b>	<p><i>1st Year</i> Sample 4 wells two times to monitor performance of the compliance wall.</p> <p><i>Every Year</i> Sample 8 wells and measure GW elevation in 67 wells, in order to monitor performance of compliance wall and to monitor possible off-site migration of plume</p> <p><i>Every 5 Years</i> Sample 60 wells on site for VOC's in order to monitor extent of chlorinated ethenes plume, test monitoring wells in or around walls for inorganics as well to monitor possible fouling of iron in walls.</p>	<p><i>Sample 11 wells two times to monitor performance of newly installed walls.</i></p> <p><i>Sample 8 wells and measure GW elevation in 73 wells, in order to monitor performance of compliance wall, and to monitor possible off-site migration of plume</i></p> <p><i>Sample 66 wells on site for VOC's in order to monitor extent of chlorinated ethenes plume, test monitoring wells in or around walls for inorganics as well to monitor possible fouling of iron in walls.</i></p>
<b>Operation and Maintenance</b>	Boundary and compliance walls	Boundary, compliance, middle and source walls
<b>Approximate Time of Remediation</b>	60 years	15 years

Notes:

See **Figure 7-1** for location of proposed walls

**Appendix G** has detailed cost calculations

Table 7-2  
Pre-Construction and Groundwater Monitoring Program for Sub-Alternative 1 of Alternative 3a  
Ash Landfill Feasibility Memorandum  
Seneca Army Depot Activity

Monitoring Well					Preconstruction		First Year				Every Year		Every 5 Years			
ID	Type	Status	Location	Purpose	Slug Testing	VOC	Inorganics	VOC	Methane, ethane, ethene	H <sub>2</sub>	VOC	Water level	Inorganics	VOC	Methane, ethane, ethene	H <sub>2</sub>
					# of times	# of times (type of analysis)	# of times	# of times (type of analysis)	# of times	# of times	# of times (type of analysis)	# of times	# of times	# of times	# of times (type of analysis)	# of times
PT-10	Bedrock	E	East of impact area	Plume monitoring								1				
PT-11	Overburden	E	South of West Smith Farm Road	Plume monitoring								1		1(CLP)		
PT-12A	Overburden	E	Upgradient side of SW	Plume monitoring	1							1		1(CLP modified)		
PT-15	Overburden	E	South of West Smith Farm Road	Plume monitoring								1		1(CLP modified)		
PT-16	Overburden	E	North of impact area	Plume monitoring								1		1(CLP modified)		
PT-17	Overburden	E	Plume	Plume monitoring								1		1(CLP)		
PT-18	Overburden	E	Plume	Plume monitoring								1		1(CLP)		
PT-19	Overburden	E	Upgradient side of SW	Plume monitoring	1							1		1(CLP modified)		
PT-20	Overburden	E	Upgradient side of MW	Plume monitoring	1							1		1(CLP modified)		
PT-21A	Overburden	E	Plume	Plume monitoring								1		1(CLP)		
PT-22	Overburden	E	Upgradient side of MW	Plume monitoring	1							1		1(CLP)		
PT-23	Overburden	E	North of impact area	Plume monitoring								1		1(CLP modified)		
PT-24	Overburden	E	Plume	Plume monitoring								1		1(CLP)		
PT-25	Overburden	E	South of West Smith Farm Road	Plume monitoring								1		1(CLP modified)		
PT-26	Overburden	E	Off of SEDA property	Plume monitoring								1		1(CLP modified)		
MW-27	Overburden	E	North of impact area	Plume monitoring								1		1(CLP modified)		
MW-28	Overburden	E	Plume	Plume monitoring								1		1(CLP modified)		
MW-29	Overburden	E	Plume	Plume monitoring								1		1(CLP modified)		
MW-30	Overburden	E	South of West Smith Farm Road	Plume monitoring								1		1(CLP)		
MW-31	Overburden	E	South of West Smith Farm Road	Plume monitoring								1		1(CLP)		
MW-32	Overburden	E	Upgradient side of MW	Plume monitoring	1							1		1(CLP)		
MW-33	Overburden	E	South of West Smith Farm Road	Plume monitoring								1		1(CLP)		
MW-34	Overburden	E	Off of Ash Landfill site	Plume monitoring								1				
MW-35D	Bedrock	E	Off of SEDA property	Plume monitoring								1		1(CLP modified)		
MW-36	Overburden	E	Off of SEDA property	Plume monitoring								1		1(CLP modified)		

Table 7-2  
 Pre-Construction and Groundwater Monitoring Program for Sub-Alternative 1 of Alternative 3a  
 Ash Landfill Feasibility Memorandum  
 Seneca Army Depot Activity

Monitoring Well					Preconstruction		First Year				Every Year		Every 5 Years			
ID	Type	Status	Location	Purpose	Slug Testing	VOC	Inorganics	VOC	Methane, ethane, ethene	H <sub>2</sub>	VOC	Water level	Inorganics	VOC	Methane, ethane, ethene	H <sub>2</sub>
					# of times	# of times (type of analysis)	# of times	# of times (type of analysis)	# of times	# of times	# of times (type of analysis)	# of times	# of times	# of times (type of analysis)	# of times	# of times
MW-37	Overburden	E	North of impact area	Plume monitoring								1				
MW-38D	Bedrock	E	North of impact area	Plume monitoring								1		1(CLP modified)		
MW-39	Overburden	E	NE of impact area	Plume monitoring								1		1(CLP modified)		
MW-40	Overburden	E	East of impact area	Plume monitoring								1		1(CLP)		
MW-41D	Bedrock	E	Upgradient of Ash Landfill site	Plume monitoring								1				
MW-42D	Bedrock	E	Upgradient of Ash Landfill site	Plume monitoring								1				
MW-43	Overburden	E	East of impact area	Plume monitoring								1		1(CLP)		
MW-44A	Overburden	E	Plume	Plume monitoring								1		1(CLP modified)		
MW-45	Overburden	E	Upgradient side of SW	Plume monitoring	1							1		1(CLP)		
MW-46	Overburden	E	Upgradient side of SW	Plume monitoring	1							1		1(CLP)		
MW-47	Overburden	E	Off of SEDA property	Plume monitoring								1		1(CLP modified)		
MW-48	Overburden	E	Upgradient side of MW	Plume monitoring	1							1		1(CLP)		
MW-49D	Bedrock	E	Plume	Plume monitoring								1		1(CLP modified)		
MW-50D	Bedrock	E	Plume	Plume monitoring								1		1(CLP modified)		
MW-51D	Bedrock	E	Off of SEDA property	Plume monitoring								1		1(CLP modified)		
MW-52D	Bedrock	E	Off of SEDA property	Plume monitoring								1		1(CLP modified)		
MW-53	Overburden	E	Plume	Plume monitoring								1		1(CLP modified)		
MW-54D	Bedrock	E	Plume	Plume monitoring								1		1(CLP)		
MW-55D	Bedrock	E	Plume	Plume monitoring								1		1(CLP)		
MW-56	Overburden	E	250 ft West of boundary of SEDA	Sentry well	1						1(524.2)	1		1(CLP modified)		
MW-57D	Bedrock	E	Off of SEDA property	Plume monitoring								1		1(CLP modified)		
MW-58D	Bedrock	E	Off of SEDA property	Plume monitoring								1		1(CLP modified)		
MW-59	Overburden	E	South of West Smith Farm Road	Plume monitoring								1				
MW-60	Overburden	E	South of West Smith Farm Road	Plume monitoring								1				
MW-61	Overburden	N	10 ft West of railroad tracks	design of CW, plume monitoring	1	1(524.2)	2	2(524.2)	2		1(524.2)	1	1	1(CLP)	1	

Table 7-2  
Pre-Construction and Groundwater Monitoring Program for Sub-Alternative 1 of Alternative 3a  
Ash Landfill Feasibility Memorandum  
Seneca Army Depot Activity

Monitoring Well					Preconstruction		First Year				Every Year		Every 5 Years			
ID	Type	Status	Location	Purpose	Slug Testing	VOC	Inorganics	VOC	Methane, ethane, ethene	H <sub>2</sub>	VOC	Water level	Inorganics	VOC	Methane, ethane, ethene	H <sub>2</sub>
					# of times	# of times (type of analysis)	# of times	# of times (type of analysis)	# of times	# of times	# of times (type of analysis)	# of times	# of times	# of times	# of times (type of analysis)	# of times
MW-62	Overburden	N	10 ft West of railroad tracks	design of CW, plume monitoring	1	1(524.2)	2	2(524.2)	2		1(524.2)	1	1	1(CLP modified)	1	
MW-63	Overburden	N	10 ft West of railroad tracks	design of CW, plume monitoring	1	1(524.2)	2	2(524.2)	2		1(524.2)	1	1	1(CLP modified)	1	
MW-64	Overburden	N	Halfway between RR tracks and MW-56	design of CW, plume monitoring	1	1(524.2)	2	2(524.2)	2		1(524.2)	1	1	1(CLP)	1	
MW-65	Overburden	N	Between MW-56 and Farmhouse	Trigger well							1(524.2)	1		1(524.2)		
MW-66	Overburden	N	At Farmhouse	Compliance well							1(524.2)	1		1(CLP)		
MWT-1	Overburden	E	Plume	BW performance, plume monitoring								1	1	1(524.2)	1	
MWT-2	Overburden	E	Plume	BW performance								1	1	1(524.2)	1	1
MWT-3	Overburden	E	Plume	BW performance, plume monitoring								1	1	1(524.2)	1	
MWT-4	Overburden	E	Plume	BW performance, plume monitoring								1	1	1(524.2)	1	
MWT-5	Overburden	E	Plume	BW performance								1	1	1(524.2)	1	1
MWT-6	Overburden	E	Plume	BW performance, plume monitoring								1	1	1(CLP modified)	1	
MWT-7	Overburden	E	Plume	BW performance, plume monitoring								1	1	1(CLP)	1	
MWT-8	Overburden	E	Plume	BW performance								1	1	1(CLP modified)	1	1
MWT-9	Overburden	E	Plume	BW performance, plume monitoring								1	1	1(CLP)	1	
MWT-10	Overburden	E	North of impact area	BW performance, plume monitoring								1	1	1(524.2)	1	
MWT-11	Overburden	E	South of impact area	BW performance, plume monitoring								1	1	1(CLP)	1	
MWT-12	Overburden	N	In CW	CW performance			2	2(524.2)	2	2	1(524.2)	1	1	1(524.2)	1	1
<b>Total Samples</b>					<b>13</b>	<b>4</b>	<b>10</b>	<b>10</b>	<b>10</b>	<b>2</b>	<b>8</b>	<b>67</b>	<b>16</b>	<b>60</b>	<b>16</b>	<b>4</b>
<b>Total QA/QC</b>						<b>2</b>	<b>10</b>	<b>10</b>	<b>10</b>	<b>0</b>	<b>5</b>	<b>0</b>	<b>5</b>	<b>17</b>	<b>9</b>	<b>0</b>
<b>Total</b>						<b>4</b>	<b>20</b>	<b>20</b>	<b>20</b>	<b>2</b>	<b>13</b>	<b>67</b>	<b>21</b>	<b>77</b>	<b>25</b>	<b>4</b>

**Notes:**

H<sub>2</sub> = hydrogen

SW = source well, MW = middle well, CW = compliance wall, BW = boundary wall

If VOC concentrations in MW-64 meet GA standard, compliance wall will be placed between monitoring wells along the railroad tracks and MW-64. If VOC concentrations in MW-64 do not meet

GA standard, compliance wall will be placed between and MW-56 and MW-64. MW-64 will be left in place and used during the performance evaluation of the compliance wall.

Inorganic analysis includes analysis of sulfate, alkalinity, nitrate, total dissolved solids, phosphate, chloride, calcium, magnesium, potassium, sodium, iron, manganese, and pH. pH, conductivity, temperature, turbidity, redox potential, dissolved oxygen, and ferrous iron, are measured in field in monitoring wells from which inorganic samples are collected.

Table 7-3  
 Pre-Construction and Groundwater Monitoring Program For Sub-Alternative 2 of Alternative 3a  
 Ash Landfill Feasibility Memorandum  
 Seneca Army Depot Activity

Monitoring Well					Preconstruction		First Year				Every Year		Every 5 Years			
ID	Type	Status	Location	Purpose	Slug Test	VOC	Inorganics	VOC	Methane, ethane, ethene	H <sub>2</sub>	VOC	Water level	Inorganics	VOC	Methane, ethane, ethene	H <sub>2</sub>
					# of times	# of times (type of analysis)	# of times	# of times (type of analysis)	# of times	# of times	# of times (type of analysis)	# of times	# of times	# of times (type of analysis)	# of times	# of times (type of analysis)
PT-10	Bedrock	E	East of impact area	Plume monitoring							1					
PT-11	Overburden	E	South of West Smith Farm Road	Plume monitoring							1			1(CLP modified)		
PT-12A	Overburden	E	Upgradient side of SW	Design of SW, plume monitoring	1						1			1(CLP)		
PT-15	Overburden	E	South of West Smith Farm Road	Plume monitoring							1			1(CLP modified)		
PT-16	Overburden	E	North of impact area	Plume monitoring							1			1(CLP modified)		
PT-17	Overburden	E	Plume	Plume monitoring							1			1(CLP)		
PT-18	Overburden	E	Plume	Plume monitoring							1			1(CLP)		
PT-19	Overburden	E	Upgradient side of SW	Design of SW, plume monitoring	1						1			1(CLP modified)		
PT-20	Overburden	E	Upgradient side of MW	Design of SW, plume monitoring	1						1			1(CLP)		
PT-21A	Overburden	E	Plume	plume monitoring							1			1(CLP)		
PT-22	Overburden	E	Upgradient side of MW	Design of MW, plume monitoring	1						1			1(CLP)		
PT-23	Overburden	E	North of impact area	Plume monitoring							1			1(CLP modified)		
PT-24	Overburden	E	Plume	Plume monitoring							1			1(CLP)		
PT-25	Overburden	E	South of West Smith Farm Road	Plume monitoring							1			1(CLP modified)		
PT-26	Overburden	E	Off of SEDA property	Plume monitoring							1			1(CLP modified)		
MW-27	Overburden	E	North of impact area	Plume monitoring							1			1(CLP modified)		
MW-28	Overburden	E	Plume	Plume monitoring							1			1(CLP)		
MW-29	Overburden	E	Plume	Plume monitoring							1			1(CLP)		
MW-30	Overburden	E	South of West Smith Farm Road	Plume monitoring							1			1(CLP modified)		
MW-31	Overburden	E	South of West Smith Farm Road	Plume monitoring							1			1(CLP modified)		
MW-32	Overburden	E	Upgradient side of MW	Design of MW, plume monitoring	1						1			1(CLP modified)		
MW-33	Overburden	E	South of West Smith Farm Road	Plume monitoring							1			1(CLP modified)		
MW-34	Overburden	E	Off of Ash Landfill site	Plume monitoring							1					
MW-35D	Bedrock	E	Downgradient of SEDA property	Plume monitoring							1			1(CLP modified)		
MW-36	Overburden	E	Downgradient of SEDA property	Plume monitoring							1			1(CLP modified)		

Table 7-3  
Pre-Construction and Groundwater Monitoring Program For Sub-Alternative 2 of Alternative 3a  
Ash Landfill Feasibility Memorandum  
Seneca Army Depot Activity

Monitoring Well					Preconstruction		First Year				Every Year		Every 5 Years			
ID	Type	Status	Location	Purpose	Slug Test	VOC	Inorganics	VOC	Methane, ethane, ethene	H <sub>2</sub>	VOC	Water level	Inorganics	VOC	Methane, ethane, ethene	H <sub>2</sub>
					# of times	# of times (type of analysis)	# of times	# of times (type of analysis)	# of times	# of times	# of times (type of analysis)	# of times	# of times	# of times (type of analysis)	# of times	# of times
MW-37	Overburden	E	North of impact area	Plume monitoring								1				
MW-38D	Bedrock	E	North of impact area	Plume monitoring								1		1(CLP modified)		
MW-39	Overburden	E	Northeast of impact area	Plume monitoring								1		1(CLP modified)		
MW-40	Overburden	E	East of impact area	Plume monitoring								1		1(CLP modified)		
MW-41D	Bedrock	E	Upgradient of Ash Landfill site	Plume monitoring								1				
MW-42D	Bedrock	E	Upgradient of Ash Landfill site	Plume monitoring								1				
MW-43	Overburden	E	East of impact area	Plume monitoring								1		1(CLP modified)		
MW-44A	Overburden	E	Plume	Plume monitoring								1		1(CLP)		
MW-45	Overburden	E	Upgradient side of SW	Design of SW, plume monitoring	1							1		1(CLP modified)		
MW-46	Overburden	E	Upgradient side of SW	Design of SW, plume monitoring	1							1		1(CLP)		
MW-47	Overburden	E	Off of SEDA property	Plume monitoring								1		1(CLP modified)		
MW-48	Overburden	E	Upgradient side of MW	Design of MW, plume monitoring	1							1		1(CLP modified)		
MW-49D	Bedrock	E	Plume	Plume monitoring								1		1(CLP)		
MW-50D	Bedrock	E	Plume	Plume monitoring								1		1(CLP)		
MW-51D	Bedrock	E	Off of SEDA property	Plume monitoring								1		1(CLP modified)		
MW-52D	Bedrock	E	Off of SEDA property	Plume monitoring								1		1(CLP modified)		
MW-53	Overburden	E	Plume	Plume monitoring								1		1(CLP)		
MW-54D	Bedrock	E	Plume	Plume monitoring								1		1(CLP)		
MW-55D	Bedrock	E	Plume	Plume monitoring								1		1(CLP)		
MW-56	Overburden	E	250 ft West of boundary of SEDA	Sentry well	1						1(524.2)	1		1(524.2)		
MW-57D	Bedrock	E	Downgradient of SEDA property	Plume monitoring								1		1(CLP modified)		
MW-58D	Bedrock	E	Downgradient of SEDA property	Plume monitoring								1		1(CLP modified)		
MW-59	Overburden	E	South of West Smith Farm Road	Plume monitoring								1				
MW-60	Overburden	E	South of West Smith Farm Road	Plume monitoring								1				
MW-61	Overburden	N	10 ft West of railroad tracks	Design of CW, plume monitoring	1	1(524.2)	2	2(524.2)	2		1(524.2)	1	1	1(524.2)	1	



Table 7-3  
Pre-Construction and Groundwater Monitoring Program For Sub-Alternative 2 of Alternative 3a  
Ash Landfill Feasibility Memorandum  
Seneca Army Depot Activity

Monitoring Well					Preconstruction		First Year				Every Year		Every 5 Years			
ID	Type	Status	Location	Purpose	Slug Test	VOC	Inorganics	VOC	Methane, ethane, ethene	H <sub>2</sub>	VOC	Water level	Inorganics	VOC	Methane, ethane, ethene	H <sub>2</sub>
					# of times	# of times (type of analysis)	# of times	# of times (type of analysis)	# of times	# of times	# of times (type of analysis)	# of times	# of times	# of times (type of analysis)	# of times	# of times (type of analysis)
MW-62	Overburden	N	10 ft West of railroad tracks	Design of CW, plume monitoring	1	1(524.2)	2	2(524.2)	2		1(524.2)	1	1	1(524.2)	1	
MW-63	Overburden	N	10 ft West of railroad tracks	Design of CW, plume monitoring	1	1(524.2)	2	2(524.2)	2		1(524.2)	1	1	1(524.2)	1	
MW-64	Overburden	N	halfway between rr tracks and MW-56	Design of CW, plume monitoring	1	1(524.2)	2	2(524.2)	2		1(524.2)	1	1	1(524.2)	1	
MW-65	Overburden	N	Between MW-56 and Farmhouse	Trigger well							1(524.2)	1		1(524.2)		
MW-66	Overburden	N	At Farmhouse	Compliance well							1(524.2)	1		1(524.2)		
MWT-1	Overburden	E	Plume	BW performance, plume monitoring								1	1	1(CLP)	1	
MWT-2	Overburden	E	Plume	BW performance								1	1	1(CLP modified)	1	1
MWT-3	Overburden	E	Plume	BW performance, plume monitoring								1	1	1(CLP)	1	
MWT-4	Overburden	E	Plume	BW performance, plume monitoring								1	1	1(CLP)	1	
MWT-5	Overburden	E	Plume	BW performance								1	1	1(CLP modified)	1	1
MWT-6	Overburden	E	Plume	BW performance, plume monitoring								1	1	1(CLP)	1	
MWT-7	Overburden	E	Plume	BW performance, plume monitoring								1	1	1(CLP)	1	
MWT-8	Overburden	E	Plume	BW performance								1	1	1(CLP modified)	1	1
MWT-9	Overburden	E	Plume	BW performance, plume monitoring								1	1	1(CLP)	1	
MWT-10	Overburden	E	North of impact area	BW performance, plume monitoring								1	1	1(CLP modified)	1	
MWT-11	Overburden	E	South of impact area	BW performance, plume monitoring								1	1	1(CLP modified)	1	
MWT-12	Overburden	N	2.5 ft upgrad. of SW	SW performance, plume monitoring	1		2	2(CLP)	2			1	1	1(CLP)	1	
MWT-13	Overburden	N	2.5 ft upgrad. of SW	SW performance, plume monitoring	1		2	2(CLP)	2			1	1	1(CLP)	1	
MWT-14	Overburden	N	in SW	SW performance, plume monitoring			2	2(CLP modified)	2	2		1	1	1(CLP modified)	1	1
MWT-15	Overburden	N	2.5 ft upgrad of MW	MW performance, plume monitoring	1		2	2(CLP)	2			1	1	1(CLP)	1	
MWT-16	Overburden	N	2.5 ft upgrad of MW	MW performance, plume monitoring	1		2	2(CLP)	2			1	1	1(CLP)	1	
MWT-17	Overburden	N	in MW	MW performance, plume monitoring			2	2(CLP modified)	2	2		1	1	1(CLP modified)	1	1
MWT-18	Overburden	N	in CW	CW performance			2	2(524.2)	2	2	1(524.2)	1	1	1(524.2)	1	1
Subtotal					17	4	22	22	22	6	8	73	22	66	22	6
Total QA/QC						2	10	10	10	0	5	0	7	17	10	0

Table 7-3  
 Pre-Construction and Groundwater Monitoring Program For Sub-Alternative 2 of Alternative 3a  
 Ash Landfill Feasibility Memorandum  
 Seneca Army Depot Activity

Monitoring Well					Preconstruction		First Year				Every Year		Every 5 Years			
ID	Type	Status	Location	Purpose	Slug Test	VOC	Inorganics	VOC	Methane, ethane, ethene	H <sub>2</sub>	VOC	Water level	Inorganics	VOC	Methane, ethane, ethene	H <sub>2</sub>
					# of times	# of times (type of analysis)	# of times	# of times (type of analysis)	# of times	# of times	# of times (type of analysis)	# of times	# of times (type of analysis)	# of times	# of times (type of analysis)	# of times
<b>Total</b>						4	32	32	32	6	13	73	29	83	32	6

**Notes:**

H<sub>2</sub> = hydrogen

SW = source wall, MW = middle wall, CW = compliance wall, BW = boundary wall

If VOC concentrations in MW-64 meet GA standard, compliance wall will be placed between monitoring wells along the railroad tracks and MW-64. If VOC concentrations in MW-64 do not meet GA standard, compliance wall will be placed between MW-56 and MW-64. MW-64 will be left in place and used during the performance evaluation of the compliance wall.

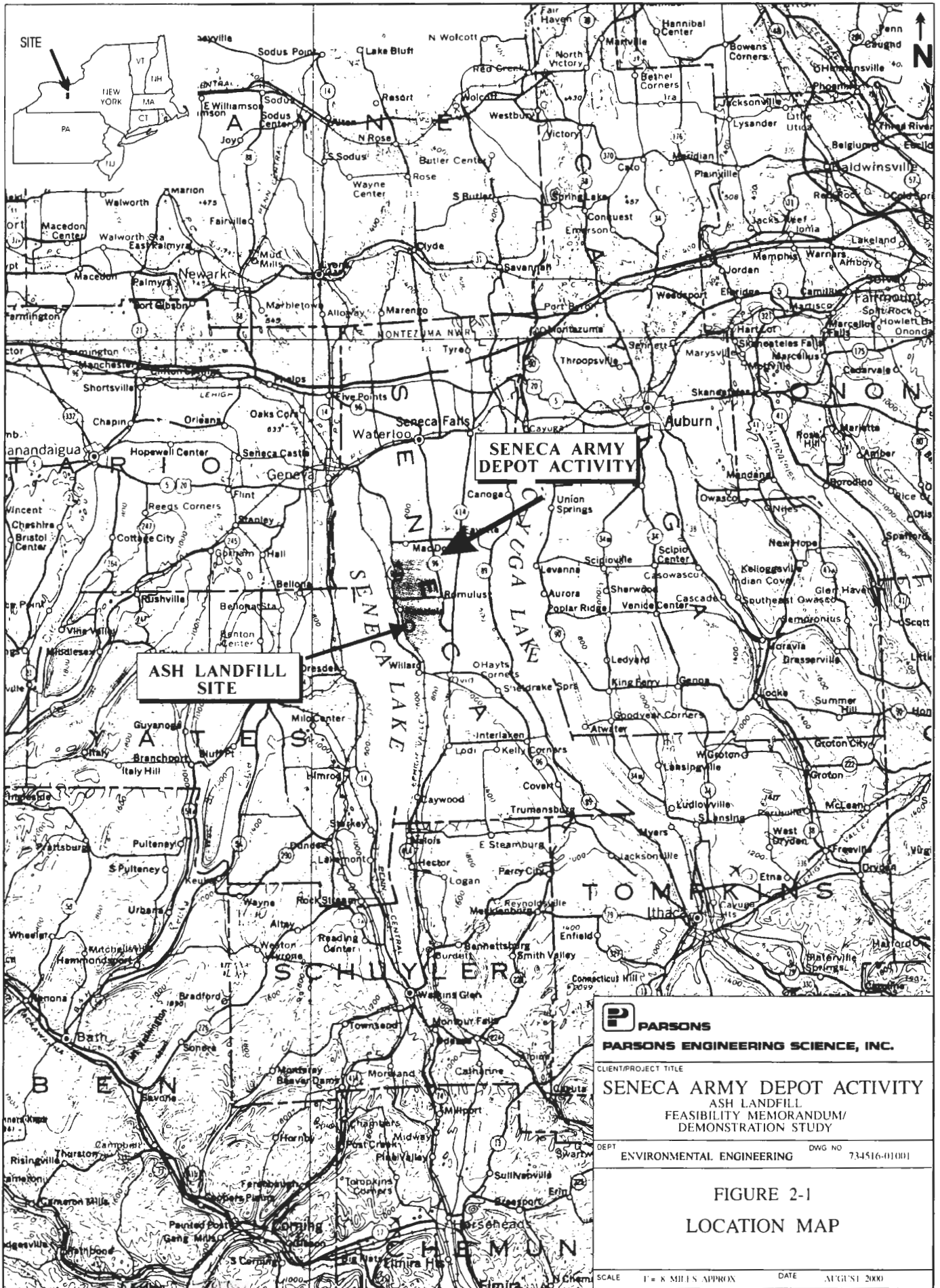
Inorganic analysis includes analysis of sulfate, alkalinity, nitrate, total dissolved solids, phosphate, chloride, calcium, magnesium, potassium, sodium, iron, manganese, and pH.


pH, conductivity, temperature, turbidity, redox potential, dissolved oxygen, and ferrous iron, are measured in field in monitoring wells from which inorganic samples are collected.

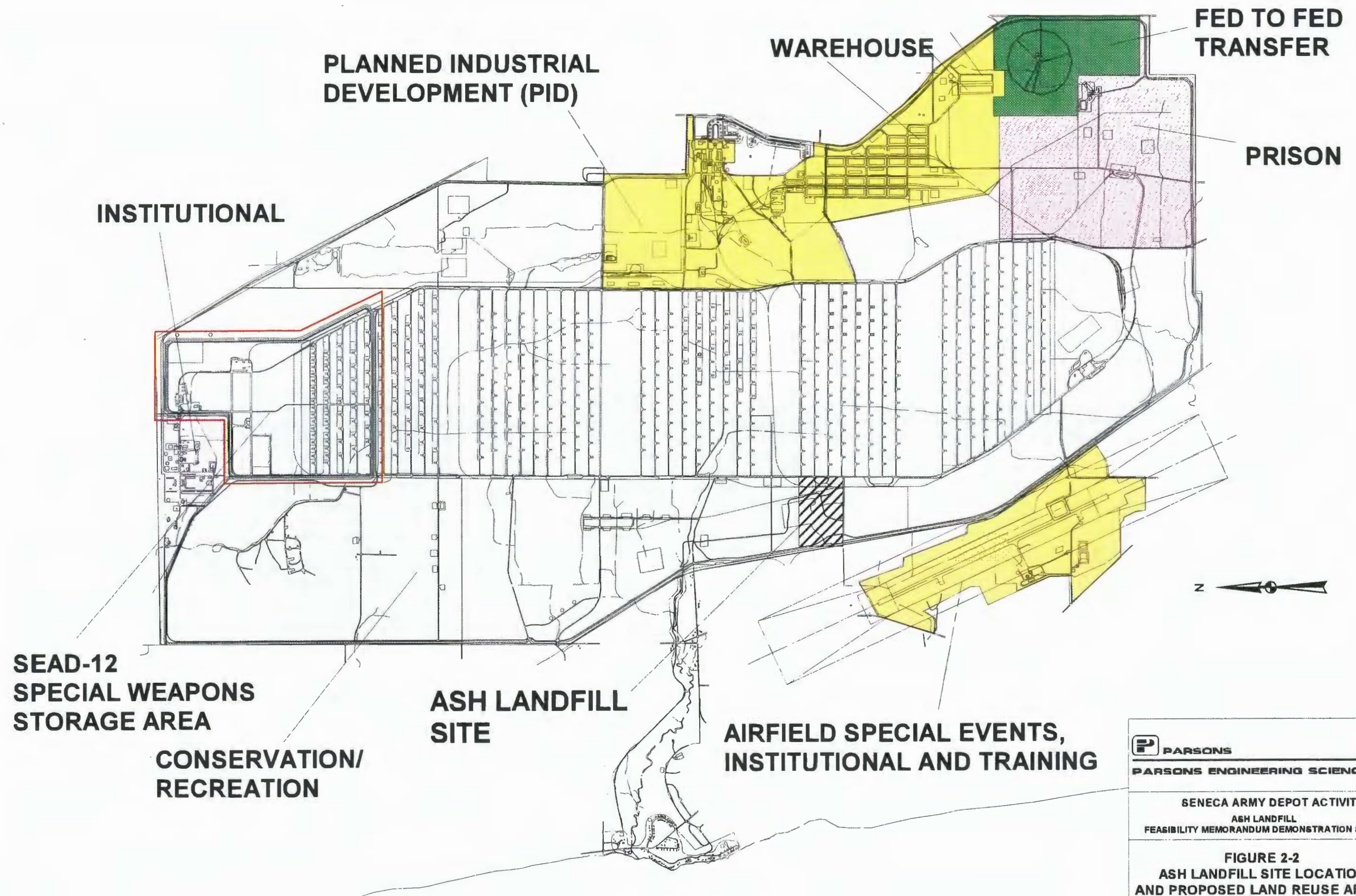
Table 7-4  
 Costs of Groundwater Treatment Alternatives at the Ash Landfill  
 Ash Landfill Feasibility Memorandum  
 Seneca Army Depot Activity

ITEM	ALTERNATIVE 1	ALTERNATIVE 2
Sub total capital	\$551,400	\$1,464,000
Contingency 20%	\$110,300	\$292,800
Engineering/oversight 20%	\$110,300	\$292,800
<b>Total capital (subtotal + contingency + engineering/oversight)</b>	<b>\$772,000</b>	<b>\$2,049,600</b>
Sub total O & M	\$56,800	\$61,600
Contingency 20%	\$11,400	\$12,300
Engineering/oversight 20%	\$11,400	\$12,300
Total O & M (subtotal + contingency + engineering/oversight)	\$79,500	\$86,200
Interest	10%	10%
Years of operation	60	15
<b>Present worth of total O &amp; M costs</b>	<b>\$792,200</b>	<b>\$655,700</b>
<b>TOTAL PRESENT WORTH COST (present worth O/M + total capital)</b>	<b>\$1,564,200</b>	<b>\$2,705,300</b>

See Appendix G for detailed costs.



 <b>PARSONS</b> <b>PARSONS ENGINEERING SCIENCE, INC.</b>	
<small>CLIENT/PROJECT TITLE</small> <b>SENECA ARMY DEPOT ACTIVITY</b> ASH LANDFILL FEASIBILITY MEMORANDUM/ DEMONSTRATION STUDY	
<small>DEPT</small> ENVIRONMENTAL ENGINEERING	<small>DWG NO</small> 734516-01001
<b>FIGURE 2-1</b> <b>LOCATION MAP</b>	
<small>SCALE</small> 1" = 8 MILES APPROX <small>DATE</small> AUGUST 2000	



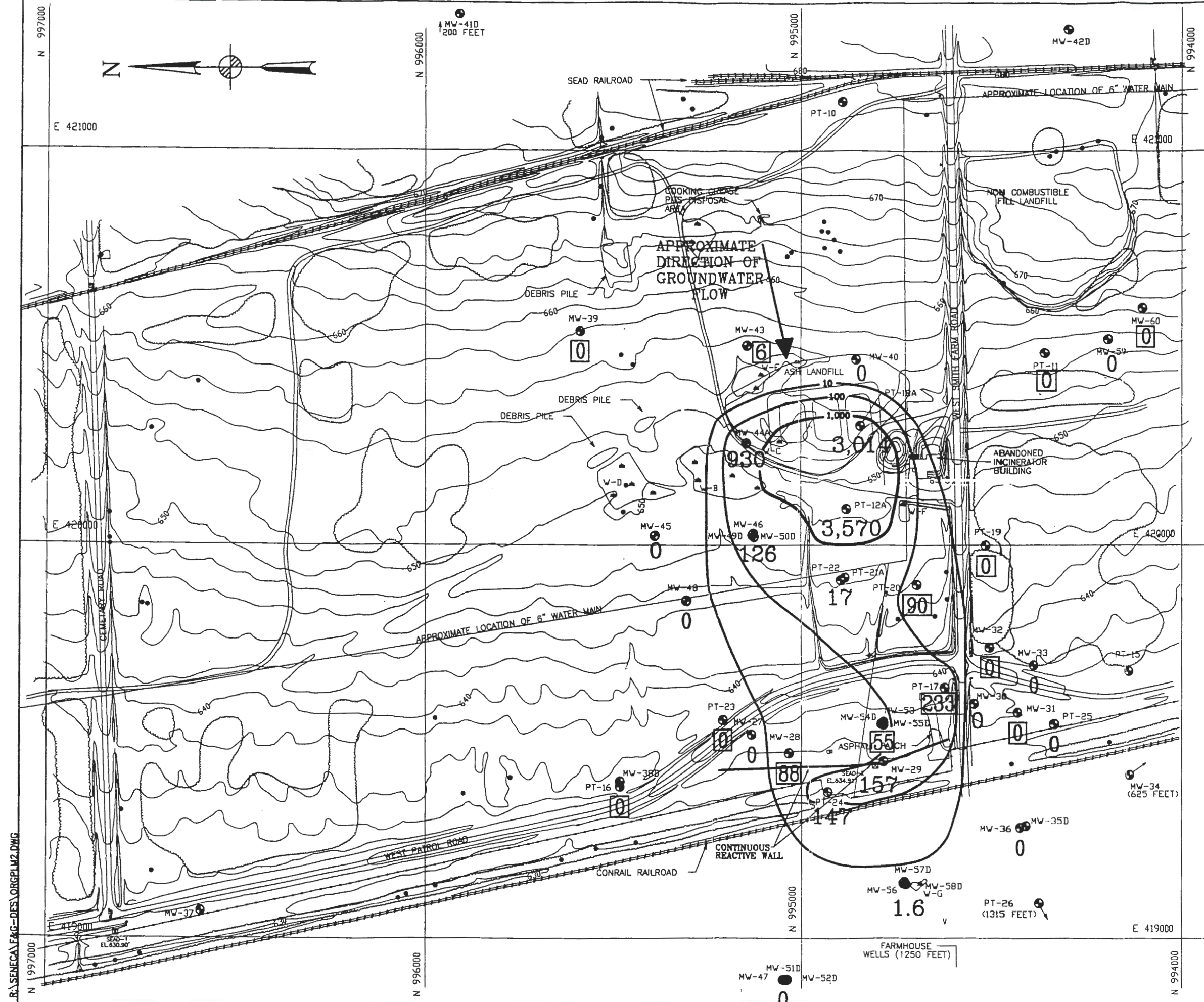
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**PARSONS ENGINEERING SCIENCE, INC.**

SENECA ARMY DEPOT ACTIVITY  
 ASH LANDFILL  
 FEASIBILITY MEMORANDUM DEMONSTRATION STUDY

**FIGURE 2-2**  
**ASH LANDFILL SITE LOCATION**  
**AND PROPOSED LAND REUSE AREAS**

APR 2000

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**LEGEND:**

- PAVED ROAD
- DIRT ROAD
- GROUND CONTOUR AND ELEVATION
- TREE
- WETLAND & DESIGNATION
- APPROXIMATE EXTENT OF FILL
- OUTLINE OF FORMER TRASH PITS (IDENTIFIED FROM AERIAL PHOTO)
- APPROXIMATE EXTENT OF DEBRIS PILE
- BRUSH
- CHAIN LINK FENCE
- UTILITY POLE
- APPROXIMATE LOCATION OF FIRE HYDRANT
- FUEL OR UNDERGROUND STORAGE TANK
- SURVEY MONUMENT
- MONITORING WELL AND DESIGNATION
- GROUNDWATER ISOCONTOUR (ug/L)
- TOTAL VOCs FROM SAMPLE COLLECTED IN JUNE 1997 DURING THE SECOND QUARTER 1997
- TOTAL VOCs FROM SAMPLE COLLECTED IN JULY 1993 DURING THE RI

**NOTE:**  
THE CONCENTRATIONS SHOWN ON THIS FIGURE ARE FOR WELLS SCREENED IN THE TILL/WEATHERED SHALE AQUIFER.

-250'      0      250'

SCALE: 1" = 250'

REV	DATE	DESCRIPTION	DRAWN	CHECKED	DES. SUPV.	RESP. ENGR.	ENV. DISCIPLINE	PROJ. MGR.
B	11/4/98	ISSUED FOR EPA REVIEW						
A	8/20/98	ISSUED FOR REVIEW						
DRAWN BY C. BROVNE DESIGN SUPV.			CHECKED BY J. TRAVERS RESP. ENGR.			MGR. OF ENGR.		
PROJECT MANAGER R. BUCHSNEAU			MGR. OF PROJECTS J. P. CHAPLICK			IN CHARGE V. D. PATTERSON		

**PARSONS ENGINEERING SCIENCE, INC.**

CLIENT/PROJECT TITLE  
**SENECA ARMY DEPOT ACTIVITY**  
ASH LANDFILL GROUNDWATER TREATABILITY STUDY  
USING ZERO VALENT IRON CONTINUOUS REACTIVE WALL

DEPT. ENVIRONMENTAL ENGINEERING      Dep. No. 728208-01004

Figure 2-3  
ASH LANDFILL SITE MAP WITH VOLATILE ORGANICS PLUME: POST-REMOVAL ACTION CONDITIONS

SCALE AS NOTED      DATE NOVEMBER 1998      REV B

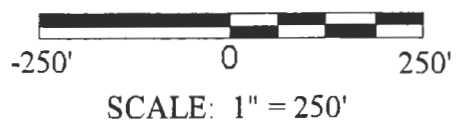
R:\SENECA\FAC-DES\ORGPLM2.DWG



**LEGEND**

- PAVED ROAD
- GROUND CONTOUR AND ELEVATION
- WETLAND & DESIGNATION
- OUTLINE OF FORMER TRASH PITS (IDENTIFIED FROM AERIAL PHOTO)
- APPROXIMATE EXTENT OF DEBRIS PILE
- BRUSH
- CHAIN LINK FENCE
- UTILITY POLE
- APPROXIMATE LOCATION OF FIRE HYDRANT
- PT-22 MONITORING WELL AND DESIGNATION
- MW-37 RAILROAD
- 6" WATER MAIN
- GROUNDWATER ISOCONTOUR (ug/L)
- 1,000
- 75
- ND NO CHLORINATED ETHENES DETECTED

NOTE:  
THE CONCENTRATIONS SHOWN ON THIS FIGURE ARE FOR WELLS SCREENED IN THE TILLED/WEATHERED SHALE AQUIFER.



**PARSONS**  
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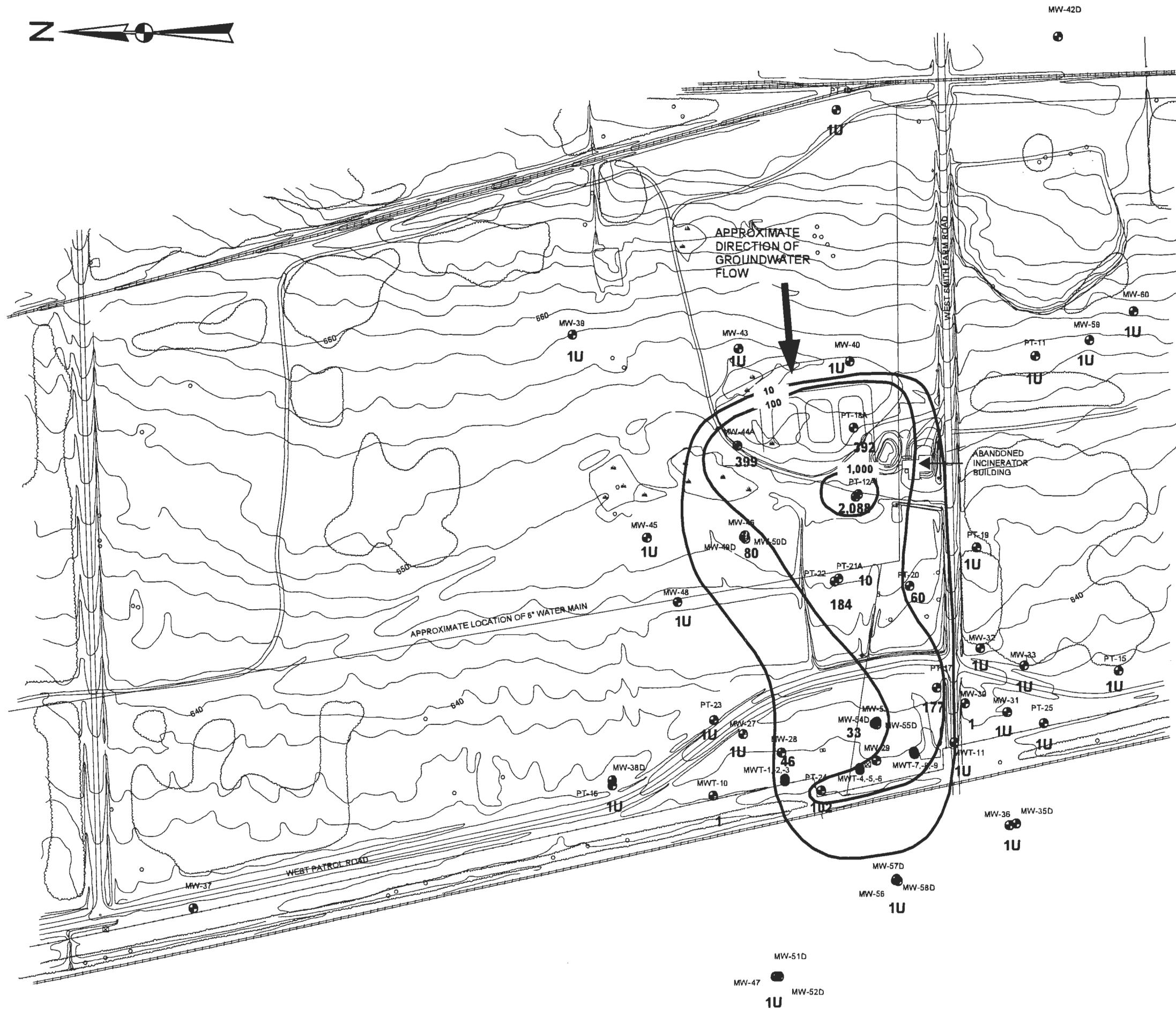
SENECA ARMY DEPOT ACTIVITY  
ASH LANDFILL GROUNDWATER FEASIBILITY  
MEMORANDUM FOR ZERO VALENT IRON  
CONTINUOUS REACTIVE WALL

ENVIRONMENTAL ENGINEERING 726209-01000

**FIGURE 2-4**  
ASH LANDFILL SITE MAP WITH  
TOTAL CHLORINATED ETHENES  
IN TILL/WEATHERED SHALE AQUIFER

SCALE 1 INCH = 250 FEET APRIL 2000

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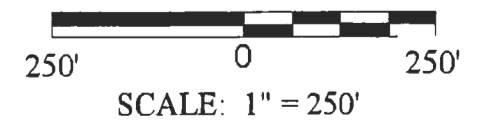


**LEGEND**

- PAVED ROAD
- GROUND CONTOUR AND ELEVATION
- WETLAND & DESIGNATION
- OUTLINE OF FORMER TRASH PITS (IDENTIFIED FROM AERIAL PHOTO)
- APPROXIMATE EXTENT OF DEBRIS PILE
- BRUSH
- CHAIN LINK FENCE
- UTILITY POLE
- APPROXIMATE LOCATION OF FIRE HYDRANT
- PT-22 MONITORING WELL AND DESIGNATION
- RAILROAD
- 6" WATER MAIN

- GROUNDWATER ISOCONTOUR (ug/L)  
1,000
- TOTAL CHLORINATED ETHENES (ug/L) FROM SAMPLES COLLECTED IN JANUARY 2000  
75
- NO CHLORINATED ETHENES DETECTED  
10U

NOTE:  
THE CONCENTRATIONS SHOWN ON THIS FIGURE ARE FOR WELLS SCREENED IN THE TILLED/WEATHERED SHALE AQUIFER.



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SENECA ARMY DEPOT ACTIVITY  
ASH LANDFILL GROUNDWATER FEASIBILITY  
MEMORANDUM FOR ZERO VALENT IRON  
CONTINUOUS REACTIVE WALL

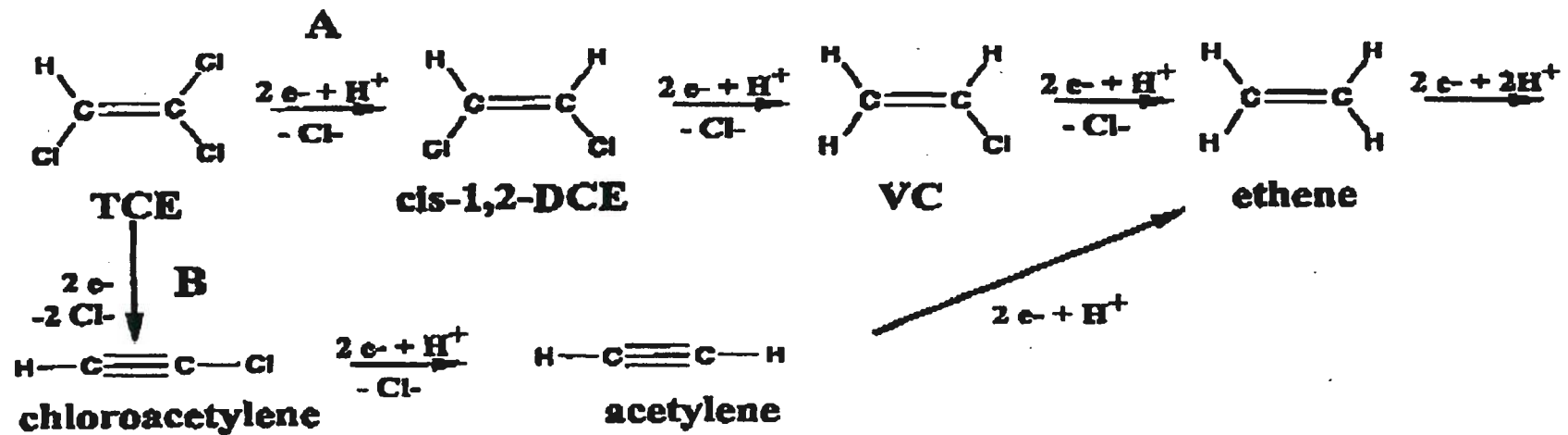
ENVIRONMENTAL ENGINEERING 7262D9-01000

**FIGURE 2-5**  
ASH LANDFILL SITE MAP WITH  
TOTAL CHLORINATED ETHENES  
IN TILLWEATHERED SHALE AQUIFER


SCALE: 1 INCH = 250 FEET APRIL 2000

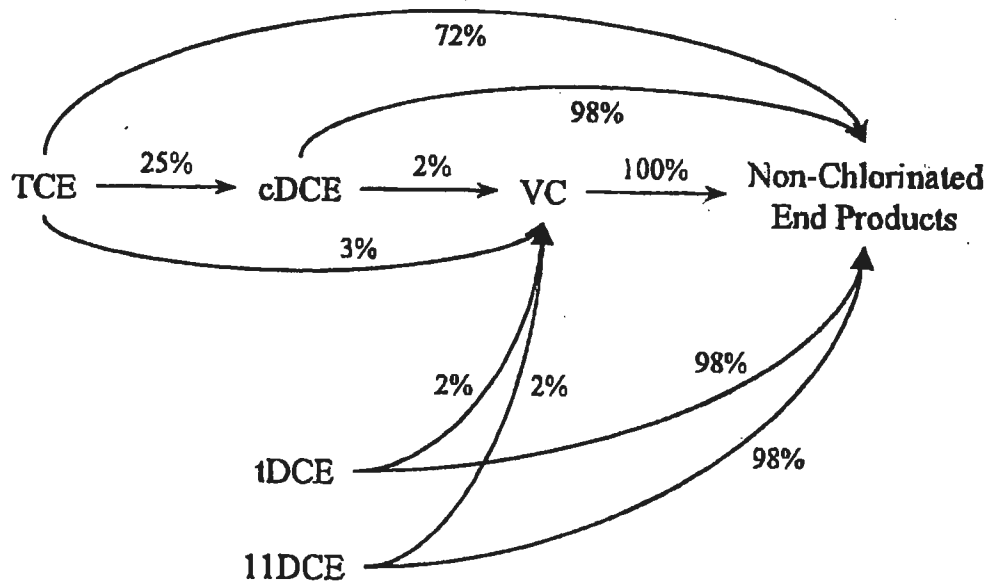
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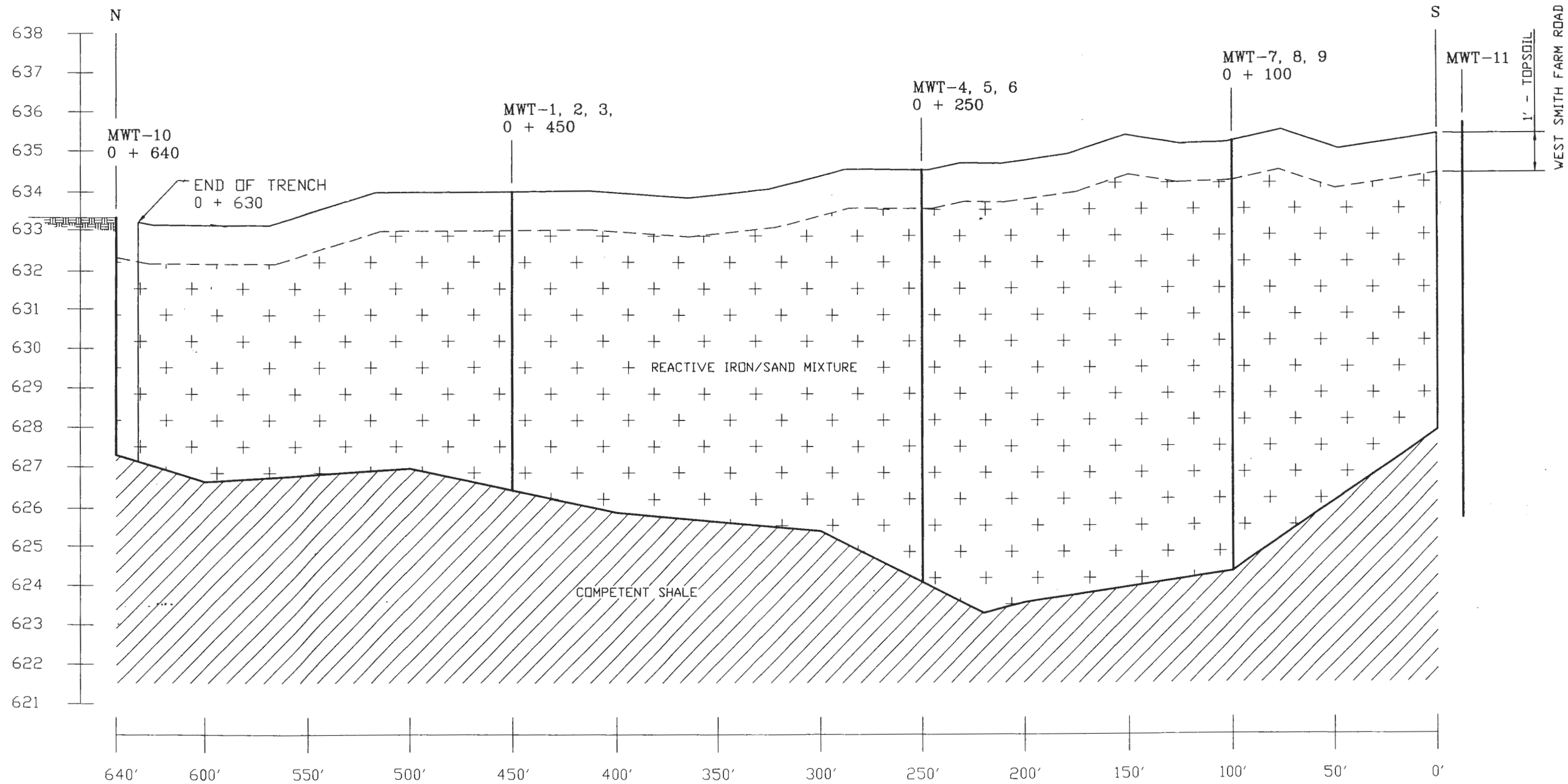


Source: EPA/600/f-97/008 July 1997

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<small>CLIENT/PROJECT TITLE</small> <b>Seneca Army Depot Activity</b> <small>Ash Landfill Groundwater Treatability Study          Using Zero Valent Iron Continuous Reactive Wall</small>	
<small>DEPT</small>	<small>DWG NO</small>
<b>FIGURE 3-1</b> <b>Reductive Dechlorination of TCE</b> <b>to Ethene and Ethane</b>	
<small>SCALE</small>	<small>DATE</small>



 <b>PARSONS</b>	
<b>PARSONS ENGINEERING SCIENCE, INC.</b>	
<small>CLIENT/PROJECT TITLE</small> <b>Seneca Army Depot Activity</b> Ash Landfill Groundwater Treatability Study Using Zero Valent Iron Continuous Reactive Wall	
<small>DEPT</small> ENVIRONMENTAL ENGINEERING	<small>DWG NO</small>
<b>FIGURE 3-2</b> <b>Typical Molar Conversions</b> <b>for Chlorinated Ethenes</b>	
<small>SCALE</small>	<small>DATE</small>
















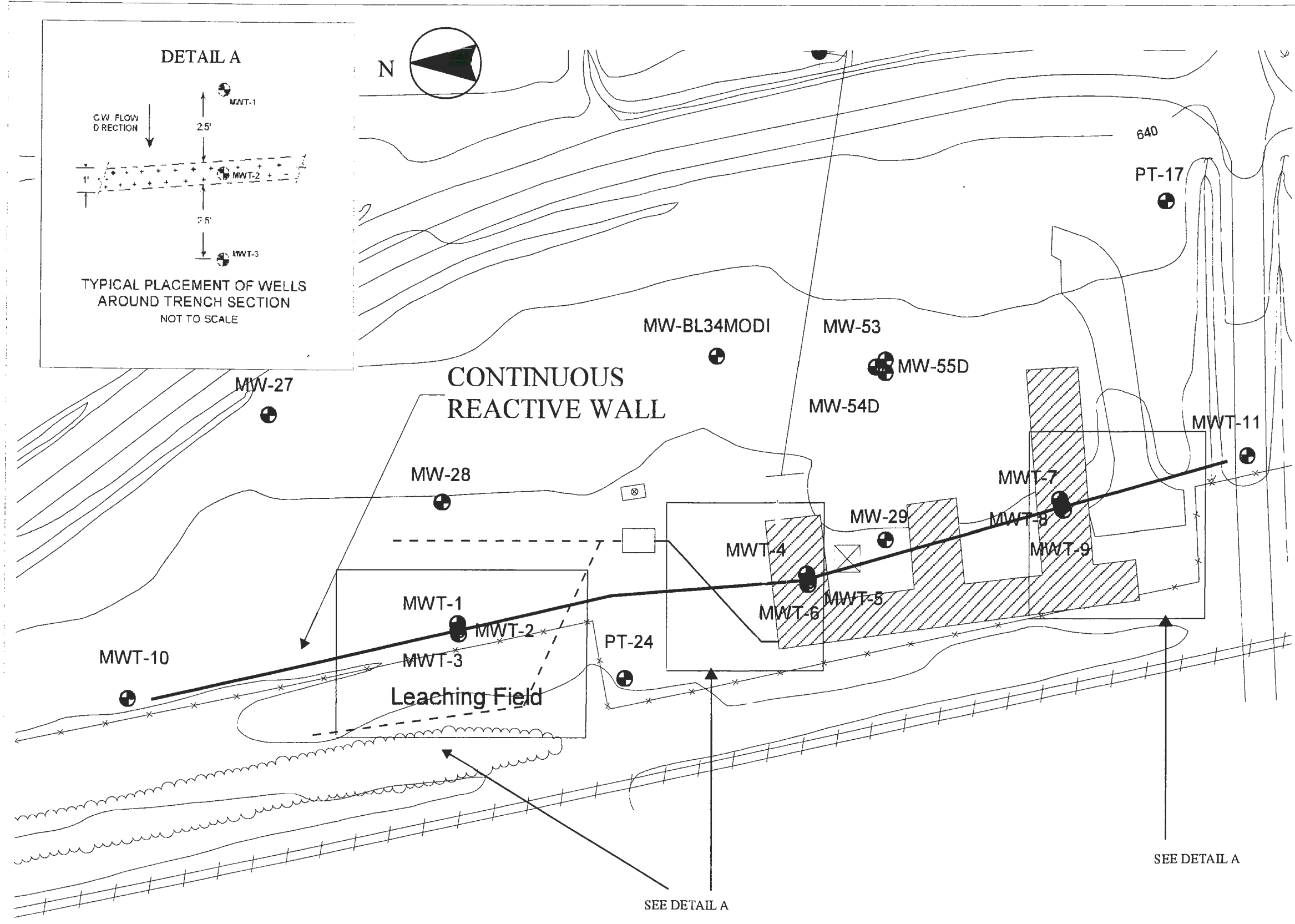
R:\SENECA\F&G-DES\X-TRENCH.DWG



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CLIENT/PROJECT TITLE	
SENECA ARMY DEPOT ACTIVITY	
ASH LANDFILL GROUNDWATER TREATABILITY STUDY	
USING ZERO VALENT IRON CONTINUOUS TRENCH SYSTEM	
DEPT.	DEPT. No.
ENVIRONMENTAL ENGINEERING	728209-01004
Figure 4-1	
REACTIVE WALL	
CROSS SECTION	
SCALE	DATE
AS NOTED	JULY 1999
REV	A

**LEGEND**

-  PAVED ROAD
-  GROUND CONTOUR AND ELEVATION
-  WETLAND & DESIGNATION
  
-  BRUSH
-  CHAIN LINK FENCE
-  UTILITY POLE
-  APPROXIMATE LOCATION OF FIRE HYDRANT
  
-  PT-22  
MONITORING WELL AND DESIGNATION
-  MW-37  
RAILROAD
  
-  8" WATER MAIN
  
-  CONTINUOUS REACTIVE WALL
-  APPROXIMATE BOUNDARY OF LEACHING FIELD
-  APPROXIMATE LOCATION OF BUILDING



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SENECA ARMY DEPOT ACTIVITY  
 ASH LANDFILL GROUNDWATER FEASIBILITY  
 MEMORANDUM FOR ZERO VALENT IRON  
 CONTINUOUS REACTIVE WALL

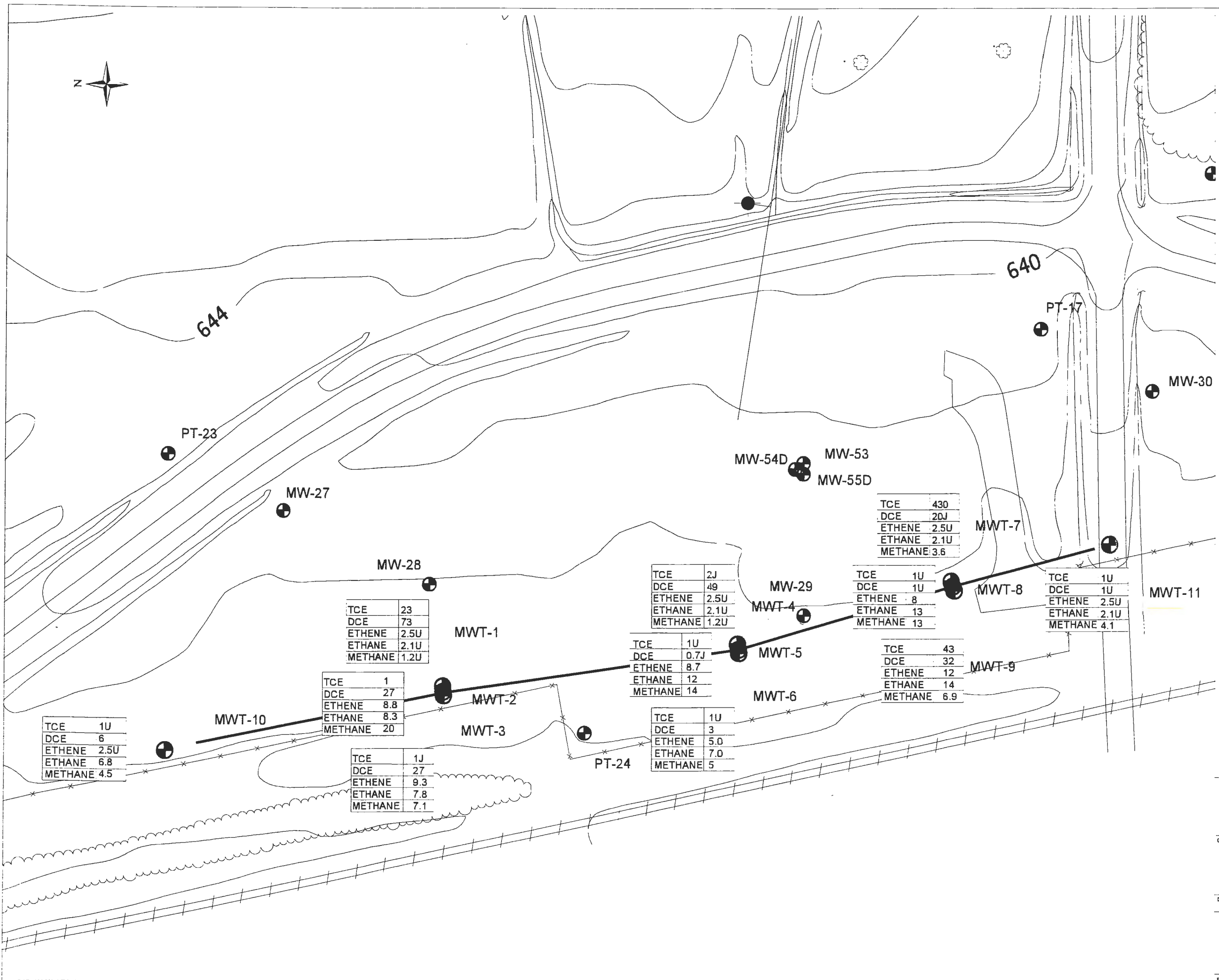
ENVIRONMENTAL ENGINEERING 726209-01000

**FIGURE 4-2**

APPROXIMATE LOCATION OF FORMER  
 BLDG AND LEACHING FIELD IN THE  
 AREA OF CONTINUOUS REACTIVE WALL

SCALE 1 INCH = 60 FEET APRIL 2000

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**LEGEND:**

- PAVED ROAD
- DIRT ROAD
- GROUND CONTOUR AND ELEVATION
- TREE
- WETLAND AND DESIGNATION
- APPROXIMATE EXTENT OF FILL
- OUTLINE OF FORMER TRASH PITS (IDENTIFIED FROM AERIALPHOTO)
- APPROXIMATE EXTENT OF DEBRIS PILE
- BRUSH
- CHAIN LINK FENCE
- UTILITY POLE
- APPROXIMATE LOCATION OF FIRE HYDRANT
- FUEL OR UNDERGROUND STORAGE TANK
- MONITORING WELL AND DESIGNATION
- RAILROAD TRACKS
- TREATMENT WALL

8" WATER MAIN  
 TCE - TRICHLOROETHENE  
 DCE - CIS-1,2DICHLOROETHENE  
 U - NOT DETECTED  
 J - APPROXIMATION  
 Analytes measured in ug/L  
 SCALE (FEET)  
 0 50'

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CLIENT/PROJECT TITLE  
**SENECA ARMY DEPOT ACTIVITY**  
 ASH LANDFILL GROUNDWATER TREATABILITY STUDY  
 USING ZERO VALENT IRON CONTINUOUS REACTIVE WALL

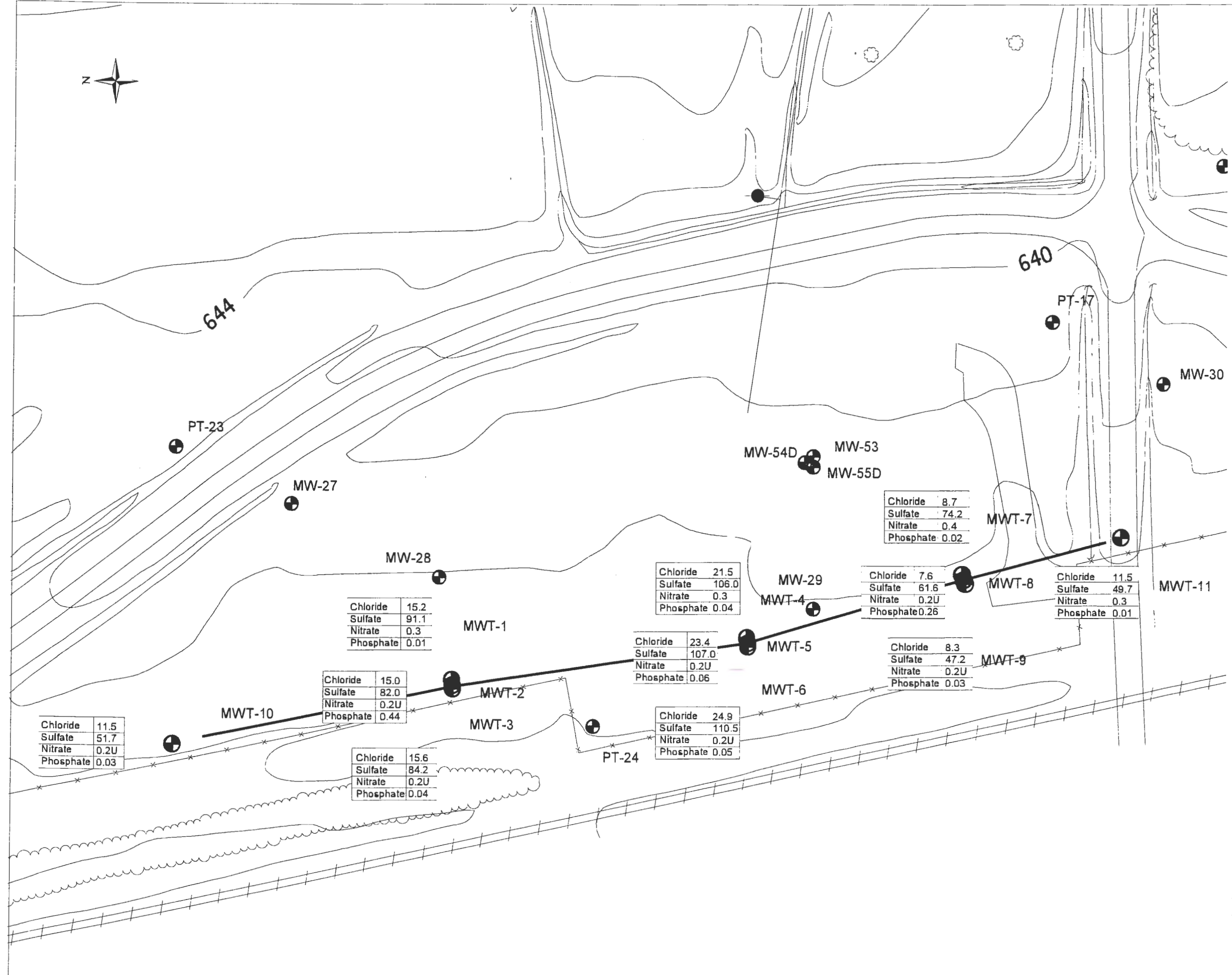
DEPT. ENVIRONMENTAL ENGINEERING DWG. NO.  
 FIGURE 6-1  
 TRICHLOROETHENE, CIS-1,2DICHLOROETHENE, ETHENE  
 ETHANE, AND METHANE CONCENTRATIONS  
 OF GROUNDWATER SAMPLES  
 COLLECTED IN APRIL, 1999

SCALE AS NOTED DATE MARCH 2000



**LEGEND:**

- PAVED ROAD
- DIRT ROAD
- GROUND CONTOUR AND ELEVATION
- TREE
- WETLAND AND DESIGNATION
- APPROXIMATE EXTENT OF FILL
- OUTLINE OF FORMER TRASH PITS (IDENTIFIED FROM AERIALPHOTO)
- APPROXIMATE EXTENT OF DEBRIS PILE
- BRUSH
- CHAIN LINK FENCE
- UTILITY POLE
- APPROXIMATE LOCATION OF FIRE HYDRANT
- FUEL OR UNDERGROUND STORAGE TANK
- MONITORING WELL AND DESIGNATION
- RAILROAD TRACKS
- TREATMENT WALL
- 8" WATER MAIN



Chloride	8.7
Sulfate	74.2
Nitrate	0.4
Phosphate	0.02

Chloride	15.2
Sulfate	91.1
Nitrate	0.3
Phosphate	0.01

Chloride	21.5
Sulfate	106.0
Nitrate	0.3
Phosphate	0.04

Chloride	7.6
Sulfate	61.6
Nitrate	0.2U
Phosphate	0.26

Chloride	11.5
Sulfate	49.7
Nitrate	0.3
Phosphate	0.01

Chloride	15.0
Sulfate	82.0
Nitrate	0.2U
Phosphate	0.44

Chloride	23.4
Sulfate	107.0
Nitrate	0.2U
Phosphate	0.06

Chloride	8.3
Sulfate	47.2
Nitrate	0.2U
Phosphate	0.03

Chloride	11.5
Sulfate	51.7
Nitrate	0.2U
Phosphate	0.03

Chloride	15.6
Sulfate	84.2
Nitrate	0.2U
Phosphate	0.04

Chloride	24.9
Sulfate	110.5
Nitrate	0.2U
Phosphate	0.05

Analytes measured in mg/L

SCALE (FEET)



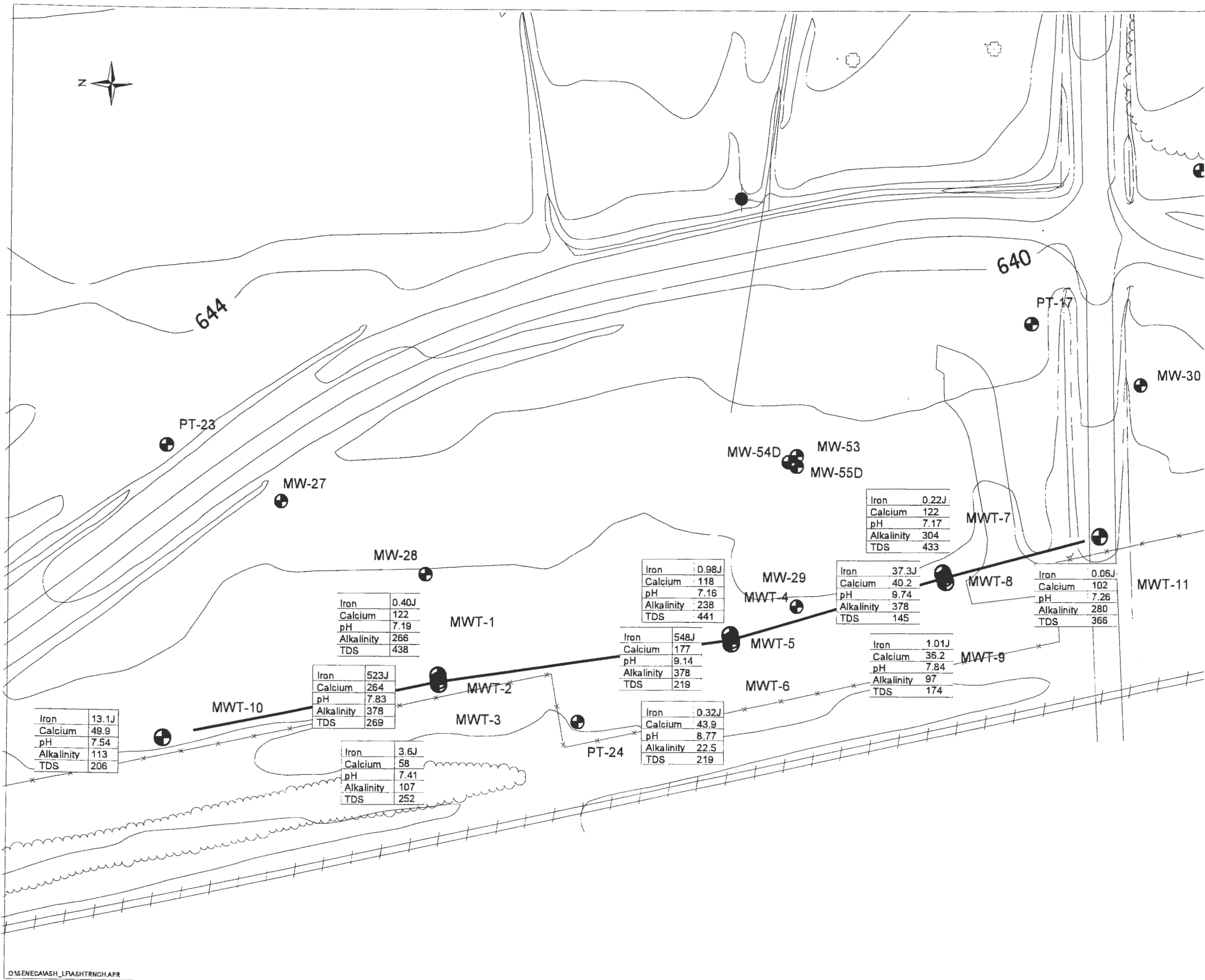
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**PARSONS ENGINEERING SCIENCE, INC.**

CLIENT/PROJECT TITLE  
**SENECA ARMY DEPOT ACTIVITY**  
 ASH LANDFILL GROUNDWATER TREATABILITY STUDY  
 USING ZERO VALENT IRON CONTINUOUS REACTIVE WALL

DEPT. ENVIRONMENTAL ENGINEERING      DWG. NO. 726209-01004

FIGURE 6-2  
 CHLORIDE, SULFATE, NITRATE, AND  
 PHOSPHATE CONCENTRATIONS  
 OF GROUNDWATER SAMPLES  
 COLLECTED IN APRIL, 1999

SCALE AS NOTED      DATE      MARCH 2000



**LEGEND:**

- PAVED ROAD
- DIRT ROAD
- GROUND CONTOUR AND ELEVATION
- TREE
- WETLAND AND DESIGNATION
- APPROXIMATE EXTENT OF FILL
- OUTLINE OF FORMER TRASH PITS (IDENTIFIED FROM AERIALPHOTO)
- APPROXIMATE EXTENT OF DEBRIS PILE
- BRUSH
- CHAIN LINK FENCE
- UTILITY POLE
- APPROXIMATE LOCATION OF FIRE HYDRANT
- FUEL OR UNDERGROUND STORAGE TANK
- MONITORING WELL AND DESIGNATION
- RAILROAD TRACKS
- TREATMENT WALL
- 8" WATER MAIN

TDS - Total Dissolved Solids  
 J - Approximation  
 Analytes measured in mg/L  
 pH measure in standard units  
**SCALE (FEET)**



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CLIENT/PROJECT TITLE  
**SENECA ARMY DEPOT ACTIVITY**  
 ASH LANDFILL GROUNDWATER TREATABILITY STUDY  
 USING ZERO VALENT IRON CONTINUOUS REACTIVE WALL

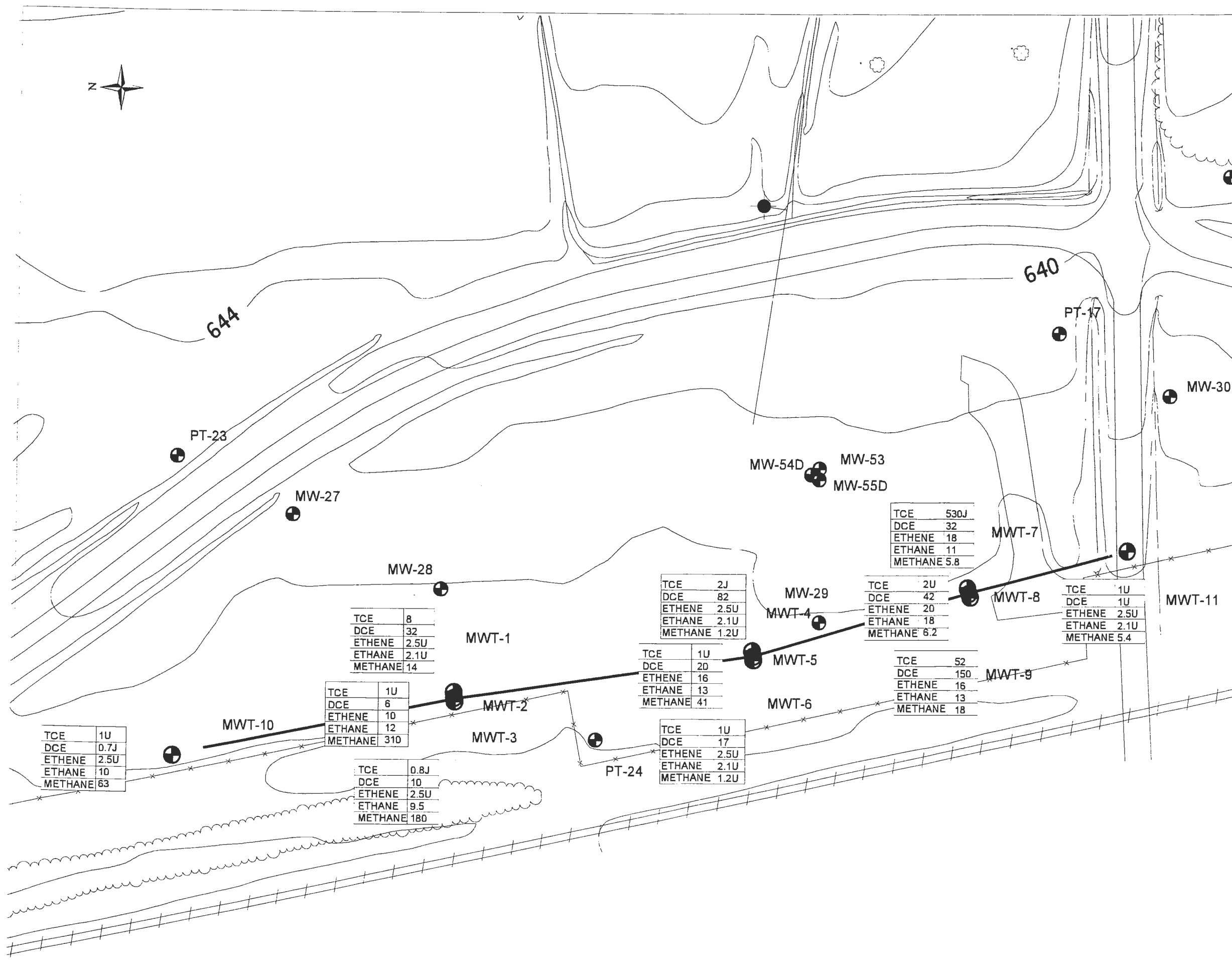
DEPT. ENVIRONMENTAL ENGINEERING      DWG. NO. 726209-01004

FIGURE 6-3  
 IRON AND CALCIUM CONCENTRATIONS  
 pH, ALKALINITY AND TOTAL DISSOLVED SOLIDS  
 CONTENTS OF GROUNDWATER SAMPLES  
 COLLECTED IN APRIL, 1999



**LEGEND:**

- PAVED ROAD
- DIRT ROAD
- GROUND CONTOUR AND ELEVATION
- TREE
- WETLAND AND DESIGNATION
- APPROXIMATE EXTENT OF FILL
- OUTLINE OF FORMER TRASH PITS (IDENTIFIED FROM AERIALPHOTO)
- APPROXIMATE EXTENT OF DEBRIS PILE
- BRUSH
- CHAIN LINK FENCE
- UTILITY POLE
- APPROXIMATE LOCATION OF FIRE HYDRANT
- FUEL OR UNDERGROUND STORAGE TANK
- MONITORING WELL AND DESIGNATION
- RAILROAD TRACKS
- TREATMENT WALL



8" WATER MAIN  
 TCE - TRICHLOROETHENE  
 DCE - CIS-1,2DICHLOROETHENE  
 U - NOT DETECTED  
 J - APPROXIMATION  
 Analytes measured in ug/L  
 SCALE (FEET)  
 50' 0 50'

**PARSONS**  
**PARSONS ENGINEERING SCIENCE, INC.**

CLIENT/PROJECT TITLE  
**SENECA ARMY DEPOT ACTIVITY**  
 ASH LANDFILL GROUNDWATER TREATABILITY STUDY  
 USING ZERO VALENT IRON CONTINUOUS REACTIVE WALL

DEPT. ENVIRONMENTAL ENGINEERING DWG. NO. 726209-01004

FIGURE 6-4  
 TRICHLOROETHENE, CIS-1,2DICHLOROETHENE, ETHANE,  
 ETHANE, AND METHANE CONCENTRATIONS  
 OF GROUNDWATER SAMPLES  
 COLLECTED IN JUNE, 1999

SCALE AS NOTED DATE MARCH 2000



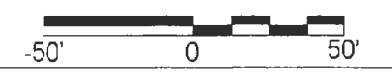


**LEGEND:**

- PAVED ROAD
- DIRT ROAD
- GROUND CONTOUR AND ELEVATION
- TREE
- WETLAND AND DESIGNATION
- APPROXIMATE EXTENT OF FILL
- OUTLINE OF FORMER TRASH PITS (IDENTIFIED FROM AERIALPHOTO)
- APPROXIMATE EXTENT OF DEBRIS PILE
- BRUSH
- CHAIN LINK FENCE
- UTILITY POLE
- APPROXIMATE LOCATION OF FIRE HYDRANT
- FUEL OR UNDERGROUND STORAGE TANK
- MONITORING WELL AND DESIGNATION
- RAILROAD TRACKS
- TREATMENT WALL
- 8" WATER MAIN

Analytes measured in mg/L

SCALE (FEET)



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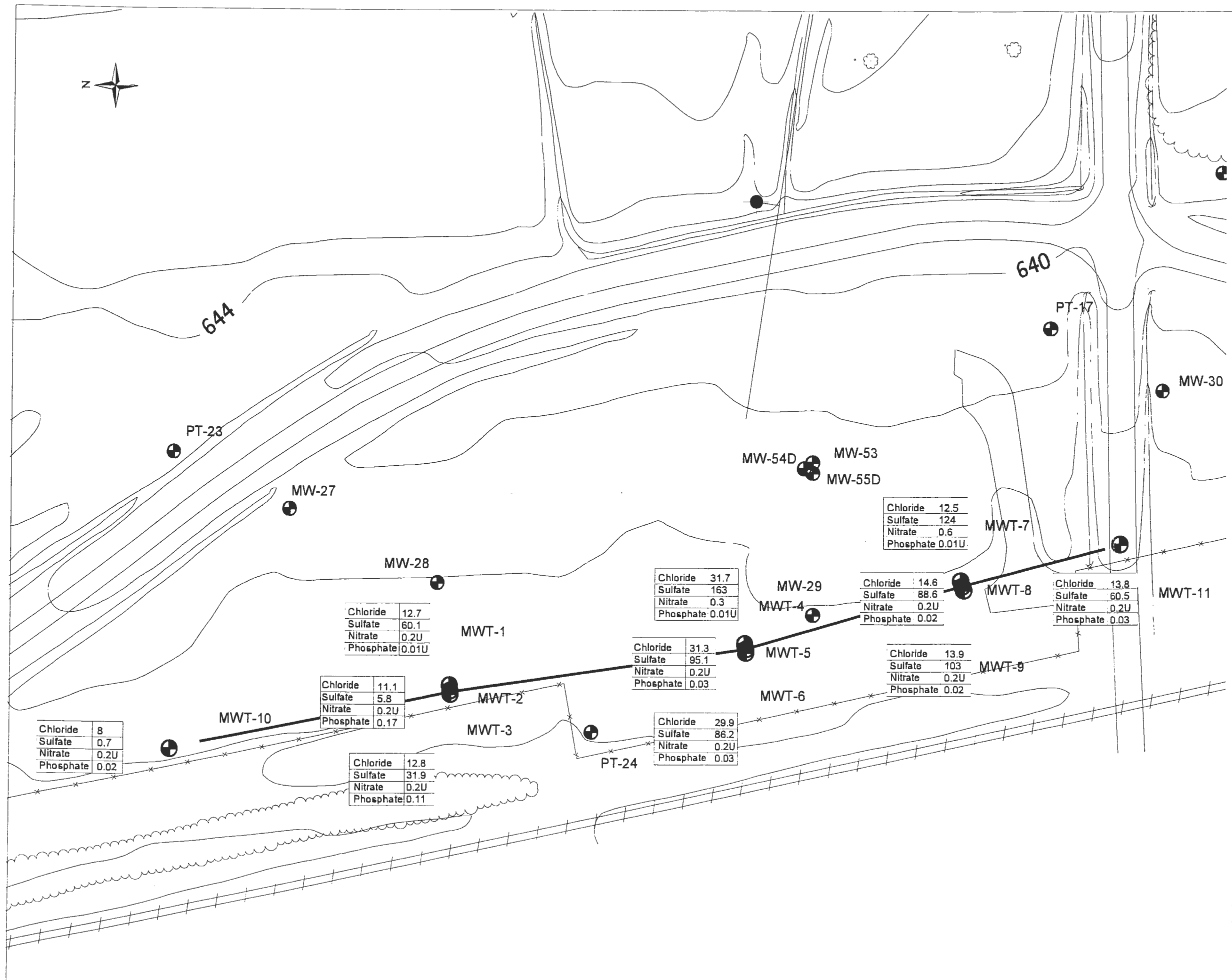
CLIENT/PROJECT TITLE  
**SENECA ARMY DEPOT ACTIVITY**

ASH LANDFILL GROUNDWATER TREATABILITY STUDY  
 USING ZERO VALENT IRON CONTINUOUS REACTIVE WALL

DEPT. ENVIRONMENTAL ENGINEERING      DWG. NO. 25209-01004

FIGURE 6-5  
 CHLORIDE, SULFATE, NITRATE, AND  
 PHOSPHATE CONCENTRATIONS  
 OF GROUNDWATER SAMPLES  
 COLLECTED IN JUNE, 1999

SCALE AS NOTED      DATE MARCH 2000



Chloride	8
Sulfate	0.7
Nitrate	0.2U
Phosphate	0.02

Chloride	12.7
Sulfate	60.1
Nitrate	0.2U
Phosphate	0.01U

Chloride	11.1
Sulfate	5.8
Nitrate	0.2U
Phosphate	0.17

Chloride	12.8
Sulfate	31.9
Nitrate	0.2U
Phosphate	0.11

Chloride	31.7
Sulfate	163
Nitrate	0.3
Phosphate	0.01U

Chloride	31.3
Sulfate	95.1
Nitrate	0.2U
Phosphate	0.03

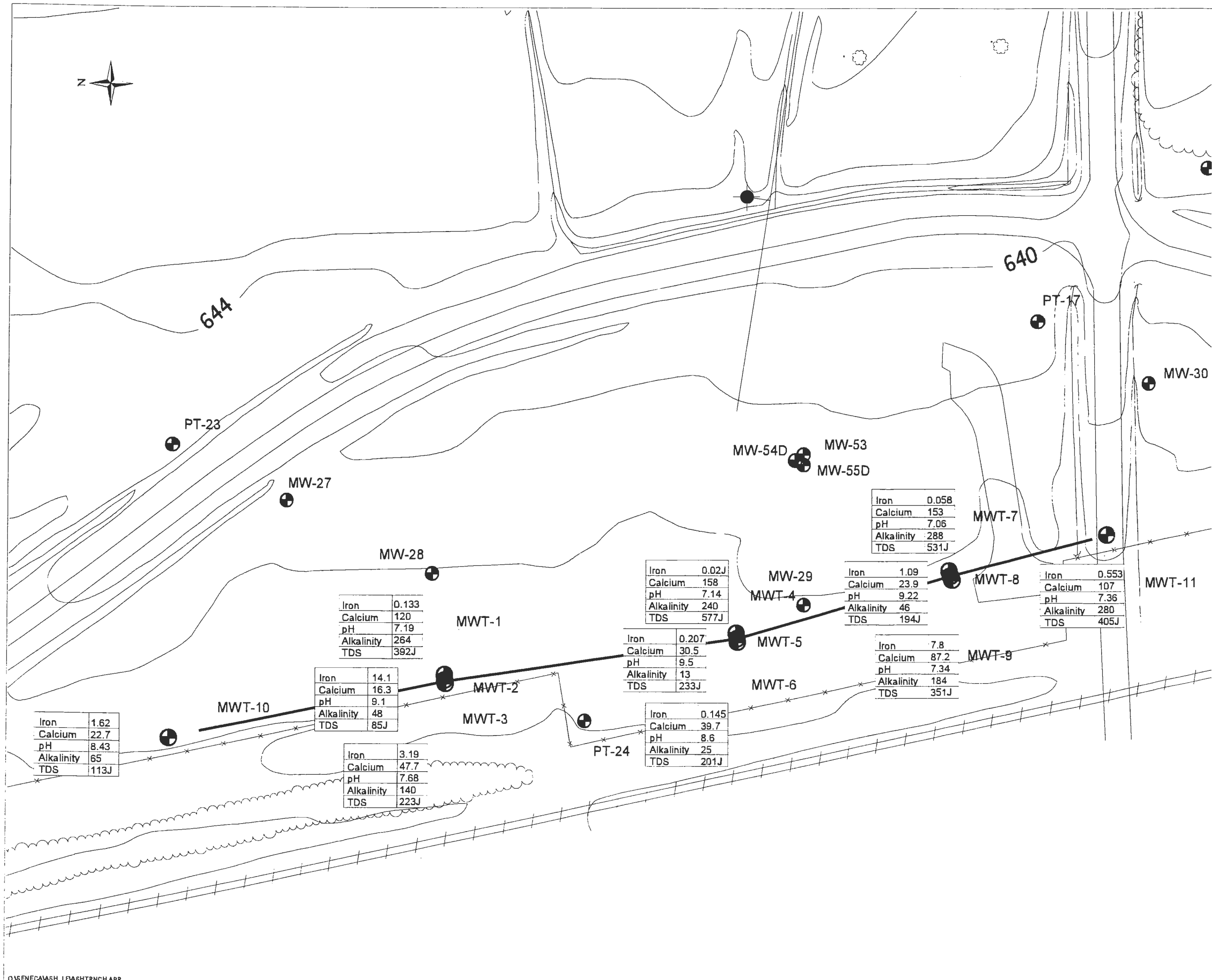
Chloride	29.9
Sulfate	86.2
Nitrate	0.2U
Phosphate	0.03

Chloride	12.5
Sulfate	124
Nitrate	0.6
Phosphate	0.01U

Chloride	14.6
Sulfate	88.6
Nitrate	0.2U
Phosphate	0.02

Chloride	13.8
Sulfate	60.5
Nitrate	0.2U
Phosphate	0.03

Chloride	13.9
Sulfate	103
Nitrate	0.2U
Phosphate	0.02

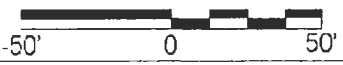


**LEGEND:**

- PAVED ROAD
- DIRT ROAD
- GROUND CONTOUR AND ELEVATION
- TREE
- WETLAND AND DESIGNATION
- APPROXIMATE EXTENT OF FILL
- OUTLINE OF FORMER TRASH PITS (IDENTIFIED FROM AERIAL PHOTO)
- APPROXIMATE EXTENT OF DEBRIS PILE
- BRUSH
- CHAIN LINK FENCE
- UTILITY POLE
- APPROXIMATE LOCATION OF FIRE HYDRANT
- FUEL OR UNDERGROUND STORAGE TANK
- PT-22  
MW-37
- RAILROAD TRACKS
- TREATMENT WALL
- 8" WATER MAIN

TDS - Total Dissolved Solids  
 J - Approximation  
 Analytes measured in mg/L  
 pH measure in standard units

**SCALE (FEET)**



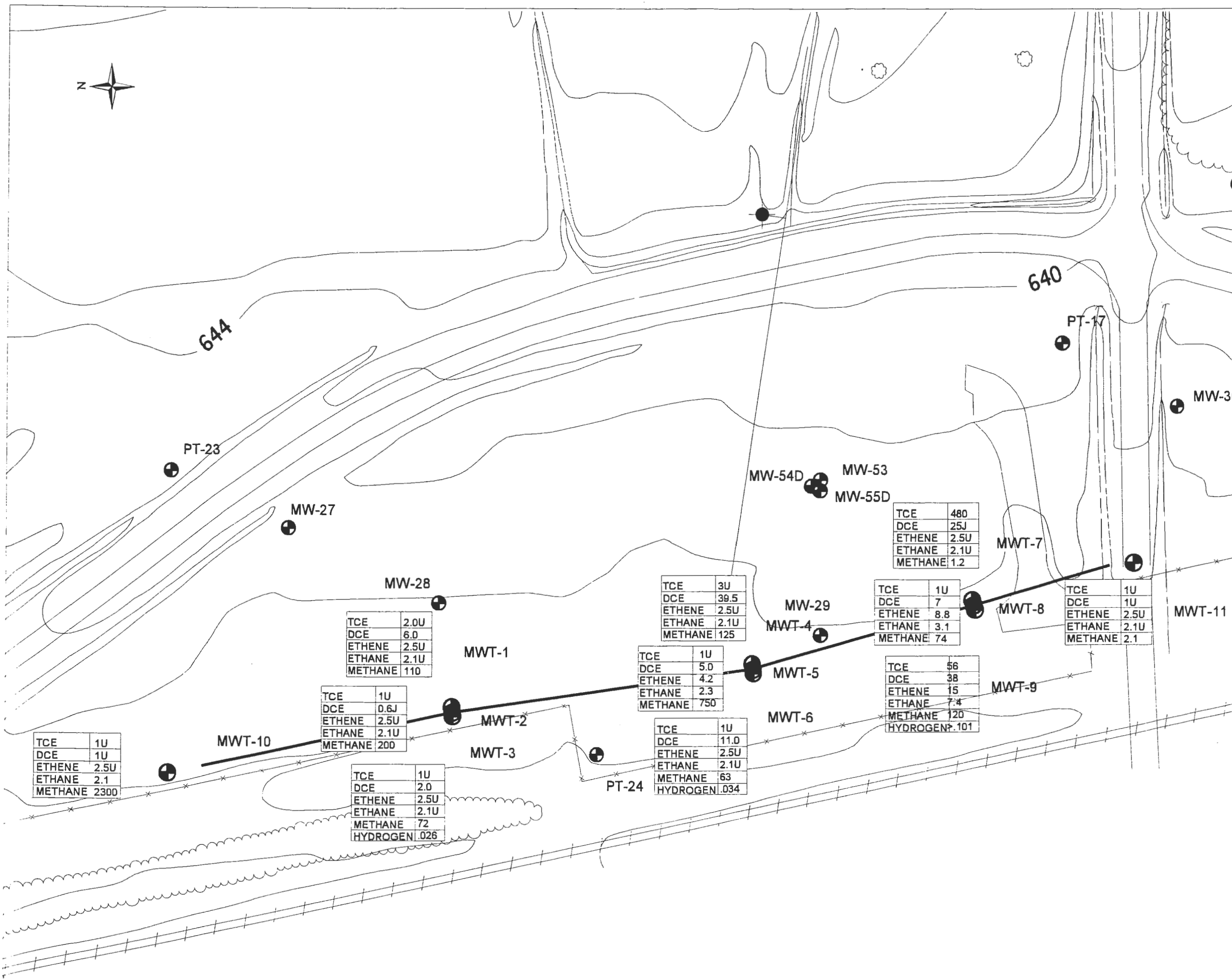
**PARSONS**  
**PARSONS ENGINEERING SCIENCE, INC.**

CLIENT/PROJECT TITLE  
**SENECA ARMY DEPOT ACTIVITY**  
 ASH LANDFILL GROUNDWATER TREATABILITY STUDY  
 USING ZERO VALENT IRON CONTINUOUS REACTIVE WALL

DEPT ENVIRONMENTAL ENGINEERING DWG. NO. 726209-01004

FIGURE 6-6  
 IRON AND CALCIUM CONCENTRATIONS  
 pH, ALKALINITY AND TOTAL DISSOLVED SOLIDS  
 CONTENTS OF GROUNDWATER SAMPLES  
 COLLECTED IN JUNE, 1999

SCALE AS NOTED DATE MARCH 2000



**LEGEND:**

- PAVED ROAD
- DIRT ROAD
- GROUND CONTOUR AND ELEVATION
- TREE
- WETLAND AND DESIGNATION
- APPROXIMATE EXTENT OF FILL
- OUTLINE OF FORMER TRASH PITS (IDENTIFIED FROM AERIAL PHOTO)
- APPROXIMATE EXTENT OF DEBRIS PILE
- BRUSH
- CHAIN LINK FENCE
- UTILITY POLE
- APPROXIMATE LOCATION OF FIRE HYDRANT
- FUEL OR UNDERGROUND STORAGE TANK
- MONITORING WELL AND DESIGNATION
- RAILROAD TRACKS
- TREATMENT WALL
- 8" WATER MAIN

TCE - TRICHLOROETHENE  
DCE - CIS-1,2DICHLOROETHENE  
U - NOT DETECTED  
J - APPROXIMATION  
Analytes measured in ug/L  
SCALE (FEET)

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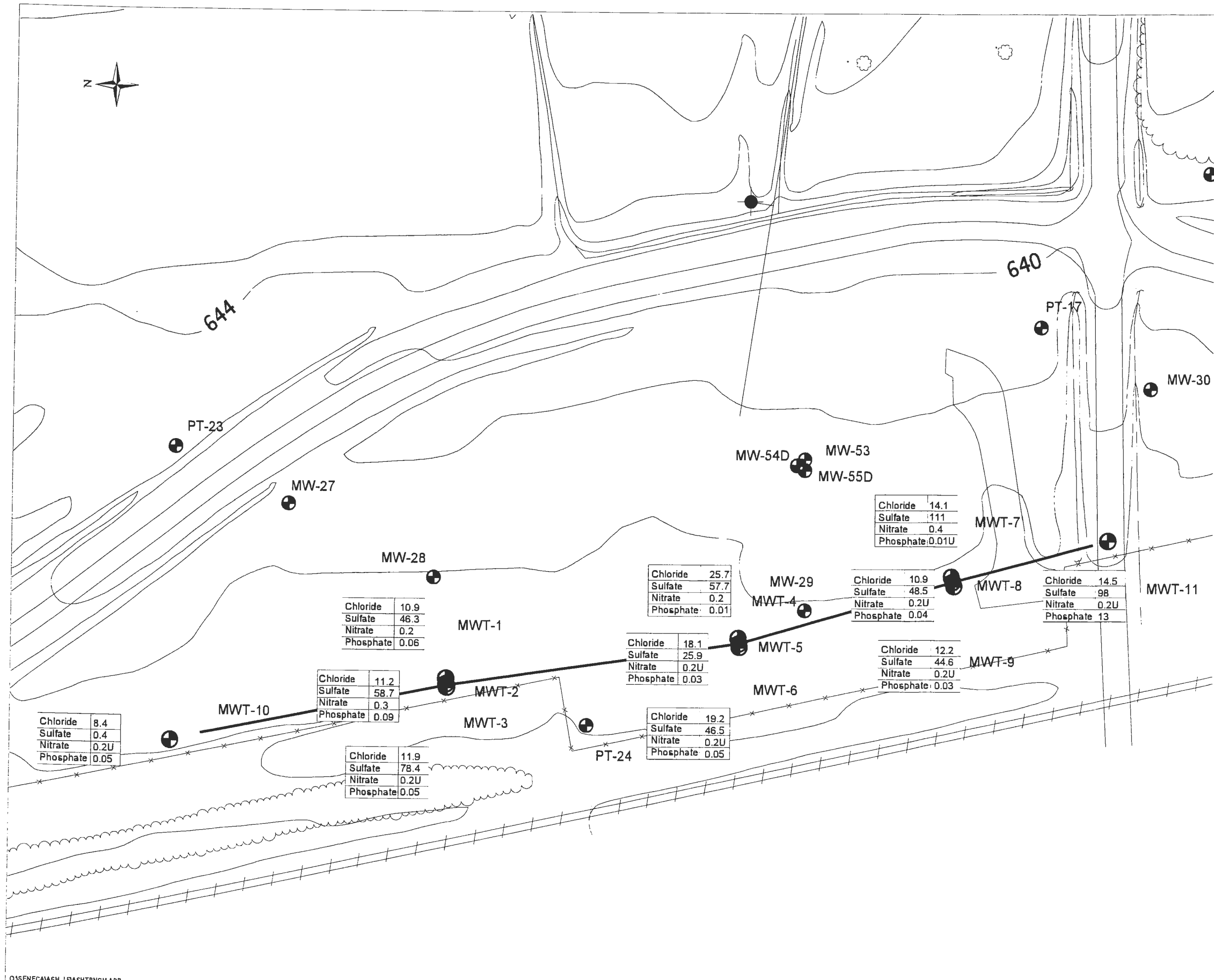
CLIENT/PROJECT TITLE  
**SENECA ARMY DEPOT ACTIVITY**

ASH LANDFILL GROUNDWATER TREATABILITY STUDY  
USING ZERO VALENT IRON CONTINUOUS REACTIVE WALL

DEPT. ENVIRONMENTAL ENGINEERING      DWG. NO. 726209-01004

**FIGURE 6-7**  
TRICHLOROETHENE, CIS-1,2DICHLOROETHENE, ETHENE,  
ETHANE, METHANE AND HYDROGEN CONCENTRATIONS  
OF GROUNDWATER SAMPLES  
COLLECTED IN SEPTEMBER, 1999

SCALE AS NOTED      DATE MARCH 2000

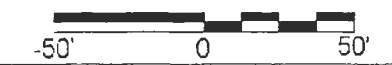


**LEGEND:**

- PAVED ROAD
- DIRT ROAD
- GROUND CONTOUR AND ELEVATION
- TREE
- WETLAND AND DESIGNATION
- APPROXIMATE EXTENT OF FILL
- OUTLINE OF FORMER TRASH PITS (IDENTIFIED FROM AERIALPHOTO)
- APPROXIMATE EXTENT OF DEBRIS PILE
- BRUSH
- CHAIN LINK FENCE
- UTILITY POLE
- APPROXIMATE LOCATION OF FIRE HYDRANT
- FUEL OR UNDERGROUND STORAGE TANK
- MONITORING WELL AND DESIGNATION
- RAILROAD TRACKS
- TREATMENT WALL
- 8" WATER MAIN

Analytes measured in mg/L

SCALE (FEET)



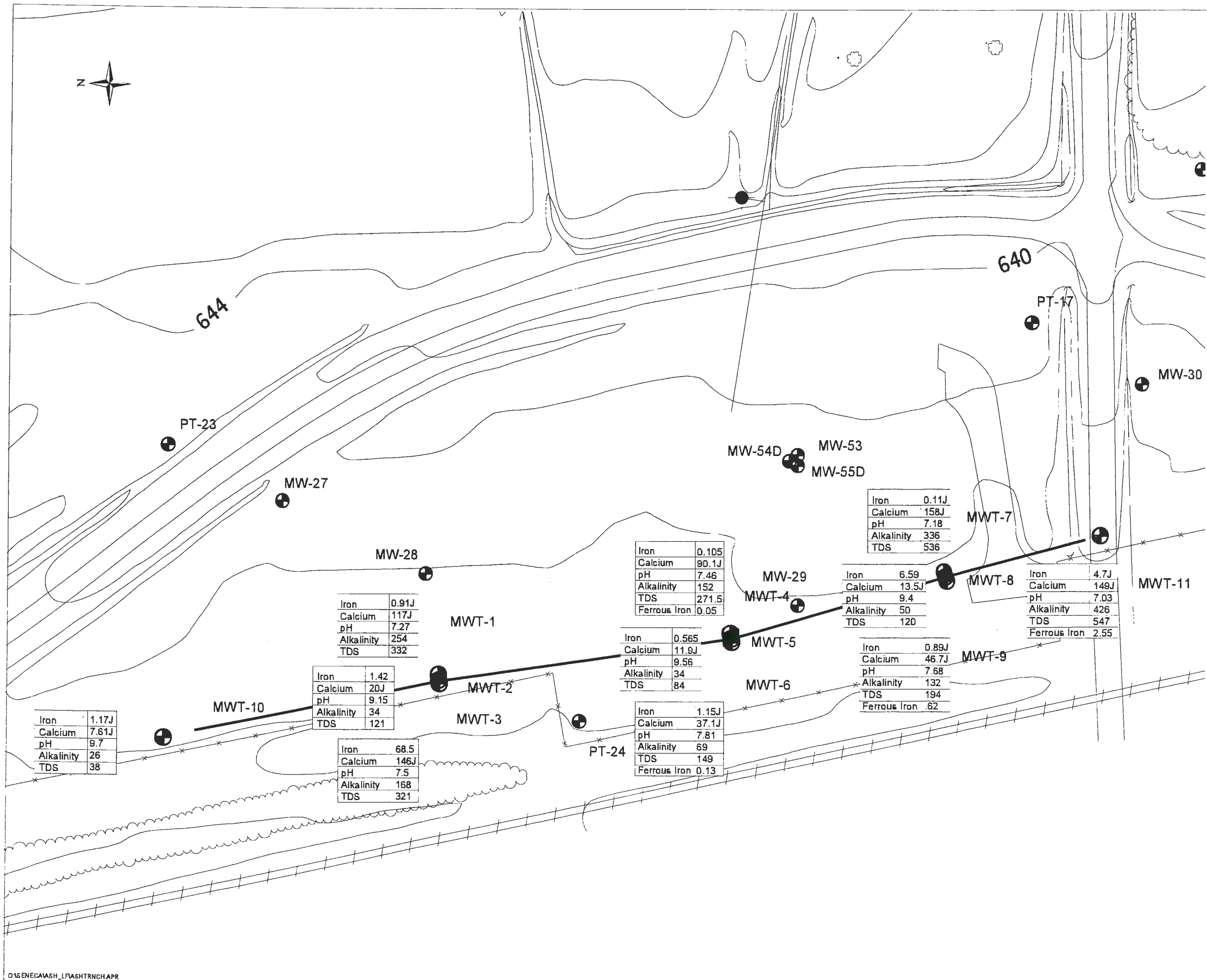
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**SENECA ARMY DEPOT ACTIVITY**  
 ASH LANDFILL GROUNDWATER TREATABILITY STUDY  
 USING ZERO VALENT IRON CONTINUOUS REACTIVE WALL







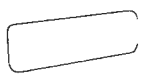










DEPT. ENVIRONMENTAL ENGINEERING DWD. NO. 726209-01004

**FIGURE 6-8**  
 CHLORIDE, SULFATE, NITRATE, AND  
 PHOSPHATE CONCENTRATIONS  
 OF GROUNDWATER SAMPLES  
 COLLECTED IN SEPTEMBER, 1999

SCALE AS NOTED DATE MARCH 2000



**LEGEND:**

-  PAVED ROAD
-  DIRT ROAD
-  GROUND CONTOUR AND ELEVATION
-  TREE
-  WETLAND AND DESIGNATION
-  APPROXIMATE EXTENT OF FILL
-  OUTLINE OF FORMER TRASH PITS (IDENTIFIED FROM AERIALPHOTO)
-  APPROXIMATE EXTENT OF DEBRIS PILE
-  BRUSH
-  CHAIN LINK FENCE
-  UTILITY POLE
-  APPROXIMATE LOCATION OF FIRE HYDRANT
-  FUEL OR UNDERGROUND STORAGE TANK
-  MONITORING WELL AND DESIGNATION
-  RAILROAD TRACKS
-  TREATMENT WALL
-  8" WATER MAIN

TDS - Total Dissolved Solids  
 J - APPROXIMATE  
 Analytes measured in mg/L  
 pH measure in standard units

**SCALE (FEET)**



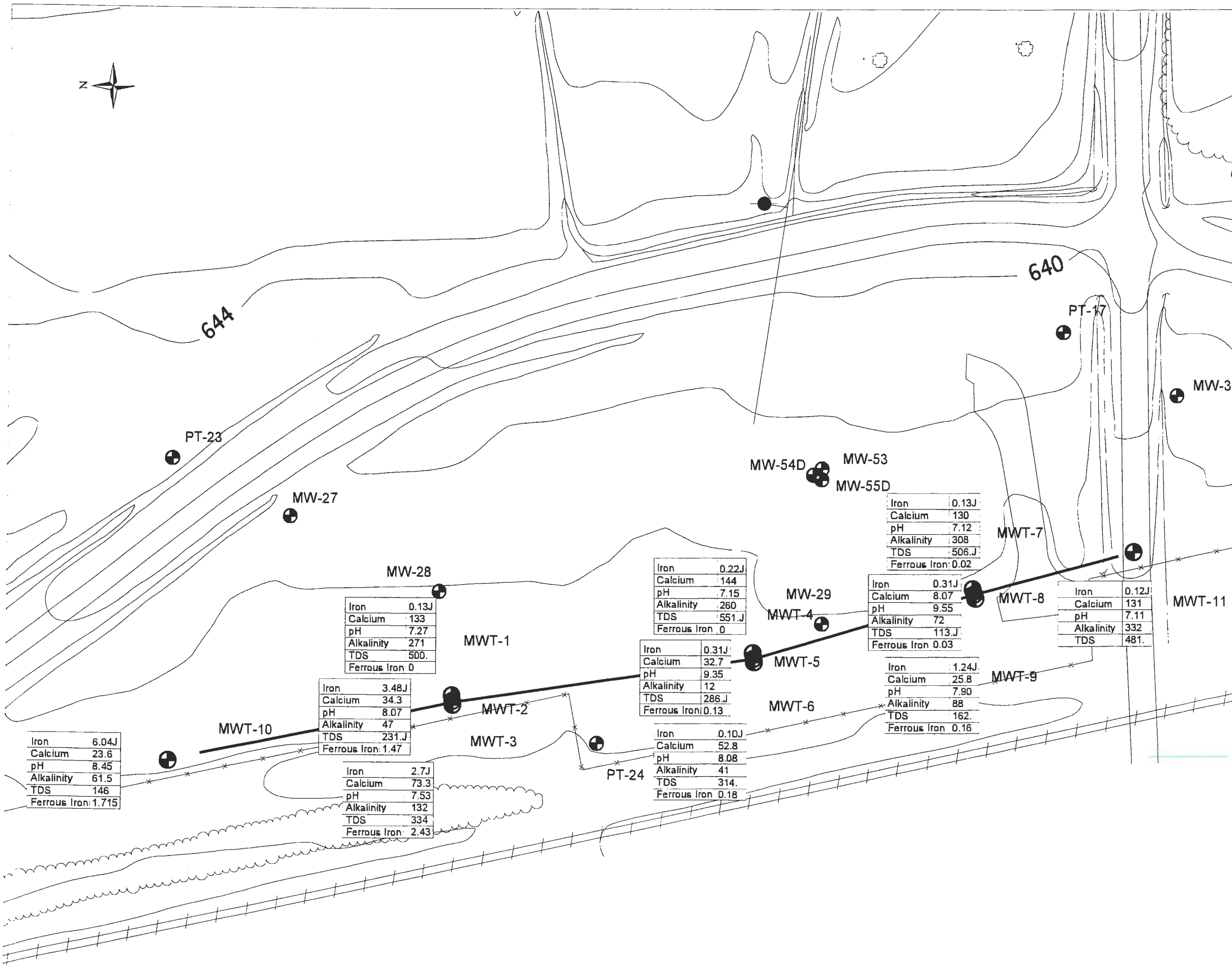
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CLIENT/PROJECT TITLE  
**SENECA ARMY DEPOT ACTIVITY**  
 ASH LANDFILL GROUNDWATER TREATABILITY STUDY  
 USING ZERO VALENT IRON CONTINUOUS REACTIVE WALL

DEPT ENVIRONMENTAL ENGINEERING DWG. NO. 726209-01004

FIGURE 6-9  
 IRON AND CALCIUM CONCENTRATIONS  
 pH, ALKALINITY AND TOTAL DISSOLVED SOLIDS  
 CONTENTS OF GROUNDWATER SAMPLES  
 COLLECTED IN SEPTEMBER, 1999

SCALE AS NOTED DATE MARCH 2000



**LEGEND:**

- PAVED ROAD
- DIRT ROAD
- GROUND CONTOUR AND ELEVATION
- TREE
- WETLAND AND DESIGNATION
- APPROXIMATE EXTENT OF FILL
- OUTLINE OF FORMER TRASH PITS (IDENTIFIED FROM AERIAL PHOTO)
- APPROXIMATE EXTENT OF DEBRIS PILE
- BRUSH
- CHAIN LINK FENCE
- UTILITY POLE
- APPROXIMATE LOCATION OF FIRE HYDRANT
- FUEL OR UNDERGROUND STORAGE TANK
- MONITORING WELL AND DESIGNATION
- RAILROAD TRACKS
- TREATMENT WALL
- 8" WATER MAIN

TDS - Total Dissolved Solids  
 J - APPROXIMATE  
 Analytes measured in mg/L  
 pH measure in standard units

**SCALE (FEET)**



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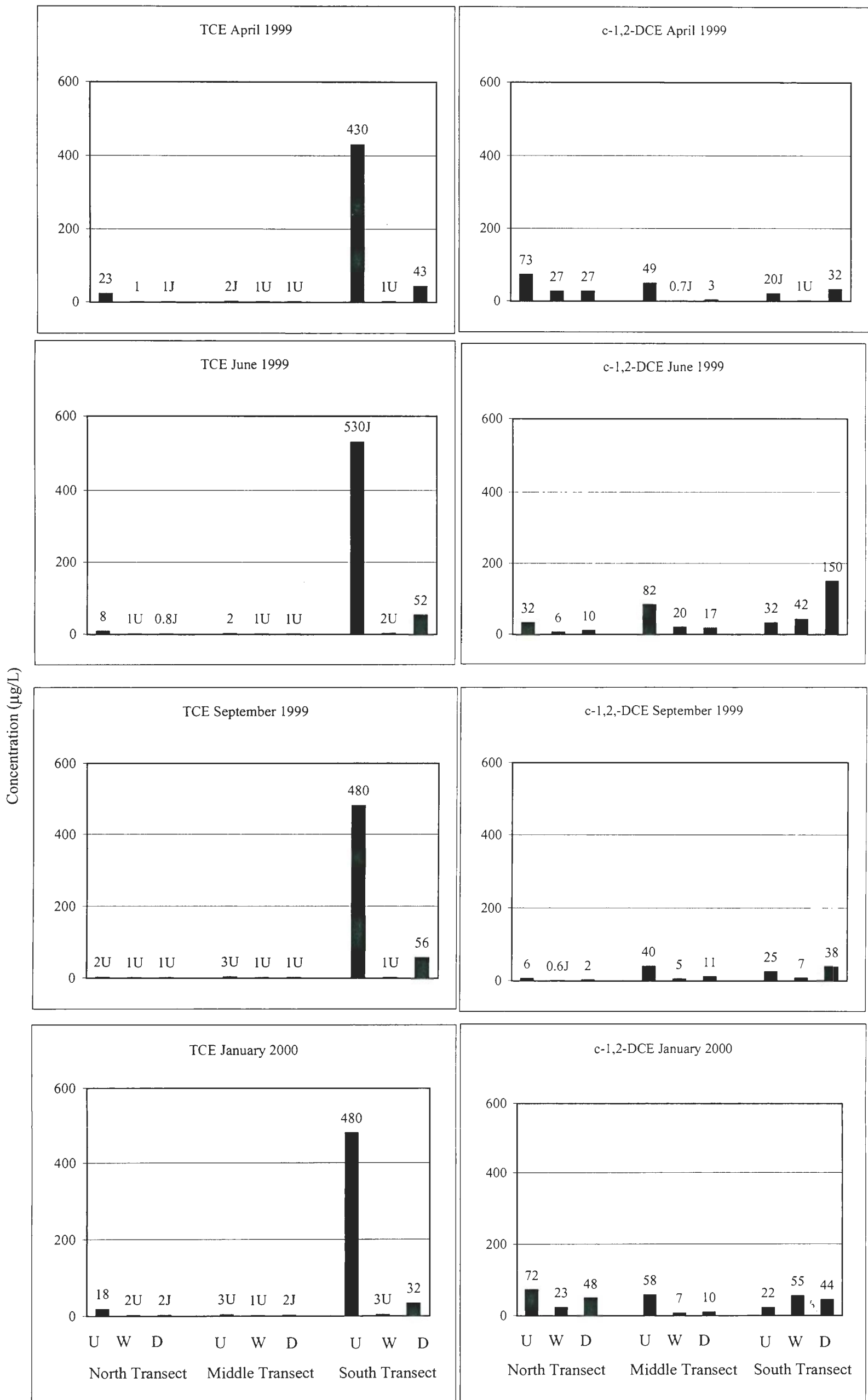
CLIENT/PROJECT TITLE  
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 ASH LANDFILL GROUNDWATER TREATABILITY STUDY  
 USING ZERO VALENT IRON CONTINUOUS REACTIVE WALL

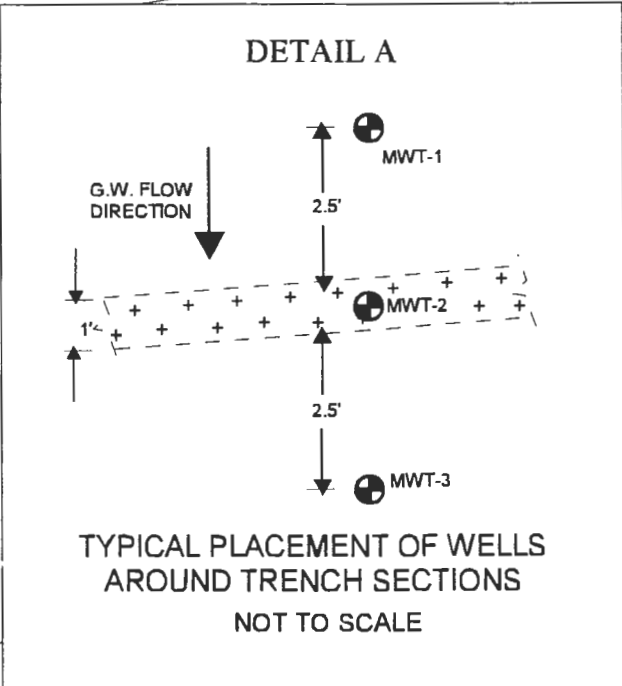
DEPT. ENVIRONMENTAL ENGINEERING      DWG. NO. 726209-01004

FIGURE 6-12  
 IRON AND CALCIUM CONCENTRATIONS  
 pH, ALKALINITY AND TOTAL DISSOLVED SOLIDS  
 CONTENTS OF GROUNDWATER SAMPLES  
 COLLECTED IN JANUARY, 2000

SCALE AS NOTED      DATE MARCH 2000

Figure 6-13  
 Trichloroethene and Cis-1,2-Dichloroethene Results for April 1999-January 2000, Reactive Iron Wall  
 Ash Landfill Feasibility Memorandum  
 Seneca Army Depot  
 Romulus, NY

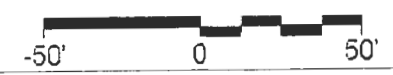




**LEGEND:**

- PAVED ROAD
- DIRT ROAD
- GROUND CONTOUR AND ELEVATION
- TREE
- WETLAND AND DESIGNATION
- APPROXIMATE EXTENT OF FILL
- OUTLINE OF FORMER TRASH PITS (IDENTIFIED FROM AERIALPHOTO)
- APPROXIMATE EXTENT OF DEBRIS PILE
- BRUSH
- CHAIN LINK FENCE
- UTILITY POLE
- APPROXIMATE LOCATION OF FIRE HYDRANT
- FUEL OR UNDERGROUND STORAGE TANK
- MONITORING WELL AND DESIGNATION, ELEVATION
- RAILROAD TRACKS
- TREATMENT WALL
- 8" WATER MAIN
- GROUNDWATER LEVEL CONTOUR

**SCALE (FEET)**



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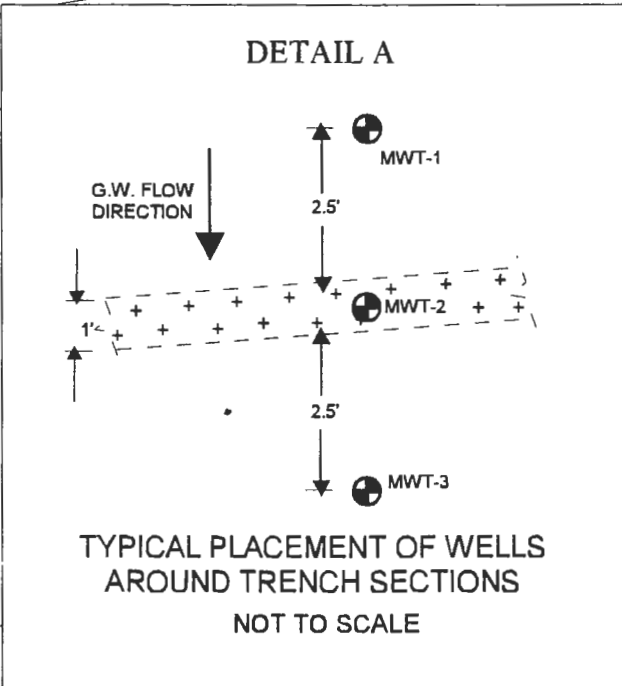
CLIENT/PROJECT TITLE  
**SENECA ARMY DEPOT ACTIVITY**  
ASH LANDFILL GROUNDWATER TREATABILITY STUDY  
USING ZERO VALENT IRON CONTINUOUS REACTIVE WALL

DEPT. ENVIRONMENTAL ENGINEERING      DWG. NO. 726209-01004

**FIGURE 6-14**  
**GROUNDWATER ELEVATIONS FOR**  
**CONTINUOUS REACTIVE WALL (APRIL 1999)**

SCALE AS NOTED      DATE JANUARY 2000





**LEGEND:**

- PAVED ROAD
- DIRT ROAD
- GROUND CONTOUR AND ELEVATION
- TREE
- WETLAND AND DESIGNATION
- APPROXIMATE EXTENT OF FILL
- OUTLINE OF FORMER TRASH PITS (IDENTIFIED FROM AERIAL PHOTO)
- APPROXIMATE EXTENT OF DEBRIS PILE
- BRUSH
- CHAIN LINK FENCE
- UTILITY POLE
- APPROXIMATE LOCATION OF FIRE HYDRANT
- FUEL OR UNDERGROUND STORAGE TANK
- MONITORING WELL AND DESIGNATION, ELEVATION
- RAILROAD TRACKS
- TREATMENT WALL
- 8" WATER MAIN
- GROUNDWATER LEVEL CONTOUR

**SCALE (FEET)**

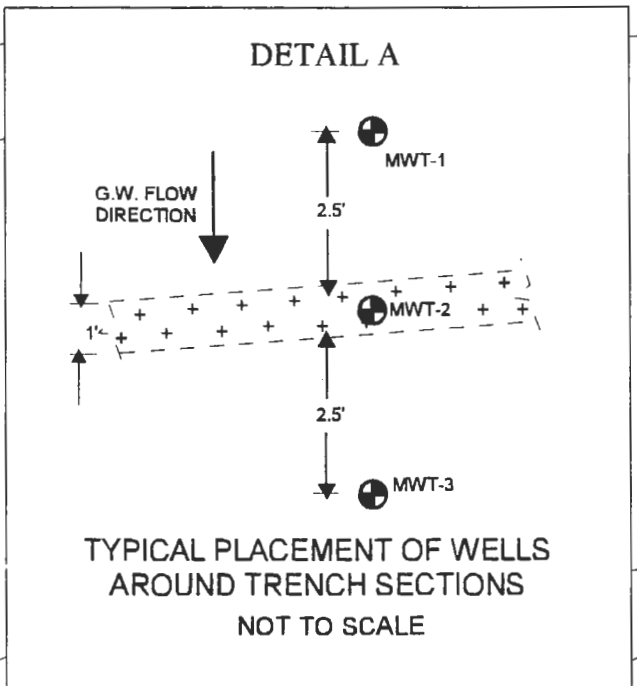
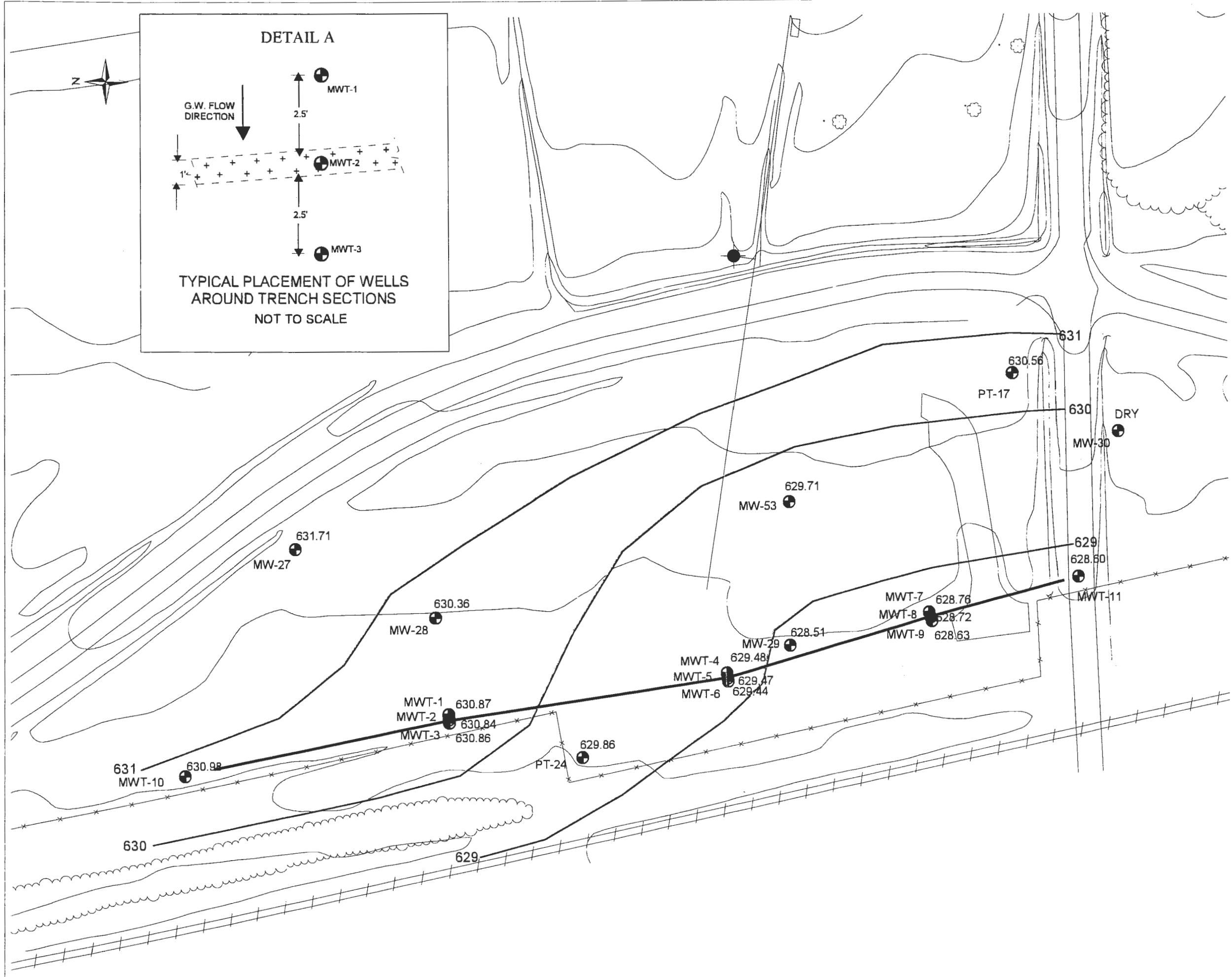


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 ASH LANDFILL GROUNDWATER TREATABILITY STUDY  
 USING ZERO VALENT IRON CONTINUOUS REACTIVE WALL  
 DEPT. ENVIRONMENTAL ENGINEERING DWG. NO. 726209-01004

**FIGURE 6-15**  
**GROUNDWATER ELEVATIONS FOR**  
**CONTINUOUS REACTIVE WALL (MAY, 1999)**

SCALE AS NOTED DATE JANUARY 2000



**LEGEND:**

- PAVED ROAD
- DIRT ROAD
- GROUND CONTOUR AND ELEVATION
- TREE
- WETLAND AND DESIGNATION
- APPROXIMATE EXTENT OF FILL
- OUTLINE OF FORMER TRASH PITS (IDENTIFIED FROM AERIAL PHOTO)
- APPROXIMATE EXTENT OF DEBRIS PILE
- BRUSH
- CHAIN LINK FENCE
- UTILITY POLE
- APPROXIMATE LOCATION OF FIRE HYDRANT
- FUEL OR UNDERGROUND STORAGE TANK
- MONITORING WELL AND DESIGNATION, ELEVATION
- RAILROAD TRACKS
- TREATMENT WALL
- 8" WATER MAIN
- GROUNDWATER LEVEL CONTOUR

**SCALE (FEET)**

0 50'

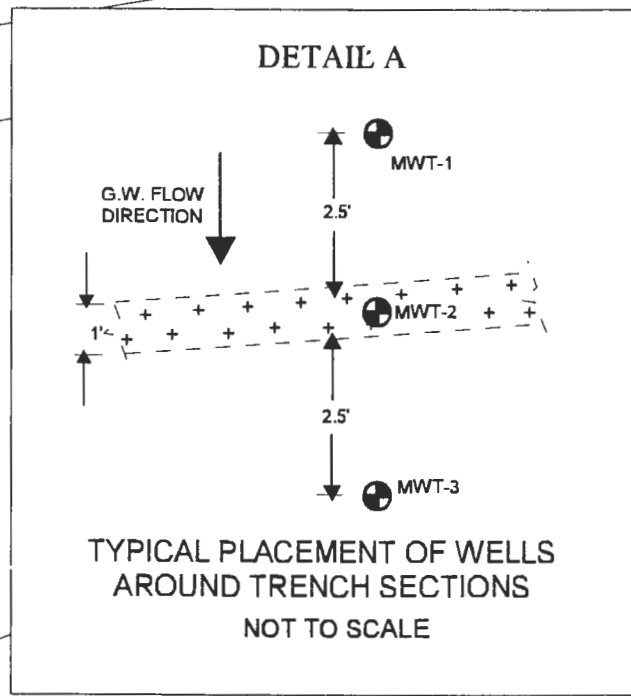
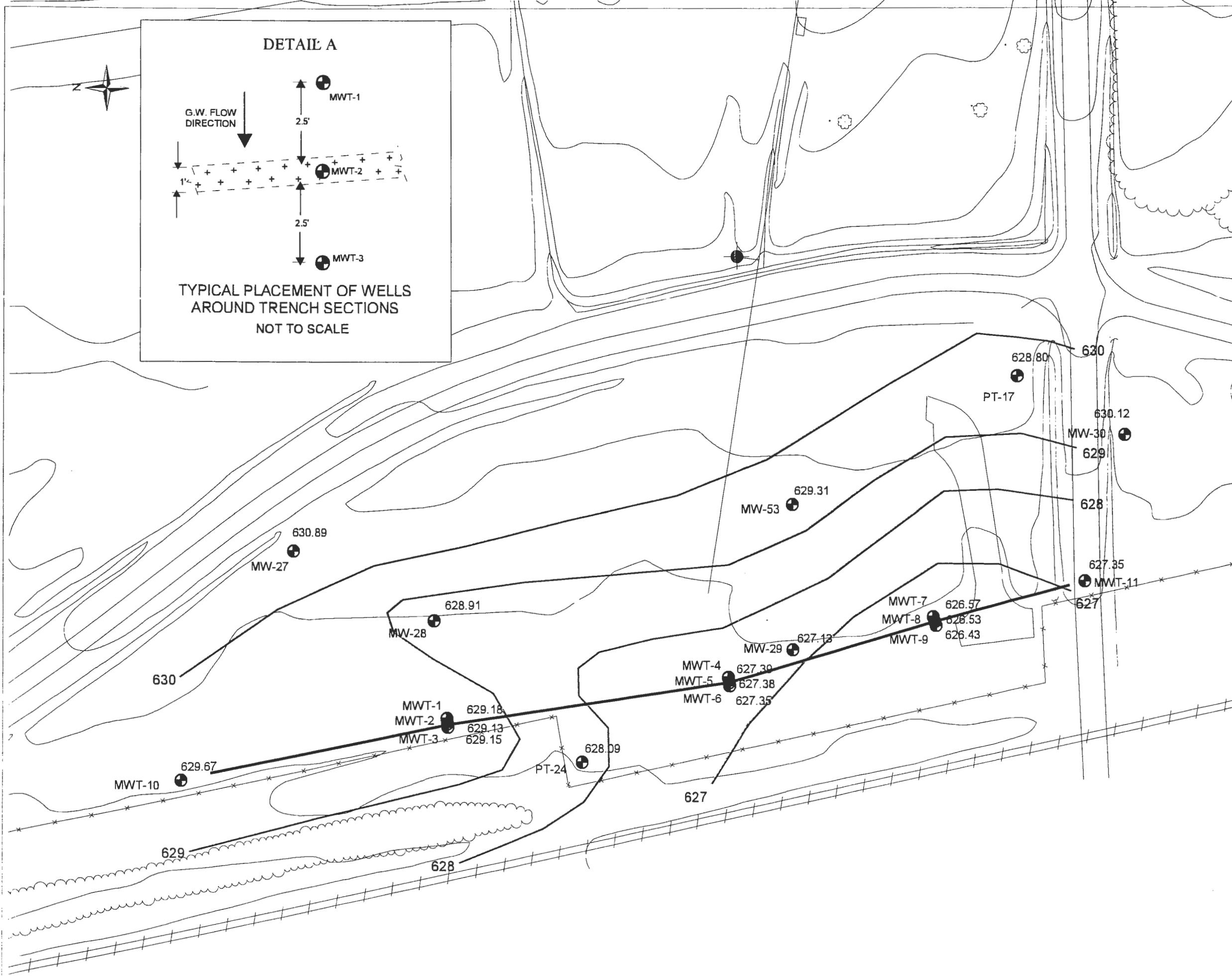
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CLIENT/PROJECT TITLE  
**SENECA ARMY DEPOT ACTIVITY**  
 ASH LANDFILL GROUNDWATER TREATABILITY STUDY  
 USING ZERO VALENT IRON CONTINUOUS REACTIVE WALL

DEPT. ENVIRONMENTAL ENGINEERING DWG. NO. 726209-01004

**FIGURE 6-16**  
**GROUNDWATER ELEVATIONS FOR**  
**CONTINUOUS REACTIVE WALL (JUNE, 1999)**

SCALE AS NOTED DATE JANUARY 2000



**LEGEND:**

- PAVED ROAD
- DIRT ROAD
- GROUND CONTOUR AND ELEVATION
- TREE
- WETLAND AND DESIGNATION
- APPROXIMATE EXTENT OF FILL
- OUTLINE OF FORMER TRASH PITS (IDENTIFIED FROM AERIAL PHOTO)
- APPROXIMATE EXTENT OF DEBRIS PILE
- BRUSH
- CHAIN LINK FENCE
- UTILITY POLE
- APPROXIMATE LOCATION OF FIRE HYDRANT
- FUEL OR UNDERGROUND STORAGE TANK
- MONITORING WELL AND DESIGNATION, ELEVATION
- RAILROAD TRACKS
- TREATMENT WALL
- 8" WATER MAIN
- GROUNDWATER LEVEL CONTOUR

**SCALE (FEET)**



**PARSONS**  
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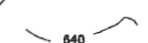













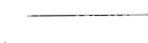

CLIENT/PROJECT TITLE  
**SENECA ARMY DEPOT ACTIVITY**  
 ASH LANDFILL GROUNDWATER TREATABILITY STUDY  
 USING ZERO VALENT IRON CONTINUOUS REACTIVE WALL

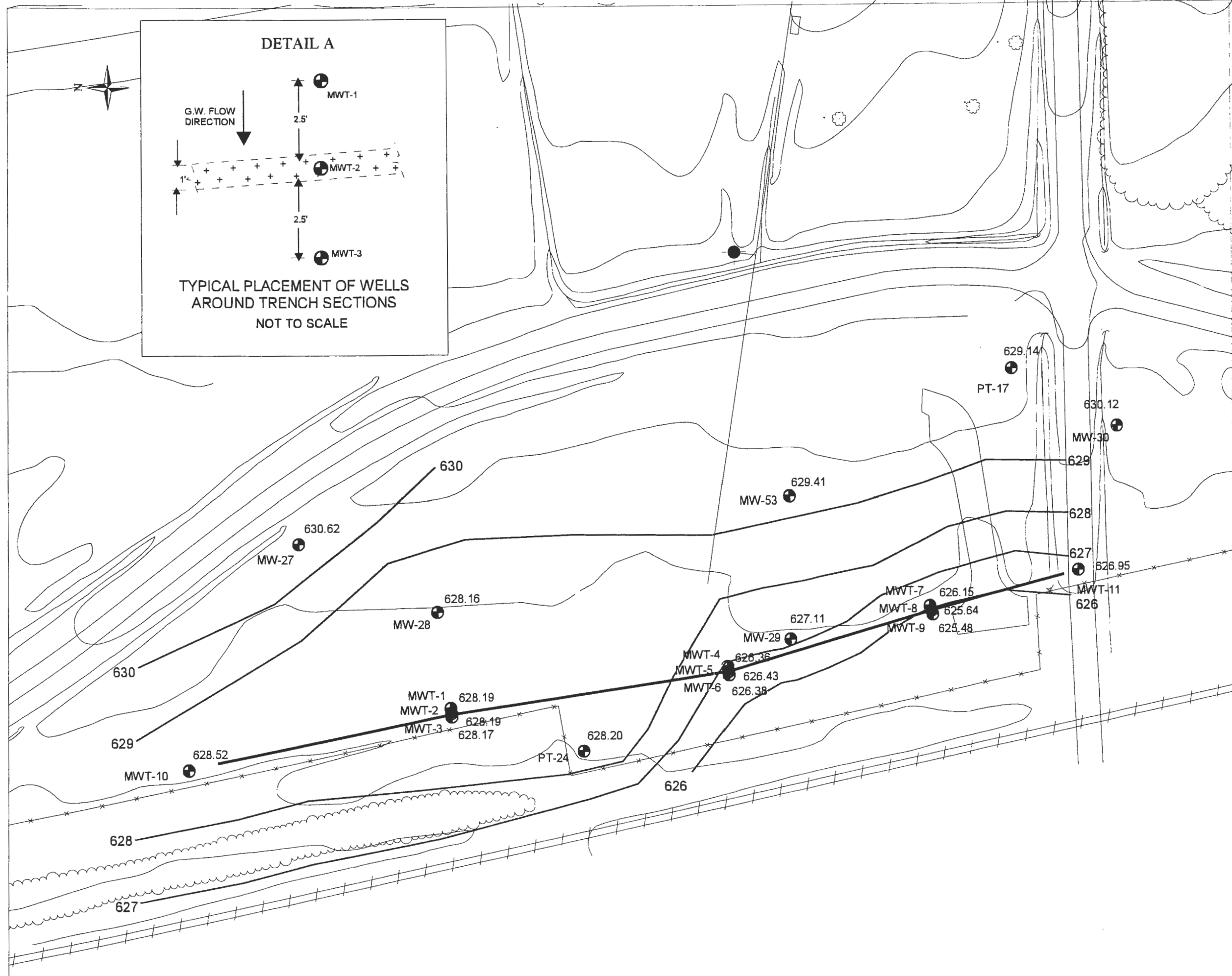
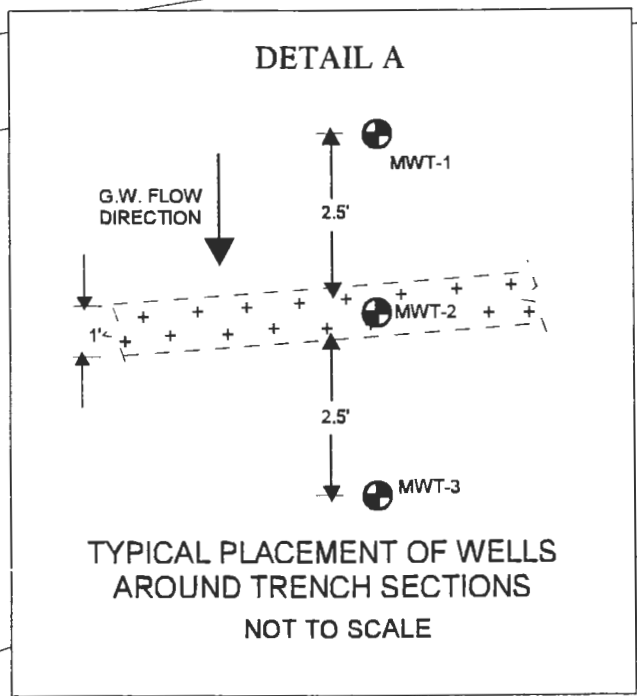
DEPT. ENVIRONMENTAL ENGINEERING DWD. NO. 726209-01004

**FIGURE 6-17**  
**GROUNDWATER ELEVATIONS FOR**  
**CONTINUOUS REACTIVE WALL (JULY, 1999)**

SCALE AS NOTED DATE JANUARY 2000

**LEGEND:**

-  PAVED ROAD
-  DIRT ROAD
-  GROUND CONTOUR AND ELEVATION
-  TREE
-  WETLAND AND DESIGNATION
-  APPROXIMATE EXTENT OF FILL
-  OUTLINE OF FORMER TRASH PITS (IDENTIFIED FROM AERIALPHOTO)
-  APPROXIMATE EXTENT OF DEBRIS PILE
-  BRUSH
-  CHAIN LINK FENCE
-  UTILITY POLE
-  APPROXIMATE LOCATION OF FIRE HYDRANT
-  FUEL OR UNDERGROUND STORAGE TANK
-  MONITORING WELL AND DESIGNATION, ELEVATION
-  RAILROAD TRACKS
-  TREATMENT WALL
-  8" WATER MAIN
-  GROUNDWATER LEVEL CONTOUR



SCALE (FEET)



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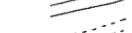

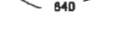



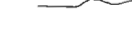










CLIENT/PROJECT TITLE  
**SENECA ARMY DEPOT ACTIVITY**  
ASH LANDFILL GROUNDWATER TREATABILITY STUDY  
USING ZERO VALENT IRON CONTINUOUS REACTIVE WALL

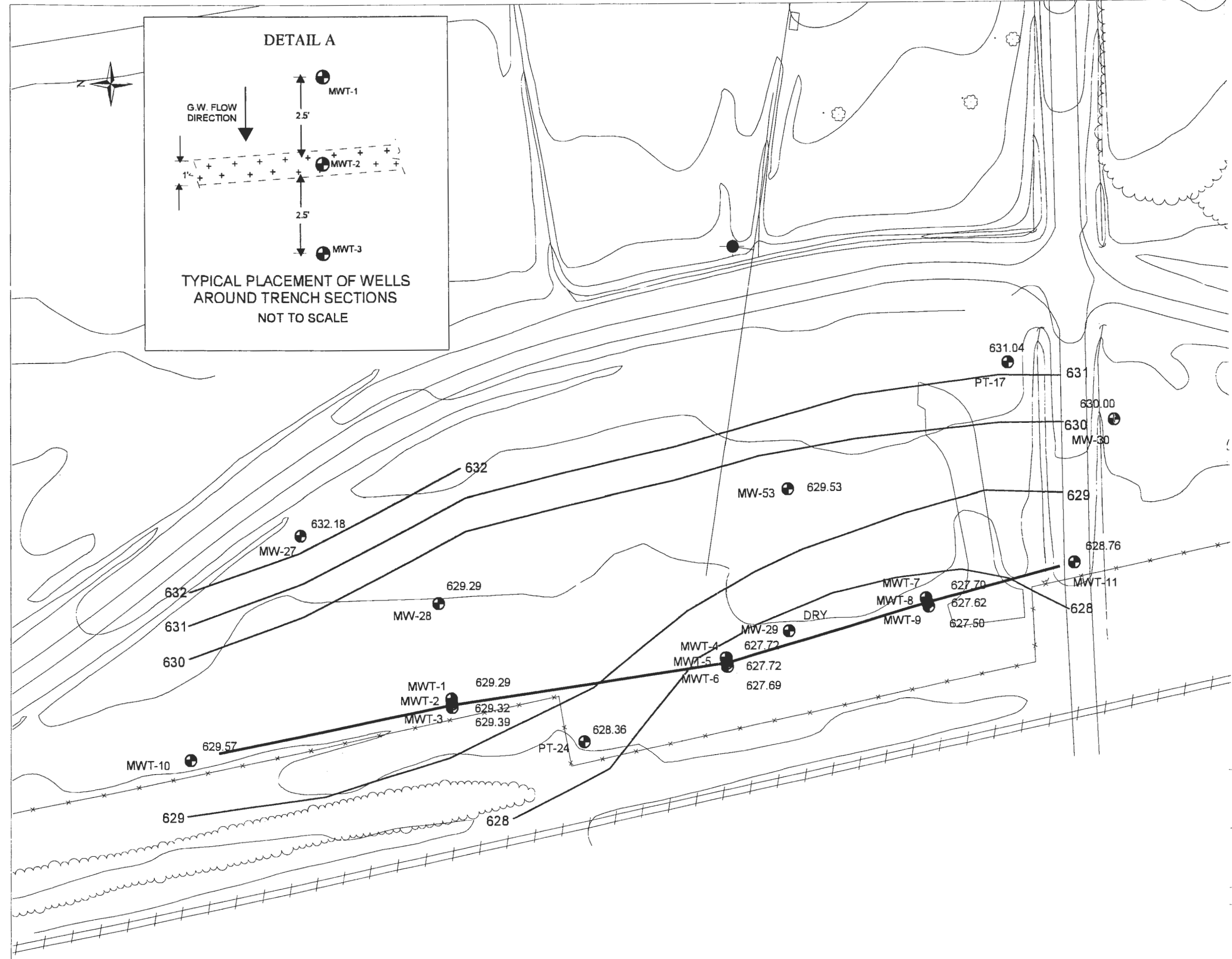
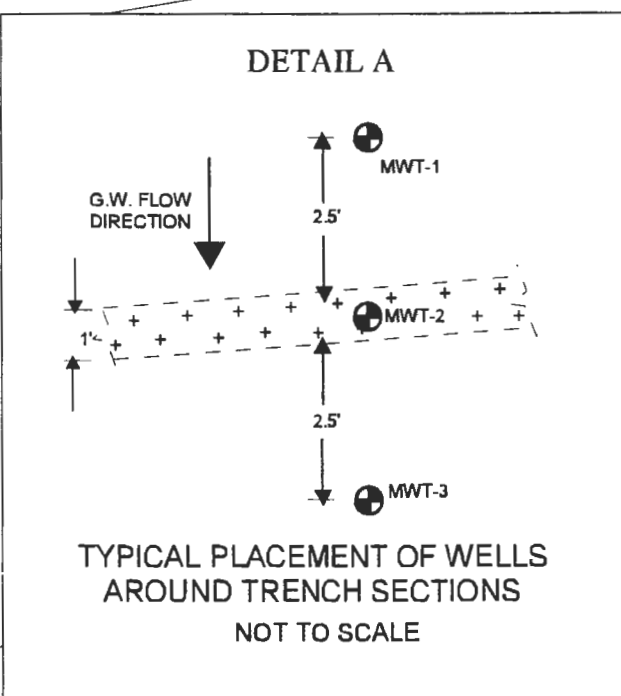
DEPT. ENVIRONMENTAL ENGINEERING      DWG. NO. 736209-01004

**FIGURE 6-18**  
GROUNDWATER ELEVATIONS FOR  
CONTINUOUS REACTIVE WALL (AUGUST 1999)

SCALE AS NOTED      DATE JANUARY 2000

**LEGEND:**

-  PAVED ROAD
-  DIRT ROAD
-  GROUND CONTOUR AND ELEVATION
-  TREE
-  WETLAND AND DESIGNATION
-  APPROXIMATE EXTENT OF FILL
-  OUTLINE OF FORMER TRASH PITS (IDENTIFIED FROM AERIALPHOTO)
-  APPROXIMATE EXTENT OF DEBRIS PILE
-  BRUSH
-  CHAIN LINK FENCE
-  UTILITY POLE
-  APPROXIMATE LOCATION OF FIRE HYDRANT
-  FUEL OR UNDERGROUND STORAGE TANK
-  MONITORING WELL AND DESIGNATION, ELEVATION
-  RAILROAD TRACKS
-  TREATMENT WALL
-  8" WATER MAIN
-  GROUNDWATER LEVEL CONTOUR



SCALE (FEET)



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**PARSONS ENGINEERING SCIENCE, INC.**



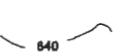



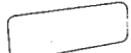











CLIENT/PROJECT TITLE  
**SENECA ARMY DEPOT ACTIVITY**  
 ASH LANDFILL GROUNDWATER TREATABILITY STUDY  
 USING ZERO VALENT IRON CONTINUOUS REACTIVE WALL

DEPT. ENVIRONMENTAL ENGINEERING      DWG. NO. 726209-01004

**FIGURE 6-19**  
**GROUNDWATER ELEVATIONS FOR**  
**CONTINUOUS REACTIVE WALL (SEPTEMBER, 1999)**

SCALE AS NOTED      DATE JANUARY 2000

**LEGEND:**

-  PAVED ROAD
-  DIRT ROAD
-  GROUND CONTOUR AND ELEVATION
-  TREE
-  WETLAND AND DESIGNATION
-  APPROXIMATE EXTENT OF FILL
-  OUTLINE OF FORMER TRASH PITS (IDENTIFIED FROM AERIALPHOTO)
-  APPROXIMATE EXTENT OF DEBRIS PILE
-  BRUSH
-  CHAIN LINK FENCE
-  UTILITY POLE
-  APPROXIMATE LOCATION OF FIRE HYDRANT
-  FUEL OR UNDERGROUND STORAGE TANK
-  <sup>643.2</sup>  
MW-37
-  RAILROAD TRACKS
-  TREATMENT WALL
-  8" WATER MAIN
-  GROUNDWATER LEVEL CONTOUR

**SCALE (FEET)**



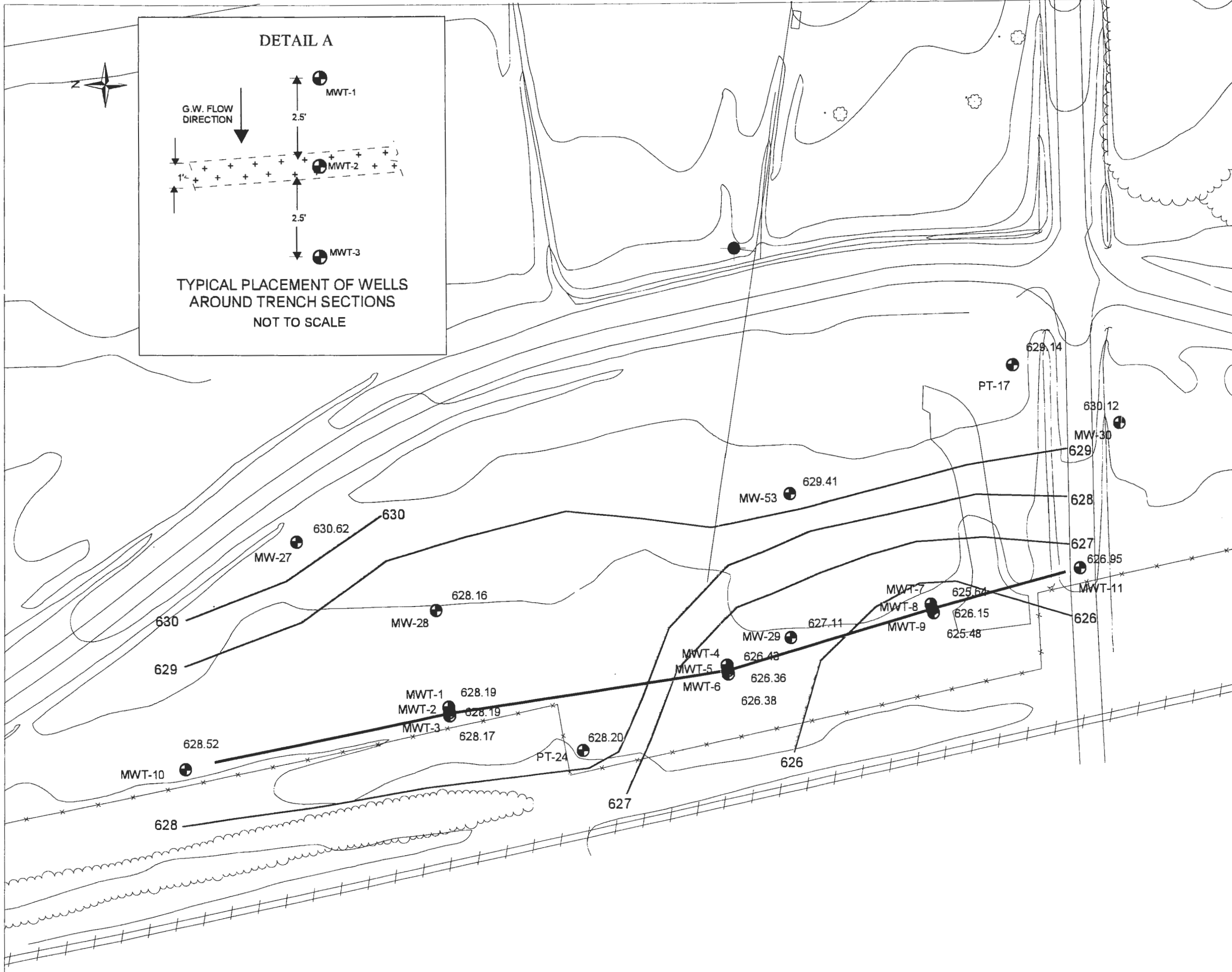
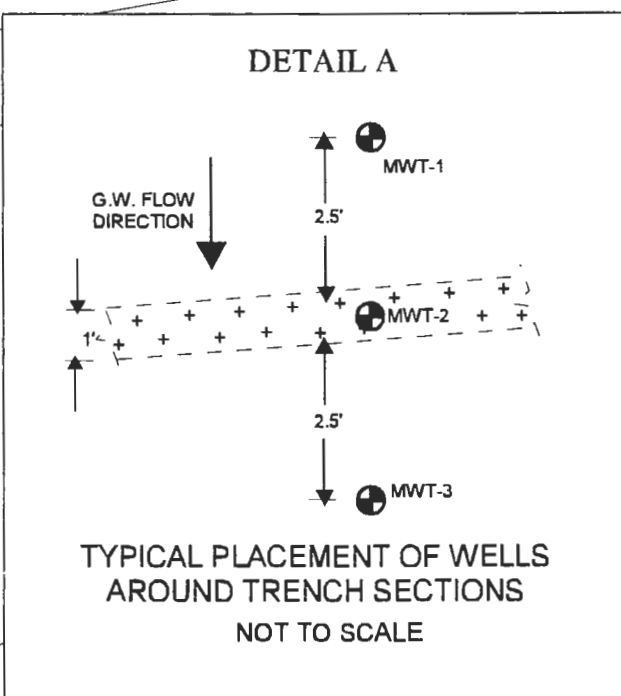
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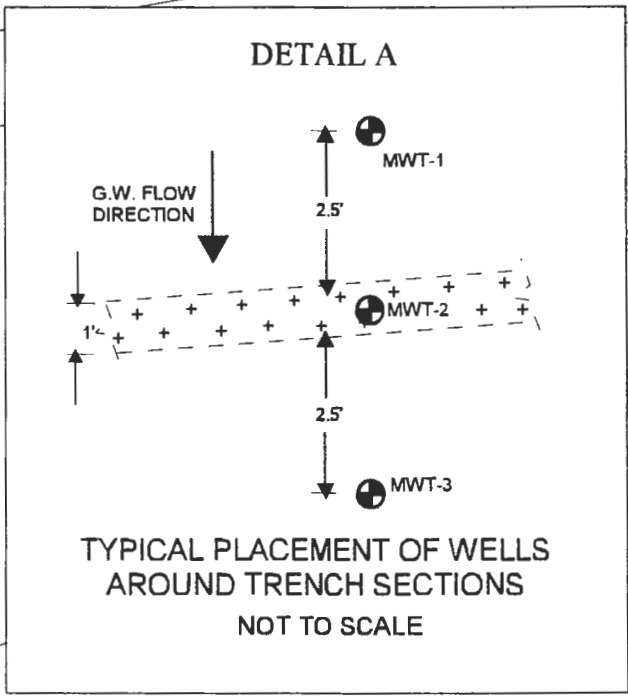
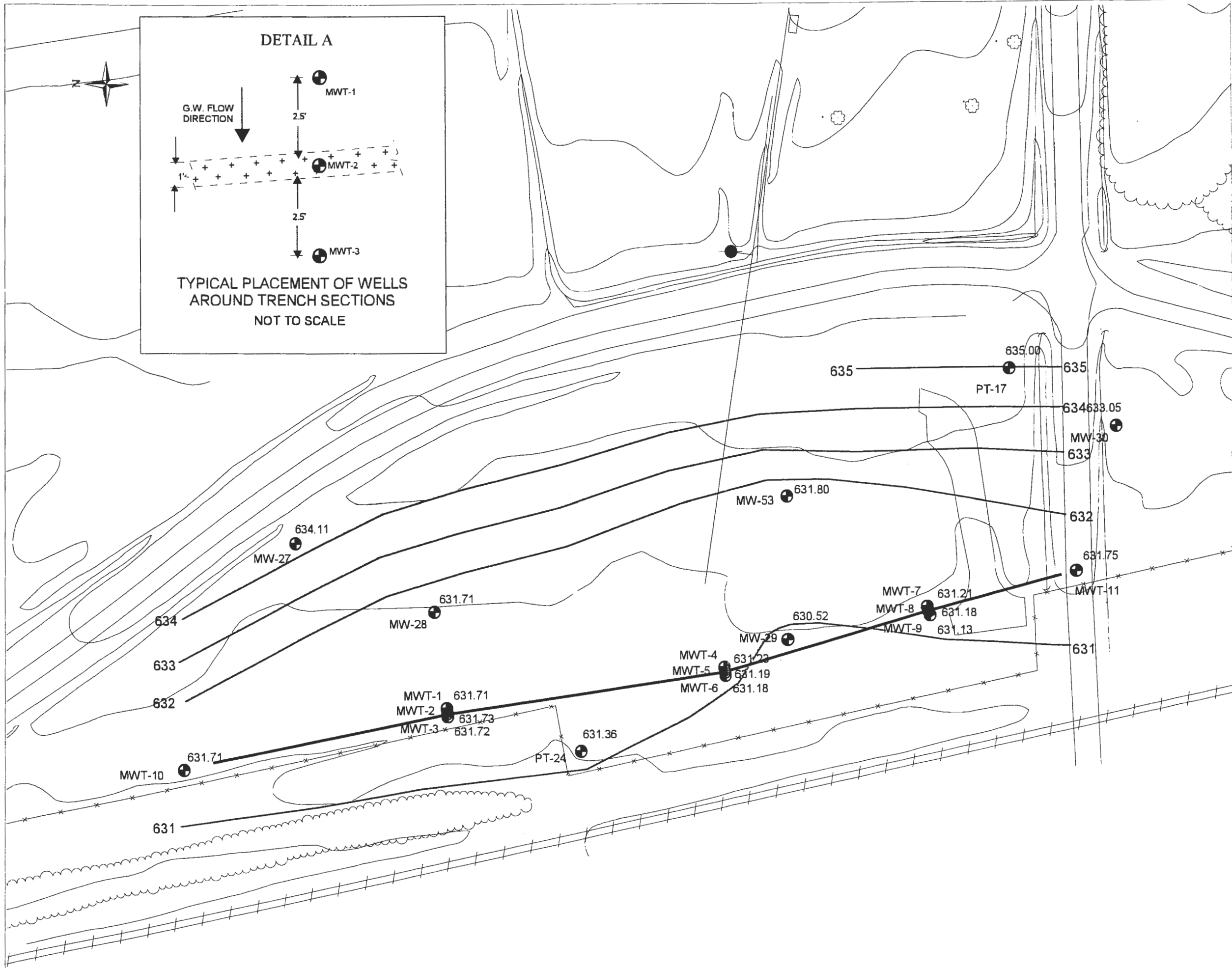
CLIENT/PROJECT TITLE  
**SENECA ARMY DEPOT ACTIVITY**  
ASH LANDFILL GROUNDWATER TREATABILITY STUDY  
USING ZERO VALENT IRON CONTINUOUS REACTIVE WALL

DEPT. ENVIRONMENTAL ENGINEERING      DWG. NO. 726209-01004

**FIGURE 6-20**  
GROUNDWATER ELEVATIONS FOR  
CONTINUOUS REACTIVE WALL (OCTOBER, 1999)

SCALE AS NOTED      DATE JANUARY 2000





- LEGEND:**
- PAVED ROAD
  - DIRT ROAD
  - GROUND CONTOUR AND ELEVATION
  - TREE
  - WETLAND AND DESIGNATION
  - APPROXIMATE EXTENT OF FILL
  - OUTLINE OF FORMER TRASH PITS (IDENTIFIED FROM AERIALPHOTO)
  - APPROXIMATE EXTENT OF DEBRIS PILE
  - BRUSH
  - CHAIN LINK FENCE
  - UTILITY POLE
  - APPROXIMATE LOCATION OF FIRE HYDRANT
  - FUEL OR UNDERGROUND STORAGE TANK
  - MONITORING WELL AND DESIGNATION, ELEVATION
  - RAILROAD TRACKS
  - TREATMENT WALL
  - 8" WATER MAIN
  - GROUNDWATER LEVEL CONTOUR

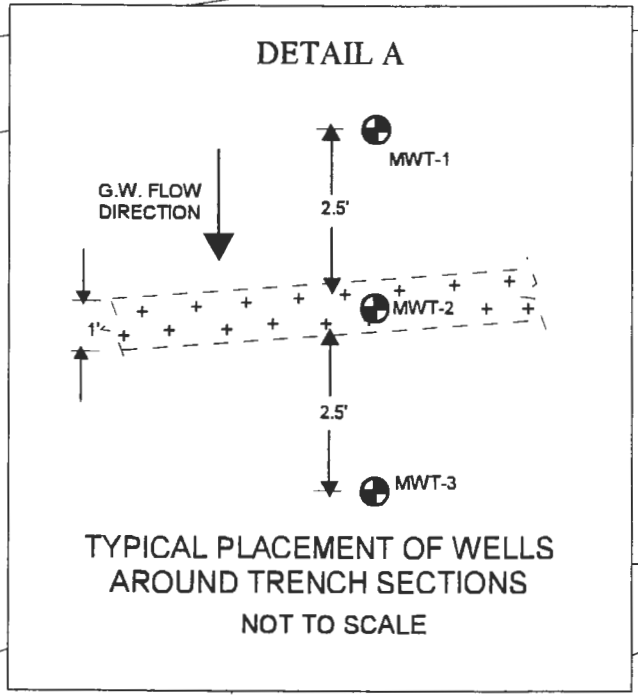
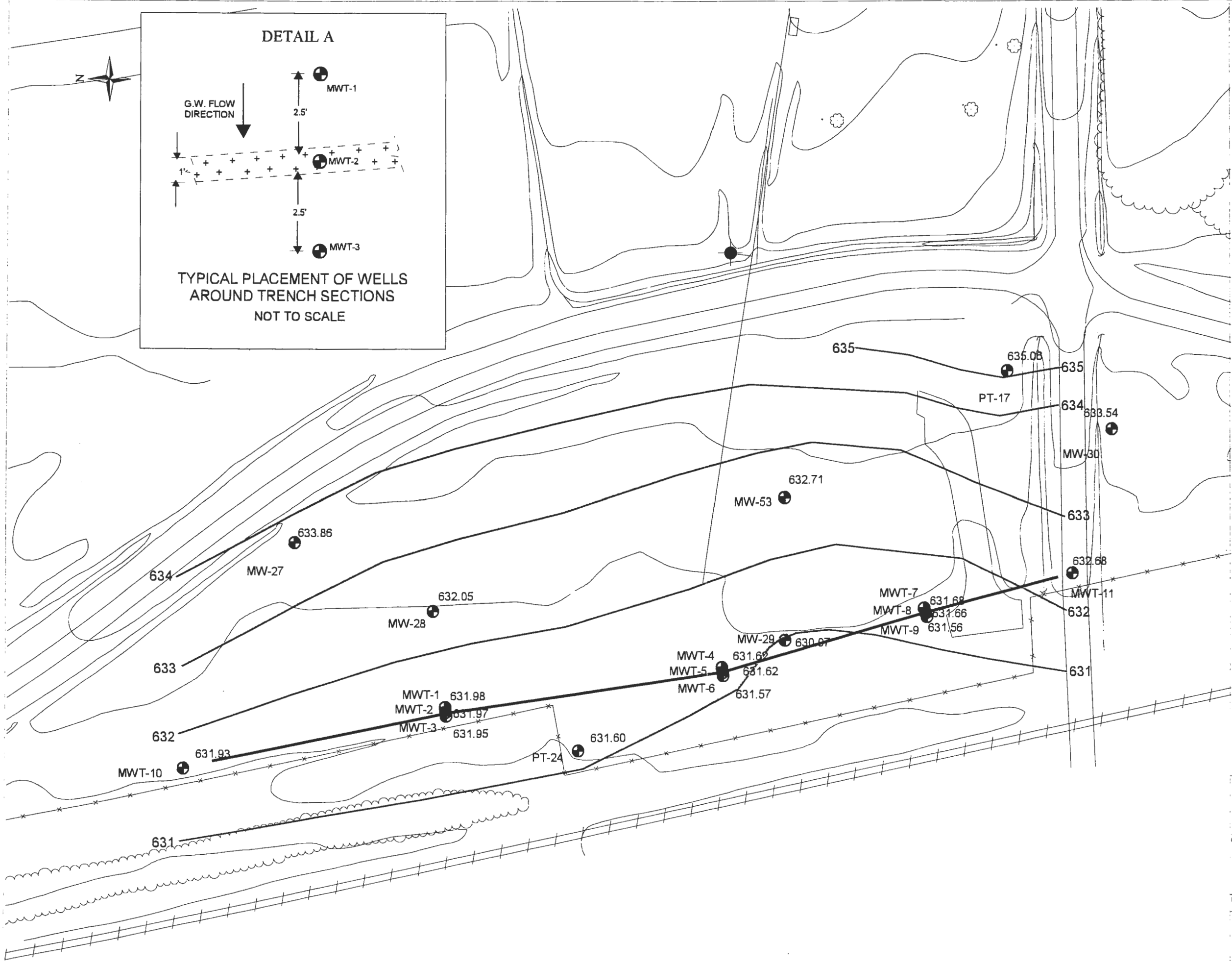


**PARSONS**  
**PARSONS ENGINEERING SCIENCE, INC.**

CLIENT/PROJECT TITLE  
**SENECA ARMY DEPOT ACTIVITY**  
 ASH LANDFILL GROUNDWATER TREATABILITY STUDY  
 USING ZERO VALENT IRON CONTINUOUS REACTIVE WALL

DEPT. ENVIRONMENTAL ENGINEERING      DWG. NO. 726209-01004

**FIGURE 6-21**  
**GROUNDWATER ELEVATIONS FOR**  
**CONTINUOUS REACTIVE WALL (DECEMBER, 1999)**



**LEGEND:**

- PAVED ROAD
- DIRT ROAD
- GROUND CONTOUR AND ELEVATION
- TREE
- WETLAND AND DESIGNATION
- APPROXIMATE EXTENT OF FILL
- OUTLINE OF FORMER TRASH PITS (IDENTIFIED FROM AERIALPHOTO)
- APPROXIMATE EXTENT OF DEBRIS PILE
- BRUSH
- CHAIN LINK FENCE
- UTILITY POLE
- APPROXIMATE LOCATION OF FIRE HYDRANT
- FUEL OR UNDERGROUND STORAGE TANK
- MONITORING WELL AND DESIGNATION, ELEVATION
- RAILROAD TRACKS
- TREATMENT WALL
- 8" WATER MAIN
- GROUNDWATER LEVEL CONTOUR

**SCALE (FEET)**

50' 0 50'

**PARSONS**  
**PARSONS ENGINEERING SCIENCE, INC.**

CLIENT/PROJECT TITLE  
**SENECA ARMY DEPOT ACTIVITY**

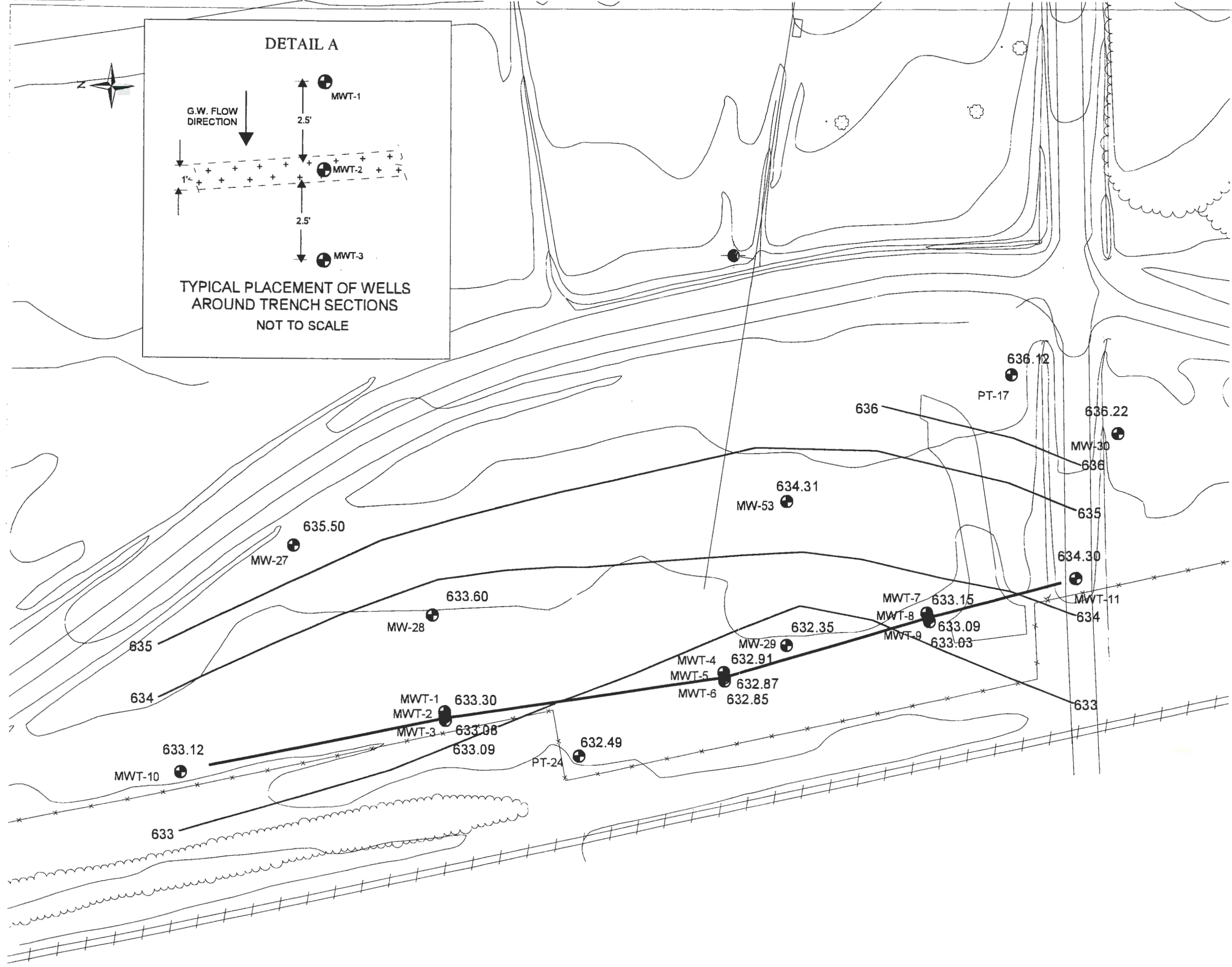
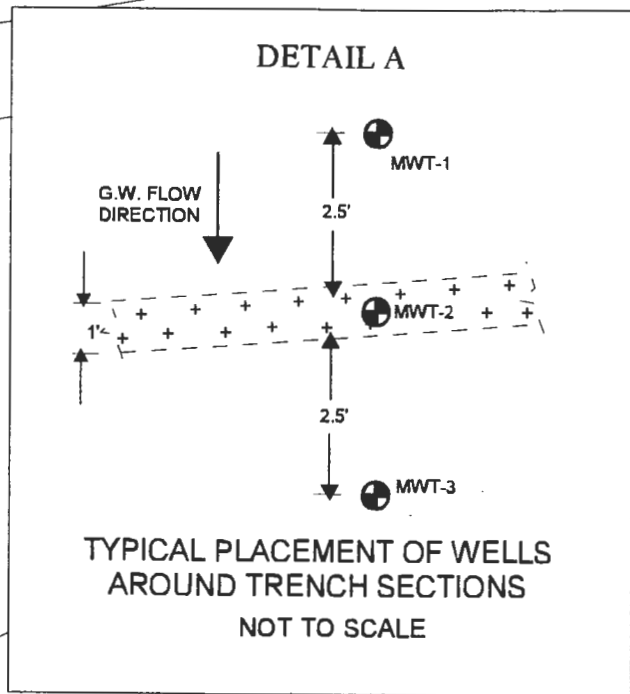
ASH LANDFILL GROUNDWATER TREATABILITY STUDY  
 USING ZERO VALENT IRON CONTINUOUS REACTIVE WALL

DEPT. ENVIRONMENTAL ENGINEERING DWG. NO. 726209-01004

**FIGURE 6-22**  
**GROUNDWATER ELEVATIONS FOR**  
**CONTINUOUS REACTIVE WALL (JANUARY, 2000)**

SCALE AS NOTED DATE JANUARY 2000

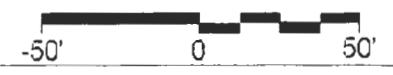




**LEGEND:**

- PAVED ROAD
- DIRT ROAD
- GROUND CONTOUR AND ELEVATION
- TREE
- WETLAND AND DESIGNATION
- APPROXIMATE EXTENT OF FILL
- OUTLINE OF FORMER TRASH PITS (IDENTIFIED FROM AERIALPHOTO)
- APPROXIMATE EXTENT OF DEBRIS PILE
- BRUSH
- CHAIN LINK FENCE
- UTILITY POLE
- APPROXIMATE LOCATION OF FIRE HYDRANT
- FUEL OR UNDERGROUND STORAGE TANK
- MONITORING WELL AND DESIGNATION, ELEVATION
- RAILROAD TRACKS
- TREATMENT WALL
- 8" WATER MAIN
- GROUNDWATER LEVEL CONTOUR

SCALE (FEET)

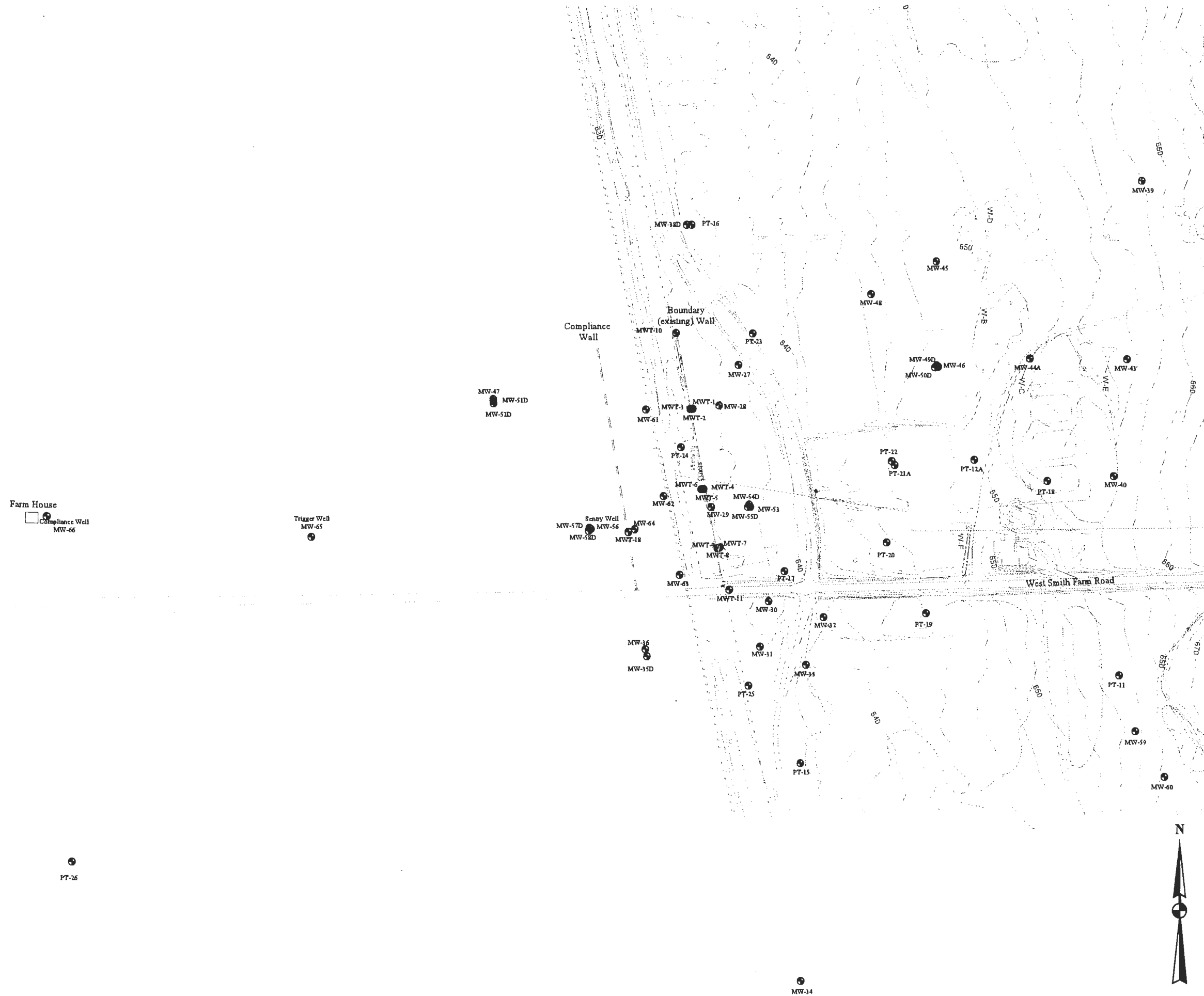


**PARSONS**  
PARSONS ENGINEERING SCIENCE, INC.

CLIENT/PROJECT TITLE  
**SENECA ARMY DEPOT ACTIVITY**  
ASH LANDFILL GROUNDWATER TREATABILITY STUDY  
USING ZERO VALENT IRON CONTINUOUS REACTIVE WALL

DEPT. ENVIRONMENTAL ENGINEERING DWD. NO. 726209-01004

**FIGURE 6-23**  
GROUNDWATER ELEVATIONS FOR  
CONTINUOUS REACTIVE WALL (FEBRUARY, 2000)

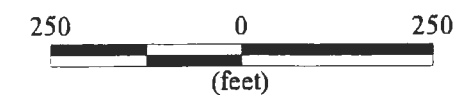


**LEGEND**

- Reactive Iron Wall
- MW-27 Monitoring Well with LOC\_ID
- Railroad Tracks
- Ground Contour and Elevation
- 6" Water Main
- Paved Road
- Utility Pole
- Outline of former trash pits (identified from aerial photo)
- Wetland and designation
- Chain link fence
- Brush
- Approximate location of fire hydrant

**Notes:**

Location of Compliance Wall might change based on results of preconstruction sampling consisting of slug tests and VOC analyses (See Table 7-2).



**PARSONS**  
**PARSONS ENGINEERING SCIENCE, INC.**

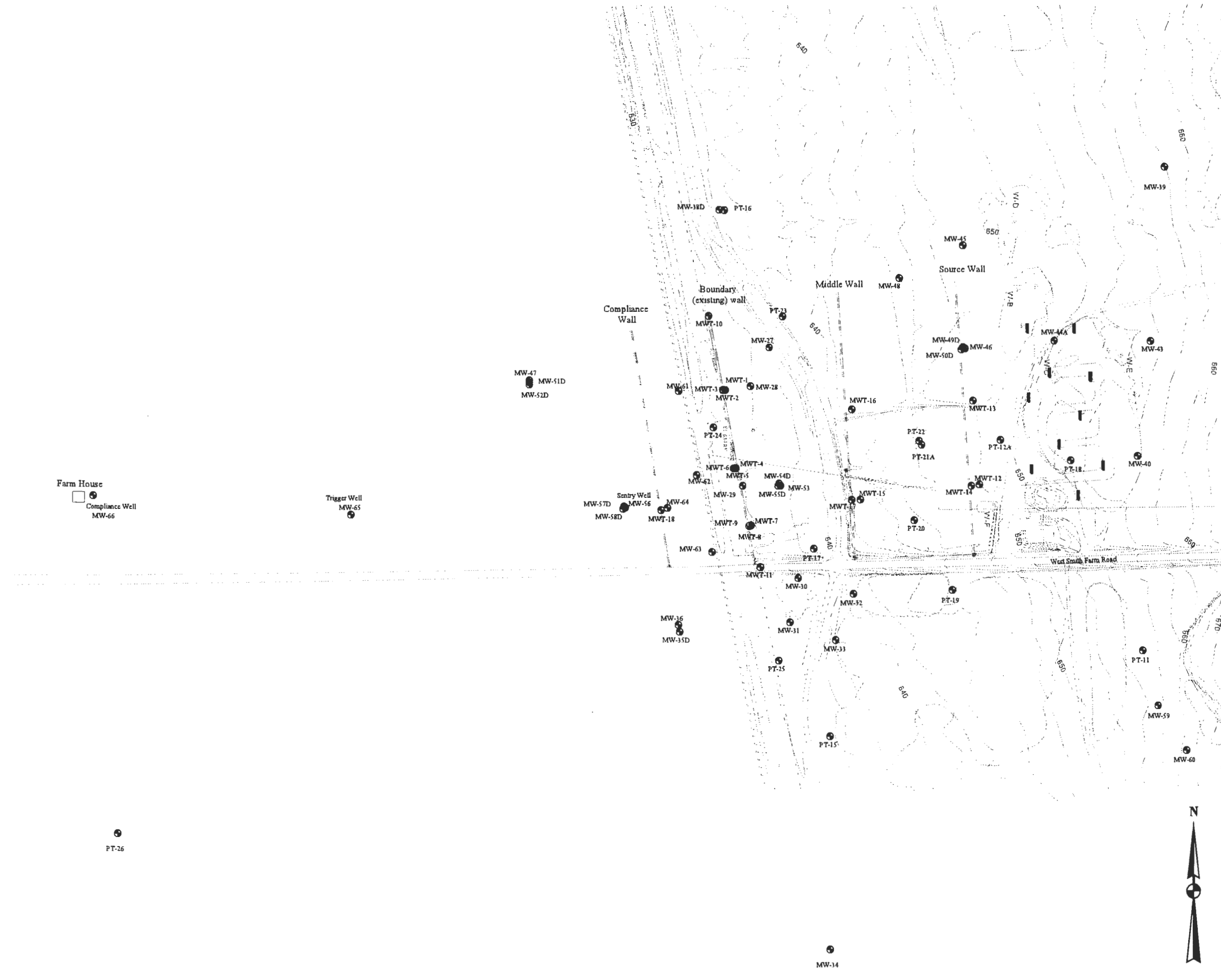
**SENECA ARMY DEPOT ACTIVITY**  
 ASH LANDFILL GROUNDWATER TREATABILITY STUDY  
 USING ZERO VALENT IRON CONTINUOUS REACTIVE WALL

Figure 7-1  
 Alternative 1  
 Location of Iron Walls and  
 Monitoring Wells

SCALE 1:250	DATE June 2000	REV Sheet 1 of 1
----------------	-------------------	---------------------



a.Ash lf.ash\_wells.apr

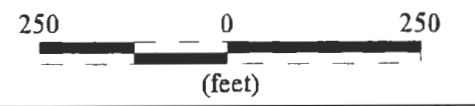


**LEGEND**

- Reactive Iron Wall
- MW-27 Monitoring Well with LOC\_ID
- Trenches for Vegetable Oil Addition (20 ft. long x 3 ft. wide x 10 ft. deep)
- Railroad Tracks
- Ground Contour and Elevation
- 6" Water Main
- Paved Road
- Utility Pole
- Outline of former trash pits (identified from aerial photo)
- Wetland and designation
- Chain link fence
- Brush
- Approximate location of fire hydrant

**Notes:**

Locations of Source Wall, Middle Wall, and Compliance Wall might change based on results of preconstruction sampling consisting of slug tests and VOC analyses (See Table 7-3).



**PARSONS**  
**PARSONS ENGINEERING SCIENCE, INC.**

**SENECA ARMY DEPOT ACTIVITY**  
 ASH LANDFILL GROUNDWATER TREATABILITY STUDY  
 USING ZERO VALENT IRON CONTINUOUS REACTIVE WALL

**Figure 7-2**  
**Alternative 2**  
**Location of Iron Walls, Monitoring Wells, and Vegetable Oil Trenches**

SCALE	DATE	REV
1:250	June 2000	Sheet 1 of 1



Appendix A  
Design and Installation of Boundary (Existing) Continuous Reactive Wall

Design of Boundary (Existing) Continuous Reactive Wall

- Table A-1 Maximum VOC Concentrations Detected in Monitoring Wells in Vicinity of Continuous Reactive Wall Prior to Installation
- Table A-2 Design of Continuous Reactive Wall for Ash Landfill – Quantity of Iron Required in Trench

Installation of Boundary (Existing) Continuous Reactive Iron Wall

- Organic Analysis Results of Sand Fill Material and Topsoil
- Sieve Analysis Results of Sand Fill Material
- Permeability Test Results of Sand/Iron Mixture
- Volatile Organic Analysis Results of Soil Samples for Backfill Material
- Sieve Analysis Results of Iron
- Field Check of Iron/Sand Ratio
- Moisture Content Results of Sand Fill Material

**Table A-1**  
**Maximum VOC Concentrations Detected in Monitoring Wells**  
**in the Vicinity of the Continuous Reactive Wall**  
**Prior to Installation**  
**Ash Landfill Groundwater Treatability Study**  
**Seneca Army Depot Activity, Romulus, NY**

Well ID	Well Location and Concentration					
	PT-17	MW-28	MW-53	PT-24	MW-29	MW-27
Date of Data Collection	Jul-93	Jul-93	Nov-93	Jun-97	Jun-97	Jun-97
Post Removal Action?	No	No	No	Yes	Yes	Yes
<b>VOC</b>	<b>ug/L</b>					
Trichloroethene	190	35	4	7	5	ND
1,2-Dichloroethene	43	53	51	140	150	ND
Vinyl Chloride	ND	ND	ND	ND	ND	ND

Table A-2

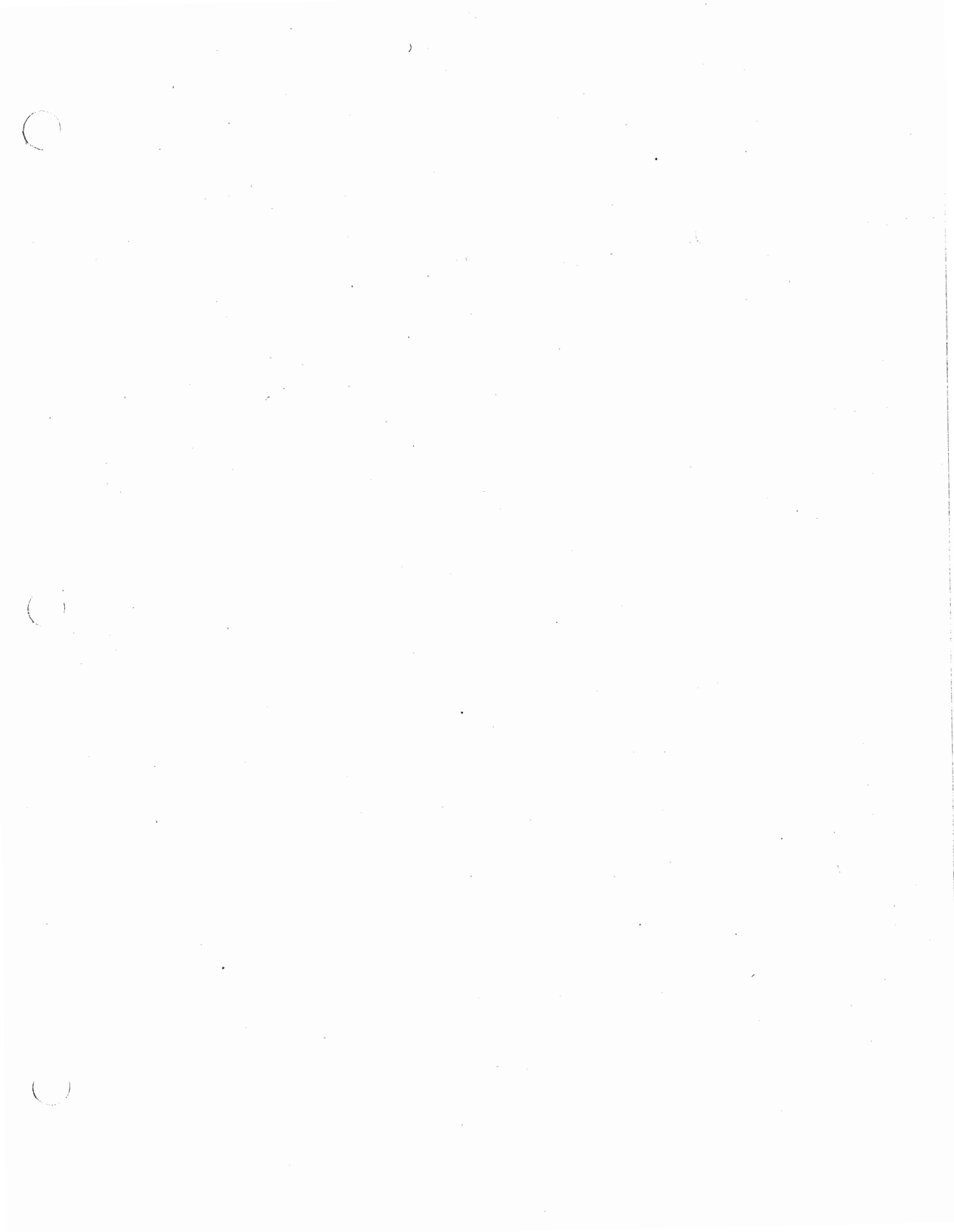
Design of Continuous Reactive Wall for Ash Landfill  
 Quantity of Iron Required in Trench  
 Seneca Army Depot Activity

Residence Time (days) (1)	Thickness of 100% Iron at $v = 0.2$ ft/day (2)	Thickness of 100 % Iron with Safety Factor of 2	Volume of Iron Required for Treatment (cu.ft) (3)	Volume of Trench (1'x9'x645') (cu.ft.)	Total Sand cu.ft.	Percentage iron
1.25	0.25	0.5	2,774	5,805	3,032	48%

(1) Residence time is based on results from Envirometals (10/29/98).

(2) The velocity of groundwater is approx. 0.2 ft/day (60.5 ft/year).

(3) Volume = thickness of 100% iron required \* maximum saturated thickness (est. 8.6') \* length (645')



FROM : DEWIND DEWATERING INC

PHONE NO. : 616 875 7334

Dec. 04 1998 12:11PM P2



**ENVIRONMENTAL TESTING & CONSULTING, INC.**  
 2924 Walnut Grove Road • Memphis, TN 38111 • (901) 827-2750 • FAX (901) 827-6834

*Founded 1972*

November 25, 1998

Ms. Becky DeWind  
 DeWind Dewatering  
 7778 116th Street  
 Holland, MI 49424

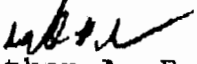
Ref: Analytical Testing  
 ETC Order # 9811550  
 Project Description Seneca Army Depot

The above referenced project has been analyzed per your instructions. The analyses were performed in our laboratory in accordance with Standard Methods 17th/18th Edition; The Solid Waste Manual SW-846; EPA Methods for the Analysis of Water and Wastes and/or 40 CFR part 136.

The results are shown on the attached analysis sheet(s).

Please do not hesitate to contact our office if you have any questions.

Sincerely,

  
 Nathan A. Pera, IV  
 Chief Executive Officer

rt  
 Attachment

DEWIND

**Certifications**

Tennessee #TN02027  
 Arkansas  
 Alabama #40730  
 Kentucky #90047  
 North Carolina #415  
 South Carolina #84002002

Mississippi  
 Oklahoma #9311  
 Virginia #00106  
 Washington #C248  
 US Army Corps of Engineers



PHONE NO. : 616 875 7334  
 Dec. 04 1998 12:22PM P10  
 ROM : DEWIND DEWATERING INC



# CHAIN OF CUSTODY RECORD

Environmental Testing & Consulting, Inc.  
 2924 Walnut Grove Rd.  
 Memphis, TN 38111  
 (901)327-2750 FAX (901)327-8334

ETC Work Order : 9811-SSD

Company Name <b>DEWIND DEWATERING</b>			Phone # : <b>423-220-9057</b>		Fax Results <input checked="" type="checkbox"/>	Analysis Requested (Note special detection limits or methods)																							
Project/Site <b>SEVIECA ARMY DEPT</b>			Fax # : <b>423-220-9922</b>		RUSH	<table style="width: 100%; text-align: center;"> <tr> <td>TOTAL B260</td> <td>TOTAL B270</td> <td>TOTAL PEST</td> <td>TOTAL PCBs</td> <td>TOTAL PCBs</td> <td>TOTAL TALL METALS</td> <td>CA-T 9016</td> <td>NEW</td> <td>7471</td> <td></td> <td></td> <td></td> <td></td> <td></td> </tr> </table>										TOTAL B260	TOTAL B270	TOTAL PEST	TOTAL PCBs	TOTAL PCBs	TOTAL TALL METALS	CA-T 9016	NEW	7471					
TOTAL B260	TOTAL B270	TOTAL PEST	TOTAL PCBs	TOTAL PCBs	TOTAL TALL METALS											CA-T 9016	NEW	7471											
Project #			FID # :		Ice																								
Project Manager/Contact <b>DAN OAKLEY</b>			PO # :																										
Matrix			1 Wastewater		4 Sludge																								
			2 Aqueous		5 Oil/Solvent																								
			3 Soil/Sediment		6 Other																								
# of cont.	Sample ID/Number	Depth	Sample Date	Sample Time	Matrix	Type Grab/Comp	TOTAL B260	TOTAL B270	TOTAL PEST	TOTAL PCBs	TOTAL PCBs	TOTAL TALL METALS	CA-T 9016	NEW	7471	Comments													
2	TOPSOIL	0	11/17/98	15:00	SOIL	GRAB	X	X	X	X	X	X	X	X															
2	SAND	0	11/17/98	15:15	SOIL	GRAB	X	X	X	X	X	X	X	X															
Sampled By <b>DANIEL B. OAKLEY</b>			Method of Shipment <b>FED-X</b>		Blank/ Cooler Temp <b>1400</b>	Remarks																							
RELINQUISHED BY (sign)			DATE	TIME	RECEIVED BY (sign)			DATE	TIME	Sample Delivery Group ID																			
RELINQUISHED BY (sign)			DATE	TIME	RECEIVED BY (sign)			DATE	TIME																				
RELINQUISHED BY (sign)			DATE	TIME	RECEIVED BY LAB (print/sign)			DATE	TIME																				

Distribution : Original and Yellow accompany samples to the laboratory. Pink copy for Field Group

12/04/98 11:59 PAA 4232209922  
 DIVERSE-SOLUTION

**ENVIRONMENTAL TESTING & CONSULTING, INC.**  
 2924 Walnut Grove Road - Memphis, TN 38111 - (901)327-2750  
**ORGANIC ANALYSIS DATA SHEET**

Client Name **DeWind Dewatering**  
 7778 116th Street  
 Holland, MI 49424

Project #  
 FID #

Site ID **Seneca Army Depot**

Date Arrived 11/18/98  
 ETC Order Number 9811550

ETC Lab ID 9811550-01  
**Sample ID: Topsoil**

Matrix :SOIL  
 Sample Date :11/17/98

TEST	RESULT	UNITS	DETECTION LIMIT	DATE EXTRACTED	DATE ANALYZED	BY	METHOD
GC/MS Volatile Organics							8260B
					11/19/98	LS	
Acetone	ND	ug/Kg	20.0				
Acrolain	ND	ug/Kg	20.0				
Acetonitrile	ND	ug/Kg	10.0				
Acrylonitrile	ND	ug/Kg	20.0				
Benzene	ND	ug/Kg	1.00				
Bromobenzene	ND	ug/Kg	1.00				
Bromochloromethane	ND	ug/Kg	1.00				
Bromodichloromethane	ND	ug/Kg	1.00				
Bromoform	ND	ug/Kg	1.00				
Bromomethane (Methyl Bromide)	ND	ug/Kg	1.00				
Butylbenzene	ND	ug/Kg	1.00				
<i>n</i> -Butylbenzene	ND	ug/Kg	1.00				
<i>tert</i> -Butylbenzene	ND	ug/Kg	1.00				
Carbon Disulfide	ND	ug/Kg	1.00				
Carbon Tetrachloride	ND	ug/Kg	1.00				
Chlorobenzene	ND	ug/Kg	1.00				
Chlorodibromomethane	ND	ug/Kg	1.00				
Chloroethane	ND	ug/Kg	1.00				
2-Chloroethylvinyl Ether	ND	ug/Kg	20.0				
Chloroform	ND	ug/Kg	1.00				
Chloromethane	ND	ug/Kg	1.00				
2-Chlorotoluene	ND	ug/Kg	1.00				
4-Chlorotoluene	ND	ug/Kg	1.00				
1,2-Dibromo-3-Chloropropane	ND	ug/Kg	1.00				
1,2-Dibromoethane	ND	ug/Kg	1.00				
Dibromomethane	ND	ug/Kg	1.00				
1,2-Dichlorobenzene	ND	ug/Kg	1.00				
1,3-Dichlorobenzene	ND	ug/Kg	1.00				
1,4-Dichlorobenzene	ND	ug/Kg	1.00				
Dichlorodifluoromethane	ND	ug/Kg	1.00				
1,1-Dichloroethane	ND	ug/Kg	1.00				
1,2-Dichloroethane	ND	ug/Kg	1.00				
1,1-Dichloroethene	ND	ug/Kg	1.00				
<i>cis</i> -1,2-Dichloroethene	ND	ug/Kg	1.00				
<i>trans</i> -1,2-Dichloroethene	ND	ug/Kg	1.00				
1,2-Dichloropropane	ND	ug/Kg	1.00				
1,3-Dichloropropane	ND	ug/Kg	1.00				
2,2-Dichloropropane	ND	ug/Kg	1.00				
1,1-Dichloropropene	ND	ug/Kg	1.00				
<i>cis</i> -1,3-Dichloropropene	ND	ug/Kg	1.00				
<i>trans</i> -1,3-Dichloropropene	ND	ug/Kg	1.00				
Ethyl Acetate	ND	ug/Kg	20.0				
Ethylbenzene	ND	ug/Kg	1.00				

  
 LABORATORY MANAGER

ND - Not Detected

FROM : DEWIND DEWATERING INC

PHONE NO. : 616 875 7334

Dec. 04 1998 12:12PM P4

# ENVIRONMENTAL TESTING & CONSULTING, INC.

2924 Walnut Grove Road - Memphis, TN 38111 - (901)327-2750  
ORGANIC ANALYSIS DATA SHEET

Client Name DeWind Dewatering  
7778 116th Street  
Holland, MI 49424

Project #  
FID #

Site ID Seneca Army Depot

Date Arrived 11/18/98  
ETC Order Number 9811550

ETC Lab ID 9811550-01  
Sample ID: Topsoil

Matrix :SOIL  
Sample Date :11/17/98

TEST	RESULT	UNITS	DETECTION LIMIT	DATE EXTRACTED	DATE ANALYZED	BY	METHOD
GC/MS Volatile Organics							8260B
Hexachlorobutadiene	ND	ug/Kg	1.00		11/19/98	LS	
2-Hexanone (MBK)	ND	ug/Kg	5.00				
Isopropylbenzene	ND	ug/Kg	1.00				
4-Isopropyltoluene	ND	ug/Kg	1.00				
Methylene Chloride	ND	ug/Kg	10.0				
Methyl Ethyl Ketone	ND	ug/Kg	20.0				
4-Methyl-2-pentanone (MIBK)	ND	ug/Kg	20.0				
Methyl-tertbutyl-Ether	ND	ug/Kg	1.00				
Naphthalene	ND	ug/Kg	1.00				
Propylbenzene	ND	ug/Kg	1.00				
Styrene	ND	ug/Kg	1.00				
1,1,1,2-Tetrachloroethane	ND	ug/Kg	1.00				
1,1,2,2-Tetrachloroethane	ND	ug/Kg	1.00				
Tetrachloroethene	ND	ug/Kg	1.00				
Toluene	ND	ug/Kg	1.00				
1,2,3-Trichlorobenzene	ND	ug/Kg	1.00				
1,2,4-Trichlorobenzene	ND	ug/Kg	1.00				
1,1,1-Trichloroethane	ND	ug/Kg	1.00				
1,1,2-Trichloroethane	ND	ug/Kg	1.00				
Trichloroethene	ND	ug/Kg	1.00				
Trichlorofluoromethane	ND	ug/Kg	1.00				
1,2,3-Trichloropropane	ND	ug/Kg	1.00				
1,2,4-Trimethylbenzene	ND	ug/Kg	1.00				
1,3,5-Trimethylbenzene	ND	ug/Kg	1.00				
Vinyl Acetate	ND	ug/Kg	20.0				
Vinyl Chloride	ND	ug/Kg	1.00				
Xylenes (Total)	ND	ug/Kg	1.00				

Surrogate Standard	% Recovery	OC Limits
S1 - Dibromofluoromethane	105	70 134
S2 - Toluene-d8	101	85 111
S3 - 4-Bromofluorobenzene	102	81 117

  
LABORATORY MANAGER

ND - Not Detected

**ENVIRONMENTAL TESTING & CONSULTING, INC.**  
 2924 Walnut Grove Road - Memphis, TN 38111 - (901)327-2750  
**ORGANIC ANALYSIS DATA SHEET**

Client Name **DeWind Dewatering**  
 7778 116th Street  
 Holland, MI 49424

Project #  
 FID #

Site ID **Seneca Army Depot**

Date Arrived 11/18/98  
 ETC Order Number 9811550

ETC Lab ID 9811550-01  
**Sample ID: Topsoil**

Matrix :SOIL  
 Sample Date :11/17/98

TEST	RESULT	UNITS	DETECTION LIMIT	DATE EXTRACTED	DATE ANALYZED	BY	METHOD
GC/MS Base/Neutral & Acid							8270C
Acenaphthene	ND	ug/Kg	167	11/24/98	11/24/98	CB	
Acenaphthylene	ND	ug/Kg	167				
Aniline	ND	ug/Kg	167				
Anthracene	ND	ug/Kg	167				
Benzidine	ND	ug/Kg	667				
Benzoic Acid	ND	ug/Kg	1670				
Benzo(a)anthracene	ND	ug/Kg	167				
Benzo(b)fluoranthene	ND	ug/Kg	167				
Benzo(k)fluoranthene	ND	ug/Kg	167				
Benzo(g,h,i)perylene	ND	ug/Kg	167				
Benzo(a)pyrene	ND	ug/Kg	167				
Benzyl Alcohol	ND	ug/Kg	167				
Bis(2-chloroethyl)ether	ND	ug/Kg	167				
Bis(2-chloroethoxy)methane	ND	ug/Kg	167				
Bis(2-chloroisopropyl)ether	ND	ug/Kg	167				
Bis(2-ethylhexyl) phthalate	ND	ug/Kg	167				
4-Bromophenyl phenyl ether	ND	ug/Kg	167				
Butyl benzyl phthalate	ND	ug/Kg	167				
Carbazole	ND	ug/Kg	333				
4-Chloroaniline	ND	ug/Kg	167				
4-Chloro-3-methylphenol	ND	ug/Kg	167				
2-Chloronaphthalene	ND	ug/Kg	167				
2-Chlorophenol	ND	ug/Kg	167				
4-Chlorophenyl phenyl ether	ND	ug/Kg	167				
Chrysene	ND	ug/Kg	167				
Dibenzo(a,h)anthracene	ND	ug/Kg	167				
Dibenzofuran	ND	ug/Kg	167				
Di-n-butyl phthalate	ND	ug/Kg	167				
1,2-Dichlorobenzene	ND	ug/Kg	167				
1,3-Dichlorobenzene	ND	ug/Kg	167				
1,4-Dichlorobenzene	ND	ug/Kg	167				
3,3'-Dichlorobenzidine	ND	ug/Kg	167				
2,4-Dichlorophenol	ND	ug/Kg	167				
Diethyl phthalate	ND	ug/Kg	167				
2,4-Dimethylphenol	ND	ug/Kg	167				
Dimethyl phthalate	ND	ug/Kg	167				
4,6-Dinitro-2-methylphenol	ND	ug/Kg	333				
2,4-Dinitrophenol	ND	ug/Kg	670				
2,4-Dinitrotoluene	ND	ug/Kg	167				
2,6-Dinitrotoluene	ND	ug/Kg	167				
Di-n-octyl phthalate	ND	ug/Kg	167				
1,2-Diphenylhydrazine	ND	ug/Kg	167				
Fluoranthene	ND	ug/Kg	167				

  
 LABORATORY MANAGER

ND - Not Detected

FROM : DEWIND DEWATERING INC

PHONE NO. : 616 875 7334

Dec. 04 1998 12:18PM P3

**ENVIRONMENTAL TESTING & CONSULTING, INC.**

2924 Walnut Grove Road - Memphis, TN 38111 - (901)327-2750

**ORGANIC ANALYSIS DATA SHEET**

Client Name **DeWind Dewatering**  
 7778 116th Street  
 Holland, MI 49424

Project #  
 FID #

Site ID **Seneca Army Depot**

Date Arrived 11/18/98  
 BTC Order Number 9811550

BTC Lab ID 9811550-01

**Sample ID: Topsoil**

Matrix :SOIL  
 Sample Date :11/17/98

TEST	RESULT	UNITS	DETECTION LIMIT	DATE EXTRACTED	DATE ANALYZED	BY	METHOD
GC/MS Base/Neutral & Acid							8270C
Fluorene	ND	ug/Kg	167	11/24/98	11/24/98	CB	
Hexachlorobenzene	ND	ug/Kg	167				
Hexachlorobutadiene	ND	ug/Kg	167				
Hexachlorocyclopentadiene	ND	ug/Kg	167				
Hexachloroethane	ND	ug/Kg	167				
Indeno (1,2,3-cd) pyrene	ND	ug/Kg	167				
Isophorone	ND	ug/Kg	167				
2-Methylnaphthalene	ND	ug/Kg	167				
2-Methylphenol	ND	ug/Kg	167				
Methylphenol	ND	ug/Kg	167				
Methylphenol	ND	ug/Kg	167				
Naphthalene	ND	ug/Kg	167				
2-Nitroaniline	ND	ug/Kg	167				
3-Nitroaniline	ND	ug/Kg	167				
4-Nitroaniline	ND	ug/Kg	167				
Nitrobenzene	ND	ug/Kg	167				
2-Nitrophenol	ND	ug/Kg	167				
4-Nitrophenol	ND	ug/Kg	167				
N-Nitrosodimethylamine	ND	ug/Kg	167				
N-Nitrosodiphenylamine	ND	ug/Kg	167				
N-Nitroso-di-n-propylamine	ND	ug/Kg	167				
Pentachlorophenol	ND	ug/Kg	333				
Phenanthrene	ND	ug/Kg	167				
Phenol	ND	ug/Kg	167				
Pyrene	ND	ug/Kg	167				
Pyridine	ND	ug/Kg	167				
1,2,4-Trichlorobenzene	ND	ug/Kg	167				
2,4,5-Trichlorophenol	ND	ug/Kg	167				
2,4,6-Trichlorophenol	ND	ug/Kg	167				

Surrogate Standard	% Recovery	QC Limits
S1 - Nitrobenzene-d5	86	25 110
S2 - 2-Fluorobiphenyl	86	33 114
S3 - 4-Terphenyl-d14	89	37 115
S4 - Phenol-d6	82	11 125
S5 - 2,4,6-Tribromophenol	95	9 134
S6 - 2-Fluorophenol	89	10 119

ND - Not Detected

FROM : DEWIND DEWATERING INC

PHONE NO. : 616 875 7334

Dec. 04 1998 12:20PM P6

**ENVIRONMENTAL TESTING & CONSULTING, INC.**

2924 Walnut Grove Road - Memphis, TN 38111 - (901)327-2750

**ORGANIC ANALYSIS DATA SHEET**

Client Name DeWind Dewatering  
 7778 116th Street  
 Holland, MI 49424

Project #  
 FID #

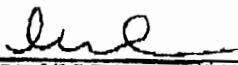
Site ID Seneca Army Depot

Date Arrived 11/18/98  
 ETC Order Number 9811550

ETC Lab ID 9811550-01  
**Sample ID: Topsoil**

Matrix :SOIL  
 Sample Date :11/17/98

TEST	RESULT	UNITS	DETECTION LIMIT	DATE EXTRACTED	DATE ANALYZED	BY	METHOD
TCL Pesticides				11/23/98	11/24/98	RG	8081A
Alpha-BHC	ND	ug/Kg	2.00				
Beta-BHC	ND	ug/Kg	2.00				
Delta-BHC	ND	ug/Kg	2.00				
Gamma-BHC (Lindane)	ND	ug/Kg	2.00				
Heptachlor	ND	ug/Kg	2.00				
Aldrin	ND	ug/Kg	2.00				
Heptachlor Epoxide	ND	ug/Kg	2.00				
Endosulfan I	ND	ug/Kg	2.00				
Dieldrin	ND	ug/Kg	2.00				
4'-DDE	ND	ug/Kg	2.00				
drin	ND	ug/Kg	2.00				
Endosulfan II	ND	ug/Kg	2.00				
4,4'-DDD	ND	ug/Kg	2.00				
Endosulfan Sulfate	ND	ug/Kg	2.00				
4,4'-DDT	ND	ug/Kg	2.00				
Endrin Aldehyde	ND	ug/Kg	2.00				
Endrin Ketone	ND	ug/Kg	2.00				
Methoxychlor	ND	ug/Kg	2.00				
alpha-Chlordane	ND	ug/Kg	2.00				
gamma-Chlordane	ND	ug/Kg	2.00				
Chlordane - Technical	ND	ug/Kg	25.0				
Toxaphene	ND	ug/Kg	35.0				
<b>Surrogate Standard</b>		<b>% Recovery</b>					<b>OC Limits</b>
S1 - Decachlorobiphenyl	84		64	154			
S2 - Tetrachloro-m-xylene	67		39	130			

  
 LABORATORY MANAGER

ND - Not Detected

FROM : DEWIND DEWATERING INC

PHONE NO. : 616 875 7334

Dec. 04 1998 12:21PM PB

**ENVIRONMENTAL TESTING & CONSULTING, INC.**  
 2924 Walnut Grove Road - Memphis, TN 38111 - (901)327-2750  
**ORGANIC ANALYSIS DATA SHEET**

Client Name DeWind Dewatering

Project #  
FID #7778 116th Street  
Holland, MI 49424

Site ID Seneca Army Depot

Date Arrived 11/18/98  
ETC Order Number 9811550ETC Lab ID 9811550-01  
Sample ID: TopsoilMatrix : SOIL  
Sample Date : 11/17/98

TEST	RESULT	UNITS	DETECTION LIMIT	DATE EXTRACTED	DATE ANALYZED	BY	METHOD
TCL PCBs				11/23/98	11/24/98	RG	8082
PCB-1016	ND	ug/Kg	35.0				
PCB-1221	ND	ug/Kg	35.0				
PCB-1232	ND	ug/Kg	35.0				
PCB-1242	ND	ug/Kg	35.0				
PCB-1248	ND	ug/Kg	35.0				
PCB-1254	ND	ug/Kg	35.0				
PCB-1260	ND	ug/Kg	35.0				

Surrogate Standard	% Recovery	OC Limits
- Decachlorobiphenyl	82	17 141
s. - Tetrachloro-m-xylene	62	20 122


  
 LABORATORY MANAGER

ND - Not Detected

**ENVIRONMENTAL TESTING & CONSULTING, INC.**  
 2924 Walnut Grove Road - Memphis, TN 38111 - (901)327-2750  
**INORGANIC ANALYSIS DATA SHEET**

Client Name **DeWind Dewatering**  
 7778 116th Street  
 Holland, MI 49424

Project #

Site ID **Seneca Army Depot**

Date Arrived **11/18/98**  
 ETC Order Number **9811550**

ETC Lab ID **9811550-01**  
**Sample ID: Topsoil**

Matrix : **SOIL**  
 Sample Date : **11/17/98**

TEST	RESULT	UNITS	DETECTION LIMIT	TIME ANALYZED	DATE ANALYZED	BY	METHOD
Cyanide	<1.00	mg/Kg	1.00	0845	11/20/98	GD	9010B
Silver	<0.700	mg/Kg	0.700	1028	11/24/98	TD	6010B
Aluminum	8,390	mg/Kg	4.00	1028	11/24/98	TD	6010B
Arsenic	<5.00	mg/Kg	5.00	1028	11/24/98	TD	6010B
Barium	41.6	mg/Kg	0.200	1028	11/24/98	TD	6010B
Beryllium	0.332	mg/Kg	0.100	1028	11/24/98	TD	6010B
Calcium	1,590	mg/Kg	1.00	1028	11/24/98	TD	6010B
Cadmium	<0.400	mg/Kg	0.400	1028	11/24/98	TD	6010B
Cobalt	5.01	mg/Kg	0.700	1028	11/24/98	TD	6010B
Cromium	9.85	mg/Kg	0.700	1028	11/24/98	TD	6010B
Copper	8.09	mg/Kg	0.600	1028	11/24/98	TD	6010B
Iron	10,700	mg/Kg	0.700	1028	11/24/98	TD	6010B
Mercury	0.042	mg/Kg	0.020	1306	11/19/98	RM	7471A
Potassium	972	mg/Kg	20.0	1028	11/24/98	TD	6010B
Magnesium	1,790	mg/Kg	3.00	1028	11/24/98	TD	6010B
Manganese	397	mg/Kg	0.200	1028	11/24/98	TD	6010B
Sodium	53.5	mg/Kg	20.0	1028	11/24/98	TD	6010B
Nickel	8.32	mg/Kg	1.50	1028	11/24/98	TD	6010B
Lead	15.0	mg/Kg	4.50	1028	11/24/98	TD	6010B
Antimony	<3.20	mg/Kg	3.20	1028	11/24/98	TD	6010B
Selenium	<7.50	mg/Kg	7.50	1028	11/24/98	TD	6010B
Thallium	<5.00	mg/Kg	5.00	1028	11/24/98	TD	6010B
Vanadium	14.2	mg/Kg	0.800	1028	11/24/98	TD	6010B
Zinc	39.6	mg/Kg	1.00	1028	11/24/98	TD	6010B

ETC Lab ID **9811550-02**  
**Sample ID: Sand**

Matrix : **SOIL**  
 Sample Date : **11/17/98**

TEST	RESULT	UNITS	DETECTION LIMIT	TIME ANALYZED	DATE ANALYZED	BY	METHOD
Cyanide	<1.00	mg/Kg	1.00	0845	11/20/98	GD	9010B
Silver	<0.700	mg/Kg	0.700	1028	11/24/98	TD	6010B
Aluminum	3,120	mg/Kg	4.00	1028	11/24/98	TD	6010B
Arsenic	<5.00	mg/Kg	5.00	1028	11/24/98	TD	6010B
Barium	14.7	mg/Kg	0.200	1028	11/24/98	TD	6010B

  
 LABORATORY MANAGER



FROM : DEWIND DEWATERING INC

PHONE NO. : 616 875 7334

Dec. 04 1998 12:35PM P2

**ENVIRONMENTAL TESTING & CONSULTING, INC.**  
2924 Walnut Grove Road - Memphis, TN 38111 - (901)327-2750  
**INORGANIC ANALYSIS DATA SHEET**

Client Name **DeWind Dewatering**  
  
7778 116th Street  
Holland, MI 49424

Project #

Site ID **Seneca Army Depot**

Date Arrived 11/18/98  
ETC Order Number 9811550  
ETC Lab ID 9811550-02

Matrix :SOIL  
Sample Date :11/17/98

**Sample ID: Sand**

TEST	RESULT	UNITS	DETECTION LIMIT	TIME ANALYZED	DATE ANALYZED BY	METHOD
Beryllium	0.154	mg/Kg	0.100	1028	11/24/98 TD	6010B
Calcium	86,700	mg/Kg	1.00	1028	11/24/98 TD	6010B
Cadmium	<0.400	mg/Kg	0.400	1028	11/24/98 TD	6010B
Cobalt	2.57	mg/Kg	0.700	1028	11/24/98 TD	6010B
Chromium	5.88	mg/Kg	0.700	1028	11/24/98 TD	6010B
Copper	12.3	mg/Kg	0.600	1028	11/24/98 TD	6010B
Iron	6,980	mg/Kg	0.700	1028	11/24/98 TD	6010B
Mercury	<0.020	mg/Kg	0.020	1306	11/19/98 RM	7471A
Potassium	711	mg/Kg	20.0	1028	11/24/98 TD	6010B
Naesium	35,500	mg/Kg	3.00	1028	11/24/98 TD	6010B
ganese	311	mg/Kg	0.200	1028	11/24/98 TD	6010B
Sodium	107	mg/Kg	20.0	1028	11/24/98 TD	6010B
Nickel	6.63	mg/Kg	1.50	1028	11/24/98 TD	6010B
Lead	6.66	mg/Kg	4.50	1028	11/24/98 TD	6010B
Antimony	<3.20	mg/Kg	3.20	1028	11/24/98 TD	6010B
Selenium	8.45	mg/Kg	7.50	1028	11/24/98 TD	6010B
Thallium	<5.00	mg/Kg	5.00	1028	11/24/98 TD	6010B
Vanadium	6.46	mg/Kg	0.800	1028	11/24/98 TD	6010B
Zinc	38.3	mg/Kg	1.00	1028	11/24/98 TD	6010B

  
LABORATORY MANAGER

FROM : DEWIND DEWATERING INC

PHONE NO. : 616 875 7334

Dec. 04 1998 12:13PM P5

**ENVIRONMENTAL TESTING & CONSULTING, INC.**

2924 Walnut Grove Road - Memphis, TN 38111 - (901)327-2750

**ORGANIC ANALYSIS DATA SHEET**

Client Name DeWind Dewatering  
7778 116th Street  
Holland, MI 49424

Project #  
FID #

Site ID Seneca Army Depot

Date Arrived 11/18/98  
ETC Order Number 9811550

ETC Lab ID 9811550-02  
Sample ID: Sand

Matrix :SOIL  
Sample Date :11/17/98

TEST	RESULT	UNITS	DETECTION LIMIT	DATE EXTRACTED	DATE ANALYZED	BY	METHOD
GC/MS Volatile Organics					11/19/98	LS	8260B
Acetone	ND	ug/KG	20.0				
Acrolein	ND	ug/KG	20.0				
Acetonitrile	ND	ug/KG	10.0				
Acrylonitrile	ND	ug/KG	20.0				
Benzene	ND	ug/KG	1.00				
Bromobenzene	ND	ug/KG	1.00				
Bromochloromethane	ND	ug/KG	1.00				
Bromodichloromethane	ND	ug/KG	1.00				
Bromoform	ND	ug/KG	1.00				
Dimethylmethane (Methyl Bromide)	ND	ug/KG	1.00				
n-Butylbenzene	ND	ug/KG	1.00				
sec-Butylbenzene	ND	ug/KG	1.00				
tert-Butylbenzene	ND	ug/KG	1.00				
Carbon Disulfide	ND	ug/KG	1.00				
Carbon Tetrachloride	ND	ug/KG	1.00				
Chlorobenzene	ND	ug/KG	1.00				
Chlorodibromomethane	ND	ug/KG	1.00				
Chloroethane	ND	ug/KG	1.00				
2-Chloroethylvinyl Ether	ND	ug/KG	20.0				
Chloroform	ND	ug/KG	1.00				
Chloromethane	ND	ug/KG	1.00				
2-Chlorotoluene	ND	ug/KG	1.00				
4-Chlorotoluene	ND	ug/KG	1.00				
1,2-Dibromo-3-Chloropropane	ND	ug/KG	1.00				
1,2-Dibromoethane	ND	ug/KG	1.00				
Dibromomethane	ND	ug/KG	1.00				
1,2-Dichlorobenzene	ND	ug/KG	1.00				
1,3-Dichlorobenzene	ND	ug/KG	1.00				
1,4-Dichlorobenzene	ND	ug/KG	1.00				
Dichlorodifluoromethane	ND	ug/KG	1.00				
1,1-Dichloroethane	ND	ug/KG	1.00				
1,2-Dichloroethane	ND	ug/KG	1.00				
1,1-Dichloroethene	ND	ug/KG	1.00				
cis-1,2-Dichloroethene	ND	ug/KG	1.00				
trans-1,2-Dichloroethene	ND	ug/KG	1.00				
1,2-Dichloropropane	ND	ug/KG	1.00				
1,3-Dichloropropane	ND	ug/KG	1.00				
2,2-Dichloropropane	ND	ug/KG	1.00				
1,1-Dichloropropane	ND	ug/KG	1.00				
cis-1,3-Dichloropropene	ND	ug/KG	1.00				
trans-1,3-Dichloropropene	ND	ug/KG	1.00				
Ethyl Acetate	ND	ug/KG	20.0				
Ethylbenzene	ND	ug/KG	1.00				

  
LABORATORY MANAGER

ND - Not Detected

FROM : DEWIND DEWATERING INC

PHONE NO. : 616 875 7334

Dec. 04 1998 12:17PM P1

**ENVIRONMENTAL TESTING & CONSULTING, INC.**

2924 Walnut Grove Road - Memphis, TN 38111 - (901)327-2750

**ORGANIC ANALYSIS DATA SHEET**

Client Name **DeWind Dewatering**  
**7778 116th Street**  
**Holland, MI 49424**

Project #  
 FID #

Site ID **Seneca Army Depot**

Date Arrived **11/18/98**  
 ETC Order Number **9811550**

ETC Lab ID **9811550-02**

**Sample ID: Sand**

Matrix : **SOIL**  
 Sample Date : **11/17/98**

TEST	RESULT	UNITS	DETECTION LIMIT	DATE EXTRACTED	DATE ANALYZED	BY	METHOD
GC/MS Volatile Organics							8260B
Hexachlorobutadiene	ND	ug/KG	1.00		11/19/98	LS	
2-Hexanone (MBK)	ND	ug/KG	5.00				
Isopropylbenzene	ND	ug/KG	1.00				
4-Isopropyltoluene	ND	ug/KG	1.00				
Methylene Chloride	ND	ug/KG	10.0				
Methyl Ethyl Ketone	ND	ug/KG	20.0				
4-Methyl-2-pentanone (MIBK)	ND	ug/KG	20.0				
Methyl-tertbutyl-Ether	ND	ug/KG	1.00				
Naphthalene	ND	ug/KG	1.00				
Propylbenzene	ND	ug/KG	1.00				
ylene	ND	ug/KG	1.00				
1,1,1,2-Tetrachloroethane	ND	ug/KG	1.00				
1,1,2,2-Tetrachloroethane	ND	ug/KG	1.00				
Tetrachloroethene	ND	ug/KG	1.00				
Toluene	ND	ug/KG	1.00				
1,2,3-Trichlorobenzene	ND	ug/KG	1.00				
1,2,4-Trichlorobenzene	ND	ug/KG	1.00				
1,1,1-Trichloroethane	ND	ug/KG	1.00				
1,1,2-Trichloroethane	ND	ug/KG	1.00				
Trichloroethene	ND	ug/KG	1.00				
Trichlorofluoromethane	ND	ug/KG	1.00				
1,2,3-Trichloropropane	ND	ug/KG	1.00				
1,2,4-Trimethylbenzene	ND	ug/KG	1.00				
1,3,5-Trimethylbenzene	ND	ug/KG	1.00				
Vinyl Acetate	ND	ug/KG	20.0				
Vinyl Chloride	ND	ug/KG	1.00				
Xylenes (Total)	ND	ug/KG	1.00				

Surrogate Standard	% Recovery	OC Limits
S1 - Dibromofluoromethane	103	70 134
S2 - Toluene-d8	101	85 111
S3 - 4-Bromofluorobenzene	105	61 117

  
 LABORATORY MANAGER

ND - Not Detected

**ENVIRONMENTAL TESTING & CONSULTING, INC.**

2924 Walnut Grove Road - Memphis, TN 38111 - (901)327-2750

**ORGANIC ANALYSIS DATA SHEET**

Client Name **DeWind Dewatering**  
 7778 116th Street  
 Holland, MI 49424

Project #  
 FID #

Site ID **Seneca Army Depot**

Date Arrived 11/18/98  
 ETC Order Number 9811550

ETC Lab ID 9811550-02  
**Sample ID: Sand**

Matrix :SOIL  
 Sample Date :11/17/98

TEST	RESULT	UNITS	DETECTION LIMIT	DATE EXTRACTED	DATE ANALYZED	BY	METHOD
GC/MS Base/Neutral & Acid							8270C
				11/24/98	11/24/98	CB	
Acenaphthene	ND	ug/Kg	167				
Acenaphthylene	ND	ug/Kg	167				
Aniline	ND	ug/Kg	167				
Anthracene	ND	ug/Kg	167				
Benxidine	ND	ug/Kg	667				
Benzoic Acid	ND	ug/Kg	1670				
Benzo (a) anthracene	ND	ug/Kg	167				
Benzo (b) Fluoranthene	ND	ug/Kg	167				
Benzo (k) Fluoranthene	ND	ug/Kg	167				
Benzo (g, h, i) perylene	ND	ug/Kg	167				
benzo (a) pyrene	ND	ug/Kg	167				
Benzyl Alcohol	ND	ug/Kg	167				
Bis (2-chloroethyl) ether	ND	ug/Kg	167				
Bis (2-chloroethoxy) methane	ND	ug/Kg	167				
Bis (2-chloroisopropyl) ether	ND	ug/Kg	167				
Bis (2-ethylhexyl) phthalate	ND	ug/Kg	167				
4-Bromophenyl phenyl ether	ND	ug/Kg	167				
Butyl benzyl phthalate	ND	ug/Kg	167				
Carbazole	ND	ug/Kg	333				
4-Chloroaniline	ND	ug/Kg	167				
4-Chloro-3-methylphenol	ND	ug/Kg	167				
2-Chloronaphthalene	ND	ug/Kg	167				
2-Chlorophenol	ND	ug/Kg	167				
4-Chlorophenyl phenyl ether	ND	ug/Kg	167				
Chrysene	ND	ug/Kg	167				
Dibenzo (a, h) anthracene	ND	ug/Kg	167				
Dibenzofuran	ND	ug/Kg	167				
Di-n-butyl phthalate	ND	ug/Kg	167				
1,2-Dichlorobenzene	ND	ug/Kg	167				
1,3-Dichlorobenzene	ND	ug/Kg	167				
1,4-Dichlorobenzene	ND	ug/Kg	167				
3,3'-Dichlorobenzidine	ND	ug/Kg	167				
2,4-Dichlorophenol	ND	ug/Kg	167				
Diethyl phthalate	ND	ug/Kg	167				
2,4-Dimethylphenol	ND	ug/Kg	167				
Dimethyl phthalate	ND	ug/Kg	167				
4,6-Dinitro-2-methylphenol	ND	ug/Kg	333				
2,4-Dinitrophenol	ND	ug/Kg	670				
2,4-Dinitrotoluene	ND	ug/Kg	167				
2,6-Dinitrotoluene	ND	ug/Kg	167				
Di-n-octyl phthalate	ND	ug/Kg	167				
1,2-Diphenylhydrazine	ND	ug/Kg	167				
Fluoranthene	ND	ug/Kg	167				

  
 LABORATORY MANAGER

ND - Not Detected

FROM : DEWIND DEWATERING INC

PHONE NO. : 616 875 7334

Dec. 04 1998 12:19PM P5

**ENVIRONMENTAL TESTING & CONSULTING, INC.**

2924 Walnut Grove Road - Memphis, TN 38111 - (901)327-2750

**ORGANIC ANALYSIS DATA SHEET**

Client Name **DeWind Dewatering**  
 7778 116th Street  
 Holland, MI 49424

Project #  
 FID #

Site ID **Seneca Army Depot**

Date Arrived **11/18/98**  
 ETC Order Number **9811550**

ETC Lab ID **9811550-02**

**Sample ID: Sand**

Matrix : **SOIL**  
 Sample Date : **11/17/98**

TEST	RESULT	UNITS	DETECTION LIMIT	DATE EXTRACTED	DATE ANALYZED	BY	METHOD
GC/MS Base/Neutral & Acid							8270C
Fluorene	ND	ug/Kg	167	11/24/98	11/24/98	CB	
Hexachlorobenzene	ND	ug/Kg	167				
Hexachlorobutadiene	ND	ug/Kg	167				
Hexachlorocyclopentadiene	ND	ug/Kg	167				
Hexachloroethane	ND	ug/Kg	167				
Indeno (1,2,3-cd) pyrene	ND	ug/Kg	167				
Isophorone	ND	ug/Kg	167				
2-Methylnaphthalene	ND	ug/Kg	167				
2-Methylphenol	ND	ug/Kg	167				
3-Methylphenol	ND	ug/Kg	167				
4-Methylphenol	ND	ug/Kg	167				
naphthalene	ND	ug/Kg	167				
2-Nitroaniline	ND	ug/Kg	167				
3-Nitroaniline	ND	ug/Kg	167				
4-Nitroaniline	ND	ug/Kg	167				
Nitrobenzene	ND	ug/Kg	167				
2-Nitrophenol	ND	ug/Kg	167				
4-Nitrophenol	ND	ug/Kg	167				
N-Nitrosodimethylamine	ND	ug/Kg	167				
N-Nitrosodiphenylamine	ND	ug/Kg	167				
N-Nitroso-di-n-propylamine	ND	ug/Kg	167				
Pentachlorophenol	ND	ug/Kg	333				
Phenanthrene	ND	ug/Kg	167				
Phenol	ND	ug/Kg	167				
Pyrene	ND	ug/Kg	167				
Pyridine	ND	ug/Kg	167				
1,2,4-Trichlorobenzene	ND	ug/Kg	167				
2,4,5-Trichlorophenol	ND	ug/Kg	167				
2,4,6-Trichlorophenol	ND	ug/Kg	167				

Surrogate Standard	% Recovery	OC Limits
S1 - Nitrobenzene-d5	29	25 110
S2 - 2-Fluorobiphenyl	33	33 114
S3 - 4-Terphenyl-d14	40	37 115
S4 - Phenol-d6	25	11 125
S5 - 2,4,6-Tribromophenol	32	9 134
S6 - 2-Fluorophenol	29	10 119

LABORATORY MANAGER

ND - Not Detected

**ENVIRONMENTAL TESTING & CONSULTING, INC.**  
 2924 Walnut Grove Road - Memphis, TN 38111 - (901)327-2750  
**ORGANIC ANALYSIS DATA SHEET**

Client Name DeWind Dewatering  
 7778 116th Street  
 Holland, MI 49424

Project #  
 FID #

Site ID Seneca Army Depot

Date Arrived 11/18/98  
 ETC Order Number 9811550

ETC Lab ID 9811550-02  
**Sample ID: Sand**

Matrix :SOIL  
 Sample Date :11/17/98

TEST	RESULT	UNITS	DETECTION LIMIT	DATE EXTRACTED	DATE ANALYZED	BY	METHOD
TCL Pesticides				11/23/98	11/24/98	RG	8081A
Alpha-BHC	ND	ug/Kg	2.00				
Beta-BHC	ND	ug/Kg	2.00				
Delta-BHC	ND	ug/Kg	2.00				
Gamma-BHC (Lindane)	ND	ug/Kg	2.00				
Heptachlor	ND	ug/Kg	2.00				
Aldrin	ND	ug/Kg	2.00				
Heptachlor Epoxide	ND	ug/Kg	2.00				
Endosulfan I	ND	ug/Kg	2.00				
Dieldrin	ND	ug/Kg	2.00				
4,4'-DDE	ND	ug/Kg	2.00				
drin	ND	ug/Kg	2.00				
Endosulfan II	ND	ug/Kg	2.00				
4,4'-DDD	ND	ug/Kg	2.00				
Endosulfan Sulfate	ND	ug/Kg	2.00				
4,4'-DDT	ND	ug/Kg	2.00				
Endrin Aldehyde	ND	ug/Kg	2.00				
Endrin Ketone	ND	ug/Kg	2.00				
Methoxychlor	ND	ug/Kg	2.00				
alpha-Chlordane	ND	ug/Kg	2.00				
gamma-Chlordane	ND	ug/Kg	2.00				
Chlordane - Technical	ND	ug/Kg	25.0				
Toxaphene	ND	ug/Kg	35.0				

Surrogate Standard	% Recovery	OC Limits
S1 - Decachlorobiphenyl	87	64 154
S2 - Tetrachloro-m-xylene	65	39 130

  
 LABORATORY MANAGER

ND - Not Detected

**ENVIRONMENTAL TESTING & CONSULTING, INC.**  
 2924 Walnut Grove Road - Memphis, TN 38111 - (901)327-2750  
**ORGANIC ANALYSIS DATA SHEET**

Client Name **DeWind Dewatering**  
 7778 116th Street  
 Holland, MI 49424

Project #  
 FID #

Site ID **Seneca Army Depot**

Date Arrived 11/18/98  
 ETC Order Number 9811550

ETC Lab ID **9811550-02**

Matrix :SOIL

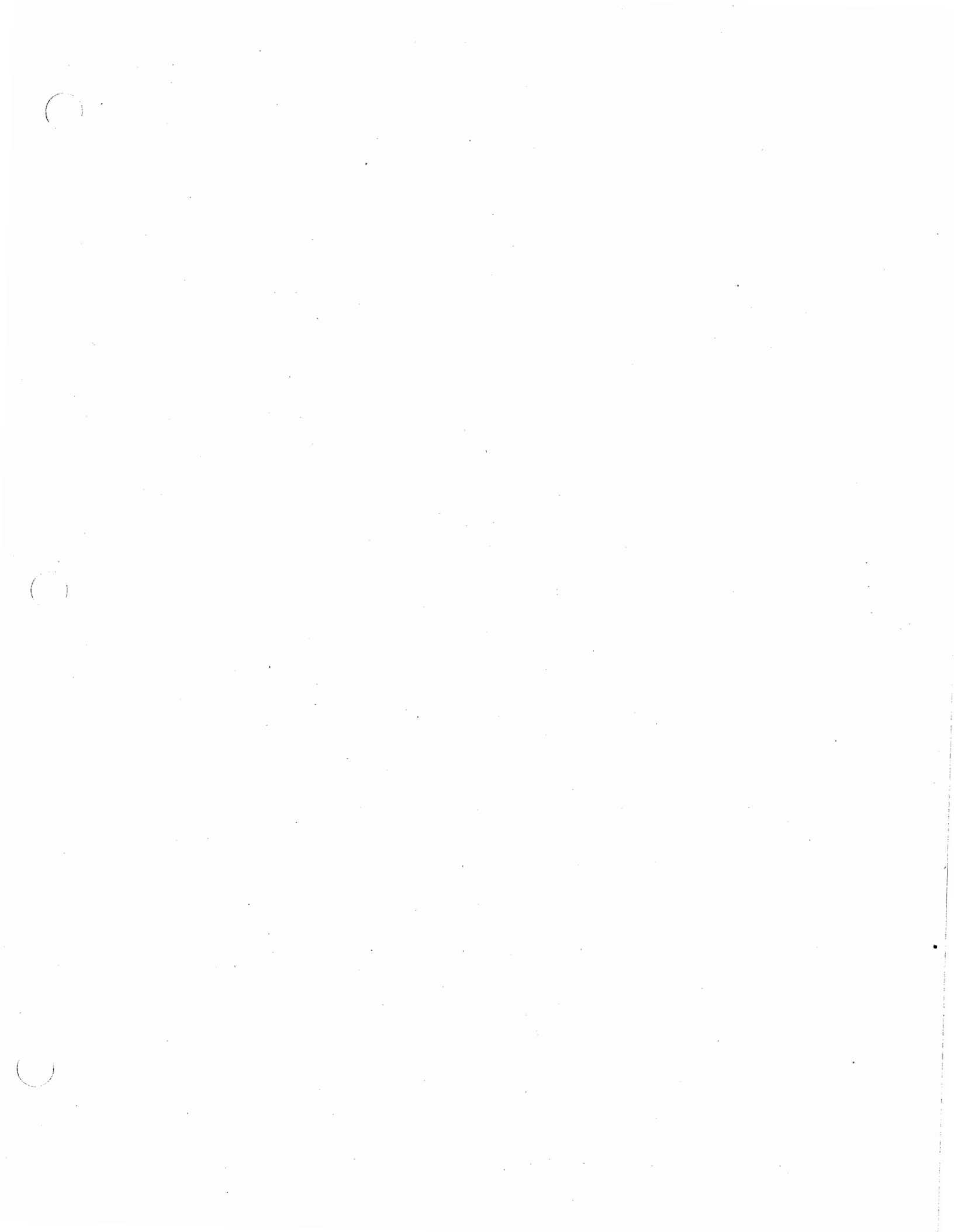
**Sample ID: Sand**

Sample Date :11/17/98

TEST	RESULT	UNITS	DETECTION LIMIT	DATE EXTRACTED	DATE ANALYZED	BY	METHOD
TCL PCBs				11/23/98	11/24/98	RG	8082
PCB-1016	ND	ug/Kg	35.0				
PCB-1221	ND	ug/Kg	35.0				
PCB-1232	ND	ug/Kg	35.0				
PCB-1242	ND	ug/Kg	35.0				
PCB-1248	ND	ug/Kg	35.0				
PCB-1254	ND	ug/Kg	35.0				
PCB-1260	ND	ug/Kg	35.0				
<u>Surrogate Standard</u>	<u>% Recovery</u>		<u>OC Limits</u>				
9 - Decachlorobiphenyl	87		17	141			
1 - Tetrachloro-m-xylene	62		20	122			

  
 LABORATORY MANAGER

ND - Not Detected





**NORTHEAST  
Technical Services, Inc.**

**Material:** Natural Sand  
**Source:** B. R. DeWitt, Inc., Phelps, NY

May 28, 1998  
Report no. 201.435  
Page 10

**SIEVE ANALYSIS**

<u>Sieve Size</u>	<u>Sample, Percent Passing</u>	<u>ASTM C-33 Specification</u>	
3/8"	100	100	100
#4	100	95-100	100
#8	88.0	80-100	85.5
#16	69.8	50-85	53.2
#30	36.4	25-60	29.6
#50	10.4	10-30	12.5
#100	3.3	2-10	5.1
#200			1.4
Fineness Modulus	2.92	2.3 - 3.1	
Specific Gravity (ssd):	2.682		
Absorption, Percent:	1.57		
Unit Weight (ASTM C29):	105.5 lb/cf		

**DELETERIOUS SUBSTANCES**

<u>Item</u>	<u>Sample</u>	<u>ASTM C-33 Specification</u>
Material finer than #200 sieve (ASTM C-117)	1.71%	5.0% Max.***
Clay lumps and friable particles (ASTM C-142)	0.20%	3.0% max.
Coal and Lignite (ASTM C-123)	0.0%	1.0% max.****
Organic impurities (ASTM C-40)	Lighter than standard	Lighter than standard

\*\*\* - Concrete subject to abrasion is 3% maximum.

\*\*\*\* - When the surface appearance of concrete is of importance - 0.5% maximum.



SLING HEAD PERMEABILITY TESTING

PROJECT NAME : Seneca Army Depot

PROJECT NUMBER : 98-607

CLIENT : Dewind Dewatering Inc.

DATE : November 25, 1998

SAMPLE LOCATION AND CONDITIONSSample Id. : Composite of Concrete Sand (52% by volume) & Cast Iron Aggregate Size ETI 8/50 (48% by volume)Remolded : Yes

Note : Unit weight determinations were made for each material in accordance with ASTM C29 by the shoveling method. The composite sample was also remolded following the shoveling method procedures. A copy of ASTM C29 is attached with this report. The concrete sand unit weight determination was 72 pcf and the cast iron aggregate was 123 pcf.

INITIAL SPECIMEN PROPERTIES

Length (cm.):	<u>11.66</u>	Volume (ft <sup>3</sup> ):	<u>0.0333</u>	Wet Density (PCF):	<u>96.6</u>
Diameter (cm.):	<u>10.16</u>	Weight (lbs):	<u>3.22</u>	Dry Density (PCF):	<u>na</u>
Area (ft <sup>2</sup> ):	<u>0.0873</u>	Moisture (%):	<u>na</u>		

PERMEABILITY CALCULATIONS

k = Hydraulic Conductivity, (cm/sec)

$$k = \frac{aL}{At} * \ln \frac{h^1}{h^2}$$

a = Cross-sectional area of burette, (cm<sup>2</sup>)A = Cross-sectional area of specimen, (cm<sup>2</sup>)

$$k = \frac{(0.3167)(11.66)}{(81.07)(6)} * \ln \frac{96.5}{36.6}$$

h<sup>1</sup> = Hydraulic head across sample at beginning of test, (cm)h<sup>2</sup> = Hydraulic head across sample at end of test, (cm)

$$k = \frac{3.69}{486.42} * 0.9695$$

L = Length of specimen, (cm)

t = Elapsed time of test, (sec)

$$k = 0.0076 * 0.9695$$

ln = Logarithm to base

$$k = 7.4 \times 10^{-3} \text{ cm/sec}$$

$$= 7.4 \times 10^{-3} \text{ CM/SEC}$$





1A  
VOLATILE ORGANICS ANALYSIS DATA SHEET

EPA SAMPLE NO.

ASH1

Lab Name: SEVERN TRENT LABORATORIES Contract: 98035

Lab Code: INCHVT Case No.: 98035 SAS No.: SDG No.: 71813

Matrix: (soil/water) SOIL Lab Sample ID: 373788

Sample wt/vol: 3.0 (g/mL) G Lab File ID: 0373788DV

Level: (low/med) LOW Date Received: 12/11/98

% Moisture: not dec. 11 Date Analyzed: 12/11/98

GC Column: DB-624 ID: 0.53 (mm) Dilution Factor: 1.0

Soil Extract Volume: \_\_\_\_\_ (uL) Soil Aliquot Volume: \_\_\_\_\_ (uL)

CAS NO.	COMPOUND	CONCENTRATION UNITS: (ug/L or ug/Kg) UG/KG	Q
74-87-3	Chloromethane	19	U
74-83-9	Bromomethane	19	U
75-01-4	Vinyl Chloride	19	U
75-00-3	Chloroethane	19	U
75-09-2	Methylene Chloride	19	U
67-64-1	Acetone	19	U
75-15-0	Carbon Disulfide	19	U
75-35-4	1,1-Dichloroethene	19	U
75-34-3	1,1-Dichloroethane	19	U
540-59-0	1,2-Dichloroethene (total)	2	J
67-66-3	Chloroform	19	U
107-06-2	1,2-Dichloroethane	19	U
78-93-3	2-Butanone	19	U
71-55-6	1,1,1-Trichloroethane	19	U
56-23-5	Carbon Tetrachloride	19	U
75-27-4	Bromodichloromethane	19	U
78-87-5	1,2-Dichloropropane	19	U
10061-01-5	cis-1,3-Dichloropropene	19	U
79-01-6	Trichloroethene	160	
124-48-1	Dibromochloromethane	19	U
79-00-5	1,1,2-Trichloroethane	19	U
71-43-2	Benzene	19	U
10061-02-6	trans-1,3-Dichloropropene	19	U
75-25-2	Bromoform	19	U
108-10-1	4-Methyl-2-Pentanone	19	U
591-78-6	2-Hexanone	19	U
127-18-4	Tetrachloroethene	19	U
79-34-5	1,1,2,2-Tetrachloroethane	19	U
108-88-3	Toluene	4	J
108-90-7	Chlorobenzene	19	U
100-41-4	Ethylbenzene	19	U
100-42-5	Styrene	19	U
1330-20-7	Xylene (total)	19	U

1A  
VOLATILE ORGANICS ANALYSIS DATA SHEET

EPA SAMPLE NO.

ASH2

Lab Name: SEVERN TRENT LABORATORIES Contract: 98035

Lab Code: INCHVT Case No.: 98035 SAS No.: SDG No.: 71878

Matrix: (soil/water) SOIL Lab Sample ID: 374267

Sample wt/vol: 5.0 (g/mL) G Lab File ID: 0374267V

Level: (low/med) LOW Date Received: 12/15/98

% Moisture: not dec. 12 Date Analyzed: 12/21/98

GC Column: DB-624 ID: 0.53 (mm) Dilution Factor: 1.0

Soil Extract Volume: \_\_\_\_\_ (uL) Soil Aliquot Volume: \_\_\_\_\_ (uL)

CONCENTRATION UNITS:  
(ug/L or ug/Kg) UG/KG

CAS NO. COMPOUND Q

74-87-3	-----Chloromethane	11	U
74-83-9	-----Bromomethane	11	U
75-01-4	-----Vinyl Chloride	11	U
75-00-3	-----Chloroethane	11	U
75-09-2	-----Methylene Chloride	11	U
67-64-1	-----Acetone	6	JB
75-15-0	-----Carbon Disulfide	11	U
75-35-4	-----1,1-Dichloroethene	11	U
75-34-3	-----1,1-Dichloroethane	11	U
540-59-0	-----1,2-Dichloroethene (total)	20	
67-66-3	-----Chloroform	11	U
107-06-2	-----1,2-Dichloroethane	11	U
78-93-3	-----2-Butanone	11	U
71-55-6	-----1,1,1-Trichloroethane	11	U
56-23-5	-----Carbon Tetrachloride	11	U
75-27-4	-----Bromodichloromethane	11	U
78-87-5	-----1,2-Dichloropropane	11	U
10061-01-5	-----cis-1,3-Dichloropropene	11	U
79-01-6	-----Trichloroethene	3	J
124-48-1	-----Dibromochloromethane	11	U
79-00-5	-----1,1,2-Trichloroethane	11	U
71-43-2	-----Benzene	11	U
10061-02-6	-----trans-1,3-Dichloropropene	11	U
75-25-2	-----Bromoform	11	U
108-10-1	-----4-Methyl-2-Pentanone	11	U
591-78-6	-----2-Hexanone	11	U
127-18-4	-----Tetrachloroethene	11	U
79-34-5	-----1,1,2,2-Tetrachloroethane	11	U
108-88-3	-----Toluene	2	J
108-90-7	-----Chlorobenzene	11	U
100-41-4	-----Ethylbenzene	11	U
100-42-5	-----Styrene	11	U
1330-20-7	-----Xylene (total)	11	U

1E  
VOLATILE ORGANICS ANALYSIS DATA SHEET  
TENTATIVELY IDENTIFIED COMPOUNDS

EPA SAMPLE NO.

ASH2

Lab Name: SEVERN TRENT LABORATORIES Contract: 98035

Lab Code: INCHVT Case No.: 98035 SAS No.: SDG No.: 71878

Matrix: (soil/water) SOIL Lab Sample ID: 374267

Sample wt/vol: 5.0 (g/mL) G Lab File ID: 0374267V

Level: (low/med) LOW Date Received: 12/15/98

% Moisture: not dec. 12 Date Analyzed: 12/21/98

GC Column: DB-624 ID: 0.53 (mm) Dilution Factor: 1.0

Soil Extract Volume: \_\_\_\_\_ (uL) Soil Aliquot Volume: \_\_\_\_\_ (uL)

Number TICs found: 1 CONCENTRATION UNITS:  
(ug/L or ug/Kg) ug/Kg

CAS NUMBER	COMPOUND NAME	RT	EST. CONC.	Q
1.	UNKNOWN SILOXANE DERIVATIVE	14.37	15	J
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				
11.				
12.				
13.				
14.				
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29.				
30.				







**Peerless Metal Powders & Abrasive**

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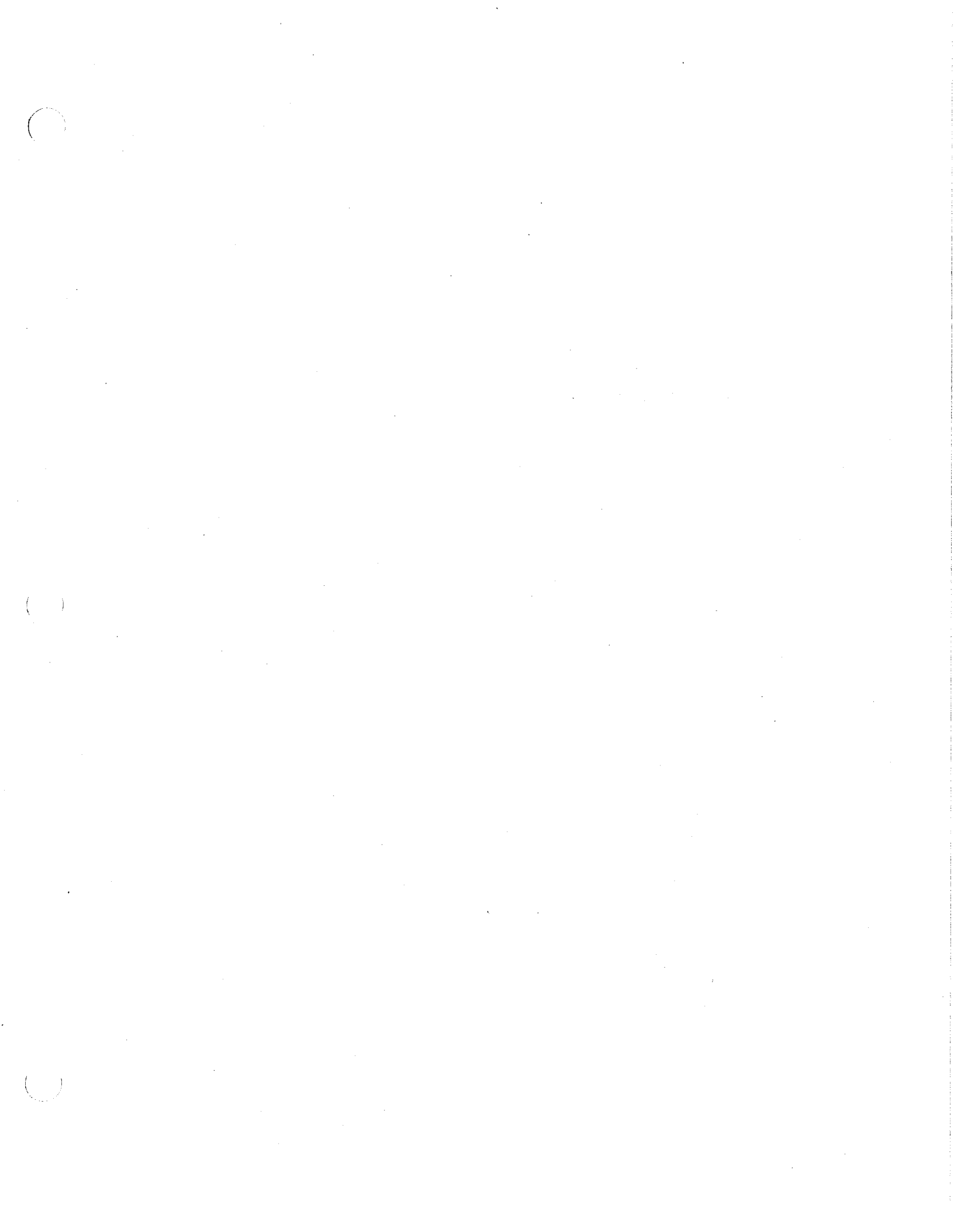
FAX # 781-401-2043 PHONE #

FROM GreenWaves DATE 12-9-98

**REMARKS:**

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_





Mix Volume

X = not sampled  
 - = do not know Truck #

Density of Iron: \_\_\_\_\_  
 Density of Sand: \_\_\_\_\_

Sampler: E. Schacht

	Date	Time	Load No.	Sample ID Truck	Description (bags of iron, qty of sand)	Mixing Time minutes	Wt. of Iron g	Total Wt. g	Vol. of Iron	Total Volume	% Iron by Volume
MC-plant	<del>12-10-98</del>		1	81	5 bags /	10 min	1 1/8 C	1 7/8 C	1 3/4 C	3.08 C	<del>57%</del> 60%
	12-11-98		2	X	5				-		
			3	X					-		
			4	X					-		
			5	117					1 3/4 C	2 1/4 C	78%
			6	81					1 C	2 C	50%
			7	91					1 1/4 C	2 C	63%
			8	116					1 1/8 C	2 C	56%
			9	127		10 min.			1 C	1 3/4 C	57%
			10	X					-		
	12-11-98		11	81					1 Cup	1 1/2 Cup	58%
MC-P. Wolfe			12	91					1 1/3 C	2 C	67%
			13	116	5 bags /				1 1/4 C	1.75 C	71%
MC-plant			14	127					1 1/3 C	2 C	67%
			15	117					1 1/4 C	2 C	63%
			16	81					1 Cup	1 1/2 Cup	58%
			17	91					1 1/2 C	2 C	75%
			18	X					-		
			19	X					-		
MC-P. Wolfe			20	X					-		
			11	81					1 C	1 7/8 C	53%
			16	81	5 bags /				1 C	1 3/4 C	57%
MC-plant	12-10-98		1	127					1 3/4 C	3.08 C	57%
			2	117					1 1/2 C	2.2 C	69%
			3	116					1 1/8 C	2 C	67%
			4	108					1 1/2 C	2 C	75%
			5	127					1 3/4 C	2 C	68%
			6	-					1 1/2 C	2 C	75%
			7	-					1 1/3 C	2 C	67%
MC-P. Wolfe			8	127					1 1/3 C	2 C	67%
			9	-					1 1/3 C	2 C	67%
			10	-					1 1/4 C	2 C	63%



December 11, 1998

L-98219  
Laboratory Testing  
Seneca Army Depot  
Ash Landfill Treatability Study

NATURAL MOISTURE CONTENT  
ASTM D2216

<u>Lab ID. #</u>	<u>Sample</u>	<u>Moisture Content as a Percent of Dry Weight</u>
11628	Sand Truck #127 Load # 8 12/10/98 14:45	5.4

December 15, 1998

L-98219  
Laboratory Testing  
Seneca Army Depot  
Ash Landfill Treatability Study

NATURAL MOISTURE CONTENT  
ASTM D2216

<u>Lab I.D. #</u>	<u>Sample</u>	<u>Moisture Content as a Percent of Dry Weight</u>
11629	Truck #91 Load 12	4.5
11630	Truck #85 Load 20	4.9

Appendix B  
Well Diagrams, Slug Test Results, Hydraulic Conductivity Results,  
and Selected Boring Logs

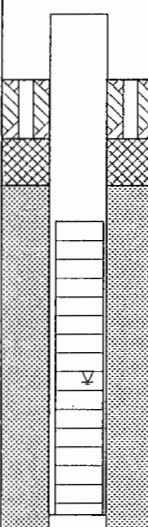
- Monitoring well completion reports for MWT-1 through MWT-11, March 1999
- Hydraulic Conductivity results of aquifer wells installed for groundwater treatability study, May 1999
- Rising head slug test results of aquifer wells installed for groundwater treatability study, May 1999
- Hydraulic Conductivity Results for Till/Weathered Shale from Remedial Investigation
- Selected boring logs of 1987 and before



# MONITORING WELL COMPLETION REPORT: MWT-1

**PROJECT:** Ash Landfill Reactive Wall  
**PROJECT LOCATION:** Seneca Army Depot Activity, Romulus, NY  
**ASSOCIATED AREA/UNIT:** Ash Landfill  
**PROJECT NO.:** 726209-01001  
**WELL INSTALLATION STARTED:** 3/31/99  
**WELL INSTALLATION COMPLETED:** 3/31/99  
**DRILLING CONTRACTOR:** Maxim  
**DRILLING METHOD:** HSA  
**SAMPLING METHOD:** 2" Split Spoon

**TOTAL DEPTH:** 7.41  
**DEPTH TO WATER:** 5.15  
**BORING LOCATION:** 995064.36707  
 739688.41709  
**COORDINATE SYSTEM:** NAD-83  
**GROUND SURFACE ELEVATION:** 634.9  
**ELEVATION DATUM:** NAVD 88  
**INSPECTOR:** EDS  
**CHECKED BY:**

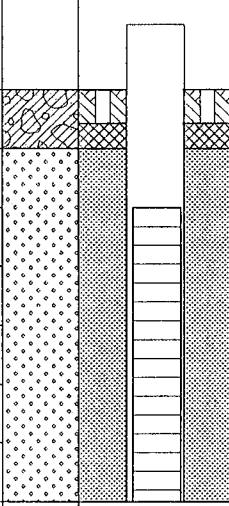
DEPTH (ft)	MACRO SYMBOL	WELL DETAILS	DEPTH (ft)	WELL DETAILS	ELEVATION (ft)	WELL CONSTRUCTION DETAILS																																
			-2.34	TOC	637.24	<p><b>PROTECTIVE COVER</b>                      Diameter (ID) (in): 4"                      Type: Riser                      Length (ft):</p> <p><b>RISER</b>                      Diameter (ID) (in): 2"                      Type: SCH. 40-PVC                      Length (ft): 4.76</p> <p><b>SCREEN</b>                      Diameter (ID) (in): 2"                      Type: Wire Wrapped PVC                      Length (ft): 5.0                      Slot Size (in): 0.010</p> <p><b>GROUT</b>                      Type:                      Length (ft): 1.0</p> <p><b>SEAL</b>                      Type: Bentonite pellets                      Length (ft): 0.8</p> <p><b>SANDPACK</b>                      Type:                      Length (ft): 5.9</p> <p><b>SURFACE SEAL</b>                      Type:                      Size:</p>																																
0			0	GS	634.9																																	
1			1	TBS	633.9																																	
2			1.66	TSP	633.24																																	
3			2.42	TSC	632.48																																	
4						<p style="text-align: center;"><b>WELL DEVELOPMENT DATA</b></p> <p style="text-align: center;"><b>WATER LEVELS</b></p> <p>Date: 04/10/2099                      Method: Development                      Duration: 4/10/99                      Rate:                      Total Volume Removed (gals): 18.5</p> <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th>Date</th> <th>Time</th> <th>Depth, TOC</th> </tr> </thead> <tbody> <tr> <td>4/10/99</td> <td></td> <td style="text-align: center;">5.15</td> </tr> </tbody> </table> <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th>pH</th> <th>Temperature (degrees F)</th> <th>Conductivity (micromhos/cm)</th> <th>Turbidity (NTUs)</th> </tr> </thead> <tbody> <tr> <td style="text-align: center;">7.25</td> <td style="text-align: center;">53.2</td> <td style="text-align: center;">685</td> <td style="text-align: center;">1.39</td> </tr> </tbody> </table> <p style="text-align: center;"><b>LEGEND</b></p> <table border="0" style="width: 100%;"> <tr> <td style="width: 50%; vertical-align: top;"> <p><b>WELL DETAILS</b></p> <p>TOC TOP OF WELL RISER                      GS GROUND SURFACE                      TBS TOP BENTONITE SEAL                      TSP TOP OF SANDPACK                      TSC TOP OF SCREEN                      BSC BOTTOM OF SCREEN                      POW POINT OF WELL                      BOD BOTTOM OF DRILL HOLE                      in INCHES                      ft FEET                      ID INSIDE DIAMETER                      gals GALLONS                      SCH SCHEDULE                      NA NOT APPLICABLE</p> </td> <td style="width: 50%; vertical-align: top;"> <p><b>LITHOLOGY</b></p> <table border="0"> <tr> <td style="text-align: center;"></td> <td>SEAL</td> <td style="text-align: center;"></td> <td>ORGANIC SILT</td> </tr> <tr> <td style="text-align: center;"></td> <td>GROUT</td> <td style="text-align: center;"></td> <td>BACKFILL</td> </tr> <tr> <td style="text-align: center;"></td> <td>SANDPACK</td> <td style="text-align: center;"></td> <td>SILT</td> </tr> <tr> <td style="text-align: center;"></td> <td>IRON SAND</td> <td style="text-align: center;"></td> <td>SHALE</td> </tr> </table> </td> </tr> </table>	Date	Time	Depth, TOC	4/10/99		5.15	pH	Temperature (degrees F)	Conductivity (micromhos/cm)	Turbidity (NTUs)	7.25	53.2	685	1.39	<p><b>WELL DETAILS</b></p> <p>TOC TOP OF WELL RISER                      GS GROUND SURFACE                      TBS TOP BENTONITE SEAL                      TSP TOP OF SANDPACK                      TSC TOP OF SCREEN                      BSC BOTTOM OF SCREEN                      POW POINT OF WELL                      BOD BOTTOM OF DRILL HOLE                      in INCHES                      ft FEET                      ID INSIDE DIAMETER                      gals GALLONS                      SCH SCHEDULE                      NA NOT APPLICABLE</p>	<p><b>LITHOLOGY</b></p> <table border="0"> <tr> <td style="text-align: center;"></td> <td>SEAL</td> <td style="text-align: center;"></td> <td>ORGANIC SILT</td> </tr> <tr> <td style="text-align: center;"></td> <td>GROUT</td> <td style="text-align: center;"></td> <td>BACKFILL</td> </tr> <tr> <td style="text-align: center;"></td> <td>SANDPACK</td> <td style="text-align: center;"></td> <td>SILT</td> </tr> <tr> <td style="text-align: center;"></td> <td>IRON SAND</td> <td style="text-align: center;"></td> <td>SHALE</td> </tr> </table>		SEAL		ORGANIC SILT		GROUT		BACKFILL		SANDPACK		SILT		IRON SAND		SHALE
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	GROUT		BACKFILL																																			
	SANDPACK		SILT																																			
	IRON SAND		SHALE																																			
7			7.41	BSC	627.49																																	
8			7.41	BOD	627.489																																	

NOTES:

# MONITORING WELL COMPLETION REPORT: MWT-2

**PROJECT:** Ash Landfill Reactive Wall  
**PROJECT LOCATION:** Seneca Army Depot Activity, Romulus, NY  
**ASSOCIATED AREA/UNIT:** Ash Landfill  
**PROJECT NO.:** 726209-01001  
**WELL INSTALLATION STARTED:** 3/30/99  
**WELL INSTALLATION COMPLETED:** 3/30/99  
**DRILLING CONTRACTOR:** Maxim  
**DRILLING METHOD:** HSA  
**SAMPLING METHOD:** 2" Split Spoon

**TOTAL DEPTH:** 7  
**DEPTH TO WATER:**  
**BORING LOCATION:** 995064.10703  
 739694.79697  
**COORDINATE SYSTEM:** NAD-83  
**GROUND SURFACE ELEVATION:** 634.8  
**ELEVATION DATUM:** NAVD 88  
**INSPECTOR:** EDS  
**CHECKED BY:**

DEPTH (ft)	MACRO SYMBOL	WELL DETAILS	DEPTH (ft)	WELL DETAILS	ELEVATION (ft)	WELL CONSTRUCTION DETAILS																		
			-2.39	TOC	637.19	<p style="text-align: center;"><b>PROTECTIVE COVER</b></p> <p>Diameter (ID) (in): 4" Type: Riser Length (ft):</p> <p style="text-align: center;"><b>RISER</b></p> <p>Diameter (ID) (in): 1" Type: SCH. 40-PVC Length (ft): 4.39</p> <p style="text-align: center;"><b>SCREEN</b></p> <p>Diameter (ID) (in): 1" Type: Wire Wrapped PVC Length (ft): 5.0 Slot Size (in): 0.010</p> <p style="text-align: center;"><b>GROUT</b></p> <p>Type: Length (ft): 0.60</p> <p style="text-align: center;"><b>SEAL</b></p> <p>Type: Fine Sand/Bentonite Length (ft): 0.4</p> <p style="text-align: center;"><b>SANDPACK</b></p> <p>Type: Length (ft): 6.0</p> <p style="text-align: center;"><b>SURFACE SEAL</b></p> <p>Type: Size:</p>																		
0			0	GS	634.8																			
1			0.6	TBS	633.8																			
2			1	TSP	632.8																			
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14						<b>LITHOLOGY</b>																		
15						<table style="width: 100%;"> <tr> <td style="width: 50%;">                     TOC TOP OF WELL RISER                      GS GROUND SURFACE                      TBS TOP BENTONITE SEAL                      TSP TOP OF SANDPACK                      TSC TOP OF SCREEN                      BSC BOTTOM OF SCREEN                      POW POINT OF WELL                      BOD BOTTOM OF DRILL HOLE                      in INCHES                      ft FEET                      ID INSIDE DIAMETER                      gals GALLONS                      SCH SCHEDULE                      NA NOT APPLICABLE                 </td> <td style="width: 50%;"> <table style="width: 100%;"> <tr> <td style="width: 50%;"></td> <td>SEAL</td> </tr> <tr> <td></td> <td>GROUT</td> </tr> <tr> <td></td> <td>SANDPACK</td> </tr> <tr> <td></td> <td>IRON SAND</td> </tr> </table> </td> </tr> <tr> <td style="width: 50%;"></td> <td>ORGANIC SILT</td> </tr> <tr> <td></td> <td>BACKFILL</td> </tr> <tr> <td></td> <td>SILT</td> </tr> <tr> <td></td> <td>SHALE</td> </tr> </table>	TOC TOP OF WELL RISER GS GROUND SURFACE TBS TOP BENTONITE SEAL TSP TOP OF SANDPACK TSC TOP OF SCREEN BSC BOTTOM OF SCREEN POW POINT OF WELL BOD BOTTOM OF DRILL HOLE in INCHES ft FEET ID INSIDE DIAMETER gals GALLONS SCH SCHEDULE NA NOT APPLICABLE	<table style="width: 100%;"> <tr> <td style="width: 50%;"></td> <td>SEAL</td> </tr> <tr> <td></td> <td>GROUT</td> </tr> <tr> <td></td> <td>SANDPACK</td> </tr> <tr> <td></td> <td>IRON SAND</td> </tr> </table>		SEAL		GROUT		SANDPACK		IRON SAND		ORGANIC SILT		BACKFILL		SILT		SHALE
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	SHALE																							
16																								
17																								
18																								
19																								

NOTES:

# MONITORING WELL COMPLETION REPORT: MWT-3

**PROJECT:** Ash Landfill Reactive Wall  
**PROJECT LOCATION:** Seneca Army Depot Activity, Romulus, NY  
**ASSOCIATED AREA/UNIT:** Ash Landfill  
**PROJECT NO.:** 726209-01001  
**WELL INSTALLATION STARTED:** 3/31/99  
**WELL INSTALLATION COMPLETED:** 3/31/99  
**DRILLING CONTRACTOR:** Maxim  
**DRILLING METHOD:** HSA  
**SAMPLING METHOD:** 2" Split Spoon

**TOTAL DEPTH:** 7.5  
**DEPTH TO WATER:** 5.16  
**BORING LOCATION:** 995063.787000  
 739692.44690  
**COORDINATE SYSTEM:** NAD-83  
**GROUND SURFACE ELEVATION:** 634.8  
**ELEVATION DATUM:** NAVD 88  
**INSPECTOR:** EDS  
**CHECKED BY:**

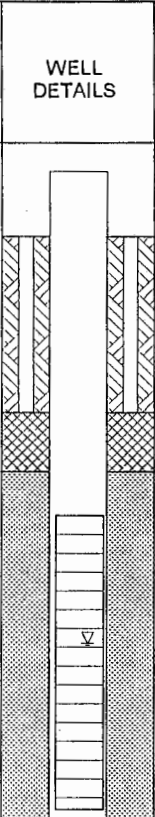
DEPTH (ft)	MACRO SYMBOL	WELL DETAILS	DEPTH (ft)	WELL DETAILS	ELEVATION (ft)	WELL CONSTRUCTION DETAILS																														
		-2.51	TOC	637.31		<p><b>PROTECTIVE COVER</b>                      Diameter (ID) (in): 4"                      Type: Riser                      Length (ft):</p> <p><b>RISER</b>                      Diameter (ID) (in): 2"                      Type: SCH. 40-PVC                      Length (ft): 4.76</p> <p><b>SCREEN</b>                      Diameter (ID) (in): 2"                      Type: Wire Wrapped PVC                      Length (ft): 5.0                      Slot Size (in): 0.010</p> <p><b>GROUT</b>                      Type:                      Length (ft): 1.0</p> <p><b>SEAL</b>                      Type: Bentonite Pellets                      Length (ft): 0.6</p> <p><b>SANDPACK</b>                      Type:                      Length (ft): 5.9</p> <p><b>SURFACE SEAL</b>                      Type:                      Size:</p>																														
0		0	GS	634.8																																
1		1	TBS	633.8																																
2		1.6	TSP	633.2																																
3		2.25	TSC	632.55																																
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7																																				
7.25			BSC	627.55																																
7.5			POW	627.3																																
8						<b>WELL DEVELOPMENT DATA</b>																														
						<b>WATER LEVELS</b>																														
						Date: 04/10/2099 Method: Duration: Development, 4/10/99 Rate: Total Volume Removed (gals): 5.0																														
						<table style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 15%;">pH</th> <th style="width: 15%;">Temperature (degrees F)</th> <th style="width: 15%;">Conductivity (micromhos/cm)</th> <th style="width: 15%;">Turbidity (NTUs)</th> </tr> </thead> <tbody> <tr> <td style="text-align: center;">8.0</td> <td style="text-align: center;">47.7</td> <td style="text-align: center;">416</td> <td style="text-align: center;">1.2</td> </tr> </tbody> </table>	pH	Temperature (degrees F)	Conductivity (micromhos/cm)	Turbidity (NTUs)	8.0	47.7	416	1.2																						
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gals GALLONS																																				
SCH SCHEDULE																																				
NA NOT APPLICABLE																																				

NOTES:

# MONITORING WELL COMPLETION REPORT: MWT-4

**PROJECT:** Ash Landfill Reactive Wall  
**PROJECT LOCATION:** Seneca Army Depot Activity, Romulus, NY  
**ASSOCIATED AREA/UNIT:** Ash Landfill  
**PROJECT NO.:** 726209-01001  
**WELL INSTALLATION STARTED:** 3/30/99  
**WELL INSTALLATION COMPLETED:** 3/30/99  
**DRILLING CONTRACTOR:** Maxim  
**DRILLING METHOD:** HSA  
**SAMPLING METHOD:** 2" Split Spoon

**TOTAL DEPTH:** 10  
**DEPTH TO WATER:** 6.92  
**BORING LOCATION:** 994865.74647  
 739726.14867  
**COORDINATE SYSTEM:** NAD-83  
**GROUND SURFACE ELEVATION:** 635.4  
**ELEVATION DATUM:** NAVD 88  
**INSPECTOR:** EDS  
**CHECKED BY:**

DEPTH (ft)	MACRO SYMBOL	WELL DETAILS	DEPTH (ft)	WELL DETAILS	ELEVATION (ft)	WELL CONSTRUCTION DETAILS							
			-2.28	TOC	637.68	<p><b>PROTECTIVE COVER</b>                      Diameter (ID) (in): 4"                      Type: Riser                      Length (ft):</p> <p><b>RISER</b>                      Diameter (ID) (in): 2"                      Type: SCH. 40-PVC                      Length (ft): 7.03</p> <p><b>SCREEN</b>                      Diameter (ID) (in): 2"                      Type: Wire Wrapped PVC                      Length (ft): 5.0                      Slot Size (in):</p> <p><b>GROUT</b>                      Type:                      Length (ft): 3.0</p> <p><b>SEAL</b>                      Type: Bentonite Pellets                      Length (ft): 1.0</p> <p><b>SANDPACK</b>                      Type:                      Length (ft): 6.0</p> <p><b>SURFACE SEAL</b>                      Type:                      Size:</p>							
0			0	GS	635.4								
1													
2													
3			3	TBS	632.4								
4			4	TSP	631.4								
5			4.75	TSC	630.65								
6													
7													
8													
9													
10			9.75	BSC	625.65								
			10	POW	625.4								
11													
12													
13													
14													
15													
16													
17													
18													
19													
<b>WELL DEVELOPMENT DATA</b>													
<p>Date: 04/02/2099                      Method:                      Duration:                      Rate:                      Total Volume                      Removed (gals): 12.0</p>													
<b>WATER LEVELS</b>													
<table style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 30%;">Date</th> <th style="width: 15%;">Time</th> <th style="width: 15%;">Depth, TOC</th> <th style="width: 10%;"></th> </tr> </thead> <tbody> <tr> <td>Development</td> <td>4/2/99</td> <td>6.92</td> <td style="text-align: center;">▽</td> </tr> </tbody> </table>						Date	Time	Depth, TOC		Development	4/2/99	6.92	▽
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pH	Temperature (degrees F)	Conductivity (micromhos/cm)	Turbidity (NTUs)										
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<b>LEGEND</b>													
<b>WELL DETAILS</b>			<b>LITHOLOGY</b>										
TOC	TOP OF WELL RISER			SEAL		ORGANIC SILT							
GS	GROUND SURFACE			GROUT		BACKFILL							
TBS	TOP BENTONITE SEAL			SANDPACK		SILT							
TSP	TOP OF SANDPACK			IRON SAND		SHALE							
TSC	TOP OF SCREEN												
BSC	BOTTOM OF SCREEN												
POW	POINT OF WELL												
BOD	BOTTOM OF DRILL HOLE												
in	INCHES												
ft	FEET												
ID	INSIDE DIAMETER												
gals	GALLONS												
SCH	SCHEDULE												
NA	NOT APPLICABLE												

NOTES:



**UNITED STATES ARMY**  
**CORPS OF ENGINEERS**  
 Seneca Army Depot  
 Romulus, New York

**COMPLETION REPORT**  
**MWT-4**

# MONITORING WELL COMPLETION REPORT: MWT-5

**PROJECT:** Ash Landfill Reactive Wall  
**PROJECT LOCATION:** Seneca Army Depot Activity, Romulus, NY  
**ASSOCIATED AREA/UNIT:** Ash Landfill  
**PROJECT NO.:** 726209-01001  
**WELL INSTALLATION STARTED:** 3/30/99  
**WELL INSTALLATION COMPLETED:** 3/30/99  
**DRILLING CONTRACTOR:** Maxim  
**DRILLING METHOD:** HSA  
**SAMPLING METHOD:** 2" Split Spoon

**TOTAL DEPTH:** 10.5  
**DEPTH TO WATER:**  
**BORING LOCATION:** 994865.03642  
 739722.60856  
**COORDINATE SYSTEM:** NAD-83  
**GROUND SURFACE ELEVATION:** 635.5  
**ELEVATION DATUM:** NAVD 88  
**INSPECTOR:** EDS  
**CHECKED BY:**

DEPTH (ft)	MACRO SYMBOL	WELL DETAILS	DEPTH (ft)	WELL DETAILS	ELEVATION (ft)	WELL CONSTRUCTION DETAILS							
			-2.22	TOC	637.72	<p><b>PROTECTIVE COVER</b>                      Diameter (ID) (in): 4"                      Type: Riser                      Length (ft):</p> <p><b>RISER</b>                      Diameter (ID) (in): 1"                      Type: SCH. 40-PVC                      Length (ft): 7.72</p> <p><b>SCREEN</b>                      Diameter (ID) (in): 1"                      Type: Wire Wrapped PVC                      Length (ft): 5.0                      Slot Size (in): 0.010</p> <p><b>GROUT</b>                      Type:                      Length (ft): 0.60</p> <p><b>SEAL</b>                      Type: Fine Sand/Bentonite                      Length (ft): 0.4</p> <p><b>SANDPACK</b>                      Type:                      Length (ft): 9.5</p> <p><b>SURFACE SEAL</b>                      Type:                      Size:</p>							
0			0	GS	635.5								
1			1	TSP	634.5								
2													
3													
4													
5													
5.5			5.5	TSC	630								
6													
7													
8													
<b>WELL DEVELOPMENT DATA</b>													
<b>WATER LEVELS</b>													
Date: _____ Method: _____ Duration: _____ Rate: _____ Total Volume Removed (gals): _____													
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Date	Time	Depth, TOC											
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<b>LEGEND</b>													
<table style="width: 100%;"> <tr> <td style="width: 50%; vertical-align: top;"> <b>WELL DETAILS</b>                      TOC TOP OF WELL RISER                      GS GROUND SURFACE                      TBS TOP BENTONITE SEAL                      TSP TOP OF SANDPACK                      TSC TOP OF SCREEN                      BSC BOTTOM OF SCREEN                      POW POINT OF WELL                      BOD BOTTOM OF DRILL HOLE                      in INCHES                      ft FEET                      ID INSIDE DIAMETER                      gals GALLONS                      SCH SCHEDULE                      NA NOT APPLICABLE                 </td> <td style="width: 50%; vertical-align: top;"> <b>LITHOLOGY</b>   SEAL   GROUT   SANDPACK   IRON SAND   ORGANIC SILT   BACKFILL   SILT   SHALE                 </td> </tr> </table>						<b>WELL DETAILS</b> TOC TOP OF WELL RISER GS GROUND SURFACE TBS TOP BENTONITE SEAL TSP TOP OF SANDPACK TSC TOP OF SCREEN BSC BOTTOM OF SCREEN POW POINT OF WELL BOD BOTTOM OF DRILL HOLE in INCHES ft FEET ID INSIDE DIAMETER gals GALLONS SCH SCHEDULE NA NOT APPLICABLE	<b>LITHOLOGY</b> SEAL GROUT SANDPACK IRON SAND ORGANIC SILT BACKFILL SILT SHALE						
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NOTES:

# MONITORING WELL COMPLETION REPORT: MWT-6

**PROJECT:** Ash Landfill Reactive Wall  
**PROJECT LOCATION:** Seneca Army Depot Activity, Romulus, NY  
**ASSOCIATED AREA/UNIT:** Ash Landfill  
**PROJECT NO.:** 726209-01001  
**WELL INSTALLATION STARTED:** 3/31/99  
**WELL INSTALLATION COMPLETED:** 3/31/99  
**DRILLING CONTRACTOR:** Maxim  
**DRILLING METHOD:** HSA  
**SAMPLING METHOD:** 2" Split Spoon

**TOTAL DEPTH:** 10.33  
**DEPTH TO WATER:** 6.25  
**BORING LOCATION:** 994864.87640  
 739720.29849  
**COORDINATE SYSTEM:** NAD-83  
**GROUND SURFACE ELEVATION:** 635.5  
**ELEVATION DATUM:** NAVD 88  
**INSPECTOR:** EDS  
**CHECKED BY:**

DEPTH (ft)	MACRO SYMBOL	WELL DETAILS	DEPTH (ft)	WELL DETAILS	ELEVATION (ft)	WELL CONSTRUCTION DETAILS								
			-2.09	TOC	637.59									
0			0	GS	635.5	<div style="display: flex; justify-content: space-between;"> <div style="width: 45%;"> <p><b>PROTECTIVE COVER</b> Diameter (ID) (in): 4" Type: Riser Length (ft):</p> <p><b>RISER</b> Diameter (ID) (in): 2" Type: SCH. 40-PVC Length (ft): 6.97</p> <p><b>SCREEN</b> Diameter (ID) (in): 2" Type: Wire Wrapped PVC Length (ft): 5.0 Slot Size (in): 0.010.</p> </div> <div style="width: 45%;"> <p><b>GROUT</b> Type: Length (ft): 3.0</p> <p><b>SEAL</b> Type: Bentonite Pellets Length (ft): 1.0</p> <p><b>SANDPACK</b> Type: Length (ft): 6.33</p> <p><b>SURFACE SEAL</b> Type: Size:</p> </div> </div>								
1														
2														
3			3	TBS	632.5									
4			4	TSP	631.5									
5			4.68	TSC	630.62									
6														
7														
8														
9														
10			9.88	BSC	625.62									
11			10.33	POW	625.17									
12						<p><b>WELL DEVELOPMENT DATA</b></p> <p>Date: 04/02/2009</p> <p>Method: <span style="float: right;">Date</span></p> <p>Duration: <span style="float: right;">Time</span></p> <p>Rate: <span style="float: right;">Development</span> 4/2/99 <span style="float: right;">Depth, TOC</span> 6.25 <span style="float: right;">▽</span></p> <p>Total Volume</p> <p>Removed (gals): 11:0</p>								
13						<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 15%;">pH</th> <th style="width: 20%;">Temperature (degrees F)</th> <th style="width: 20%;">Conductivity (micromhos/cm)</th> <th style="width: 20%;">Turbidity (NTUs)</th> </tr> </thead> <tbody> <tr> <td style="text-align: center;">8.3</td> <td style="text-align: center;">49.9</td> <td style="text-align: center;">369</td> <td style="text-align: center;">10.8</td> </tr> </tbody> </table>	pH	Temperature (degrees F)	Conductivity (micromhos/cm)	Turbidity (NTUs)	8.3	49.9	369	10.8
pH	Temperature (degrees F)	Conductivity (micromhos/cm)	Turbidity (NTUs)											
8.3	49.9	369	10.8											
14						<p><b>LEGEND</b></p>								
15						<div style="width: 45%;"> <p><b>WELL DETAILS</b></p> <p>TOC TOP OF WELL RISER</p> <p>GS GROUND SURFACE</p> <p>TBS TOP BENTONITE SEAL</p> <p>TSP TOP OF SANDPACK</p> <p>TSC TOP OF SCREEN</p> <p>BSC BOTTOM OF SCREEN</p> <p>POW POINT OF WELL</p> <p>BOD BOTTOM OF DRILL HOLE</p> <p>in INCHES</p> <p>ft FEET</p> <p>ID INSIDE DIAMETER</p> <p>gals GALLONS</p> <p>SCH SCHEDULE</p> <p>NA NOT APPLICABLE</p> </div> <div style="width: 45%;"> <p><b>LITHOLOGY</b></p> <p> SEAL</p> <p> GROUT</p> <p> SANDPACK</p> <p> IRON SAND</p> <p> ORGANIC SILT</p> <p> BACKFILL</p> <p> SILT</p> <p> SHALE</p> </div>								

NOTES:

# MONITORING WELL COMPLETION REPORT: MWT-7

**PROJECT:** Ash Landfill Reactive Wall  
**PROJECT LOCATION:** Seneca Army Depot Activity, Romulus, NY  
**ASSOCIATED AREA/UNIT:** Ash Landfill  
**PROJECT NO.:** 726209-01001  
**WELL INSTALLATION STARTED:** 3/30/99  
**WELL INSTALLATION COMPLETED:** 3/30/99  
**DRILLING CONTRACTOR:** Maxim  
**DRILLING METHOD:** HSA  
**SAMPLING METHOD:** 2" Split Spoon

**TOTAL DEPTH:** 11.98  
**DEPTH TO WATER:** 6.70  
**BORING LOCATION:** 994721.01625  
 739767.31049  
**COORDINATE SYSTEM:** NAD-83  
**GROUND SURFACE ELEVATION:** 636.4  
**ELEVATION DATUM:** NAVD 88  
**INSPECTOR:** EDS  
**CHECKED BY:**

DEPTH (ft)	MACRO SYMBOL	WELL DETAILS	DEPTH (ft)	WELL DETAILS	ELEVATION (ft)	WELL CONSTRUCTION DETAILS																													
			-1.94	TOC	638.34	<p><b>PROTECTIVE COVER</b>                      Diameter (ID) (in): 4"                      Type: Riser                      Length (ft):</p> <p><b>GROUT</b>                      Type:                      Length (ft): 0.95</p> <p><b>SEAL</b>                      Type: Bentonite Pellets                      Length (ft): 0.25</p> <p><b>RISER</b>                      Diameter (ID) (in): 2"                      Type: SCH. 40-PVC                      Length (ft): 3.36</p> <p><b>SCREEN</b>                      Diameter (ID) (in): 2"                      Type: Wire Wrapped PVC                      Length (ft): 10.0                      Slot Size (in): 0.010</p> <p><b>SANDPACK</b>                      Type:                      Length (ft): 10.5</p> <p><b>SURFACE SEAL</b>                      Type:                      Size:</p>																													
0			0	GS	638.4																														
1			0.95	TBS	635.45																														
2			1.2	TSP	635.2																														
2			1.42	TSC	634.98																														
3																																			
4																																			
5																																			
6																																			
7																																			
8																																			
<b>WELL DEVELOPMENT DATA</b>																																			
<b>WATER LEVELS</b>																																			
Date: 04/01/2099 Method: Development Duration: 4/1/99 Rate: Total Volume Removed (gals): 8.0																																			
<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 15%;">pH</th> <th style="width: 15%;">Temperature (degrees F)</th> <th style="width: 15%;">Conductivity (micromhos/cm)</th> <th style="width: 15%;">Turbidity (NTUs)</th> </tr> </thead> <tbody> <tr> <td style="text-align: center;">7.28</td> <td style="text-align: center;">51.6</td> <td style="text-align: center;">773</td> <td style="text-align: center;">10.3</td> </tr> </tbody> </table>						pH	Temperature (degrees F)	Conductivity (micromhos/cm)	Turbidity (NTUs)	7.28	51.6	773	10.3																						
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7.28	51.6	773	10.3																																
9			Date	Time	Depth, TOC																														
9			Development	4/1/99	6.70																														
11			11.42	BSC	624.98																														
12			11.98	POW	624.42																														
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in INCHES																																			
ft FEET																																			
ID INSIDE DIAMETER																																			
gals GALLONS																																			
SCH SCHEDULE																																			
NA NOT APPLICABLE																																			

NOTES:

# MONITORING WELL COMPLETION REPORT: MWT-8

**PROJECT:** Ash Landfill Reactive Wall  
**PROJECT LOCATION:** Seneca Army Depot Activity, Romulus, NY  
**ASSOCIATED AREA/UNIT:** Ash Landfill  
**PROJECT NO.:** 726209-01001  
**WELL INSTALLATION STARTED:** 3/30/99  
**WELL INSTALLATION COMPLETED:** 3/30/99  
**DRILLING CONTRACTOR:** Maxim  
**DRILLING METHOD:** HSA  
**SAMPLING METHOD:** 2" Split Spoon

**TOTAL DEPTH:** 10.8  
**DEPTH TO WATER:**  
**BORING LOCATION:** 994719.91621  
 739763.92039  
**COORDINATE SYSTEM:** NAD-83  
**GROUND SURFACE ELEVATION:** 636.2  
**ELEVATION DATUM:** NAVD 88  
**INSPECTOR:** EDJ  
**CHECKED BY:**

DEPTH (ft)	MACRO SYMBOL	WELL DETAILS	DEPTH (ft)	WELL DETAILS	ELEVATION (ft)	WELL CONSTRUCTION DETAILS							
		-2.20	TOC	638.40		<p><b>PROTECTIVE COVER</b>                      Diameter (ID) (in): 4"                      Type: Riser                      Length (ft):</p> <p><b>RISER</b>                      Diameter (ID) (in): 1"                      Type: SCH. 40-PVC                      Length (ft): 3.0</p> <p><b>SCREEN</b>                      Diameter (ID) (in): 1"                      Type: Wire Wrapped PVC                      Length (ft): 10.0                      Slot Size (in): 0.010</p> <p><b>GROUT</b>                      Type:                      Length (ft):</p> <p><b>SEAL</b>                      Type: Fine Sand/Bentonite                      Length (ft): 0.4</p> <p><b>SANDPACK</b>                      Type:                      Length (ft): 10.0</p> <p><b>SURFACE SEAL</b>                      Type:                      Size:</p>							
0		0	GS	636.2									
		0.4	TBS	635.8									
1		0.8	TSP	635.4									
		0.81	TSC	635.39									
2													
3													
4													
5													
6													
7													
8													
9													
10													
11		10.8	BSC	625.4									
		10.81	BOD	625.39									
12													
13													
14													
15													
16													
17													
18													
19													
<b>WELL DEVELOPMENT DATA</b>													
<b>WATER LEVELS</b>													
Date: _____ Method: _____ Duration: _____ Rate: _____ Total Volume Removed (gals): _____													
<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 20%;">Date</th> <th style="width: 20%;">Time</th> <th style="width: 20%;">Depth, TOC</th> <th style="width: 40%;"></th> </tr> </thead> <tbody> <tr> <td></td> <td></td> <td></td> <td style="text-align: center;">Development</td> </tr> </tbody> </table>						Date	Time	Depth, TOC					Development
Date	Time	Depth, TOC											
			Development										
<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 25%;">pH</th> <th style="width: 25%;">Temperature (degrees F)</th> <th style="width: 25%;">Conductivity (micromhos/cm)</th> <th style="width: 25%;">Turbidity (NTUs)</th> </tr> </thead> <tbody> <tr> <td> </td> <td> </td> <td> </td> <td> </td> </tr> </tbody> </table>						pH	Temperature (degrees F)	Conductivity (micromhos/cm)	Turbidity (NTUs)				
pH	Temperature (degrees F)	Conductivity (micromhos/cm)	Turbidity (NTUs)										
<b>LEGEND</b>													
<b>WELL DETAILS</b>			<b>LITHOLOGY</b>										
TOC	TOP OF WELL RISER			SEAL		ORGANIC SILT							
GS	GROUND SURFACE			GROUT		BACKFILL							
TBS	TOP BENTONITE SEAL			SANDPACK		SILT							
TSP	TOP OF SANDPACK			IRON SAND		SHALE							
TSC	TOP OF SCREEN												
BSC	BOTTOM OF SCREEN												
POW	POINT OF WELL												
BOD	BOTTOM OF DRILL HOLE												
in	INCHES												
ft	FEET												
ID	INSIDE DIAMETER												
gals	GALLONS												
SCH	SCHEDULE												
NA	NOT APPLICABLE												

NOTES:



# MONITORING WELL COMPLETION REPORT: MWT-9

**PROJECT:** Ash Landfill Reactive Wall  
**PROJECT LOCATION:** Seneca Army Depot Activity, Romulus, NY  
**ASSOCIATED AREA/UNIT:** Ash Landfill  
**PROJECT NO.:** 726209-01001  
**WELL INSTALLATION STARTED:** 3/30/99  
**WELL INSTALLATION COMPLETED:** 3/30/99  
**DRILLING CONTRACTOR:** Maxim  
**DRILLING METHOD:** HSA  
**SAMPLING METHOD:** 2" Split Spoon

**TOTAL DEPTH:** 12  
**DEPTH TO WATER:** 6.60  
**BORING LOCATION:** 994718.99618  
 739761.48032  
**COORDINATE SYSTEM:** NAD-83  
**GROUND SURFACE ELEVATION:** 636.0  
**ELEVATION DATUM:** NAVD 88  
**INSPECTOR:** EDS  
**CHECKED BY:**

DEPTH (ft)	MACRO SYMBOL	WELL DETAILS	DEPTH (ft)	WELL DETAILS	ELEVATION (ft)	WELL CONSTRUCTION DETAILS
			-2.08	TOC	638.08	<div style="display: flex; justify-content: space-between;"> <div style="width: 45%;"> <p><b>PROTECTIVE COVER</b>                      Diameter (ID) (in): 4"                      Type: Riser                      Length (ft):</p> <p><b>RISER</b>                      Diameter (ID) (in): 2"                      Type: SCH. 40-PVC                      Length (ft): 3.83</p> <p><b>SCREEN</b>                      Diameter (ID) (in): 2"                      Type: Wire Wrapped PVC                      Length (ft): 10.0                      Slot Size (in): 0.010</p> </div> <div style="width: 45%;"> <p><b>GROUT</b>                      Type:                      Length (ft): 1.0</p> <p><b>SEAL</b>                      Type: Bentonite Pellets                      Length (ft): 0.5</p> <p><b>SANDPACK</b>                      Type:                      Length (ft): 10.5</p> <p><b>SURFACE SEAL</b>                      Type:                      Size:</p> </div> </div>
0			0	GS	636	
1			1	TBS	635	
2			1.5	TSP	634.5	
2			1.75	TSC	634.25	
3						
4						
5						
6						
7						
8						
9						
10						
11						
12			11.75	BSC	624.25	
12			12	POW	624	
13						
14						
15						
16						
17						
18						
19						

### WELL DEVELOPMENT DATA

#### WATER LEVELS

Date: 04/02/2099  
 Method:  
 Duration: Development  
 Rate:  
 Total Volume Removed (gals): 16

	Date	Time	Depth, TOC	
	4/2/99		6.60	▽

pH	Temperature (degrees F)	Conductivity (micromhos/cm)	Turbidity (NTUs)
8.1	49.6	364	22.5

### LEGEND

WELL DETAILS	LITHOLOGY
TOC TOP OF WELL RISER	SEAL
GS GROUND SURFACE	ORGANIC SILT
TBS TOP BENTONITE SEAL	BACKFILL
TSP TOP OF SANDPACK	SILT
TSC TOP OF SCREEN	SHALE
BSC BOTTOM OF SCREEN	GROUT
POW POINT OF WELL	SANDPACK
BOD BOTTOM OF DRILL HOLE	IRON SAND
in INCHES	
ft FEET	
ID INSIDE DIAMETER	
gals GALLONS	
SCH SCHEDULE	
NA NOT APPLICABLE	

**NOTES:**



**UNITED STATES ARMY  
 CORPS OF ENGINEERS**  
 Seneca Army Depot  
 Romulus, New York

**COMPLETION REPORT  
 MWT-9**

# MONITORING WELL COMPLETION REPORT: MWT-10

**PROJECT:** Ash Landfill Reactive Wall  
**PROJECT LOCATION:** Seneca Army Depot Activity, Romulus, NY  
**ASSOCIATED AREA/UNIT:** Ash Landfill  
**PROJECT NO.:** 726209-01001  
**WELL INSTALLATION STARTED:** 3/30/99  
**WELL INSTALLATION COMPLETED:** 3/30/99  
**DRILLING CONTRACTOR:** Maxim  
**DRILLING METHOD:** HSA  
**SAMPLING METHOD:** 2" Split Spoon

**TOTAL DEPTH:** 7.08  
**DEPTH TO WATER:** 3.91  
**BORING LOCATION:** 995252.63746  
 739655.66506  
**COORDINATE SYSTEM:** NAD-83  
**GROUND SURFACE ELEVATION:** 634.2  
**ELEVATION DATUM:** NAVD 88  
**INSPECTOR:** EDS  
**CHECKED BY:**

DEPTH (ft)	MACRO SYMBOL	WELL DETAILS	DEPTH (ft)	WELL DETAILS	ELEVATION (ft)	WELL CONSTRUCTION DETAILS										
			-1.87	TOC	636.07											
0			0	GS	634.2	<p><b>PROTECTIVE COVER</b>                      Diameter (ID) (in): 4"                      Type: Riser                      Length (ft):</p> <p><b>RISER</b>                      Diameter (ID) (in): 2"                      Type: SCH. 40-PVC                      Length (ft): 3.67</p> <p><b>SCREEN</b>                      Diameter (ID) (in): 2"                      Type: Wire Wrapped PVC                      Length (ft): 5.0                      Slot Size (in): 0.010</p> <p><b>GROUT</b>                      Type:                      Length (ft): 1.0</p> <p><b>SEAL</b>                      Type: Bentonite Pellets                      Length (ft): 0.5</p> <p><b>SANDPACK</b>                      Type:                      Length (ft): 5.6</p> <p><b>SURFACE SEAL</b>                      Type:                      Size:</p>										
1			1	TBS	633.2											
2			1.5	TSP	632.7											
3			1.8	TSC	632.4											
4																
5																
6																
7			6.8	BSC	627.4											
8			7.08	POW	627.12											
9						<b>WELL DEVELOPMENT DATA</b>										
10						<b>WATER LEVELS</b>										
11						Date: 04/10/2099 Method: Duration: Development 4/10/99 Rate: Total Volume Removed (gals): 21										
12						<table style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 15%;">pH</th> <th style="width: 15%;">Temperature (degrees F)</th> <th style="width: 15%;">Conductivity (micromhos/cm)</th> <th style="width: 15%;">Turbidity (NTUs)</th> </tr> </thead> <tbody> <tr> <td style="text-align: center;">7.49</td> <td style="text-align: center;">48.2</td> <td style="text-align: center;">327</td> <td style="text-align: center;">4.1</td> </tr> </tbody> </table>	pH	Temperature (degrees F)	Conductivity (micromhos/cm)	Turbidity (NTUs)	7.49	48.2	327	4.1		
pH	Temperature (degrees F)	Conductivity (micromhos/cm)	Turbidity (NTUs)													
7.49	48.2	327	4.1													
13						<b>LEGEND</b>										
14						<table style="width: 100%;"> <tr> <td style="width: 50%; vertical-align: top;"> <b>WELL DETAILS</b>                      TOC TOP OF WELL RISER                      GS GROUND SURFACE                      TBS TOP BENTONITE SEAL                      TSP TOP OF SANDPACK                      TSC TOP OF SCREEN                      BSC BOTTOM OF SCREEN                      POW POINT OF WELL                      BOD BOTTOM OF DRILL HOLE                      in INCHES                      ft FEET                      ID INSIDE DIAMETER                      gals GALLONS                      SCH SCHEDULE                      NA NOT APPLICABLE                 </td> <td style="width: 50%; vertical-align: top;"> <b>LITHOLOGY</b>  <table style="width: 100%;"> <tr> <td style="width: 50%;"> SEAL</td> <td style="width: 50%;"> ORGANIC SILT</td> </tr> <tr> <td> GROUT</td> <td> BACKFILL</td> </tr> <tr> <td> SANDPACK</td> <td> SILT</td> </tr> <tr> <td> IRON SAND</td> <td> SHALE</td> </tr> </table> </td> </tr> </table>	<b>WELL DETAILS</b> TOC TOP OF WELL RISER GS GROUND SURFACE TBS TOP BENTONITE SEAL TSP TOP OF SANDPACK TSC TOP OF SCREEN BSC BOTTOM OF SCREEN POW POINT OF WELL BOD BOTTOM OF DRILL HOLE in INCHES ft FEET ID INSIDE DIAMETER gals GALLONS SCH SCHEDULE NA NOT APPLICABLE	<b>LITHOLOGY</b> <table style="width: 100%;"> <tr> <td style="width: 50%;"> SEAL</td> <td style="width: 50%;"> ORGANIC SILT</td> </tr> <tr> <td> GROUT</td> <td> BACKFILL</td> </tr> <tr> <td> SANDPACK</td> <td> SILT</td> </tr> <tr> <td> IRON SAND</td> <td> SHALE</td> </tr> </table>	SEAL	ORGANIC SILT	GROUT	BACKFILL	SANDPACK	SILT	IRON SAND	SHALE
<b>WELL DETAILS</b> TOC TOP OF WELL RISER GS GROUND SURFACE TBS TOP BENTONITE SEAL TSP TOP OF SANDPACK TSC TOP OF SCREEN BSC BOTTOM OF SCREEN POW POINT OF WELL BOD BOTTOM OF DRILL HOLE in INCHES ft FEET ID INSIDE DIAMETER gals GALLONS SCH SCHEDULE NA NOT APPLICABLE	<b>LITHOLOGY</b> <table style="width: 100%;"> <tr> <td style="width: 50%;"> SEAL</td> <td style="width: 50%;"> ORGANIC SILT</td> </tr> <tr> <td> GROUT</td> <td> BACKFILL</td> </tr> <tr> <td> SANDPACK</td> <td> SILT</td> </tr> <tr> <td> IRON SAND</td> <td> SHALE</td> </tr> </table>	SEAL	ORGANIC SILT	GROUT	BACKFILL	SANDPACK	SILT	IRON SAND	SHALE							
SEAL	ORGANIC SILT															
GROUT	BACKFILL															
SANDPACK	SILT															
IRON SAND	SHALE															
15																
16																
17																
18																
19																

NOTES:



**UNITED STATES ARMY  
 CORPS OF ENGINEERS**  
 Seneca Army Depot  
 Romulus, New York

**COMPLETION REPORT  
 MWT-10**

# MONITORING WELL COMPLETION REPORT: MWT-11

**PROJECT:** Ash Landfill Reactive Wall  
**PROJECT LOCATION:** Seneca Army Depot Activity, Romulus, NY  
**ASSOCIATED AREA/UNIT:** Ash Landfill  
**PROJECT NO.:** 726209-01001  
**WELL INSTALLATION STARTED:** 3/31/99  
**WELL INSTALLATION COMPLETED:** 3/31/99  
**DRILLING CONTRACTOR:** Maxim  
**DRILLING METHOD:** HSA  
**SAMPLING METHOD:** 2" Split Spoon

**TOTAL DEPTH:** 10.25  
**DEPTH TO WATER:** 5.95  
**BORING LOCATION:** 994615.11603  
 739791.29163  
**COORDINATE SYSTEM:** NAD-83  
**GROUND SURFACE ELEVATION:** 636.2  
**ELEVATION DATUM:** NAVD 88  
**INSPECTOR:** EDS  
**CHECKED BY:**

DEPTH (ft)	MACRO SYMBOL	WELL DETAILS	DEPTH (ft)	WELL DETAILS	ELEVATION (ft)	WELL CONSTRUCTION DETAILS							
			0.0	TOC	636.2	<p><b>PROTECTIVE COVER</b>                      Diameter (ID) (in): 4"                      Type: Riser                      Length (ft):</p> <p><b>GROUT</b>                      Type:                      Length (ft): 2.0</p> <p><b>RISER</b>                      Diameter (ID) (in): 2"                      Type: SCH. 40-PVC                      Length (ft): 4.7</p> <p><b>SCREEN</b>                      Diameter (ID) (in): 2"                      Type: Wire Wrapped PVC                      Length (ft): 5.0                      Slot Size (in): 0.010</p> <p><b>SEAL</b>                      Type: Bentonite Pellets                      Length (ft): 1.5</p> <p><b>SANDPACK</b>                      Type:                      Length (ft): 6.75</p> <p><b>SURFACE SEAL</b>                      Type: ROAD BOX                      Size:</p>							
0			0	GS	636.2								
1			0.3	TOC	635.9								
2			2	TBS	634.2								
3			3.5	TSP	632.7								
4			5	TSC	631.2								
5													
6													
7													
8													
<b>WELL DEVELOPMENT DATA</b>													
<b>WATER LEVELS</b>													
Date: 04/10/2099 Method: <span style="float: right;">Date</span> Duration: <span style="float: right;">Time</span> Rate: <span style="float: right;">Development 4/10/99</span> Total Volume <span style="float: right;">Depth, TOC</span> Removed (gals): 21.8 <span style="float: right;">5.95</span>													
<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 15%;">pH</th> <th style="width: 15%;">Temperature (degrees F)</th> <th style="width: 15%;">Conductivity (micromhos/cm)</th> <th style="width: 15%;">Turbidity (NTUs)</th> </tr> </thead> <tbody> <tr> <td style="text-align: center;">7.19</td> <td style="text-align: center;">49.6</td> <td style="text-align: center;">608</td> <td style="text-align: center;">20</td> </tr> </tbody> </table>						pH	Temperature (degrees F)	Conductivity (micromhos/cm)	Turbidity (NTUs)	7.19	49.6	608	20
pH	Temperature (degrees F)	Conductivity (micromhos/cm)	Turbidity (NTUs)										
7.19	49.6	608	20										
<b>LEGEND</b>													
<b>WELL DETAILS</b>			<b>LITHOLOGY</b>										
TOC	TOP OF WELL RISER			SEAL		ORGANIC SILT							
GS	GROUND SURFACE			GROUT		BACKFILL							
TBS	TOP BENTONITE SEAL			SANDPACK		SILT							
TSP	TOP OF SANDPACK			IRON SAND		SHALE							
TSC	TOP OF SCREEN												
BSC	BOTTOM OF SCREEN												
POW	POINT OF WELL												
BOD	BOTTOM OF DRILL HOLE												
in	INCHES												
ft	FEET												
ID	INSIDE DIAMETER												
gals	GALLONS												
SCH	SCHEDULE												
NA	NOT APPLICABLE												

NOTES:



Seneca Army Depot Activity  
Ash Lanfill - Groundwater Treatability Study Using Zero Valent Iron Reactive Wall  
**HYDRAULIC CONDUCTIVITY RESULTS, MAY 1999**

Monitoring Well Number	Hydraulic Conductivity, ft/days
MWT-10	55
MWT-1	34
MWT-3	28
MWT-4	4
MWT-6	9
MWT-7	4
MWT-9	7
MWT-11	0.4

( )

( )

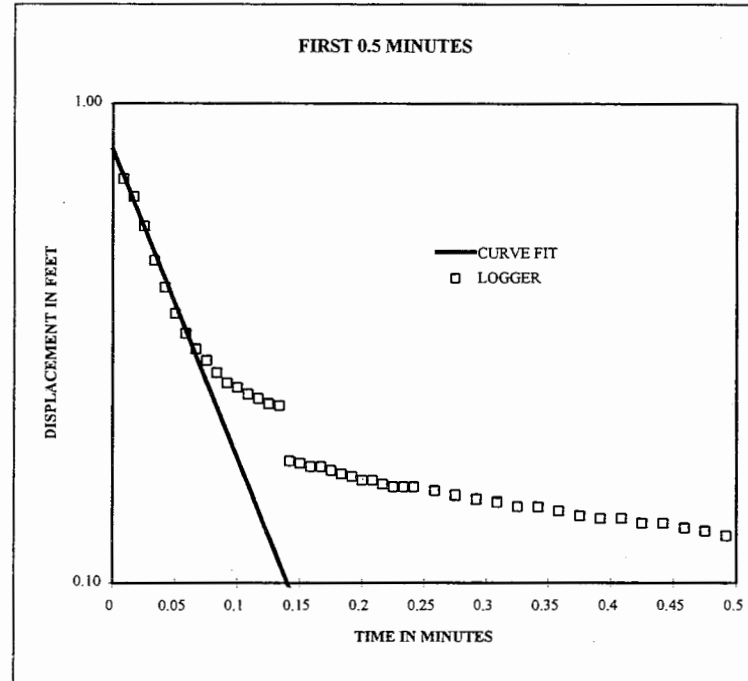
( )

Client: **SENECA ARMY DEPOT**  
 Project: **ASH LANDFILL GW TREATABILITY STUDY USING ZERO VALENT IRON WALL**  
 Project No.: **726209-01002**  
 Well No.: **MWT-1**  
 Test Date: **5/8/1999**

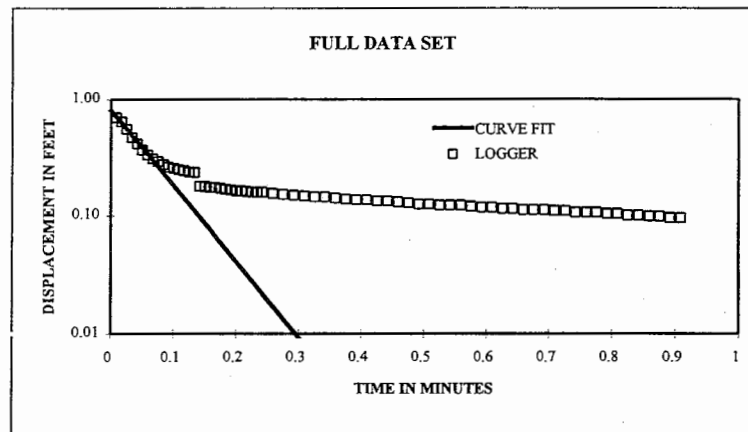
Formation Tested:  
 Rising (R) or Falling (F) Head Test: **R**

Hydraulic conductivity **1.19E-02 cm/sec**  
**2.35E-02 ft/min**  
**33.80 ft/day**

Casing stickup	1.86 feet
Static water level (from top of casing)	5.18 feet
Depth to bottom of screen (from ground level)	7.42 feet
Boring diameter	8.00 inches
Casing diameter	2.00 inches
Screen diameter	2.00 inches
Screen length	5.00 feet
Depth to "impermeable boundary"	7.67 feet
Estimated ratio of Kh/Kv	1
Porosity of filter pack	0.3
$\Delta H$ at time zero ( $Y_0$ )	0.80 feet
$\Delta H$ at time $t$ ( $Y_t$ )	0.100 feet
Time	0.14 minutes



Bouwer-Rice Parameters		
feet	cm	cm
3.32	101.19	$SW$
4.1	124.97	$H$
2.42	73.76	$T_s$
0.333	10.16	$R_w$
0.083	2.54	$R_c$
0.167	5.08	$DS$
4.10	124.97	$L$
4.35	132.59	$D$
0.8	24.38	$Y_0$
0.1	3.05	$Y_t$
	8.40	$t$ (seconds)
	1.00	$M$
	0.30	$n$
		12.30 $L/R_w$
		0.94 $H/D$
		1.87 $A$
		0.26 $B$
		1.20 $C$
		-0.29 $\ln[(D-H)/R_w]$
		-0.29 $\ln[(D-H)/R_w]$
		1.71 equation (8)
		1.87 equation (9)
		1.87 $\ln(R_c/R_w)$
		1.2E-02 equation (5)

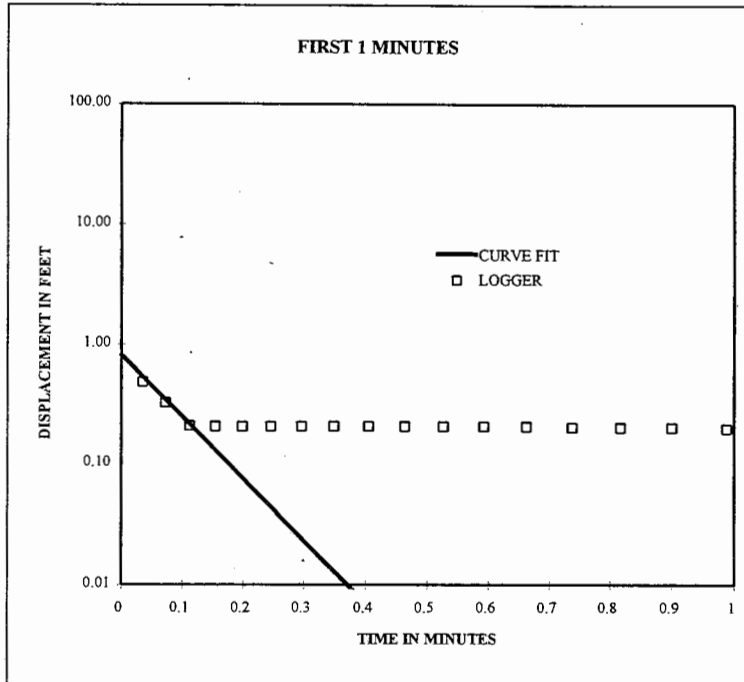


Bouwer, Herman. 1989. "The Bouwer and Rice Slug Test - An Update". Ground Water vol. 27, no. 3, May-June 1989.  
 Bouwer, H. and R.C. Rice. 1976. A Slug Test for Determining Hydraulic Conductivity of Unconfined Aquifers With Completely or Partially Penetrating Wells". Water Resources Research. vol 12, no. 3, June 1976.

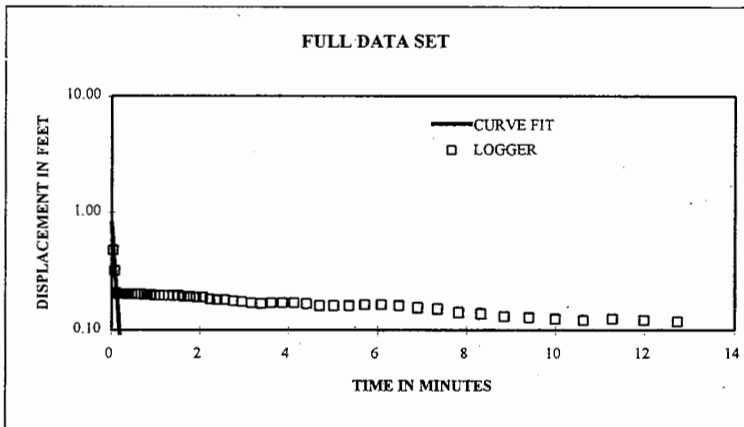
Client: **SENECA ARMY DEPOT**  
 Project: **ASH LANDFILL GW TREATABILITY STUDY USING ZERO VALENT IRON WALL**  
 Project No.: **726209-01002**  
 Well No.: **MWT-3**  
 Test Date: **5/8/1999**

Formation Tested:  
 Rising (R) or Falling (F) Head Test: **R**  
 Hydraulic conductivity **9.97E-03 cm/sec**  
**1.96E-02 ft/min**  
**28.27 ft/day**

Casing stickup	1.86 feet
Static water level (from top of casing)	5.27 feet
Depth to bottom of screen (from ground level)	7.25 feet
Boring diameter	8.00 inches
Casing diameter	2.00 inches
Screen diameter	2.00 inches
Screen length	5.00 feet
Depth to "impermeable boundary"	7.50 feet
Estimated ratio of Kh/Kv	1
Porosity of filter pack	0.3
$\Delta H$ at time zero ( $Y_0$ )	0.80 feet
$\Delta H$ at time $t$ ( $Y_t$ )	0.010 feet
Time	0.37 minutes



Bouwer-Rice Parameters			
feet	cm	cm	
3.41	103.94	SW	
3.84	117.04	H	
2.25	68.58	$T_s$	
0.333	10.16	Rw	
0.083	2.54	Rc	
0.167	5.08	DS	
3.84	117.04	L	
4.09	124.66	D	
0.8	24.38	$Y_0$	
0.01	0.30	$Y_t$	
	22.20	$t$ (seconds)	
	1.00	M	
	0.30	n	
		11.52	L/Rw
		0.94	H/D
		1.80	A
		0.25	B
		1.10	C
		-0.29	$\ln[(D-H)/Rw]$
		-0.29	$\ln[(D-H)/Rw]$
		1.67	equation (8)
		1.83	equation (9)
		1.83	$\ln(Re/Rw)$
		1.0E-02	equation (5)



Bouwer, Herman. 1989. "The Bouwer and Rice Slug Test - An Update". Ground Water vol. 27, no. 3, May-June 1989.  
 Bouwer, H. and R.C. Rice. 1976. A Slug Test for Determining Hydraulic Conductivity of Unconfined Aquifers With Completely or Partially Penetrating Wells". Water Resources Research. vol 12, no. 3, June 1976.



Client: **SENECA ARMY DEPOT**

Project: **ASH LANDFILL GW TREATABILITY STUDY USING ZERO VALENT IRON WALL**

Project No.: **726209-01002**

Well No.: **MWT-4**

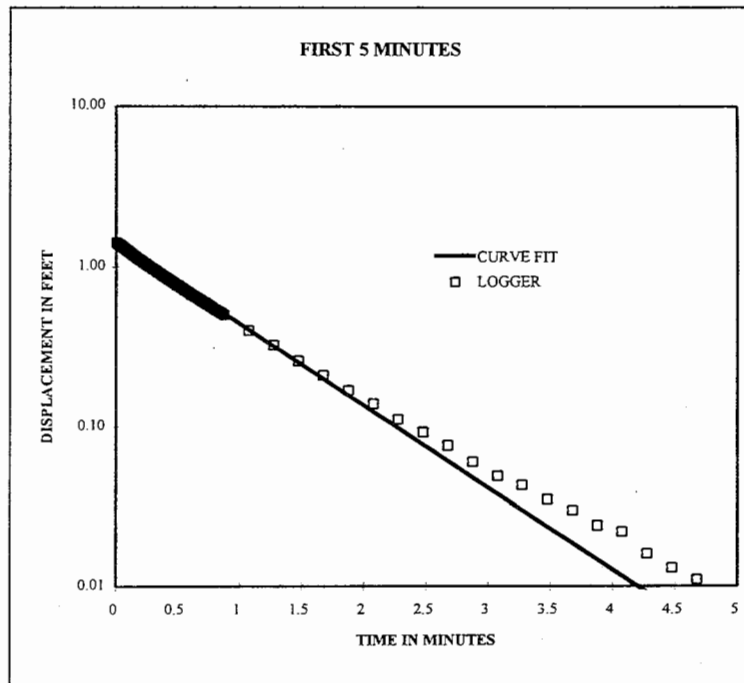
Test Date: **5/8/1999**

Formation Tested:

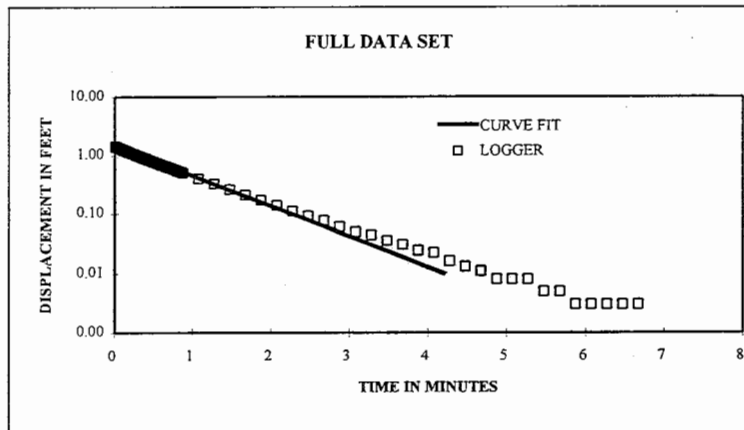
Rising (R) or Falling (F) Head Test: **R**

Hydraulic conductivity **1.36E-03 cm/sec**  
**2.68E-03 ft/min**  
**3.85 ft/day**

Casing stickup	1.86 feet
Static water level (from top of casing)	5.81 feet
Depth to bottom of screen (from ground level)	9.75 feet
Boring diameter	8.00 inches
Casing diameter	2.00 inches
Screen diameter	2.00 inches
Screen length	5.00 feet
Depth to "impermeable boundary"	10.00 feet
Estimated ratio of Kh/Kv	1
Porosity of filter pack	0.3
$\Delta H$ at time zero ( $Y_0$ )	1.45 feet
$\Delta H$ at time t ( $Y_t$ )	0.010 feet
Time	4.2 minutes



Bower-Rice Parameters		
feet	cm	cm
3.95	120.40	SW
5.8	176.78	H
4.75	144.78	$T_s$
0.083	2.54	$R_w$
0.083	2.54	$R_c$
0.167	5.08	$D_S$
5.00	152.40	L
6.05	184.40	D
1.45	44.20	$Y_0$
0.01	0.30	$Y_t$
	252.00	t (seconds)
	1.00	M
	0.30	n
		60.00 L/Rw
		0.96 H/D
		3.30 A
		0.50 B
		2.90 C
		1.10 $\ln[(D-H)/R_w]$
		1.10 $\ln[(D-H)/R_w]$
		3.09 equation (8)
		3.25 equation (9)
		3.25 $\ln(R_e/R_w)$
		1.4E-03 equation (5)



Bowser, Herman. 1989. "The Bowser and Rice Slug Test - An Update". Ground Water vol. 27, no. 3, May-June 1989.

Bowser, H. and R.C. Rice. 1976. A Slug Test for Determining Hydraulic Conductivity of Unconfined Aquifers With Completely or Partially Penetrating Wells". Water Resources Research. vol 12, no. 3, June 1976.

Client: **SENECA ARMY DEPOT**

Project: **ASH LANDFILL GW TREATABILITY STUDY USING ZERO VALENT IRON WALL**

Project No.: **726209-01002**

Well No.: **MWT-6**

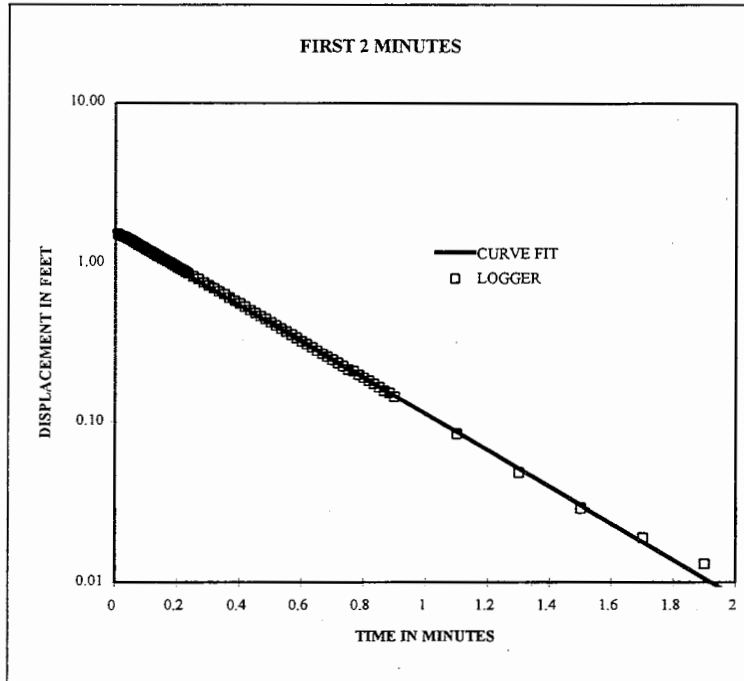
Test Date: **5/8/1999**

Formation Tested:

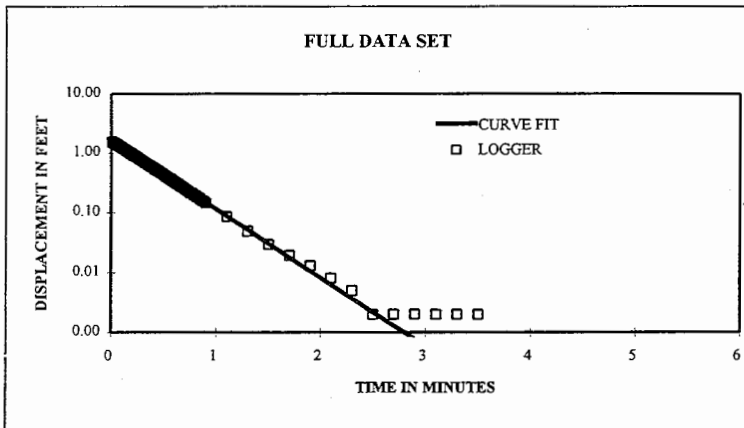
Rising (R) or Falling (F) Head Test: **R**

Hydraulic conductivity **3.03E-03 cm/sec**  
**5.96E-03 ft/min**  
**8.58 ft/day**

Casing stickup	1.86 feet
Static water level (from top of casing)	5.81 feet
Depth to bottom of screen (from ground level)	9.88 feet
Boring diameter	8.00 inches
Casing diameter	2.00 inches
Screen diameter	2.00 inches
Screen length	5.00 feet
Depth to "impermeable boundary"	10.33 feet
Estimated ratio of Kh/Kv	1
Porosity of filter pack	0.3
$\Delta H$ at time zero ( $Y_0$ )	1.55 feet
$\Delta H$ at time t ( $Y_t$ )	0.010 feet
Time	1.92 minutes



Bouwer-Rice Parameters		
feet	cm	cm
3.95	120.40	SW
5.93	180.75	H
4.88	148.74	$T_s$
0.083	2.54	$R_w$
0.083	2.54	$R_c$
0.167	5.08	$D_S$
5.00	152.40	L
6.38	194.46	D
1.55	47.24	$Y_0$
0.01	0.30	$Y_t$
	115.20	t (seconds)
	1.00	M
	0.30	n
		60.00 L/Rw
		0.93 H/D
		3.30 A
		0.50 B
		2.90 C
		1.69 $\ln[(D-H)/R_w]^*$
		1.69 $\ln[(D-H)/R_w]$
		3.06 equation (8)
		3.27 equation (9)
		3.27 $\ln(Re/R_w)$
		3.0E-03 equation (5)

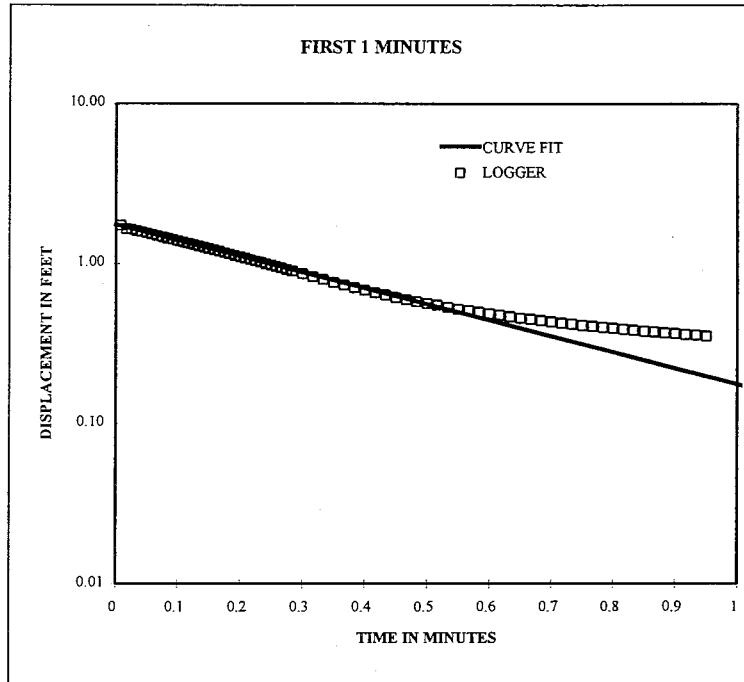


Bouwer, Herman. 1989. "The Bouwer and Rice Slug Test - An Update". Ground Water vol. 27, no. 3, May-June 1989.  
 Bouwer, H. and R.C. Rice. 1976. A Slug Test for Determining Hydraulic Conductivity of Unconfined Aquifers With Completely or Partially Penetrating Wells". Water Resources Research. vol 12, no. 3, June 1976.

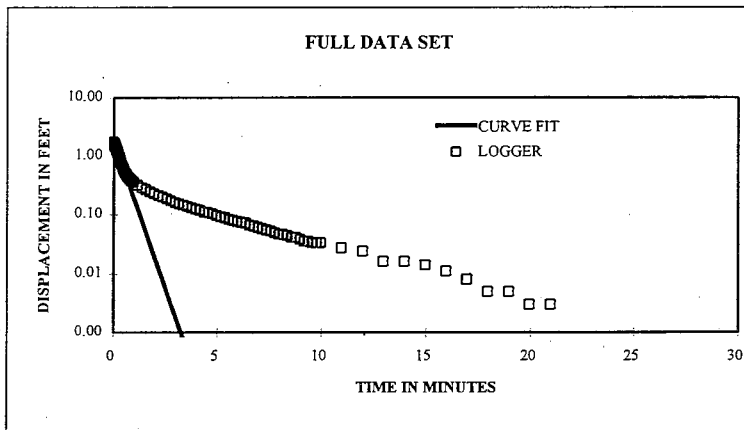
Client: **SENECA ARMY DEPOT**  
 Project: **ASH LANDFILL GW TREATABILITY STUDY USING ZERO VALENT IRON WALL**  
 Project No.: **726209-01002**  
 Well No.: **MWT-7**  
 Test Date: **5/8/1999**

Formation Tested:  
 Rising (R) or Falling (F) Head Test: **R**  
 Hydraulic conductivity **1.35E-03 cm/sec**  
**2.66E-03 ft/min**  
**3.83 ft/day**

Casing stickup	1.86 feet
Static water level (from top of casing)	6.54 feet
Depth to bottom of screen (from ground level)	11.42 feet
Boring diameter	8.00 inches
Casing diameter	2.00 inches
Screen diameter	2.00 inches
Screen length	10.00 feet
Depth to "impermeable boundary"	11.67 feet
Estimated ratio of Kh/Kv	1
Porosity of filter pack	0.3
$\Delta H$ at time zero ( $Y_0$ )	1.75 feet
$\Delta H$ at time $t$ ( $Y_t$ )	0.010 feet
Time	2.25 minutes



Bouwer-Rice Parameters		
feet	cm	cm
4.68	142.65	SW
6.74	205.44	H
1.42	43.28	$T_s$
0.333	10.16	Rw
0.083	2.54	Rc
0.167	5.08	DS
6.74	205.44	L
6.99	213.06	D
1.75	53.34	$Y_0$
0.01	0.30	$Y_t$
	135.00	$t$ (seconds)
	1.00	M
	0.30	n
		20.22 L/Rw
		0.96 H/D
		2.20 A
		0.30 B
		1.60 C
		-0.29 $\ln[(D-H)/Rw]^*$
		-0.29 $\ln[(D-H)/Rw]$
		2.13 equation (8)
		2.25 equation (9)
		2.25 $\ln(Re/Rw)$
		1.4E-03 equation (5)



Bouwer, Herman. 1989. "The Bouwer and Rice Slug Test - An Update". Ground Water vol. 27, no. 3, May-June 1989.  
 Bouwer, H. and R.C. Rice. 1976. A Slug Test for Determining Hydraulic Conductivity of Unconfined Aquifers With Completely or Partially Penetrating Wells". Water Resources Research. vol 12, no. 3, June 1976.

Client: **SENECA ARMY DEPOT**

Project: **ASH LANDFILL GW TREATABILITY STUDY USING ZERO VALENT IRON WALL**

Project No.: **726209-01002**

Well No.: **MWT-9**

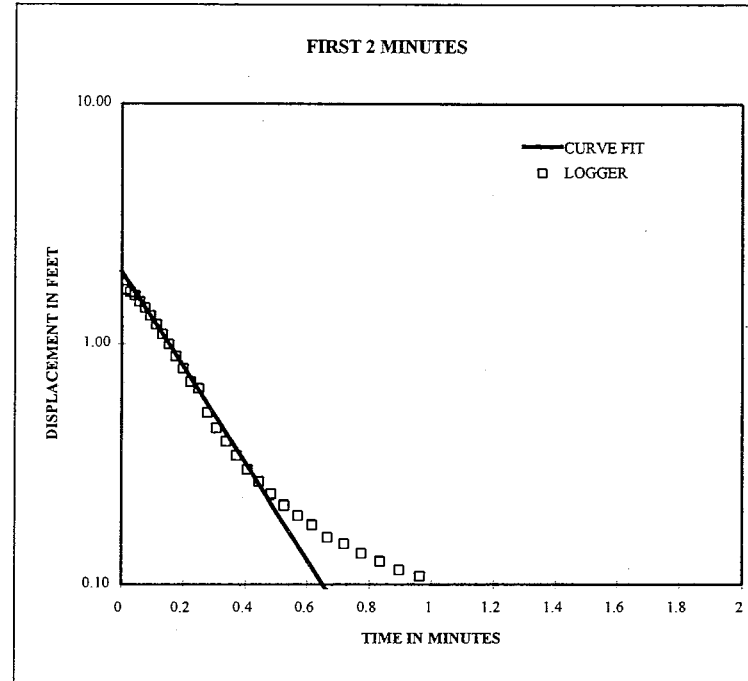
Test Date: **5/8/1999**

Formation Tested:

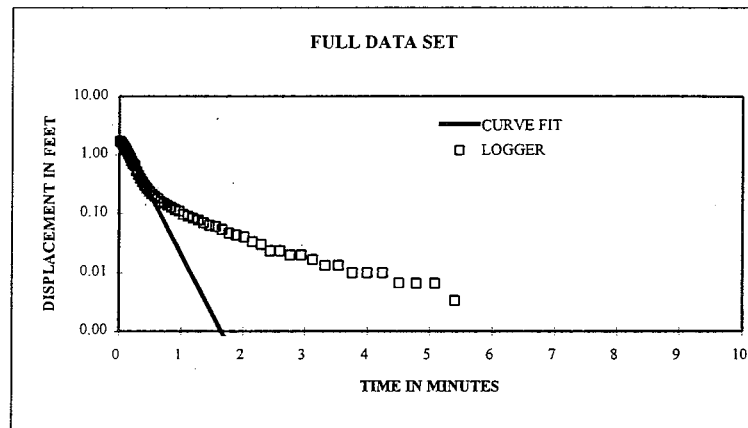
Rising (R) or Falling (F) Head Test: **R**

Hydraulic conductivity **2.61E-03 cm/sec**  
**5.13E-03 ft/min**  
**7.39 ft/day**

Casing stickup	1.86 feet
Static water level (from top of casing)	6.38 feet
Depth to bottom of screen (from ground level)	11.75 feet
Boring diameter	8.00 inches
Casing diameter	2.00 inches
Screen diameter	2.00 inches
Screen length	10.00 feet
Depth to "impermeable boundary"	12.00 feet
Estimated ratio of Kh/Kv	1
Porosity of filter pack	0.3
$\Delta H$ at time zero ( $Y_0$ )	2.00 feet
$\Delta H$ at time t ( $Y_t$ )	0.100 feet
Time	0.65 minutes



Bouwer-Rice Parameters		
feet	cm	cm
4.52	137.77	$SW$
7.23	220.37	$H$
1.75	53.34	$T_s$
0.333	10.16	$R_w$
0.083	2.54	$R_c$
0.167	5.08	$DS$
7.23	220.37	$L$
7.48	227.99	$D$
2	60.96	$Y_0$
0.1	3.05	$Y_t$
	39.00	$t$ (seconds)
	1.00	$M$
	0.30	$n$
		21.69 $L/R_w$
		0.97 $H/D$
		2.20 $A$
		0.30 $B$
		1.60 $C$
		-0.29 $\ln[(D-H)/R_w]$
		-0.29 $\ln[(D-H)/R_w]$
		2.20 equation (8)
		2.32 equation (9)
		2.32 $\ln(R_e/R_w)$
		2.6E-03 equation (5)



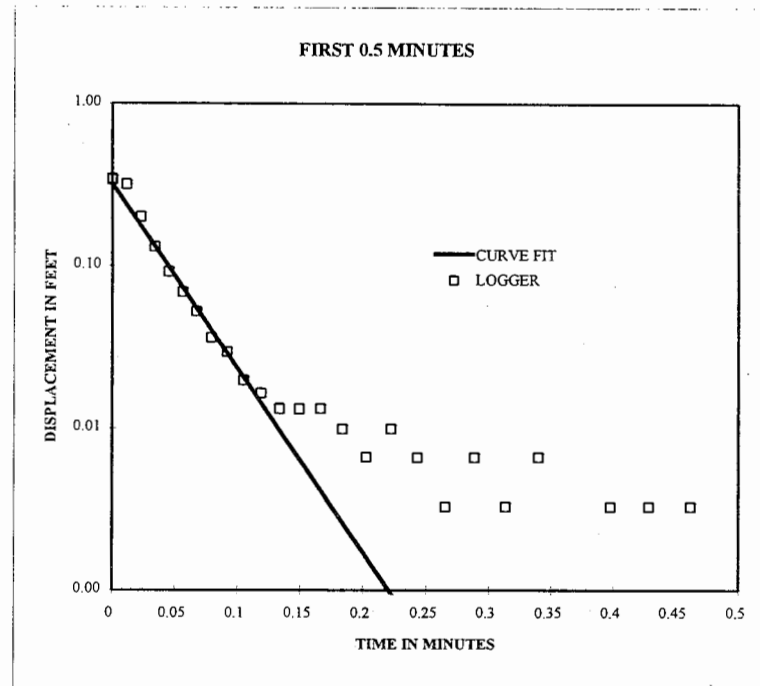
Bouwer, Herman. 1989. "The Bouwer and Rice Slug Test - An Update". Ground Water vol. 27, no. 3, May-June 1989.

Bouwer, H. and R.C. Rice. 1976. A Slug Test for Determining Hydraulic Conductivity of Unconfined Aquifers With Completely or Partially Penetrating Wells". Water Resources Research. vol 12, no. 3, June 1976.

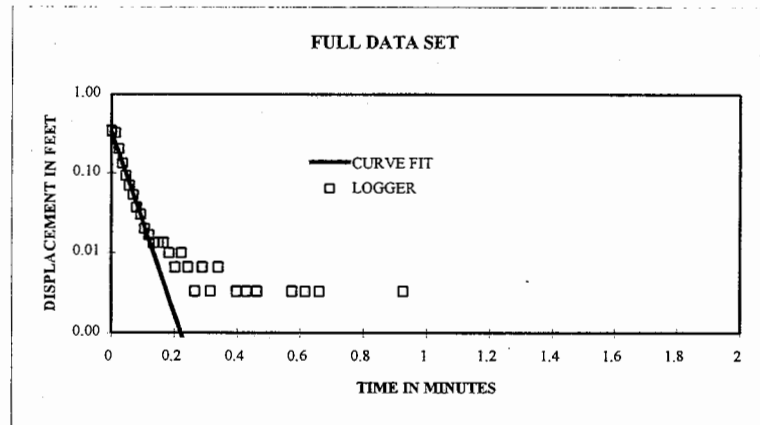
Client: **SENECA ARMY DEPOT**  
 Project: **ASH LANDFILL GW TREATABILITY STUDY USING ZERO VALENT IRON WALL**  
 Project No.: **726209-01002**  
 Well No.: **MWT-10**  
 Test Date: **5/8/1999**

Formation Tested:  
 Rising (R) or Falling (F) Head Test: **R**  
 Hydraulic conductivity **1.94E-02 cm/sec**  
**3.83E-02 ft/min**  
**55.10 ft/day**

Casing stickup	1.86 feet
Static water level (from top of casing)	4.02 feet
Depth to bottom of screen (from ground level)	6.83 feet
Boring diameter	8.00 inches
Casing diameter	2.00 inches
Screen diameter	2.00 inches
Screen length	5.00 feet
Depth to "impermeable boundary"	7.08 feet
Estimated ratio of Kh/Kv	1
Porosity of filter pack	0.3
$\Delta H$ at time zero ( $Y_0$ )	0.32 feet
$\Delta H$ at time $t$ ( $Y_t$ )	0.001 feet
Time	0.22 minutes



Bouwer-Rice Parameters		
feet	cm	cm
2.16	65.84	<i>SW</i>
4.67	142.34	<i>H</i> 14.01 <i>L/Rw</i>
1.83	55.78	<i>Ts</i> 0.95 <i>H/D</i>
0.333	10.16	<i>Rw</i> 1.93 <i>A</i>
0.083	2.54	<i>Rc</i> 0.27 <i>B</i>
0.167	5.08	<i>DS</i> 1.30 <i>C</i>
4.67	142.34	<i>L</i> -0.29 $\ln[(D-H)/Rw]^*$
4.92	149.96	<i>D</i> -0.29 $\ln[(D-H)/Rw]$
0.32	9.75	$Y_0$ 1.82 equation (8)
0.001	0.03	$Y_t$ 1.96 equation (9)
	13.20	<i>t (seconds)</i> 1.96 $\ln(Rc/Rw)$
	1.00	<i>M</i> 1.9E-02 equation (5)
	0.30	<i>n</i>



Bouwer, Herman. 1989. "The Bouwer and Rice Slug Test - An Update". Ground Water vol. 27, no. 3, May-June 1989.  
 Bouwer, H. and R.C. Rice. 1976. A Slug Test for Determining Hydraulic Conductivity of Unconfined Aquifers With Completely or Partially Penetrating Wells". Water Resources Research. vol 12, no. 3, June 1976.

Client: **SENECA ARMY DEPOT**

Project: **ASH LANDFILL GW TREATABILITY STUDY USING ZERO VALENT IRON WALL**

Project No.: **726209-01002**

Well No.: **MWT-11**

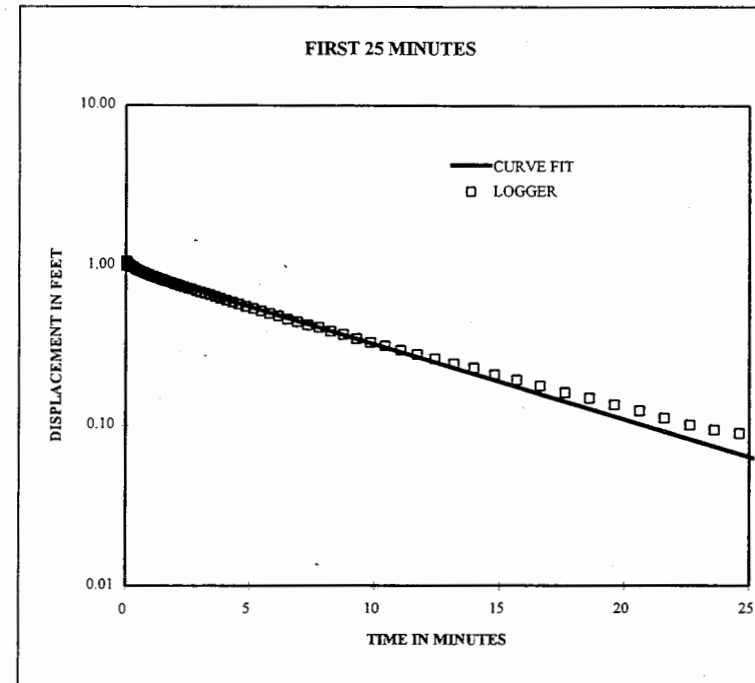
Test Date: **5/8/1999**

Formation Tested:

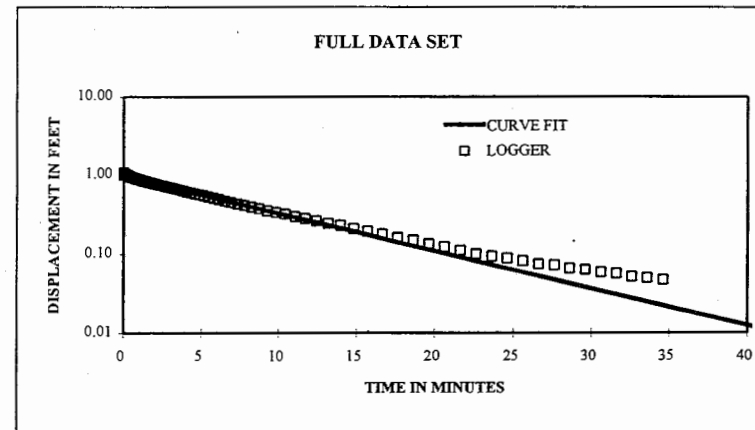
Rising (R) or Falling (F) Head Test: **R**

Hydraulic conductivity **1.37E-04 cm/sec**  
**2.69E-04 ft/min**  
**0.39 ft/day**

Casing stickup	1.86 feet
Static water level (from top of casing)	2.26 feet
Depth to bottom of screen (from ground level)	10.00 feet
Boring diameter	8.00 inches
Casing diameter	2.00 inches
Screen diameter	2.00 inches
Screen length	5.00 feet
Depth to "impermeable boundary"	10.25 feet
Estimated ratio of Kh/Kv	1
Porosity of filter pack	0.3
$\Delta H$ at time zero ( $Y_0$ )	0.95 feet
$\Delta H$ at time $t$ ( $Y_t$ )	0.010 feet
Time	42 minutes

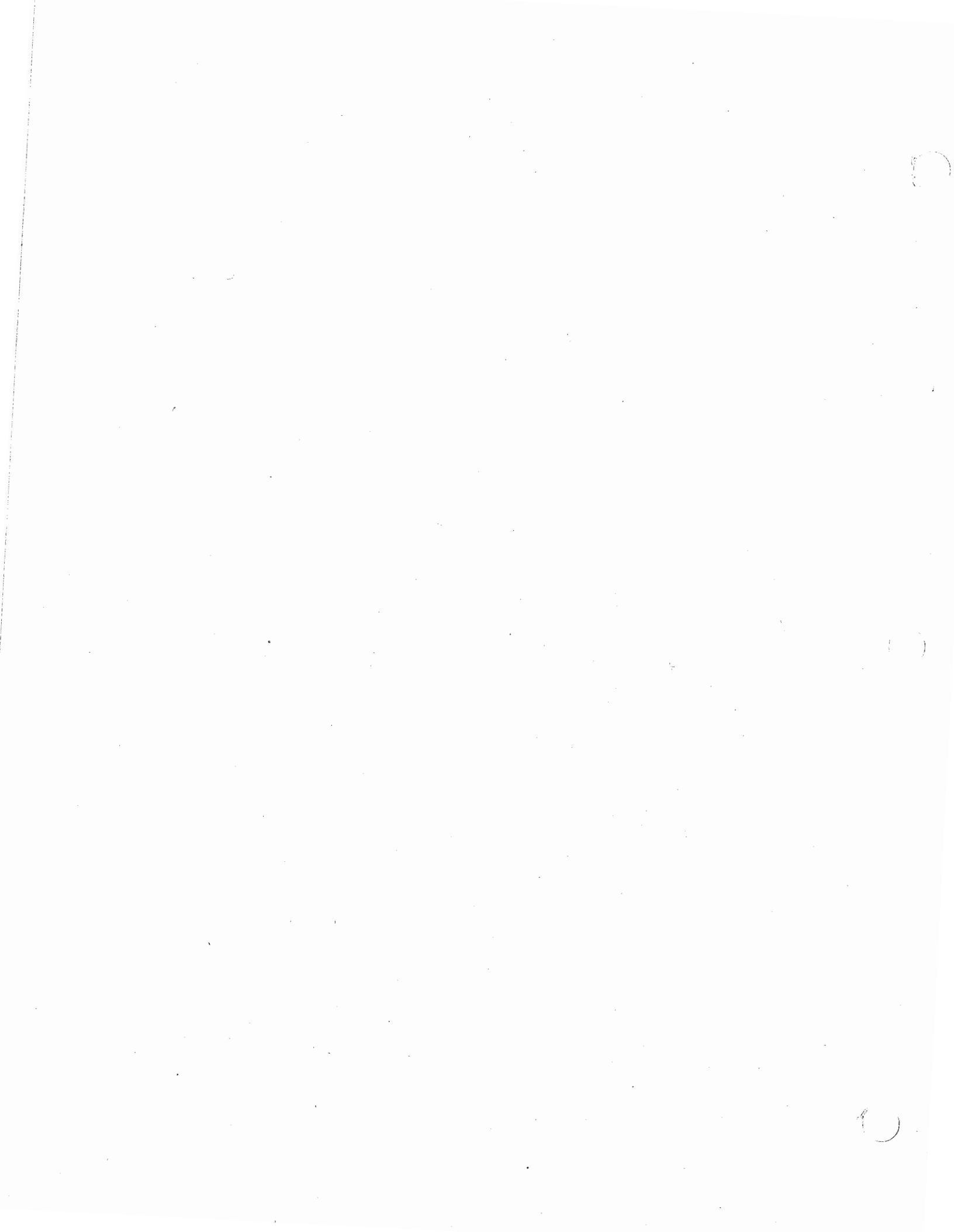


Bower-Rice Parameters		
feet	cm	cm
0.4	12.19 <i>SW</i>	
9.6	292.61 <i>H</i>	60.00 <i>L/Rw</i>
5	152.40 <i>TS</i>	0.97 <i>H/D</i>
0.083	2.54 <i>Rw</i>	3.30 <i>A</i>
0.083	2.54 <i>Rc</i>	0.50 <i>B</i>
0.167	5.08 <i>DS</i>	2.90 <i>C</i>
5.00	152.40 <i>L</i>	1.10 $\ln[(D-H)/Rw]^*$
9.85	300.23 <i>D</i>	1.10 $\ln[(D-H)/Rw]$
0.95	28.96 $Y_0$	3.38 equation (8)
0.01	0.30 $Y_t$	3.57 equation (9)
	2520.00 <i>t (seconds)</i>	3.57 $\ln(Re/Rw)$
	1.00 <i>M</i>	1.4E-04 equation (5)
	0.30 <i>n</i>	



Bowser, Herman. 1989. "The Bowser and Rice Slug Test - An Update". Ground Water vol. 27, no. 3, May-June 1989.

Bowser, H. and R.C. Rice. 1976. A Slug Test for Determining Hydraulic Conductivity of Unconfined Aquifers With Completely or Partially Penetrating Wells". Water Resources Research. vol 12, no. 3, June 1976.

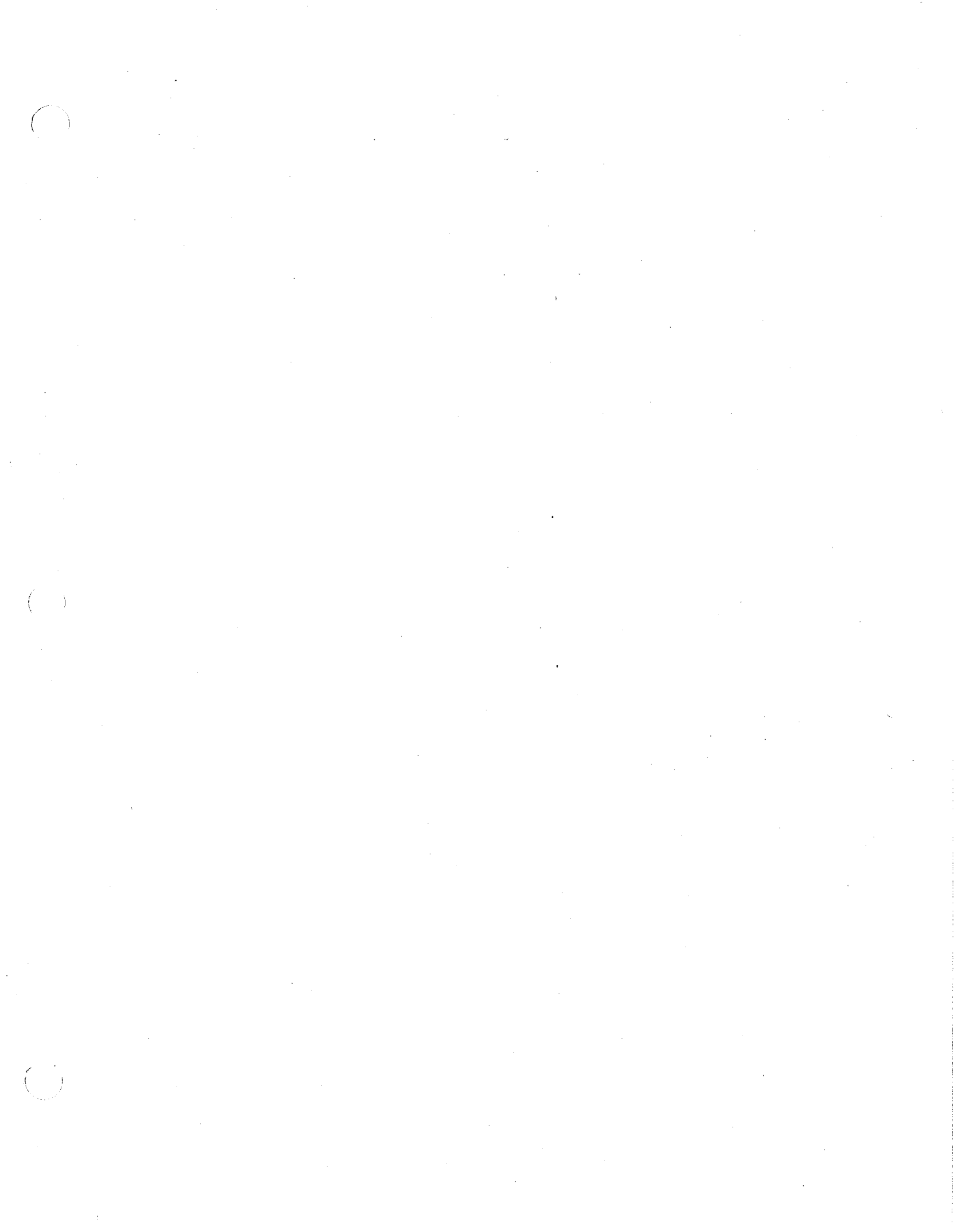


Hydraulic Conductivity Results for Till/Weathered Shale from Remedial Investigation  
Seneca Army Depot Activity  
Romulus, NY

Monitoring Well Designation	Hydraulic Conductivity	
	cm/sec	ft/day
PT-12	3.09E-05	0.1
PT-23	7.80E-04	2.2
MW-34	1.85E-04	0.5
MW-36	5.26E-04	1.5
MW-37	7.07E-04	2.0
MW-40	3.87E-05	0.1

Average: 1





US ARMY ENVIRONMENTAL HYGIENE AGENCY

DRILLING LOG

(The proponent of this form is HSHB-ES)

PROJECT Seneca Army Depot

DATE 14 November 1989

LOCATION 86.5 feet SW from PT-23  
110.5 feet from MW-28

DRILLERS D. Kestner, S. Curran

DRILL RIG Mobile B-80 with 6-inch hollow stem auger

BORE HOLE MW- 27

DEPTH	SAMPLE TYPE	DESCRIPTION	REMARKS
	BLOWS PER 6 IN.		
0		Dark brown silty clay	
1		Weathered gray shale	
5			
8		BOH	
10		Gray shale	

US ARMY ENVIRONMENTAL HYGIENE AGENCY

DRILLING LOG

(The proponent of this form is HSHD-ES)

PROJECT Seneca Army Depot

DATE 14 November 1989

LOCATION 81 feet from fence line  
110.5 feet from MW-27

DRILLERS D. Kestner, S. Curran

DRILL RIG Mobile B-80 with 6-inch hollow stem auger

BORE HOLE MW- 28

DEPTH	SAMPLE TYPE	DESCRIPTION	REMARKS
	BLOWS PER 6 IN.		
0		Dark brown silty clay	
1		Weathered gray shale	
5			
8		BOH gray shale	
10			

US ARMY ENVIRONMENTAL HYGIENE AGENCY

DRILLING LOG

(The proponent of this form is HSHD-ES)

PROJECT Seneca Army Depot DATE 14 November 1989  
 LOCATION 167 feet from PT-24 58' feet DRILLERS D. Kestner, S. Curran  
from fence  
 DRILL RIG Mobile B-80 with 6-inch BORE HOLE MW-29  
hollow stem auger

DEPTH	SAMPLE TYPE	DESCRIPTION	REMARKS
	BLOWS PER 6 IN.		
0		Dark brown silty clay	
1		Weathered gray shale	
5			
9		BOH	
10		Gray shale	

PROJECT Ground Water Monitoring Well  
 LOCATION Seneca Army Depot  
 Romulus, New York  
 DATE STARTED 9/24/87 DATE COMPLETED 9/24/87

HOLE NO. PT-17  
 SURF. EL.  
 JOB NO. 87188  
 GROUND WATER DEPTH  
 WHILE DRILLING 5.0'  
 BEFORE CASING  
 REMOVED 3.0'  
 AFTER CASING  
 REMOVED 3.0' In  
 Well

N — NO. OF BLOWS TO DRIVE SAMPLER 12" W/140# HAMMER FALLING  
 30" — ASTM D-1586, STANDARD PENETRATION TEST

C — NO. OF BLOWS TO DRIVE CASING 12" W/ # HAMMER FALLING  
 \*OR — % CORE RECOVERY

CASING TYPE - HOLLOW STEM AUGER

SHEET 1 OF 1

DEPTH	SAMPLE DEPTH	SAMPLE NUMBER	C	SAMPLE DRIVE RECORD PER 6"	N	DESCRIPTION OF MATERIAL	STRATA CHANGE DEPTH
5.0	0.0'	1		2/3		TOPSOIL	1.5'
	2.0'			3/4	6	Brown moist medium stiff SILT, fine to coarse SAND and fine to coarse GRAVEL	
	2.0'	2		3/6			
	4.0'			7/15	13		
	4.0'	3		4/6		Gray moist very stiff SILT and SHALE GRAVEL	3.5'
10.0	6.0'			16/50-		Gray wet hard silty weathered SHALE	5.0'
	6.0'	4		50-.3'			
	6.4'					Augered to 11.0'	
	8.0'	5		50-.4'			
	8.4'					Bottom of Boring	11.0'
Note: Installed 2" PVC screen 9.0' to 4.0', 2" PVC riser to surface with locking cover.							

US

# US ARMY ENVIRONMENTAL HYGIENE AGENCY

## DRILLING LOG

(The proponent of this form is HSHB-ES)

PROJECT  
LOCATION  
39-26-  
- 512

PROJECT 39-26-0313-88 Seneca AD DATE 18 Oct 87

LOCATION Corner of fence offset DRILLERS William P. Smithson

DRILL RIG Acker AD-II BORE HOLE Well PT-24

DEPTH (feet)	SAMPLE TYPE	DESCRIPTION	REMARKS
	BLOWS PER 6 IN		
3		Brown silty gravelly clay and ash	
3	Shelby	Ash, weathered shale	
4.75		▽ 3	
5	Tubes		
5.5		Hard shale	Oil slick on mud
10		BOH	

Appendix C  
Analytical Results

- Bold & Shade Summary Sheets for Round 1, 2, 3, and 4 groundwater sampling (April 1999 to January 2000) Treatability Study for Zero Valent Iron Continuous Reactive Wall at the Ash Landfill

Seneca Army Depot Activity  
Ash Landfill Groundwater Remediation  
Round 1 Groundwater Sampling

		MAXIMUM	FREQUENCY OF DETECTION	NYSDEC CLASSIFICATION STANDARD	NUMBER ABOVE TAGM	NUMBER OF DETECTS	NUMBER OF ANALYSES	ASH LANDFILL	ASH LANDFILL	ASH LANDFILL	ASH LANDFILL	ASH LANDFILL	ASH LANDFILL							
								MWT-1 GROUND WATER	MWT-10 GROUND WATER	MWT-11 GROUND WATER	MWT-2 GROUND WATER	MWT-3 GROUND WATER	MWT-4 GROUND WATER	MWT-5 GROUND WATER						
							04/26/1999	04/26/1999	04/26/1999	04/26/1999	04/27/1999	04/26/1999	04/28/1999							
							ASH TRENCH	ASH TRENCH	ASH TRENCH	ASH TRENCH	ASH TRENCH	ASH TRENCH	ASH TRENCH							
							TR2002	TR2001	TR2000	TR2008	TR2007	TR2004	TR2009							
							SA	SA	SA	SA	SA	SA	SA							
							N	N	N	N	N	N	N							
Volatile Organic Compounds																				
1,1,1-Trichloroethane	UG/L	0	0%	5	0	0	12	4	U	1	U	2	U	1	U					
1,1,2,2-Tetrachloroethane	UG/L	0	0%	5	0	0	12	4	U	1	U	2	U	3	U					
1,1,2-Trichloroethane	UG/L	0	0%	5	0	0	12	4	U	1	U	2	U	3	U					
1,1-Dichloroethane	UG/L	0	0%	5	0	0	12	4	U	1	U	2	U	3	U					
1,1-Dichloroethene	UG/L	0	0%	5	0	0	12	4	U	1	U	2	U	3	U					
1,2,4-Trichlorobenzene	UG/L	0	0%	5	0	0	12	4	U	1	U	2	U	3	U					
1,2-Dibromo-3-chloropropane	UG/L	0	0%	0	0	0	12	4	U	1	U	2	U	3	U					
1,2-Dibromoethane	UG/L	0	0%	0	0	0	12	4	U	1	U	2	U	3	U					
1,2-Dichlorobenzene	UG/L	0	0%	4.7	0	0	12	4	U	1	U	2	U	3	U					
1,2-Dichloroethane	UG/L	0	0%	5	0	0	12	4	U	1	U	2	U	3	U					
1,2-Dichloropropane	UG/L	0	0%	5	0	0	12	4	U	1	U	2	U	3	U					
1,3-Dichlorobenzene	UG/L	0	0%	5	0	0	12	4	U	1	U	2	U	3	U					
1,4-Dichlorobenzene	UG/L	0	0%	4.7	0	0	12	4	U	1	U	2	U	3	U					
Acetone	UG/L	16	42%	0	0	5	12	20	U	5	U	6	U	14	U					
Benzene	UG/L	0.9	50%	1	0	6	12	4	U	0.7	J	0.4	J	0.9	J					
Bromochloromethane	UG/L	0	0%	0	0	0	12	4	U	1	U	2	U	3	U					
Bromodichloromethane	UG/L	0	0%	0	0	0	12	4	U	1	U	2	U	3	U					
Bromoform	UG/L	0	0%	0	0	0	12	4	U	1	U	2	U	3	U					
Carbon disulfide	UG/L	1	8%	0	0	1	12	4	U	1	U	2	U	3	U					
Carbon tetrachloride	UG/L	0	0%	5	0	0	12	4	U	1	U	2	U	3	U					
Chlorobenzene	UG/L	0	0%	5	0	0	12	4	U	1	U	2	U	3	U					
Chlorodibromomethane	UG/L	0	0%	0	0	0	12	4	U	1	U	2	U	3	U					
Chloroethane	UG/L	0	0%	5	0	0	12	4	U	1	U	2	U	3	U					
Chloroform	UG/L	0	0%	7	0	0	12	4	U	1	U	2	U	3	U					
Cis-1,2-Dichloroethene	UG/L	73	83%	5	7	10	12	73	U	1	U	2	U	3	U					
Cis-1,3-Dichloropropene	UG/L	0	0%	5	0	0	12	4	U	1	U	2	U	3	U					
Ethyl benzene	UG/L	0	0%	5	0	0	12	4	U	1	U	2	U	3	U					
Methyl bromide	UG/L	0	0%	0	0	0	12	4	U	1	U	2	U	3	U					
Methyl butyl ketone	UG/L	0	0%	5	0	0	12	20	U	5	U	8	U	14	U					
Methyl chloride	UG/L	0	0%	0	0	0	12	4	U	1	U	2	U	3	U					
Methyl ethyl ketone	UG/L	0	0%	50	0	0	12	20	U	5	U	8	U	14	U					
Methyl isobutyl ketone	UG/L	0	0%	5	0	0	12	20	U	5	U	8	U	14	U					
Methylene chloride	UG/L	0	0%	5	0	0	12	8	U	2	U	3	U	6	U					
Styrene	UG/L	0	0%	0	0	0	12	4	U	1	U	2	U	3	U					
Tetrachloroethene	UG/L	0	0%	5	0	0	12	4	U	1	U	2	U	3	U					
Toluene	UG/L	0.7	17%	5	0	2	12	4	U	1	U	0.7	J	0.3	J					
Total Xylenes	UG/L	0	0%	5	0	0	12	4	U	1	U	2	U	3	U					
Trans-1,2-Dichloroethene	UG/L	0	0%	5	0	0	12	4	U	1	U	2	U	3	U					
Trans-1,3-Dichloropropene	UG/L	0	0%	5	0	0	12	4	U	1	U	2	U	3	U					
Trichloroethene	UG/L	430	50%	5	3	6	12	23	U	1	U	1	J	2	J					
Vinyl chloride	UG/L	0	0%	2	0	0	12	4	U	1	U	2	U	3	U					
Metals																				
Calcium	UG/L	264000	100%		0	12	12	122000		49900		102000		58000		118000		177000		
Iron	UG/L	548000	100%	300	9	12	12	403	J	13100	J	54.6	J	52000	J	3600	J	548000	J	
Magnesium	UG/L	74400	100%		0	12	12	13800		10600		12800		60800		13000		14300		74400
Manganese	UG/L	6260	100%	300	5	12	12	13.2	J	191	J	78	J	6260	J	611	J	37.1	J	5010
Potassium	UG/L	15100	100%		0	12	12	1460	J	1520	J	5600	J	15100	J	1900	J	1860	J	14200
Other Analytes																				
Methane	UG/L	20	75%		0	9	12	1.2	U	4.5		4.1		20		7.1		1.2	U	14
Ethane	UG/L	14	58%		0	7	12	2.1	U	6.8		2.1	U	8.3		7.8		2.1	U	12
Ethene	UG/L	12	50%		0	6	12	2.5	U	2.5	U	2.5	U	8.8		9.3		2.5	U	8.7
Sulfate	MG/L	113	100%		0	12	12	91.1		51.7		49.7		82		84.2		106		107
Nitrate	MG/L	0.4	33%	10	0	4	12	0.3		-0.2		0.3		-0.2		-0.2		0.3		-0.2
Chloride	MG/L	25.2	100%		0	12	12	15.2		11.5		11.5		15		15.6		21.5		23.4
TDS	MG/L	441	100%		0	12	12	438		206		366		269		252		441		219
pH		9.74	100%		0	12	12	7.19		7.54		7.26		7.83		7.41		7.16		9.14
Alkalinity	MG/L	378	100%		0	12	12	266		113		280		378		107		238		378
Phosphate	MG/L	0.44	100%		0	12	12	0.01		0.03		0.01		0.44		0.04		0.04		0.06



Seneca Army Depot Activity  
Ash Landfill Groundwater Remediation  
Round 1 Groundwater Sampling

		MAXIMU	FREQUENC OF DETECTION	NYSDEC CLASS GA STANDARD	NUMBER ABOVE TAGM	NUMBER OF DETECTS	NUMBER OF ANALYSES	ASH LANDFILL MWT-6 GROUND WATER		ASH LANDFILL MWT-6 GROUND WATER		ASH LANDFILL MWT-7 GROUND WATER		ASH LANDFILL MWT-8 GROUND WATER		ASH LANDFILL MWT-9 GROUND WATER		
								04/28/1999 TR2011		04/28/1999 TR2006		04/27/1999 TR2003		04/28/1999 TR2010		04/27/1999 TR2005		
								DU	SA	SA	SA	SA	SA	SA	SA			
Volatile Organic Compounds																		
1,1,1-Trichloroethane	UGL	0	0%	5	0	0	12	1	U	1	U	22	U	1	U	2	U	
1,1,2,2-Tetrachloroethane	UGL	0	0%	5	0	0	12	1	U	1	U	22	U	1	U	2	U	
1,1,2-Trichloroethane	UGL	0	0%		0	0	12	1	U	1	U	22	U	1	U	2	U	
1,1-Dichloroethane	UGL	0	0%	5	0	0	12	1	U	1	U	22	U	1	U	2	U	
1,1-Dichloroethene	UGL	0	0%	5	0	0	12	1	U	1	U	22	U	1	U	2	U	
1,2,4-Trichlorobenzene	UGL	0	0%	5	0	0	12	1	U	1	U	22	U	1	U	2	U	
1,2-Dibromo-3-chloropropane	UGL	0	0%		0	0	12	1	U	1	U	22	U	1	U	2	U	
1,2-Dibromoethane	UGL	0	0%		0	0	12	1	U	1	U	22	U	1	U	2	U	
1,2-Dichlorobenzene	UGL	0	0%	4.7	0	0	12	1	U	1	U	22	U	1	U	2	U	
1,2-Dichloroethane	UGL	0	0%	5	0	0	12	1	U	1	U	22	U	1	U	2	U	
1,2-Dichloropropane	UGL	0	0%	5	0	0	12	1	U	1	U	22	U	1	U	2	U	
1,3-Dichlorobenzene	UGL	0	0%	5	0	0	12	1	U	1	U	22	U	1	U	2	U	
1,4-Dichlorobenzene	UGL	0	0%	4.7	0	0	12	1	U	1	U	22	U	1	U	2	U	
Acetone	UGL	16	42%		0	5	12	6		5		110	U	16		11	U	
Benzene	UGL	0.9	50%	1	0	6	12	0.7	J	0.7	J	22	U	1	U	2	U	
Bromochloromethane	UGL	0	0%		0	0	12	1	U	1	U	22	U	1	U	2	U	
Bromodichloromethane	UGL	0	0%		0	0	12	1	U	1	U	22	U	1	U	2	U	
Bromoform	UGL	0	0%		0	0	12	1	U	1	U	22	U	1	U	2	U	
Carbon disulfide	UGL	1	8%		0	1	12	1	U	1	U	22	U	1	U	2	U	
Carbon tetrachloride	UGL	0	0%	5	0	0	12	1	U	1	U	22	U	1	U	2	U	
Chlorobenzene	UGL	0	0%	5	0	0	12	1	U	1	U	22	U	1	U	2	U	
Chlorodibromomethane	UGL	0	0%		0	0	12	1	U	1	U	22	U	1	U	2	U	
Chloroethane	UGL	0	0%	5	0	0	12	1	U	1	U	22	UJ	1	U	2	UJ	
Chloroform	UGL	0	0%	7	0	0	12	1	U	1	U	22	U	1	U	2	U	
Cis-1,2-Dichloroethene	UGL	73	83%	5	7	10	12	3		3		28	J	1	U	37		
Cis-1,3-Dichloropropene	UGL	0	0%	5	0	0	12	1	U	1	U	22	U	1	U	2	U	
Ethyl benzene	UGL	0	0%	5	0	0	12	1	U	1	U	22	U	1	U	2	U	
Methyl bromide	UGL	0	0%		0	0	12	1	U	1	U	22	U	1	U	2	U	
Methyl butyl ketone	UGL	0	0%		0	0	12	5	U	5	U	110	U	5	U	11	U	
Methyl chloride	UGL	0	0%	5	0	0	12	1	U	1	U	22	UJ	1	U	2	UJ	
Methyl ethyl ketone	UGL	0	0%	50	0	0	12	5	U	5	U	110	U	5	U	11	U	
Methyl isobutyl ketone	UGL	0	0%		0	0	12	5	U	5	U	110	U	5	U	11	U	
Methylene chloride	UGL	0	0%	5	0	0	12	2	U	2	U	44	U	2	U	4	U	
Styrene	UGL	0	0%		0	0	12	1	U	1	U	22	U	1	U	2	U	
Tetrachloroethene	UGL	0	0%	5	0	0	12	1	U	1	U	22	U	1	U	2	U	
Toluene	UGL	0.7	17%	5	0	2	12	1	U	1	U	22	U	1	U	2	U	
Total Xylenes	UGL	0	0%	5	0	0	12	1	U	1	U	22	U	1	U	2	U	
Trans-1,2-Dichloroethene	UGL	0	0%	5	0	0	12	1	U	1	U	22	U	1	U	2	U	
Trans-1,3-Dichloropropene	UGL	0	0%	5	0	0	12	1	U	1	U	22	U	1	U	2	U	
Trichloroethene	UGL	430	50%	5	3	6	12	1	U	1	U	49	U	1	U	43	U	
Vinyl chloride	UGL	0	0%	2	0	0	12	1	U	1	U	22	U	1	U	2	U	
<b>Metals</b>																		
Calcium	UGL	264000	100%		0	12	12	44000		43800		122000		40200		36200		
Iron	UGL	548000	100%	300	9	12	12	392	J	244	J	228	J	37300	J	1810	J	
Magnesium	UGL	74400	100%		0	12	12	4970	J	4920	J	14300		9830		9520		
Manganese	UGL	6260	100%	300	5	12	12	169		170		22.5		416		444		
Potassium	UGL	15100	100%		0	12	12	2080	J	1910	J	2030	J	6250		1600	J	
<b>Other Analytes</b>																		
Methane	UGL	20	75%		0	9	12	9.4		1.2	U	3.6		13		6.9		
Ethane	UGL	14	58%		0	7	12	13		2.1	U	2.1	U	13		14		
Ethene	UGL	12	50%		0	6	12	8.7		2.5	U	2.5	U	8		12		
Sulfate	MG/L	113	100%		0	12	12	108		113		74.2		61.6		47.2		
Nitrate	MG/L	0.4	33%	10	0	4	12	<0.2		<0.2		0.4		<0.2		<0.2		
Chloride	MG/L	25.2	100%		0	12	12	24.6		25.2		8.7		7.6		8.3		
TDS	MG/L	441	100%		0	12	12	219		219		433		145		174		
pH		9.74	100%		0	12	12	8.81		8.72		7.17		9.74		7.84		
Alkalinity	MG/L	378	100%		0	12	12	23		22		304		378		97		
Phosphate	MG/L	0.44	100%		0	12	12	0.05		0.05		0.02		0.26		0.03		

Seneca Army Depot Activity  
Ash Landfill Groundwater Remediation  
Round 2 Groundwater Sampling

	UNIT	MAXIMUM	FREQUENCY OF DETECTION	NYSDEC CLASS GA STANDARD	NUMBER ABOVE TAGM	NUMBER OF DETECTS	NUMBER OF ANALYSES	ASH LANDFILL	ASH LANDFILL	ASH LANDFILL	ASH LANDFILL	ASH LANDFILL	ASH LANDFILL
								MWT-1	MWT-10	MWT-11	MWT-2	MWT-3	MWT-4
								GROUND WATER	GROUND WATER	GROUND WATER	GROUND WATER	GROUND WATER	GROUND WATER
								8.1	7	9.5	8	8	10
								8.1	7	9.5	8	8	10
								06/29/1999	06/29/1999	06/29/1999	06/29/1999	06/29/1999	06/29/1999
								ASH TRENCH	ASH TRENCH	ASH TRENCH	ASH TRENCH	ASH TRENCH	ASH TRENCH
								TR2023	TR2020	TR2025	TR2021	TR2022	TR2025
								SA	SA	SA	SA	SA	SA
								N	N	N	N	N	N
<b>Volatile Organic Compounds</b>													
1,1,1-Trichloroethane	UG/L	0	0%	5	0	0	11	2	UJ	UJ	UJ	UJ	UJ
1,1,2,2-Tetrachloroethane	UG/L	0	0%	5	0	0	11	2	U	U	U	U	U
1,1,2-Trichloroethane	UG/L	0	0%	5	0	0	11	2	U	U	U	U	U
1,1-Dichloroethane	UG/L	0.7	9%	5	0	1	11	2	U	U	U	U	U
1,1-Dichloroethane	UG/L	0	0%	5	0	0	11	2	U	U	U	U	U
1,2,4-Trichlorobenzene	UG/L	0	0%	5	0	0	11	2	U	U	U	U	U
1,2-Dibromo-3-chloropropane	UG/L	0	0%	5	0	0	11	2	U	U	U	U	U
1,2-Dibromoethane	UG/L	0	0%	5	0	0	11	2	U	U	U	U	U
1,2-Dichlorobenzene	UG/L	0	0%	4.7	0	0	11	2	U	U	U	U	U
1,2-Dichloroethane	UG/L	0	0%	5	0	0	11	2	UJ	UJ	UJ	UJ	UJ
1,2-Dichloropropane	UG/L	0	0%	5	0	0	11	2	U	U	U	U	U
1,3-Dichlorobenzene	UG/L	0	0%	5	0	0	11	2	U	U	U	U	U
1,4-Dichlorobenzene	UG/L	0	0%	4.7	0	0	11	2	U	U	U	U	U
Acetone	UG/L	140	91%	5	0	10	11	4	J	J	J	J	J
Benzene	UG/L	0.9	36%	1	0	4	11	2	U	J	U	J	U
Bromochloromethane	UG/L	0	0%	5	0	0	11	2	U	U	U	U	U
Bromodichloromethane	UG/L	0	0%	5	0	0	11	2	U	U	U	U	U
Bromoform	UG/L	0	0%	5	0	0	11	2	U	U	U	U	U
Carbon disulfide	UG/L	0	0%	5	0	0	11	2	U	U	U	U	U
Carbon tetrachloride	UG/L	0	0%	5	0	0	11	2	U	U	U	U	U
Chlorobenzene	UG/L	0	0%	5	0	0	11	2	U	U	U	U	U
Chlorodibromomethane	UG/L	0	0%	5	0	0	11	2	U	U	U	U	U
Chloroethane	UG/L	0	0%	5	0	0	11	2	U	U	U	U	U
Chloroform	UG/L	0	0%	7	0	0	11	2	U	U	U	U	U
Cis-1,2-Dichloroethene	UG/L	150	91%	5	9	10	11	32	J	J	J	J	J
Cis-1,3-Dichloropropene	UG/L	0	0%	5	0	0	11	2	U	U	U	U	U
Ethyl benzene	UG/L	0	0%	5	0	0	11	2	U	U	U	U	U
Methyl bromide	UG/L	0	0%	5	0	0	11	2	U	U	U	U	U
Methyl butyl ketone	UG/L	0	0%	5	0	0	11	8	UJ	UJ	UJ	UJ	UJ
Methyl chloride	UG/L	0	0%	5	0	0	11	2	UJ	UJ	UJ	UJ	UJ
Methyl ethyl ketone	UG/L	14	27%	50	0	3	11	8	U	U	U	U	U
Methyl isobutyl ketone	UG/L	0	0%	5	0	0	11	8	U	U	U	U	U
Methylene chloride	UG/L	0	0%	5	0	0	11	3	U	U	U	U	U
Styrene	UG/L	0	0%	5	0	0	11	2	U	U	U	U	U
Tetrachloroethene	UG/L	0	0%	5	0	0	11	2	U	U	U	U	U
Toluene	UG/L	0	0%	5	0	0	11	2	U	U	U	U	U
Total Xylenes	UG/L	0	0%	5	0	0	11	2	U	U	U	U	U
Trans-1,2-Dichloroethene	UG/L	0	0%	5	0	0	11	2	U	U	U	U	U
Trans-1,3-Dichloropropene	UG/L	0	0%	5	0	0	11	2	U	U	U	U	U
Trichloroethene	UG/L	530	45%	5	3	5	11	8	U	U	U	U	J
Vinyl chloride	UG/L	1	27%	2	0	3	11	2	U	U	U	U	U
<b>Metals</b>													
Calcium	UG/L	158000	100%		0	11	11	120000					158000
Iron	UG/L	14100	100%	300	6	11	11	133		22700	107000	16300	47700
Magnesium	UG/L	18300	100%		0	11	11	13000		6500	16500	6080	6820
Manganese	UG/L	1280	100%	300	2	11	11	31		44.5	115	165	467
Potassium	UG/L	12300	100%		0	11	11	1590	J	1290	12300	1580	2750
<b>Other Analyses</b>													
Methane	UG/L	310	90%		0	9	10	14		63	5.4	310	180
Ethane	UG/L	18	70%		0	7	10	2.1	U	10	2.1	12	9.5
Ethene	UG/L	20	50%		0	5	10	2.5	U	2.5	2.5	10	2.5
Sulfate	MG/L	163	100%		0	11	11	60.1		0.7	60.5	5.8	31.9
Nitrate	MG/L	0.6	18%		0	2	11	<0.2		<0.2	<0.2	<0.2	0.3
Chloride	MG/L	31.7	100%		0	11	11	12.7		8	13.8	11.1	12.8
TDS	MG/L	577	100%		0	11	11	392	J	113	405	85	223
pH		9.5	100%		0	11	11	7.19		8.43	7.36	9.1	7.68
Alkalinity	MG/L	288	100%		0	11	11	264		65	280	48	140
Phosphate	MG/L	0.17	73%		0	8	11	<0.01		0.02	0.03	0.17	0.11

Seneca Army Depot Activity  
Ash Landfill Groundwater Remediation  
Round 2 Groundwater Sampling

	UNIT	MAXIMUM	FREQUENCY OF DETECTION	NYSDEC CLASS GA STANDARD	NUMBER ABOVE TAGM	NUMBER OF DETECTS	NUMBER OF ANALYSES	ASH LANDFILL	ASH LANDFILL	ASH LANDFILL	ASH LANDFILL	ASH LANDFILL			
								MWT-5	MWT-6	MWT-7	MWT-8	MWT-9			
								GROUND WATER	GROUND WATER	GROUND WATER	GROUND WATER	GROUND WATER			
								10	10	10	10	12			
							06/29/1999	06/29/1999	06/29/1999	06/29/1999	06/29/1999	06/29/1999			
							ASH TRENCH	ASH TRENCH	ASH TRENCH	ASH TRENCH	ASH TRENCH	ASH TRENCH			
							TR2024	TR2028	TR2026	TR2030	TR2027				
							SA	SA	SA	SA	SA				
<b>Volatile Organic Compounds</b>							N	N	N	N	N	N			
1,1,1-Trichloroethane	UG/L	0	0%	5	0	0	11	1	UJ	31	UJ	2	UJ	8	UJ
1,1,2,2-Tetrachloroethane	UG/L	0	0%	5	0	0	11	1	U	31	U	2	U	8	U
1,1,2-Trichloroethane	UG/L	0	0%		0	0	11	1	U	31	U	2	U	8	U
1,1-Dichloroethane	UG/L	0.7	9%	5	0	1	11	0.7	J	31	U	2	U	8	U
1,1-Dichloroethene	UG/L	0	0%	5	0	0	11	1	U	31	U	2	U	8	U
1,2,4-Trichlorobenzene	UG/L	0	0%	5	0	0	11	1	U	31	U	2	U	8	U
1,2-Dibromo-3-chloropropane	UG/L	0	0%		0	0	11	1	U	31	U	2	U	8	U
1,2-Dibromoethane	UG/L	0	0%		0	0	11	1	U	31	U	2	U	8	U
1,2-Dichlorobenzene	UG/L	0	0%	4.7	0	0	11	1	U	31	U	2	U	8	U
1,2-Dichloroethane	UG/L	0	0%	5	0	0	11	1	UJ	31	UJ	2	UJ	8	UJ
1,2-Dichloropropane	UG/L	0	0%	5	0	0	11	1	U	31	U	2	U	8	U
1,3-Dichlorobenzene	UG/L	0	0%	5	0	0	11	1	U	31	U	2	U	8	U
1,4-Dichlorobenzene	UG/L	0	0%	4.7	0	0	11	1	U	31	U	2	U	8	U
Acetone	UG/L	140	91%		0	10	11	3	J	140	J	4	J	24	J
Benzene	UG/L	0.9	36%	1	0	4	11	0.8	J	31	U	2	U	8	U
Bromochloromethane	UG/L	0	0%		0	0	11	1	U	31	U	2	U	8	U
Bromodichloromethane	UG/L	0	0%		0	0	11	1	U	31	U	2	U	8	U
Bromoform	UG/L	0	0%		0	0	11	1	U	31	U	2	U	8	U
Carbon disulfide	UG/L	0	0%		0	0	11	1	U	31	U	2	U	8	U
Carbon tetrachloride	UG/L	0	0%	5	0	0	11	1	U	31	U	2	U	8	U
Chlorobenzene	UG/L	0	0%	5	0	0	11	1	U	31	U	2	U	8	U
Chlorodibromomethane	UG/L	0	0%		0	0	11	1	U	31	U	2	U	8	U
Chloroethane	UG/L	0	0%	5	0	0	11	1	U	31	U	2	U	8	U
Chloroform	UG/L	0	0%	7	0	0	11	1	U	31	U	2	U	8	U
Cis-1,2-Dichloroethene	UG/L	150	91%	5	9	10	11	29		32		42		158	
Cis-1,3-Dichloropropene	UG/L	0	0%	5	0	0	11	1	U	31	U	2	U	8	U
Ethyl benzene	UG/L	0	0%	5	0	0	11	1	U	31	U	2	U	8	U
Methyl bromide	UG/L	0	0%		0	0	11	1	U	31	U	2	U	8	U
Methyl butyl ketone	UG/L	0	0%		0	0	11	5	UJ	5	UJ	160	UJ	8	UJ
Methyl chloride	UG/L	0	0%	5	0	0	11	1	UJ	31	UJ	2	UJ	8	UJ
Methyl ethyl ketone	UG/L	14	27%	50	0	3	11	5	U	5	U	160	U	8	U
Methyl isobutyl ketone	UG/L	0	0%		0	0	11	5	U	5	U	160	U	8	U
Methylene chloride	UG/L	0	0%	5	0	0	11	2	U	2	U	63	U	3	U
Styrene	UG/L	0	0%		0	0	11	1	U	1	U	31	U	2	U
Tetrachloroethene	UG/L	0	0%	5	0	0	11	1	U	1	U	31	U	2	U
Toluene	UG/L	0	0%	5	0	0	11	1	U	1	U	31	U	2	U
Total Xylenes	UG/L	0	0%	5	0	0	11	1	U	1	U	31	U	2	U
Trans-1,2-Dichloroethene	UG/L	0	0%	5	0	0	11	1	U	1	U	31	U	2	U
Trans-1,3-Dichloropropene	UG/L	0	0%	5	0	0	11	1	U	1	U	31	U	2	U
Trichloroethene	UG/L	530	45%	5	3	5	11	1	U	1	U	330	J	2	U
Vinyl chloride	UG/L	1	27%	2	0	3	11	1		0.7	J	31	U	1	J
<b>Metals</b>															
Calcium	UG/L	158000	100%		0	11	11	30500		39700		153000		23900	
Iron	UG/L	14100	100%	300	0	11	11	207		145		58.2	J	1090	
Magnesium	UG/L	18300	100%		0	11	11	15200		6270		17700		16300	
Manganese	UG/L	1280	100%	300	2	11	11	49.8		240		17.7		97.9	
Potassium	UG/L	12300	100%		0	11	11	1410	J	1780	J	1820	J	1430	J
<b>Other Analyses</b>															
Methane	UG/L	310	90%		0	9	10	41				5.8		6.2	
Ethane	UG/L	18	70%		0	7	10	13				11		18	
Ethene	UG/L	20	50%		0	5	10	16				18		20	
Sulfate	MG/L	163	100%		0	11	11	95.1		86.2		124		88.6	
Nitrate	MG/L	0.6	18%		0	2	11	<0.2		<0.2		0.6		<0.2	
Chloride	MG/L	31.7	100%		0	11	11	31.3		29.9		12.5		14.6	
TDS	MG/L	577	100%		0	11	11	233	J	201	J	531	J	194	J
pH		9.5	100%		0	11	11	9.5		8.6		7.06		9.22	
Alkalinity	MG/L	288	100%		0	11	11	13		25		288		46	
Phosphate	MG/L	0.17	73%		0	8	11	0.03		0.03		<.01		0.02	

Seneca Army Depot Activity  
Ash Landfill Treatability Study  
Groundwater Analysis - Round 3

		MAXIMU	FREQUENCY OF DETECTION	NYSDEC CLASS GA STANDARD	NUMBER ABOVE TAGM	NUMBER OF DETECTS	NUMBER OF ANALYSES	ASH LANDFILL	ASH LANDFILL	ASH LANDFILL	ASH LANDFILL	ASH LANDFILL	ASH LANDFILL	ASH LANDFILL	
								MWT-1 GROUND WATER	MWT-11 GROUND WATER	MWT-10 GROUND WATER	MWT-2 GROUND WATER	MWT-3 GROUND WATER	MWT-4 GROUND WATER	MWT-4 GROUND WATER	
								09/28/1999	09/29/1999	09/28/1999	09/28/1999	09/29/1999	09/29/1999	09/29/1999	
								ASH TRENCH	ASH TRENCH	ASH TRENCH	ASH TRENCH	ASH TRENCH	ASH TRENCH	ASH TRENCH	
								TR2040	TR2050	TR2049	TR2041	TR2042	TR2051	TR2043	
								SA	SA	SA	SA	SA	SA	SA	
								N	N	N	N	N	N	N	
<b>Volatile Organic Compounds</b>															
1,1,1-Trichloroethane	UG/L	0	0%	5	0	0	14	1	U	1	U	1	U	3	U
1,1,2,2-Tetrachloroethane	UG/L	0	0%	5	0	0	14	1	U	1	U	1	U	3	U
1,1,2-Trichloroethane	UG/L	5	14%	5	0	2	14	1	U	1	U	1	U	3	U
1,1-Dichloroethane	UG/L	0.5	14%	5	0	2	14	1	U	1	U	1	U	3	U
1,1-Dichloroethene	UG/L	0	0%	5	0	0	14	1	U	1	U	1	U	3	U
1,2,4-Trichlorobenzene	UG/L	5	14%	5	0	2	14	1	U	1	U	1	U	3	U
1,2-Dibromo-3-chloropropane	UG/L	0	0%	5	0	0	14	1	U	1	U	1	U	3	U
1,2-Dibromoethane	UG/L	5	14%	5	0	2	14	1	U	1	U	1	U	3	U
1,2-Dichlorobenzene	UG/L	0	0%	4.7	0	0	14	1	U	1	U	1	U	3	U
1,2-Dichloroethane	UG/L	5	14%	5	0	2	14	1	U	1	U	1	U	3	U
1,2-Dichloropropane	UG/L	5	14%	5	0	2	14	1	U	1	U	1	U	3	U
1,3-Dichlorobenzene	UG/L	0	0%	5	0	0	14	1	U	1	U	1	U	3	U
1,4-Dichlorobenzene	UG/L	4	14%	4.7	0	2	14	1	U	1	U	1	U	3	U
Acetone	UG/L	2	7%	5	0	1	14	5	UJ	5	UJ	15	UJ	6	UJ
Benzene	UG/L	5	50%	1	2	7	14	1	U	1	U	0.8	J	1	U
Bromochloromethane	UG/L	0	0%	5	0	0	14	1	U	1	U	1	U	3	U
Bromodichloromethane	UG/L	0	0%	5	0	0	14	1	U	1	U	1	U	3	U
Bromoform	UG/L	4	14%	5	0	2	14	1	U	1	U	1	U	3	U
Carbon disulfide	UG/L	0	0%	5	0	0	14	1	U	1	U	1	U	3	U
Carbon tetrachloride	UG/L	4	14%	5	0	2	14	1	U	1	U	1	U	3	U
Chlorobenzene	UG/L	0	0%	5	0	0	14	1	U	1	U	1	U	3	U
Chlorodibromomethane	UG/L	0	0%	5	0	0	14	1	U	1	U	1	U	3	U
Chloroethane	UG/L	0	0%	5	0	0	14	1	UJ	1	UJ	1	UJ	3	UJ
Chloroform	UG/L	40	85%	5	9	12	14	1	U	1	U	1	U	3	U
Cis-1,2-Dichloroethene	UG/L	5	14%	5	0	0	14	1	U	1	U	0.6	J	2	U
Cis-1,3-Dichloropropene	UG/L	5	14%	5	0	0	14	1	U	1	U	1	U	3	U
Ethyl benzene	UG/L	0	0%	5	0	0	14	1	U	1	U	1	U	3	U
Methyl bromide	UG/L	0	0%	5	0	0	14	1	UJ	1	UJ	1	UJ	3	UJ
Methyl butyl ketone	UG/L	0	0%	5	0	0	14	5	U	5	U	5	U	14	U
Methyl chloride	UG/L	0	0%	5	0	0	14	1	U	1	U	1	U	3	U
Methyl ethyl ketone	UG/L	0	0%	50	0	0	14	5	UJ	5	UJ	5	UJ	14	UJ
Methyl isobutyl ketone	UG/L	0	0%	5	0	0	14	5	U	5	U	5	U	14	U
Methylene chloride	UG/L	0	0%	5	0	0	14	2	U	2	U	2	U	6	U
Styrene	UG/L	0	0%	5	0	0	14	1	U	1	U	1	U	3	U
Tetrachloroethene	UG/L	5	14%	5	0	2	14	1	U	1	U	1	U	3	U
Toluene	UG/L	0.3	14%	5	0	0	14	1	U	1	U	0.3	J	0.2	J
Total Xylenes	UG/L	0	0%	5	0	0	14	1	U	1	U	1	U	3	U
Trans-1,2-Dichloroethene	UG/L	0	0%	5	0	0	14	1	U	1	U	1	U	3	U
Trans-1,3-Dichloropropene	UG/L	0	0%	5	0	0	14	1	U	1	U	1	U	3	U
Trichloroethene	UG/L	480	29%	5	2	4	14	2	U	1	U	1	U	3	U
Vinyl chloride	UG/L	4	14%	2	2	2	14	1	U	1	U	1	U	3	U
<b>Metals</b>															
Calcium	UG/L	158000	100%	0	0	12	12	117000	J	148000	J	7610	J	20000	J
Iron	UG/L	68500	100%	300	9	12	12	306	J	4700	J	1170	J	1400	J
Magnesium	UG/L	25500	100%	0	0	12	12	12500	J	24900	J	1490	J	9260	J
Manganese	UG/L	1780	100%	300	3	12	12	21.4	J	312	J	17.7	J	54.6	J
Potassium	UG/L	19900	100%	0	0	12	12	1960	J	17100	J	1200	J	3180	J
<b>Other Analyses</b>															
Methane	UG/L	2300	100%	0	0	12	12	110	J	2.1	J	2300	J	200	J
Ethane	UG/L	7.4	33%	0	0	4	12	2.1	U	2.1	U	2.1	U	2.1	U
Ethene	UG/L	15	25%	0	0	3	12	2.5	U	2.5	U	2.5	U	2.5	U
Sulfate	MG/L	111	100%	0	0	12	12	46.3	J	98	J	0.4	J	58.7	J
Nitrate	MG/L	0.4	42%	10	0	5	12	0.2	J	<0.2	J	<0.2	J	0.3	J
Chloride	MG/L	26	100%	0	0	12	12	10.9	J	14.5	J	8.4	J	11.2	J
TDS	MG/L	547	100%	0	0	12	12	332	J	547	J	38	J	121	J
pH		9.7	100%	0	0	12	12	7.27	J	7.03	J	9.7	J	9.15	J
Alkalinity	MG/L	426	100%	0	0	12	12	254	J	426	J	26	J	34	J
Phosphate	MG/L	13	92%	0	0	11	12	0.06	J	13	J	0.05	J	0.09	J
Ferrous Iron	MG/L	2.55	100%	0	0	4	4	2.55	J	2.55	J	0.05	J	0.09	J
Hi	nM/L	>50												12.9	

Seneca Army Depot Activity  
Ash Landfill Treatability Study  
Groundwater Analysis - Round 3

		MAXIMUM	FREQUENCY OF DETECTION	NYSDEC CLASS GA STANDARD	NUMBER ABOVE TAGM	NUMBER OF DETECTS	NUMBER OF ANALYSES	ASH LANDFILL	ASH LANDFILL	ASH LANDFILL	ASH LANDFILL	ASH LANDFILL	ASH LANDFILL	ASH LANDFILL
								MWT-4 GROUND WATER	MWT-4 GROUND WATER	MWT-5 GROUND WATER	MWT-6 GROUND WATER	MWT-7 GROUND WATER	MWT-8 GROUND WATER	MWT-9 GROUND WATER
								09/29/1999	09/29/1999	09/29/1999	09/29/1999	09/29/1999	09/29/1999	09/29/1999
								ASH TRENCH TR2043MS	ASH TRENCH TR2043MSD	ASH TRENCH TR2044	ASH TRENCH TR2045	ASH TRENCH TR2046	ASH TRENCH TR2047	ASH TRENCH TR2048
								SA N	SA N	SA N	SA N	SA N	SA N	SA N
<b>Volatile Organic Compounds</b>														
1,1,1-Trichloroethane	UG/L	0	0%	5	0	0	14	1	U	1	U	1	U	4
1,1,2,2-Tetrachloroethane	UG/L	0	0%	5	0	0	14	1	U	1	U	1	U	4
1,1,2-Trichloroethane	UG/L	5	14%	5	0	2	14	5	U	4	U	1	U	4
1,1-Dichloroethane	UG/L	0.5	14%	5	0	2	14	1	U	1	U	0.5	J	4
1,1-Dichloroethene	UG/L	0	0%	5	0	0	14	1	U	1	U	1	U	4
1,2,4-Trichlorobenzene	UG/L	5	14%	5	0	2	14	5	U	5	U	1	U	4
1,2-Dibromo-3-chloropropane	UG/L	0	0%	5	0	0	14	1	U	1	U	1	U	4
1,2-Dibromoethane	UG/L	5	14%	5	0	2	14	5	U	5	U	1	U	4
1,2-Dichlorobenzene	UG/L	0	0%	4.7	0	2	14	1	U	1	U	1	U	4
1,2-Dichloroethane	UG/L	5	14%	5	0	2	14	5	U	5	U	1	U	4
1,2-Dichloropropane	UG/L	5	14%	5	0	2	14	5	U	5	U	1	U	4
1,3-Dichlorobenzene	UG/L	0	0%	5	0	0	14	1	U	1	U	1	U	4
1,4-Dichlorobenzene	UG/L	4	14%	4.7	0	2	14	4	U	4	U	1	U	4
Acetone	UG/L	2	7%	5	0	1	14	2	J	5	U	6	U	20
Benzene	UG/L	5	50%	1	2	7	14	5	U	5	U	0.6	J	4
Bromochloromethane	UG/L	0	0%	5	0	0	14	1	U	1	U	1	U	4
Bromodichloromethane	UG/L	0	0%	5	0	0	14	1	U	1	U	1	U	4
Bromoform	UG/L	4	14%	5	0	2	14	4	U	4	U	1	U	4
Carbon disulfide	UG/L	0	0%	5	0	0	14	1	U	1	U	1	U	4
Carbon tetrachloride	UG/L	4	14%	5	0	2	14	4	U	4	U	1	U	4
Chlorobenzene	UG/L	0	0%	5	0	0	14	1	U	1	U	1	U	4
Chlorodibromomethane	UG/L	0	0%	5	0	0	14	1	U	1	U	1	U	4
Chloroethane	UG/L	0	0%	5	0	0	14	1	U	1	U	1	U	4
Chloroform	UG/L	0	0%	7	0	0	14	1	U	1	U	1	U	4
Cis-1,2-Dichloroethene	UG/L	40	86%	5	9	12	14	14	U	14	U	5	J	39
Cis-1,3-Dichloropropene	UG/L	5	14%	5	0	2	14	5	U	5	U	1	U	4
Ethyl benzene	UG/L	0	0%	5	0	0	14	1	U	1	U	1	U	4
Methyl bromide	UG/L	0	0%	5	0	0	14	1	U	1	U	1	U	4
Methyl butyl ketone	UG/L	0	0%	5	0	0	14	1	U	1	U	5	U	20
Methyl chloride	UG/L	0	0%	5	0	0	14	1	U	1	U	1	U	4
Methyl ethyl ketone	UG/L	0	0%	50	0	0	14	1	U	1	U	5	U	20
Methyl isobutyl ketone	UG/L	0	0%	5	0	0	14	1	U	1	U	5	U	20
Methylene chloride	UG/L	0	0%	5	0	0	14	2	U	2	U	2	U	8
Styrene	UG/L	5	14%	5	0	2	14	1	U	1	U	1	U	4
Tetrachloroethene	UG/L	5	14%	5	0	2	14	5	U	5	U	1	U	4
Toluene	UG/L	0.3	14%	5	0	0	14	1	U	1	U	1	U	4
Total Xylenes	UG/L	0	0%	5	0	0	14	1	U	1	U	1	U	4
Trans-1,2-Dichloroethene	UG/L	0	0%	5	0	0	14	1	U	1	U	1	U	4
Trans-1,3-Dichloropropene	UG/L	0	0%	5	0	0	14	1	U	1	U	1	U	4
Trichloroethene	UG/L	480	28%	5	2	4	14	6	U	6	U	1	U	4
Vinyl chloride	UG/L	4	14%	2	2	2	14	4	U	4	U	1	U	4
<b>Metals</b>														
Calcium	UG/L	158000	100%		0	12	12			11900	J	37100	J	46700
Iron	UG/L	68500	100%	300	0	12	12			565	J	1150	J	889
Magnesium	UG/L	25500	100%		0	12	12			6090	J	4990	J	11500
Manganese	UG/L	1790	100%	300	3	12	12			32.2	J	91.6	J	538
Potassium	UG/L	19900	100%		0	12	12			1760	J	2480	J	2870
<b>Other Analyses</b>														
Methane	UG/L	2300	100%		0	12	12			750		63		120
Ethane	UG/L	7.4	33%		0	4	12			2.3		2.1	U	7.4
Ethene	UG/L	15	25%		0	3	12			4.2		2.5	U	15
Sulfate	MG/L	111	100%		0	12	12			26.9		46.5	U	44.6
Nitrate	MG/L	0.4	42%	10	0	5	12			<0.2		<0.2	U	<0.2
Chloride	MG/L	26	100%		0	12	12			18.1		19.2	U	12.2
TDS	MG/L	547	100%		0	12	12			84		149	U	194
pH		9.7	100%		0	12	12			9.56		7.81	U	7.68
Alkalinity	MG/L	426	100%		0	12	12			34		69	U	132
Phosphate	MG/L	13	92%		0	11	12			0.03		0.05	U	0.03
Ferrous Iron	MG/L	2.55	100%		0	4	4					0.13	U	0.62
H	nM/L	>50										16.7		>50



Seneca Army Depot Activity  
Ash Landfill Groundwater Remediation  
Round 4 Groundwater Sampling

STUDY ID:	ASH TRENCH											
LOC ID:	MW-T1	MW-T3	MW-T6	MW-T9								
SDG:	76497	76497	76497	76497								
SAMP. DEPTH TOP:	9	8	10	10								
SAMP. DEPTH BOT:	9	8	10	10								
MATRIX:	WATER											
SAMP. DATE:	05-Jan-00											
SAMP_ID:	TR2068	TR2069	TR2070	TR2071								
FIELD QC CODE:	SA	SA	SA	SA								
PARAMETER	UNIT	MAXIMU	FREQUENCY OF DETECTION	NYSDEC CLASS GA STANDARD	NUMBER ABOVE TAGM	NUMBER OF DETECTS	NUMBER OF ANALYSE	TR2068 VALUE	TR2069 VALUE	TR2070 VALUE	TR2071 VALUE	
<b>Volatile Organic Compounds</b>												
1,1,1-Trichloroethane	UG/L	0	0.0%	5	0	0	14	4 U	3 U	1 U	3 U	
1,1,2,2-Tetrachloroethane	UG/L	0	0.0%	5	0	0	14	4 U	3 U	1 U	3 U	
1,1,2-Trichloroethane	UG/L	4	14.3%		0	2	14	4 U	3 U	1 U	3 U	
1,1-Dichloroethane	UG/L	0	0.0%	5	0	0	14	4 U	3 U	1 U	3 U	
1,1-Dichloroethene	UG/L	0	0.0%	5	0	0	14	4 U	3 U	1 U	3 U	
1,2,4-Trichlorobenzene	UG/L	5	14.3%	5	0	2	14	4 U	3 U	1 U	3 U	
1,2-Dibromo-3-chloropropane	UG/L	0	0.0%		0	0	14	4 U	3 U	1 U	3 U	
1,2-Dibromoethane	UG/L	4	14.3%		0	2	14	4 U	3 U	1 U	3 U	
1,2-Dichlorobenzene	UG/L	0	0.0%	4.7	0	0	14	4 U	3 U	1 U	3 U	
1,2-Dichloroethane	UG/L	5	14.3%	5	0	2	14	4 U	3 U	1 U	3 U	
1,2-Dichloropropane	UG/L	5	14.3%	5	0	2	14	4 U	3 U	1 U	3 U	
1,3-Dichlorobenzene	UG/L	0	0.0%	5	0	0	14	4 U	3 U	1 U	3 U	
1,4-Dichlorobenzene	UG/L	5	14.3%	4.7	1	2	14	4 U	3 U	1 U	3 U	
Acetone	UG/L	2	7.1%		0	1	14	22 UJ	14 UJ	2 J	14 UJ	
Benzene	UG/L	5	14.3%	1	2	2	14	4 U	3 U	1 U	3 U	
Bromochloromethane	UG/L	0	0.0%		0	0	14	4 U	3 U	1 U	3 U	
Bromodichloromethane	UG/L	0	0.0%		0	0	14	4 U	3 U	1 U	3 U	
Bromoform	UG/L	4	14.3%		0	2	14	4 U	3 U	1 U	3 U	
Carbon disulfide	UG/L	0	0.0%		0	0	14	4 U	3 U	1 U	3 U	
Carbon tetrachloride	UG/L	4	14.3%	5	0	2	14	4 U	3 U	1 U	3 U	
Chlorobenzene	UG/L	0	0.0%	5	0	0	14	4 U	3 U	1 U	3 U	
Chlorodibromomethane	UG/L	0	0.0%		0	0	14	4 U	3 U	1 U	3 U	
Chloroethane	UG/L	0	0.0%	5	0	0	14	4 U	3 U	1 U	3 U	
Chloroform	UG/L	0	0.0%	7	0	0	14	4 U	3 U	1 U	3 U	
Cis-1,2-Dichloroethene	UG/L	72	92.9%	5	9	13	14	72	48	10	44	
Cis-1,3-Dichloropropene	UG/L	4	14.3%	5	0	2	14	4 U	3 U	1 U	3 U	
Ethyl benzene	UG/L	0	0.0%	5	0	0	14	4 U	3 U	1 U	3 U	
Methyl bromide	UG/L	0	0.0%		0	0	14	4 U	3 U	1 U	3 U	
Methyl butyl ketone	UG/L	0	0.0%		0	0	14	4 U	3 U	1 U	3 U	
Methyl chloride	UG/L	0	0.0%	5	0	0	14	22 UJ	14 UJ	5 UJ	14 UJ	
Methyl ethyl ketone	UG/L	0	0.0%	50	0	0	14	22 UJ	14 UJ	5 UJ	14 UJ	
Methyl isobutyl ketone	UG/L	0	0.0%		0	0	14	22 U	14 U	5 U	14 U	
Methylene chloride	UG/L	0	0.0%	5	0	0	14	9 U	6 U	2 U	3 U	
Styrene	UG/L	0	0.0%		0	0	14	4 U	3 U	1 U	3 U	
Tetrachloroethene	UG/L	5	14.3%	5	0	2	14	4 U	3 U	1 U	3 U	
Toluene	UG/L	0	0.0%	5	0	0	14	4 U	3 U	1 U	3 U	
Total Xylenes	UG/L	0	0.0%	5	0	0	14	4 U	3 U	1 U	3 U	
Trans-1,2-Dichloroethene	UG/L	0	0.0%	5	0	0	14	4 U	3 U	1 U	3 U	
Trans-1,3-Dichloropropene	UG/L	0	0.0%	5	0	0	14	4 U	3 U	1 U	3 U	
Trichloroethene	UG/L	480	42.9%	5	3	6	14	18	2 J	1 U	32	
Vinyl chloride	UG/L	4	14.3%	2	2	2	14	4 U	3 U	1 U	3 U	
<b>Metals</b>												
Calcium	UG/L	144000	85.7%		0	12	14	133000	73300	52800	25800	
Iron	UG/L	7060	85.7%	300	7	12	14	129 J	2700 J	99.3 J	1240 J	
Magnesium	UG/L	20400	85.7%		0	12	14	15200	16700	13400	5880	
Manganese	UG/L	682	85.7%	300	1	12	14	3.7 J	682	267	226	
Potassium	UG/L	3020	85.7%		0	12	14	932 J	1120 J	1580 J	1720 J	
Sodium	UG/L	20100	85.7%		0	12	14	9260	9250	19900	17100	
<b>Other Analytes</b>												
Chloride	MG/L	36.9	100.0%		0	12	12	16.7	17.1	34.6	8.9	
Sulfate	MG/L	141	100.0%		0	12	12	106.	106.	139.	16.5	
Nitrate as N	MG/L	0.6	41.7%	10	0	5	12	.3	0.2 U	.2	0.2 U	
Total Dissolved Solids	MG/L	551	100.0%		0	12	12	500.	334.	314.	162.	
pH		9.55	100.0%		0	12	12	7.27	7.53	8.08	7.90	
Alkalinity as CaCO3	MG/L	332	100.0%		0	12	12	271	132	41	88	
Phosphate	MG/L	0.09	91.7%		0	11	12	0.020	0.020	0.040	0.090	
Methane	UG/L	4432.6	100.0%		0	3	3		2567.8	4432.6	4374	
Ethane	UG/L	12.59	100.0%		0	3	3		1.83	3.28	12.59	
Ethene	UG/L	10.41	100.0%		0	3	3		2.32	3.93	10.41	
H	nM/L	50	100.0%		0	3	3		>50	>50	>50	
Ferrous Iron	MG/L	2.43	81.8%		0	9	11	0	2.43	0.18	0.16	

Appendix D  
Correspondence with ETI

- Memorandum of October 15, 1998
- Memorandum of October 29, 1998
- Memorandum of December 18, 1998
- Memorandum of March 2, 2000
- Article on Diffusion Samplers sent on March 6, 2000
- Memorandum of March 20, 2000
- Memorandum of March 24, 2000
- Memorandum of April 20, 2000
- Memorandum of May 20, 2000





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Fax (519) 763-2378

To: Jackie Travers  
cto Parsons Engineering Science

Fax: 781-401-2043

Date: 10/15/98

From: Denise Burgess, Remediation Engineering Ext. 233  
Email: dburgess@beak.com

Re: 31317.10

Pages: 1 of 3

---

Jackie,

Further to our conversation I've attached iron volume calculations for a continuous wall scenario.

I've looked at the NYSDOT 703-07 Concrete sand grain size distribution you supplied us and it is very similar to sand that we have used at other sites for iron/sand mixes. Therefore this concrete sand is reasonable to use for the iron/sand mix.

Any other questions, don't hesitate to call!

Original To Follow: Mail  Courier  No

Denise

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for  
subject

by

project no. 31317.10  
checked by

date 10/15/98  
date checked

Ash Landfill

Volume of Iron Required For Continuous  
Wall Scenario

$$\bar{v} = 60.5 \frac{\text{ft}}{\text{yr}} = 0.17 \text{ ft/d}$$

→ this is using new VOC concentrations.

Residence Time Required = 1.25 days

length of plume = 800 ft

sat. thickness = 8.6 ft

pham: Denise said revised VOC conc. resulted in R.T = 1.25 for location near MW-29 as well. So 1.25 days should be used.

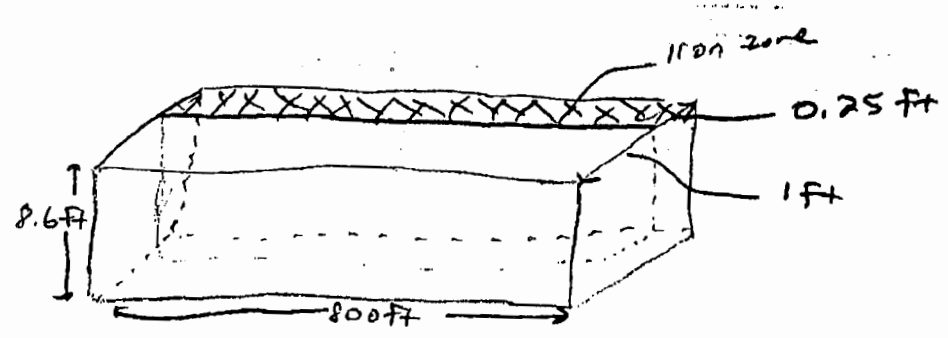
$$\begin{aligned} \text{thickness of iron required} &= \bar{v} \times \text{residence time} \\ &= 0.17 \text{ ft/d} \times 1.25 \text{ d} \\ &= 0.21 \text{ ft} \end{aligned}$$

Assume Flow through thickness will be 0.25 ft across entire length of plume.

$$\begin{aligned} \therefore V_{\text{iron}} &= 800 \text{ ft} \times 8.6 \text{ ft} \times 0.25 \text{ ft} \\ &= 1,720 \text{ ft}^3 \end{aligned}$$

If using an iron/sand mix, there must be a minimum of 20% by volume of iron in the mix.

For example, assuming a 1 ft wide trench :



$$V_{TOTAL} = 800 \times 8.6 \times 1 = 6,880 \text{ ft}^3$$

$$V_{iron} = 800 \times 8.6 \times 0.25 = 1,720 \text{ ft}^3$$

$$\% \text{ by volume iron} = \frac{1720}{6880} \times 100 = \boxed{25\%}$$

∴ The minimum 20% by volume iron requirement is satisfied.





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**To:** Jackie Travers  
cto Parsons Engineering Science

**Fax:** 781-401-2043

**Date:** 10/29/98

**From:** Denise Burgess, Remediation Engineering Ext. 233  
**Email:** dburgess@beak.com

**Re:** 31317.10

**Pages:** 1 of 6

---

Jackie,

Please find attached a memo describing all residence time calculations provided to you thus far. I've also dug up some plan view maps of monitoring well configurations used for continuous iron walls. If you have any questions, get in touch.

Regards, Denise

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**To:** Jackie Travers, Parsons Engineering Science

**From:** John Vogan, EnviroMetal Technologies Inc.  
Denise Burgess, EnviroMetal Technologies Inc.

**Date:** 29 October 1998

**Re:** Residence Time Calculations for the Ash Landfill Site – 31317.88

I have attached residence time calculations for the data sent to us on October 13, 1998 for wells PT-24, MW-29 and MW-27. Also included in the table are residence times calculated previously using data from wells PT17, MW-28 and MW-53.

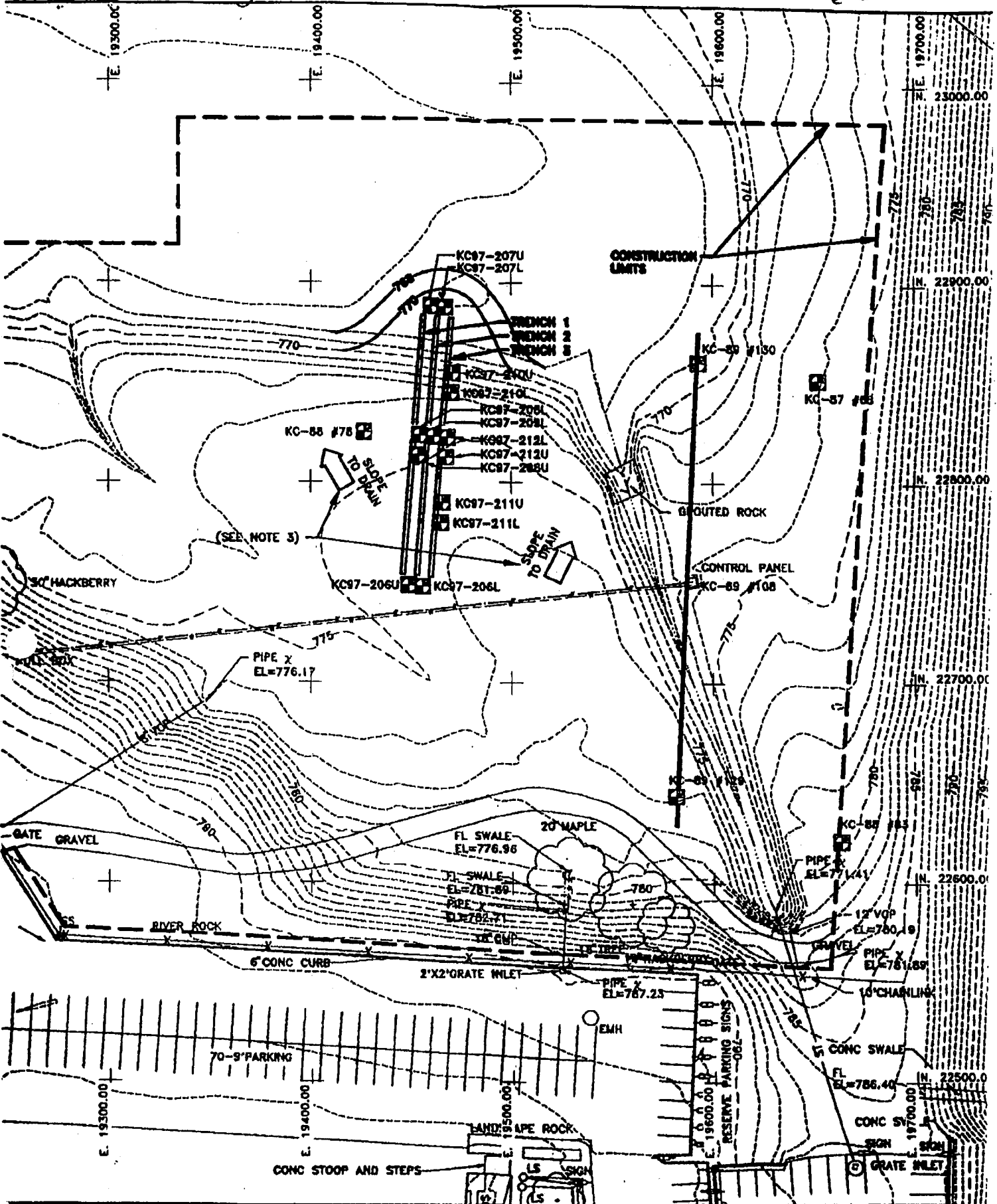
**Table 1: Residence Time Requirements, Ash Landfill**

VOC	MCL (µg/L)	Half Lives (hr)	Well Location and Concentration						
			PT17		MW-28	MW-53	PT-24	MW-29	MW-27
TCE	5	3	260	190	35	4	7	5	nd
CDCE	5	6	53	17	53	51	140	150	nd
VC	2	6	14	--	--	--	--	--	nd
RT (hrs)			30	25	23	21	29	30	--
RT (days)			<b>1.25</b>	<b>1.04</b>	<b>0.96</b>	<b>0.88</b>	<b>1.21</b>	<b>1.25</b>	--

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Based on the above table, a residence time of 1.25 days should ensure that all VOCs be remediated to below maximum contaminant levels. For a continuous wall scenario, a residence time of 1.25 days should be used to determine the volume of iron required. As sent to Parsons on October 15, 1998, the volume of iron required for a continuous wall configuration assuming a flow velocity of 0.17 ft/day, a plume width of 800 ft and a saturated thickness of 8.6 ft would be on the order of 1,700 ft<sup>3</sup>.

\\SKYWALKER\PC\_USERS\DBurgess\projects300\31317\restime.doc



E. 19300.00

E. 19400.00

E. 19500.00

E. 19600.00

E. 19700.00

N. 23000.00

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E. 19700.00



## 2.1 MONITORING WELL NETWORK

Existing monitoring well KC88-78, and a series of new monitoring wells will be utilized to provide groundwater data necessary to satisfy the monitoring objectives described in Section 1.1. The location of existing well KC88-78, and the new monitoring wells are shown on Figure 1. Monitoring well details are provided on Figure 2.

Upgradient monitoring will be performed utilizing existing well KC88-78, which is a dual completion with wells screened in both the upper (clay) and lower (basal gravel) units. KC88-78 is located relatively close to the center of the plume and will provide adequate data on groundwater conditions in the clay and the basal gravel immediately upgradient of the iron treatment wall system.

Evaluation of whether contamination bypasses the system will be performed utilizing a series of four new monitoring wells (KC97-206U, KC97-206L, KC97-207U, and KC97-207L) to be installed by the contractor following construction of the iron treatment wall system. These monitoring wells will be installed at two locations immediately side gradient of each end of Trench 1 as shown on Figure 1. One well screened in the basal gravel and one well screened in the clay will be installed at each location.

Evaluation of contaminant concentrations between trenches will be performed utilizing a series of three new monitoring wells to be installed by the contractor following construction of the iron treatment wall system. The monitoring wells will be installed at two locations. The first location will be between Trench 1 and Trench 2, directly downgradient of existing monitoring well KC88-78 as shown on Figure 1. Two wells (KC97-208U and KC97-208L) will be installed at this location with one well screened in the basal gravel and one well screened in the clay. The wells will be located as close as possible to the downgradient iron/aquifer interface of Trench 1 so as to provide data representative of groundwater as it exits Trench 1. As the treated groundwater exits each trench and re-enters the aquifer, VOC contaminants sorbed to the aquifer material will tend to desorb into the treated groundwater and make system evaluation difficult. Therefore, monitoring wells must be located where representative samples of treated water can best be collected. The second location will be between Trench 2 and Trench 3, directly downgradient of the wells installed between Trench 1 and Trench 2 as shown on Figure 1. One well (KC97-209L), screened in the basal gravel will be installed at this location. The well will be located as close as possible to the downgradient iron/aquifer interface of Trench 2.

Evaluation of contaminant concentrations downgradient of the iron treatment wall system will be performed utilizing a series of six new monitoring wells installed by the contractor following construction of the iron treatment wall system. The monitoring wells will be installed at three locations immediately downgradient of Trench 3, with one well screened in the basal gravel and one well screened in the clay at each location. Two wells (KC97-212U and KC97-212L), will be located directly downgradient of the wells installed between Trench 2 and Trench 3. Four wells (KC97-210U, KC97-210L, KC97-211U and KC97-211L), will be installed in two location equally spaced from wells KC97-212U and KC97-212L. Refer to Figure 1 for actual locations. The wells will be located as close as possible to the downgradient iron/aquifer interface of Trench 3 so as to provide data representative of groundwater as it exits Trench 3.

PLAN

Not as built.  
= 0.6 ft/day.

LOCATION DETAIL

SCALE: 1" = 40'

Industrial Facility  
Upstate New York

CONSTRUCTION LIMITS

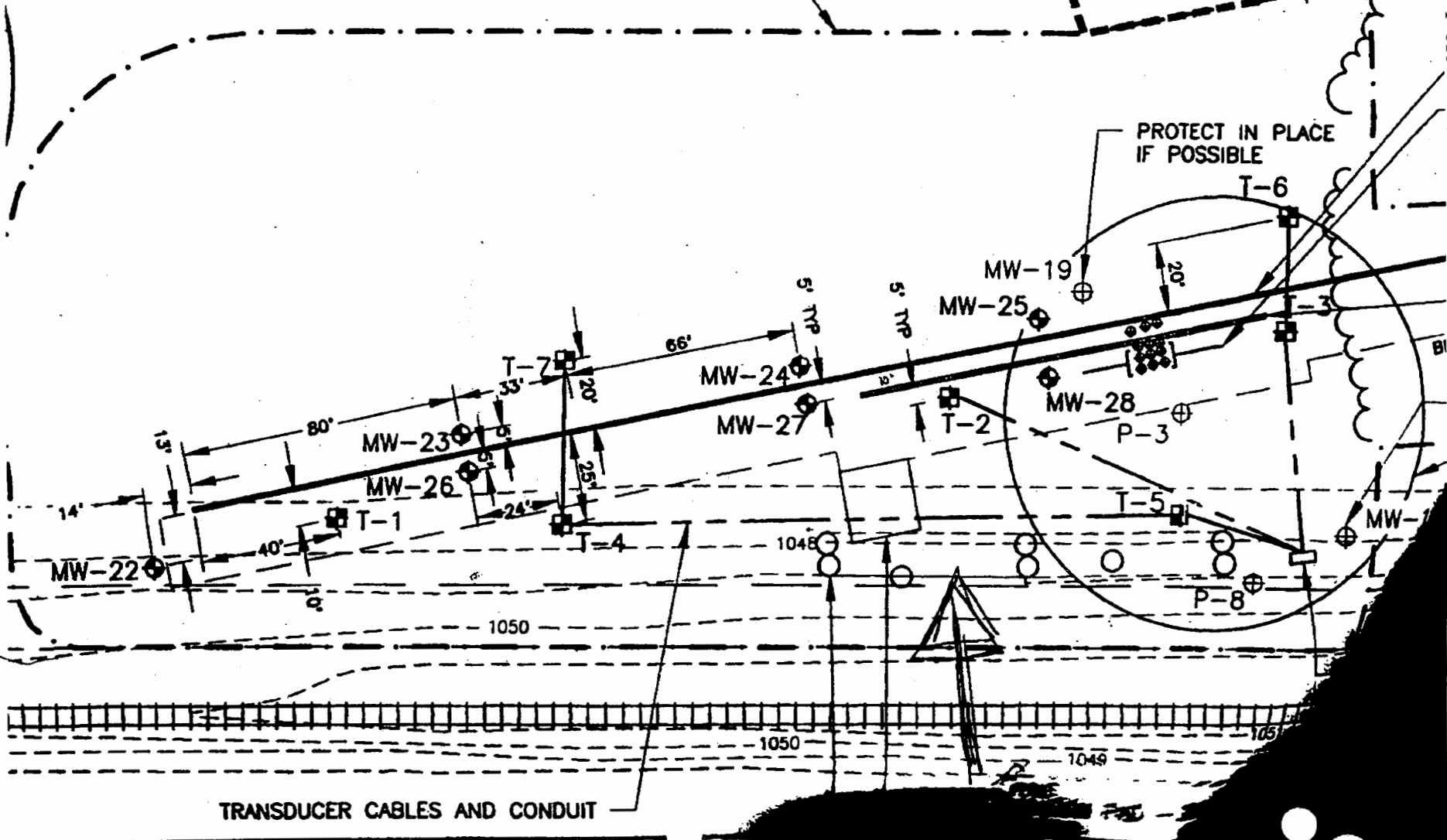
N/F  
HOWARD FARM

PROTECT IN PLACE  
IF POSSIBLE

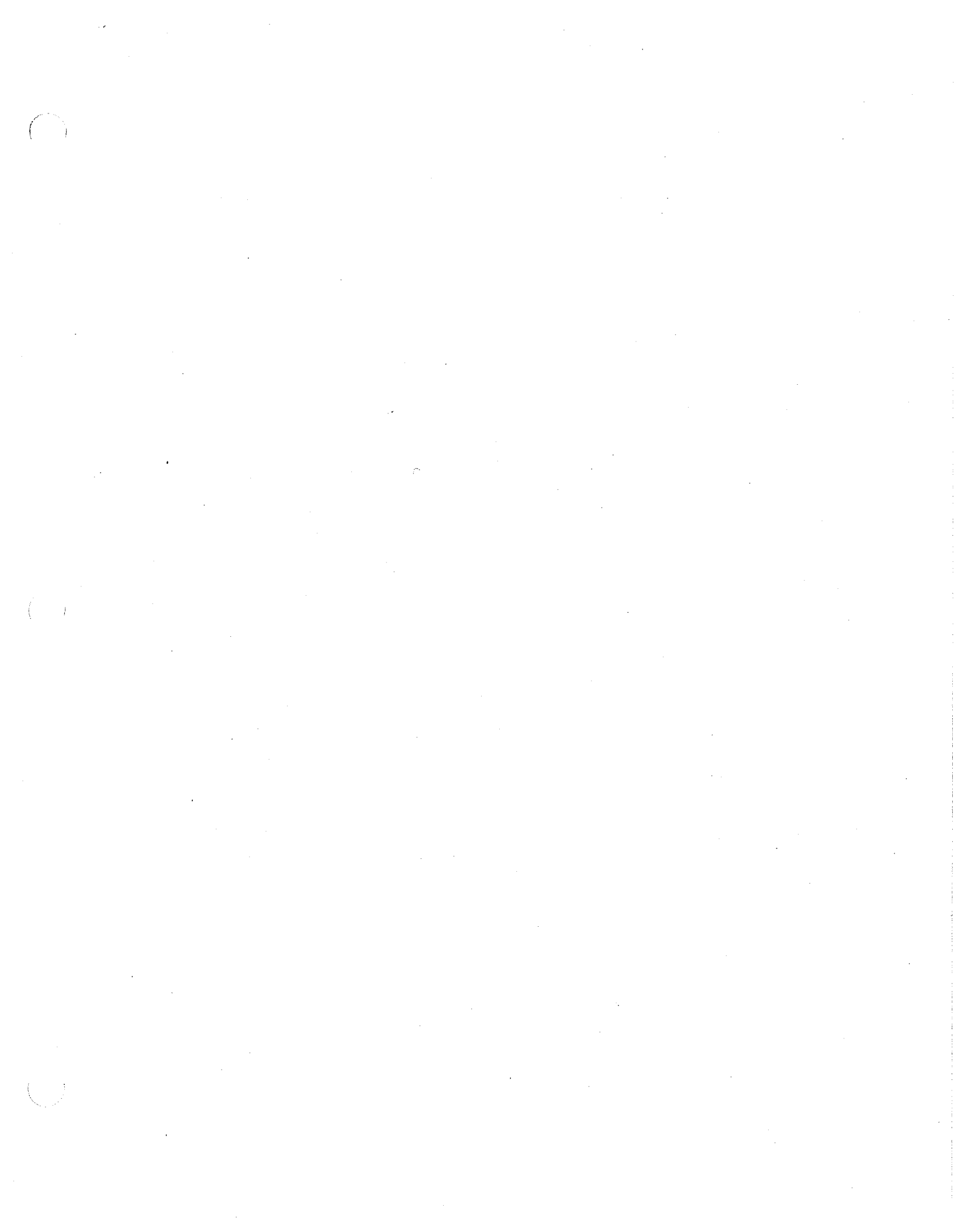
10/29/98 THU 13:16 FAX 1 519 763 2378

BEAK INT'L & ENI

21006



TRANSDUCER CABLES AND CONDUIT





**envirometal  
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745 Bridge Street West, Suite 7  
Waterloo, Ontario  
Canada N2V 2G6  
Tel: (519) 746-2204  
Fax: (519) 746-2209

**To:** Eliza Schacht  
Parsons Eng. Science.

**Fax:** (781) 401-2043

**Date:** 21 December 1998

**From:** Robert Focht, Remediation Engineer, Ext. 245  
**Email:** rfocht@eti.ca

**Re:** Seneca Army Depot - 3 1317.20

**Pages:** 1 of 7

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Eliza - attached is a summary of the recordings and observations I made during installation of the treatment system at Seneca Army Depot. Please call me if you have any questions.

*Roh*

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18 December 1998

Eliza Schacht  
Parsons Engineering Science, Inc.  
30 Dan Road  
Canton, MA 02021

**Re: Continuous Permeable Reactive Barrier Installation - 31317.20**

Dear Ms. Schacht:

A full-scale permeable reactive barrier (PRB) containing granular iron was installed at the Ash Landfill, Seneca Army Depot, Romulus, New York in December 1998. During construction, EnviroMetal Technologies Inc. (ETI) staff was present to provide on-site assistance and document construction activities. This letter provides Parsons Engineering Science, Inc. (Parsons) with ETI's observations and comments on the installation.

The full-scale PRB wall is located approximately 350 ft downgradient of the source area on the Ash Landfill Site. The PRB extends approximately 650 ft north-south adjacent the fence line with the south end starting at the West Smith Farm Road. The PRB consists of a single continuous permeable wall of granular iron and sand.

The fill material used in the PRB consisted of about 48% by volume iron and the balance a local sand. The iron was 8 to 50 US standard mesh size supplied from Peerless Metal Powders and Abrasives of Detroit, Michigan in 3,000 lb superbags. The sand was supplied by DeWitt, a local cement supplier, in cement trucks. DeWitt also used the cement trucks to mix the two materials. A total of 28 trucks, each containing 11,500 lb of sand arrived on site during the 10 and 11 of December 1998. Based on a sand bulk density of 106 lb/ft<sup>3</sup> and an iron bulk density of 150 lb/ft<sup>3</sup>, each truck was loaded at the site with 5 bags of iron to give the 48% by volume required. Using the mass of each material, this is equivalent to about 57% by weight iron. The materials were mixed for 10 minutes then stockpiled on-site for use later in the day in the trench. Two additional trucks contained more sand for a 42% by volume iron

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mixture. This 42% by volume material and 1 to 2 truck loads of the 48% by volume material were not used in the trench. Thus, based on these values the total volume of material placed in the trench was about 5,525 ft<sup>3</sup>.

The mixture was tested for the right proportions of each material by separating the iron from the mixture with a magnet. The iron was separated two to three times to remove most of the sand particles that were entrapped as the iron was picked up by the magnet. Not surprisingly the iron volume, 50% to 60%, was greater than the sand. This occurs because some sand particles remained in the iron even after three separations and also because of the assumed bulk densities of the two materials. The iron bulk density of 150 lb/ft<sup>3</sup> used in the calculation is the density of "packed" iron, however the "loose" bulk density can be as low as 110 to 125 lb/ft<sup>3</sup>. This means that because the amount of iron added was "loose" material the volume would be greater.

It is our understanding that the moisture content of the sand was 3% to 5%, which is considered appropriate for a stockpiled iron/sand mixture left on ground surface for about 1 day or less. If a sand has too high a moisture content it can cause oxidation of the iron surface, potentially reducing its reactivity. Since the mixture was used the same day as it was mixed, the moisture content should not be an issue since little oxidation should occur. The temperature of the mixture after mixing was measured once by others to be about 110 °F. This increase in temperature over background should have been largely the result of friction during mixing of the granular material. At some sites and in bench-scale tests where 100% iron has dewatered, no noticeable temperature increase has been observed because oxidation of the iron appears to occur over several days rather than several minutes.

Construction was performed by DeWind Dewatering of Holland, Michigan using a one pass continuous trencher. Continuous trenching machines have been used for several years to install horizontal groundwater collection drains and impermeable barriers. These machines allow simultaneous excavation and backfilling without an open trench. Excavation is performed by a cutting chain immediately in front of a trench-box (boot) which extends the width and depth of the finished treatment zone. Both the cutting chain and boot are attached to the trenching machine. As the trencher moves forward, iron is added to the boot creating a continuous treatment zone. Trenchers are available to install treatment zones from 1 to 2 ft in width to depths of 25 ft. The total depth may be extended to about 35 ft by excavating a bench on which to operate the trencher.

Continuous trenching was first used to install a 100% iron PRB in 1996 at a site in North Carolina. About 450 tons of iron was placed in a trench 150 ft long and 24 ft deep in about 4

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hr. Since then, trenchers have been used for PRBs at sites in South Carolina, Oregon, Louisiana, Vermont and New York.

Seven test pits were excavated using a track-hoe to determine the depth of bedrock along the line of installation. Bedrock along the alignment varied from approximately 6 to 11 ft below ground surface (bgs) (Table 1). To ensure that no groundwater flows beneath the PRB, the PRB was extended several inches into the top of bedrock (shale). Pieces of shale were observed in the excavated material from the trencher along the entire alignment. To prevent groundwater from overflowing the treatment system, the top of the wall was constructed above the expected high water table at about 1 ft bgs. A geotextile material was placed on top of the PRB and fill material added to bring the level of the trench to ground surface.

Due to the dryness of the excavated material and the geology of the aquifer, the trench consistently remained open. This means that although the trencher's box was set to the minimum of 12 inches the trench was slightly larger due to the 14 inch cutting width of the trencher. Based on an average total depth of 8.8 ft bgs (assumed to be on average 0.5 ft below the top of shale), a top depth of 1 ft bgs, and an average width of 1.1 ft, the total volume of the excavation was 5,577 ft<sup>3</sup>, which is close to the volume of material estimated to have been placed in the trench. This suggests that no significant voids were left unfilled at depth and that the dimensions of the trench are as expected. The number of loader buckets of material added for individual sections of trench are given in Table 2. There is more uncertainty in these calculations given that not each bucket full of material was the same. In fact, on day two a different loader was used with a bucket that was bigger than the trencher's hopper. Therefore, to minimize spilling of iron, the bucket was not completely filled with iron. Note that if we assume that on average each bucket was filled to 75% capacity we arrive at the same conclusion as above (i.e. that the trench width is 1.1 ft wide, 7.8 ft in depth and 650 ft long).

About 180 ft of trenching occurred the first day (10 December 1998) before several cutting teeth were broken from the cutting chain due to buried foundation. Foundations were encountered in at least three locations over the first 250 ft of the South end of the PRB. These foundations were excavated using the back-hoe to allow the trenching to proceed. The trenching was completed on the second day. The trench was extended slightly beyond the 645 ft design to empty the hopper on the trencher of iron material.

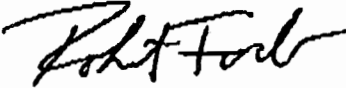
**envirometal technologies inc.**

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Please feel free to call if you have any questions on our observations made during the installation.

Sincerely,

**EnviroMetal Technologies Inc.**



Robert Focht, M.Sc., P.Eng.  
Remediation Engineer

E:\PROJECTS\31300\31317\31317 PRB Installation Letter.doc



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**Table 1: Depth to Shale Along the Alignment Measured in Test Pits**

<b>Distance Along Alignment from the Southern End (ft)</b>	<b>Depth to Shale (ft)<sup>a</sup></b>
0	7
125	11
250	9.5
300	9
425	7.5
525	6.5
640	6
<b>Weighted Average<sup>b</sup></b>	<b>8.3</b>

a Measurements taken with a tape measure.

b Average weighted depth based on distance between measurements.

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**Table 2: Estimated Volume and Amount of Iron/Sand Mixture Installed**

Distance from South End (ft)	Estimated Trench Volume (ft <sup>3</sup> )	Number of Loader Buckets of Iron/Sand Installed	Size of Loader Bucket (ft <sup>3</sup> )	Potential Volume of Iron/Sand Installed (ft <sup>3</sup> )	Percentage of Estimated Trench Volume	
					100% of Loader Bucket <sup>a</sup>	75% of Loader Bucket <sup>b</sup>
0-75	635	16	67.5	1,080	170	128
75-100	256	3	67.5	202.5	79	59
100-125	278	5	67.5	337.5	122	91
125-150	285	6	67.5	405	142	107
150-175	276	4	67.5	270	98	73
175-225	528	2	67.5	135	164	123
		9	81	729		
225-325	962	12	81	972	101	76
325-350	221	5	81	405	183	137
350-375	213	3	81	243	114	86
375-400	205	5	81	405	198	148
400-425	197	3	81	243	124	93
425-450	189	3	81	243	129	96
450-475	182	2	81	162	89	67
475-500	175	3	81	243	139	104
500-525	168	3	81	243	144	108
525-550	164	2	81	162	99	74
550-575	161	3	81	243	151	114
575-600	158	2	81	162	103	77
600-625	155	3	81	243	157	118
625-650	152	3	81	243	160	120
<b>Total</b>	<b>5,559</b>			<b>7,371</b>		
<b>Average</b>					<b>133</b>	<b>100</b>

a Assumes loader bucket filled to 100% capacity (i.e. either 67.5 or 81 ft<sup>3</sup>) on average.

b Assumes loader bucket filled to 75% capacity (i.e. either 50.6 or 60.8 ft<sup>3</sup>) on average.





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## Memorandum

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**To:** Anna Fodor, Jacqueline Travers, Parsons Engineering Science, Inc. Fax: 781-401-2575

**From:** Andrzej Przepiora, John Vogan, EnviroMetal Technologies Inc.

**Date:** 2 March 2000

**Re:** **Comments on April 1999 - January 200 Groundwater Monitoring Data, Ash Landfill, Romulus, NY - 31317.77**

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EnviroMetal Technologies Inc. (ETI) has received from Parsons Engineering and Science, Inc. (Parsons) an annual groundwater monitoring results for an in-situ permeable reactive barrier (PRB) treatment system installed at the Ash Landfill in Romulus, NY. The data included monthly groundwater level measurements (April 1999 to January 2000) and quarterly (April 1999, June 1999, September 1999 and January 2000) concentrations of chlorinated volatile organic compounds (CVOCs). Further to our discussion on 22 February 2000, this memorandum provides ETI's comments on the monitoring results and also answers the specific questions addressed by Parsons ES in the memorandum of 11 February 2000.

The iron PRB was installed in December 1999 in a continuous wall configuration. The wall contains a 1-ft thick zone of 50% iron/sand mix with a wall length of 640 ft and 8 to 12 ft in depth. The monitoring well network consists of 3 transects across the treatment system (Figure 1). Each transect is composed of three monitoring wells located 2.5 ft upgradient, inside and 2.5 ft downgradient of the iron wall.

### 1.0 Groundwater flow through the wall

Table 1 shows the hydraulic head differences between the monitoring wells for the 10-month monitoring period. Water level data indicate that flow through the treatment system is not uniform. It appears that water flows slower in the northern part of the wall than in the southern part. Also, some of the water level measurements in the northern and middle well transects show intermittent reverse hydraulic gradients between the wall and the downgradient wells, suggesting flows into the wall from the downgradient aquifer. Comparing water levels inside the wall, a pronounced gradient from N to S along the wall appears to occur (Table 1).

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The lateral flow in the wall may be an effect of a high permeability zone located in the vicinity of the southern transect. Figure 2 shows that the magnitude of the lateral gradient in the wall was inversely proportional to the groundwater water level in the middle well (MWT-5). Because the gradient is steepest at times of low water level, this may suggest that the high permeability zone is narrow, near the base of the trench and has limited capacity. This zone may be associated with the foundation remains encountered in the southern part of the trench during wall emplacement. From the 1994 site groundwater table maps, a narrow E-W regional higher conductivity zone along West Smith Farm Rd could be interpreted. The presence of a high permeability zone intersected by the southern part of the wall is also consistent with the high TCE concentrations in this part of the trench (Figure 3).

## 2.0 VOC concentrations

Figure 3 summarizes TCE and cDCE results of four monitoring events from April 1999 to January 2000. The most pronounced feature in the concentration trends along the monitoring well transects is an initial decrease in VOC concentrations in the iron wall, followed by a concentration increase in the downgradient wells. This feature has been commonly observed in the initial stages of iron wall operation at other sites. The cause of the elevated concentrations in the downgradient wells is most likely desorption and/or incomplete flushing in the silty/clayey material. For VOC data interpretation, ETI considered only the results from the wells located upgradient and inside the iron wall.

TCE concentration decreased to below detection limits in all wells located in the wall, which would suggest that the wall is working as designed. However, the trends in cDCE concentration are surprisingly different from those of TCE. In most of the iron wells the cDCE concentration remained above the MCL level of 5 µg/L; in two events at the south end the cDCE concentration increased relative to the inflowing concentration values. There may be several reasons (either alone or in combination) why the cDCE concentration is not reduced in the iron wall, including:

- 1) insufficient residence time;
- 2) insufficient iron reactivity; and
- 3) sampling artifacts; and
- 4) insufficient iron present in the mixture.

These three issues are discussed below.

### Residence time

In a memorandum of 29 October 1998 ETI specified that a residence time (RT) of 1 to 1.25 days in the reactive zone (100% iron) would be required to degrade the VOCs to below DWQs. For a 50% iron/sand mix, the residence time would need to be doubled to about 2.5

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days. In the same memorandum a "safety factor of two" was also suggested, giving the total recommended RT of 5 days.

Table 2 shows the RT calculated based on the detected hydraulic gradients across the wall and an uniform hydraulic conductivity of till material of 1.03 ft/day obtained by Parsons from a field test. All but one calculated RT values exceeded the design value implying that sufficient residence times were provided in the wall (Table 2). However, the velocity calculations may be unreliable because they are based on one uniform hydraulic conductivity value. As discussed in Section 1.0, water level measurements indicate that the conductivity may vary in the aquifer along the wall.

Iron reactivity

A bench-scale test using site water and the iron material was not performed for the Ash Landfill PRB. Instead, half-life (HL) values of 3 hrs for TCE and 6 hrs for cDCE from the ETI database were used for the PRB design. Figure 4 shows the typical molar conversion rates in the TCE-cDCE-VC system. Using these conversion rates, the field measured inflowing concentrations and the above half-life values, VOC degradation can be simulated (Figure 5). As seen on Figure 5a, simulated concentrations do not correlate well to the values obtained from the PRB. For example, in June 1999 the cDCE concentrations in the southern wall was 42  $\mu\text{g/L}$  but the TCE was not detected. According to the design simulation (Fig. 5a), TCE concentration would be in the order of 40  $\mu\text{g/L}$  when cDCE concentration reached 42  $\mu\text{g/L}$ .

In order to fit the field data the cDCE half-life would need to be 5 times higher than the half-life for TCE (Figure 5b). The actual half-lives values of TCE and cDCE can not be discerned without a reliable velocity estimate.

The half-life values for TCE and cDCE can be back calculated from the field data by inputting the field concentrations and residence times to the degradation model. Table 2 shows that the calculated half-life values for cDCE show a large variation and are much higher than the database values (usually less than 0.5 days). These values indicate that the velocity through the wall is likely unreliable.

Increased pH and decreased Eh measured across all transects indicate that iron corrosion takes place inside the wall. Increased levels of hydrocarbons in the PRB wells also indicate that VOCs are being degraded. Based on these measurements and observed TCE degradation we conclude that the iron should be reactive enough to promote the degradation of the 25-75  $\mu\text{g/L}$  cDCE observed in the upgradient aquifer.

Sampling artifacts

Comparing the cDCE trends in the southern transect in September 1999 and January 2000, it appears that the cDCE degradation was higher and thus residence time was longer in

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September. However, the water level indicate the opposite: higher gradients and velocity (thus a shorter residence time) in September. The fact that there is no apparent relationship between cDCE concentration trends and the hydraulic gradients (flow velocities) suggests that the elevated cDCE concentrations in the wall may, at least partially, be influenced by sampling artifacts.

There is a possibility that the samples collected inside the wall are not representative of the groundwater fully treated with iron. A monitoring well which is not vertical and shifted toward the upgradient side of the wall, may be screened in the zone much closer to the downgradient side than indicated by the riser location. For example, a 3° deviation from plumbness would account for about 0.7 ft shift laterally at the bottom of a 13 ft well.

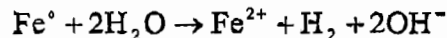
Sample results may also be influenced by the complicated flow paths in the wall. In some months, the groundwater levels indicate flow into the trench from the downgradient side in the northern and central part of the trench (Table 1). If this were occurring, the collected sample would not represent water treated by the full iron thickness.

There is also a possibility that the sampled water in the southern part of the wall comes mostly from the high conductivity zone, where the residence time is not adequate. Based on the information from Parsons, the wells were purged before sampling. It is likely that the water recharging the wells after the initial purging comes mostly from the high conductivity zone, making the VOC reading appear higher.

### **3.0 Specific answers to questions addressed by Parsons ES in the memorandum of 11 February 2000**

*1. Based on Eh and pH values, and small amount of water mounding, is it possible that iron oxide is precipitating in the iron wall, reducing its effectiveness? Is pH adjustment an option to avoid this?*

An increase pH and decrease in Eh are the effects of iron corrosion reaction:



and are commonly observed in the iron systems. In many site waters, this reaction causes the pH to increase to about 9 to 10. As pH increases, iron hydroxide ( $\text{Fe}(\text{OH})_2$ ) forms to counteract the formation of  $\text{OH}^-$ . In addition, bicarbonate ( $\text{HCO}_3^-$ ) in solution converts to carbonate ( $\text{CO}_3^{2-}$ ) to further buffer this pH increase, leading to precipitation of carbonate minerals. Formation of precipitates may cause some loss iron porosity in the long run, but should not have an influence on a system that has been operating for one year only.

The seasonal groundwater level fluctuations in the wall were significant. In fact, in October 1999 more than 60% of the iron mix in the wall was not water saturated. While we expect

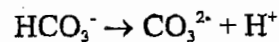
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that iron oxidation in the unsaturated (temporary) zone could cause a reduction in iron effectiveness, we would expect to see this effect reflected in both TCE and cDCE concentrations. A few years ago ETI conducted a qualitative test on iron material abandoned on the ground after a field installation. This material was exposed to the elements for more than a year. Although the iron material was covered with oxides, a laboratory test showed that some reactivity was maintained.

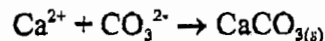
A recent study showed that pH adjustment did not influence the amount of precipitates forming in the iron system (Mackenzie et al., 1999). The pH control (pH range 7.2 - 7.8) was achieved in the study by addition of 15% of iron sulfide to the iron.

2. *We have observed a decrease in calcium concentration and alkalinity as water enters the wall. Could calcite be forming within the wall, causing fluctuation in its effectiveness? We don't have strong evidence that there is a loss in wall porosity (no mounding), however, we don't know why wall's effectiveness varies.*

As indicated in the previous answer, bicarbonate ( $\text{HCO}_3^-$ ) in solution converts to carbonate ( $\text{CO}_3^{2-}$ ) to further buffer this pH increase:



The carbonate then combines with cations ( $\text{Ca}^{2+}$ ,  $\text{Fe}^{2+}$ ,  $\text{Mg}^{2+}$ , etc.) in solution to form mineral precipitates like calcium carbonate:



Again, we don't expect the amount of carbonates formed in the system during one year of operation could have had any effect on the system performance. The maximum amount of the formed carbonates can be calculated based on a few assumptions (an iron/sand porosity of 40%, a groundwater velocity of 0.2 ft/day and an iron/sand zone thickness of 1 ft). The rate of porosity loss per pore volume of flow in the field is calculated below using these assumptions, and equated to an annual loss by assuming that the maximum flow rate through the system \* will be about 73 pore volumes (PV)/year ( $0.2 \text{ ft/day} \div 1 \text{ ft/PV} \times 365 \text{ day/yr}$ ). At an assumed field porosity of 0.4, 1  $\text{cm}^3$  of granular iron/sand contains 0.4 mL of water. The maximum (April 1999, MWT2 - MWT-3) measured difference in influent/effluent calcium concentration in the wall was 206 mg/L (5.15 mmol/L). Therefore, about 0.15 mmol/yr ( $0.0004 \text{ L} \times 5.15 \text{ mmol/L/PV} \times 73 \text{ PV/yr}$ ) of calcite may precipitate in 1  $\text{cm}^3$  of the iron/sand mix. The calcite precipitation rate needs to be equated to the volume of precipitate formed. The molar volume of calcite is 36.9  $\text{cm}^3/\text{mol}$ , therefore the yearly volume of precipitate generated in 1  $\text{cm}^3$  would be about 0.0055  $\text{cm}^3/\text{year}$  ( $0.15 \text{ mmol/yr} \times 36.9 \text{ cm}^3/\text{mol} \div 1,000 \text{ mmol/mol}$ ). This volume of precipitate would equate to about 1.4% annual porosity loss.

3. *Would you recommend core sampling at this site to better interpret our varying results?*

\* Porosity loss calculations have been updated and attached to the end of this Memorandum.



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We feel that core sampling would not provide any valuable information for current data interpretation. However, if any cores remain from the wall installation, than a simple magnetic separation test could be undertaken on core samples to confirm the % of iron in the south end meets the design value.

*4. We have observed increases in methane concentration in the wall, which is expected. Are you familiar with any sites where methane has been collected for reuse?*

We are not familiar with any efforts with methane recovery at iron wall installations. Considering that methane solubility is about 20 mg/L (1 atm., 20° C) and the highest methane concentration detected in the wall was less than 1 mg/L, we are unsure of the economic viability of methane recovery.

*5. What are your recommendations for improving the effectiveness of this trench?*

Our recommendations are given below.

### **4.0 Summary and Recommendations**

Flow through the PRB is not uniform, with a significant flow along the trench from north to south. A high permeability zone may be present in the aquifer and intersected by the southern part of the wall.

TCE is degraded at all well transects to below the target levels. Monitoring results indicate that cDCE was not reduced sufficiently in the wall. It is difficult to pinpoint one reason for the cDCE concentration trends. The residence time in the wall may be insufficient due to the presence of the high permeability zone. Also, there is a possibility that sampling artifacts contribute to the elevated cDCE concentrations inside the wall. As we understand from your comments in our conference call, regardless of the (one or more) reason for exceedance of the cDCE criterion downgradient of the wall, a remedy for these exceedances need to be developed in the near future.

ETI recommends the following steps to further understand the processes undergoing in the wall and provide data for use in addressing the cDCE remaining downgradient of the wall:

- checking the plumbness of the wells in the iron;
- changing the sampling protocol to "diffusion" or "micropurging" sampling (especially in the wall). Selected references are attached. This change in protocol would hopefully allow us to evaluate the effects of sampling artifacts on existing PRB performance; and
- conducting slug test in the aquifer wells of the monitoring transects, especially at the south end. The resulting hydraulic data will be useful not only in evaluating current

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performance, but also in providing a basis for design of a second downgradient system (i.e. the groundwater velocity needed for design);

**5.0 References**

Mackenzie, P.D., Horney, D.P. and Sivavec, T.M. 1999. Mineral precipitation and porosity losses in granular iron columns. *Journal of Hazardous Materials* 68:1-17.

Table1. In - out head difference in the well transects.

Transect wells	In - out head difference in the transects									
	04-99	05-99	06-99	07-99	08-99	09-99	10-99	11-99	12-99	01-00
<b>Across the wall</b>										
MWT-1 → MWT-3	0.07	-0.17	0.01	0.03	0.03	-0.10	0.02	na	-0.1	0.03
MWT-4 → MWT-6	0.05	0.08	0.04	0.04	-0.02	0.03	0.05	na	0.05	0.05
MWT-7 → MWT-9	0.07	0.92	0.13	0.14	0.67	0.2	0.16	na	0.08	0.12
<b>Into the wall</b>										
MWT-1 → MWT-2	0.06	-0.03	0.03	0.05	0.00	-0.03	0.00	na	-0.02	0.01
MWT-4 → MWT-5	0.05	0.10	0.01	0.01	-0.07	0.00	0.07	na	0.04	0.00
MWT-7 → MWT-8	0.01	0.06	0.04	0.04	0.51	0.08	-0.51	na	0.03	0.02
<b>Out of the wall</b>										
MWT-2 → MWT-3	0.01	-0.14	-0.02	-0.02	0.02	-0.07	0.02	na	0.01	0.02
MWT-5 → MWT-6	0.00	-0.02	0.03	0.03	0.05	0.03	-0.02	na	-0.01	0.05
MWT-8 → MWT-9	0.06	0.98	0.09	0.10	0.16	0.12	0.67	na	0.05	0.10
<b>Along the wall</b>										
MWT-2 → MWT-5	0.02	0.59	0.63	1.75	1.76	1.60	1.83	na	0.54	0.35
MWT-5 → MWT-8	-0.06	0.15	0.75	0.85	0.79	0.10	0.21	na	0.01	-0.08

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Table 2. Residence time and half-lives based on the monitoring results

Transect	Hydr. Gradient	K (ft/day)	Velocity (ft/day)	RT based on calculated velocity (hrs)	TCE concn (µg/L)		cDCE concn (µg/L)		Half-lives based on the RT (hrs)	
					Upgrd	Wall	Upgrd	Wall	TCE	cDCE
<b><i>Apr-99</i></b>										
North	0.012	31	2.5	10	23	nd	73	27	<7	17
Middle	0.008	6.2	0.3	73	2	nd	49	nd	ND	<16
South	0.012	5.6	0.4	54	430	nd	20	nd	<7	<7
<b><i>Jun-99</i></b>										
North	0.002	31	0.4	58	8	nd	32	6	ND	24
Middle	0.007	6.2	0.3	84	2	nd	82	20	ND	42
South	0.022	5.6	0.8	29	530	nd	32	42	<3.5	15
<b><i>Sept. 1999</i></b>										
North <sup>a</sup>	-	31	-		nd	nd	6	nd	ND	ND
Middle	0.005	6.2	0.2	115	nd	nd	40	5	ND	39
South	0.033	5.6	1.2	19	480	nd	25	7	<2	4
<b><i>Jan. 2000</i></b>										
North	0.005	31	1.0	24	18	nd	72	23	<7	14
Middle	0.008	6.2	0.3	72	nd	nd	58	7	ND	23
South	0.02	5.6	0.7	31	480	nd	22	55	<4	25

***This table has been updated on 3/14/2000 based on Slug test results of May 1999***

<sup>a</sup> A reversed gradient was observed in this transect  
 nd- not detected, ND - not determined

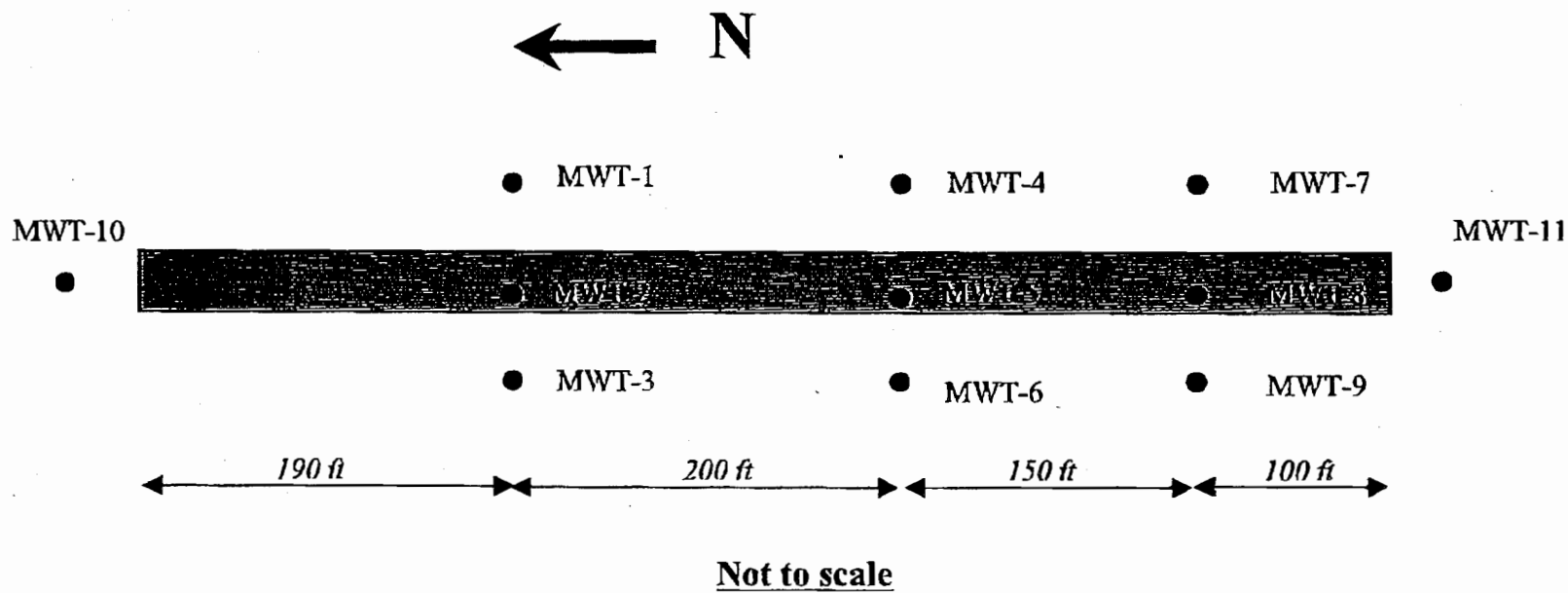


Figure 1. Location of the monitoring wells.

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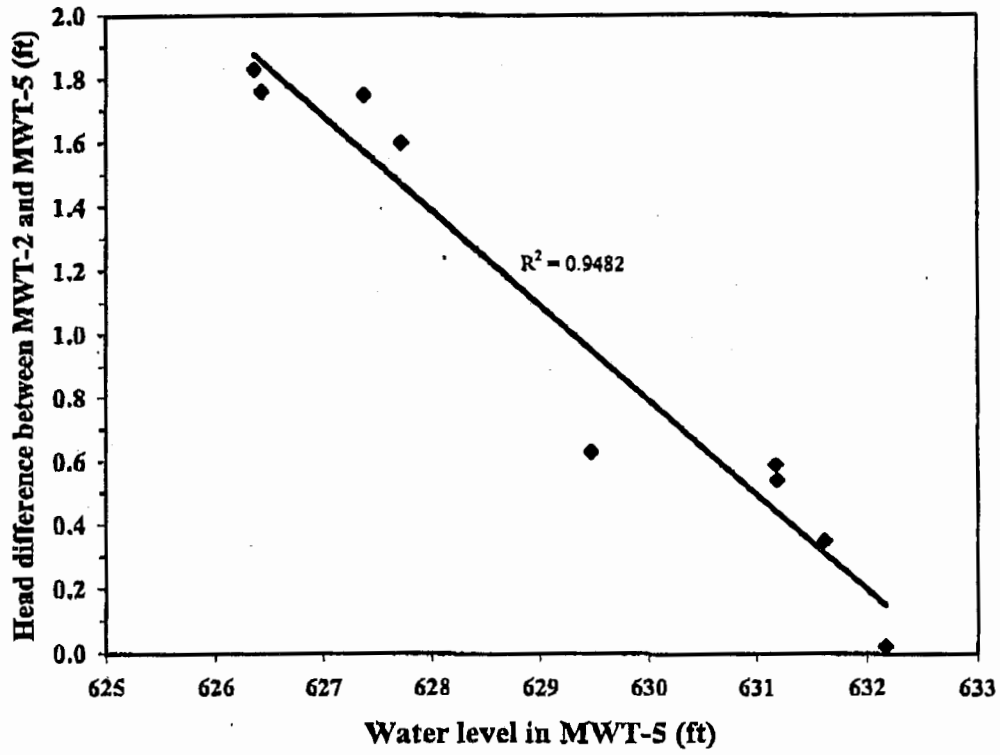


Figure 2. Magnitude of the lateral gradient and the water level inside the iron wall.

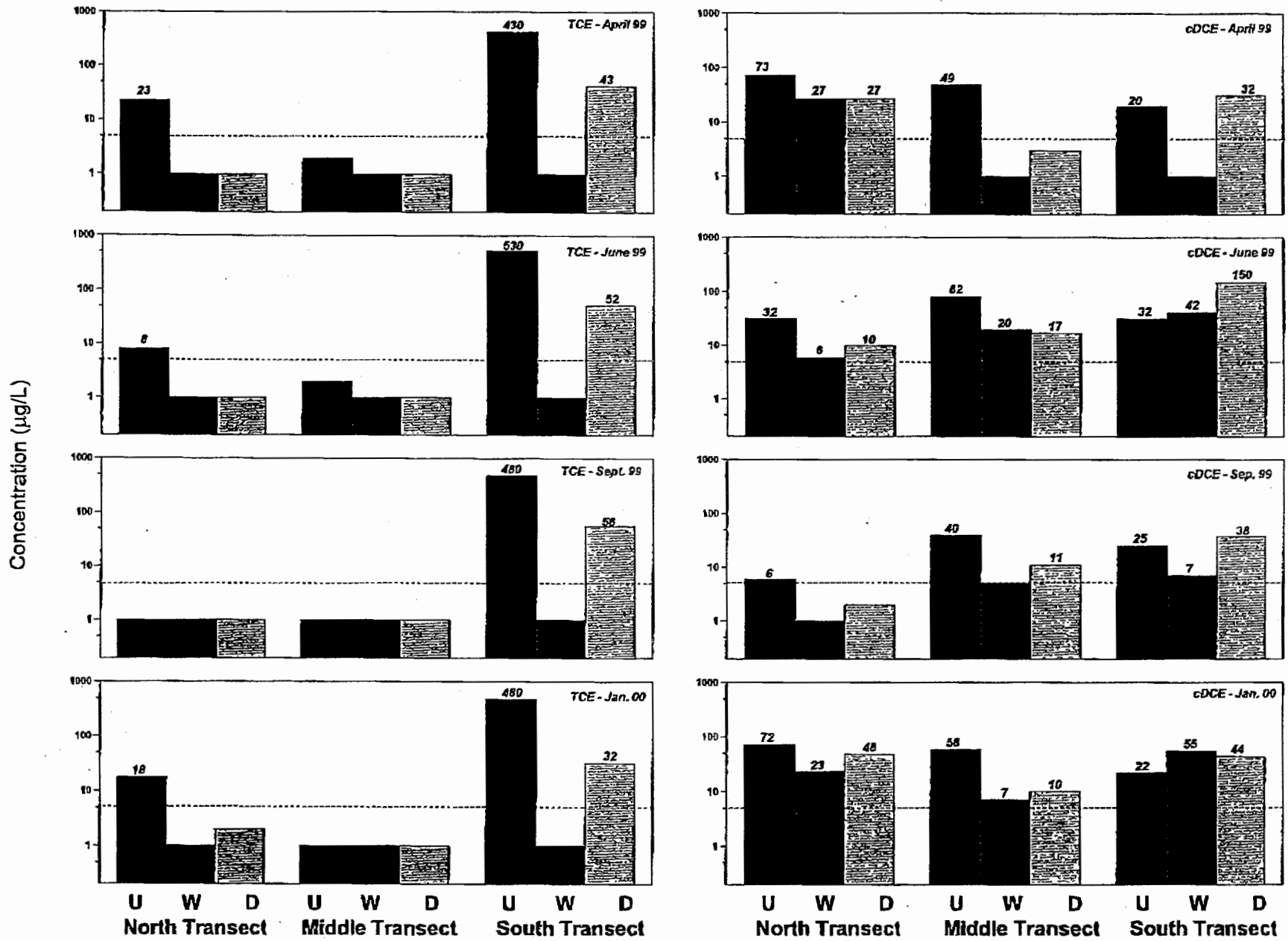


Figure 3. Ash Landfill, iron wall monitoring results.

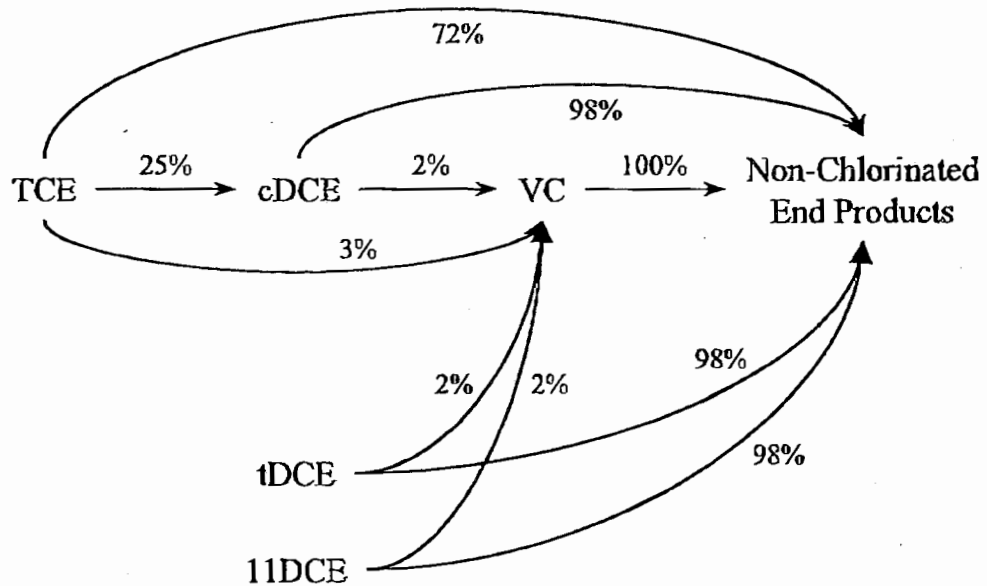
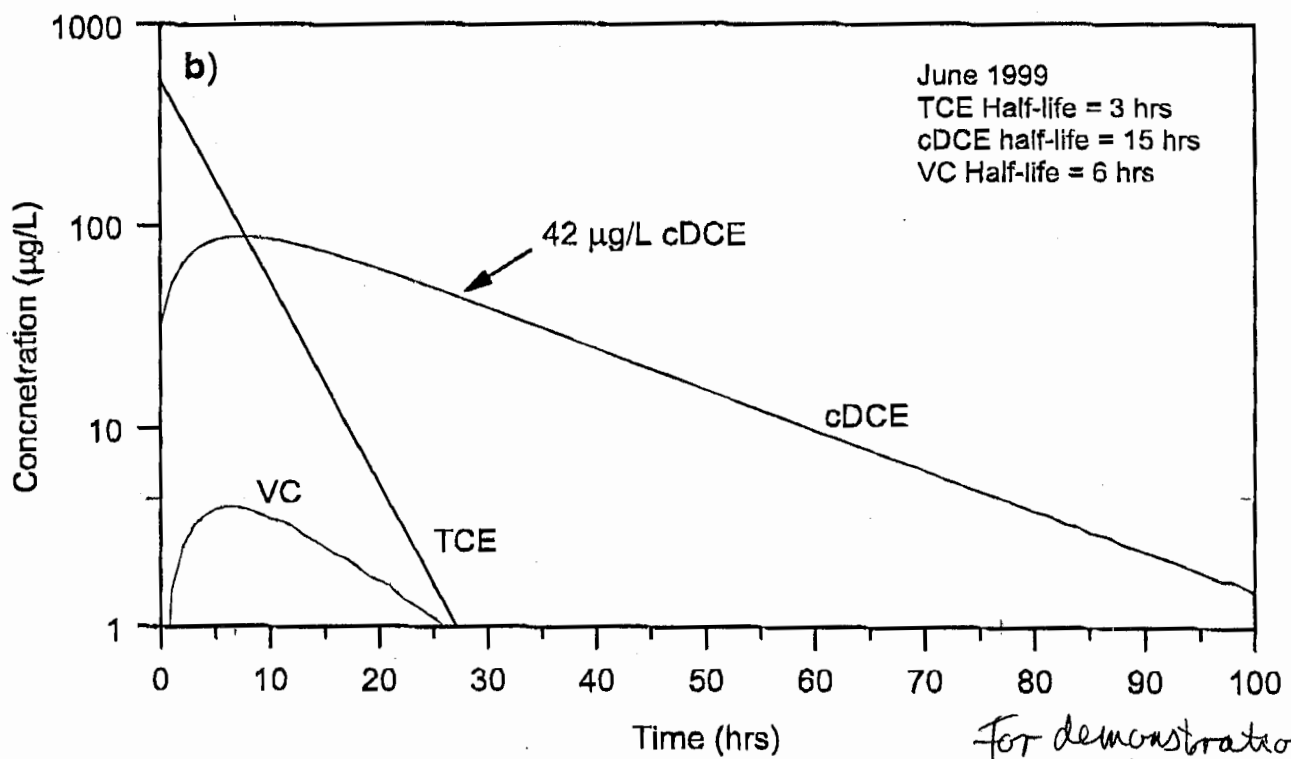
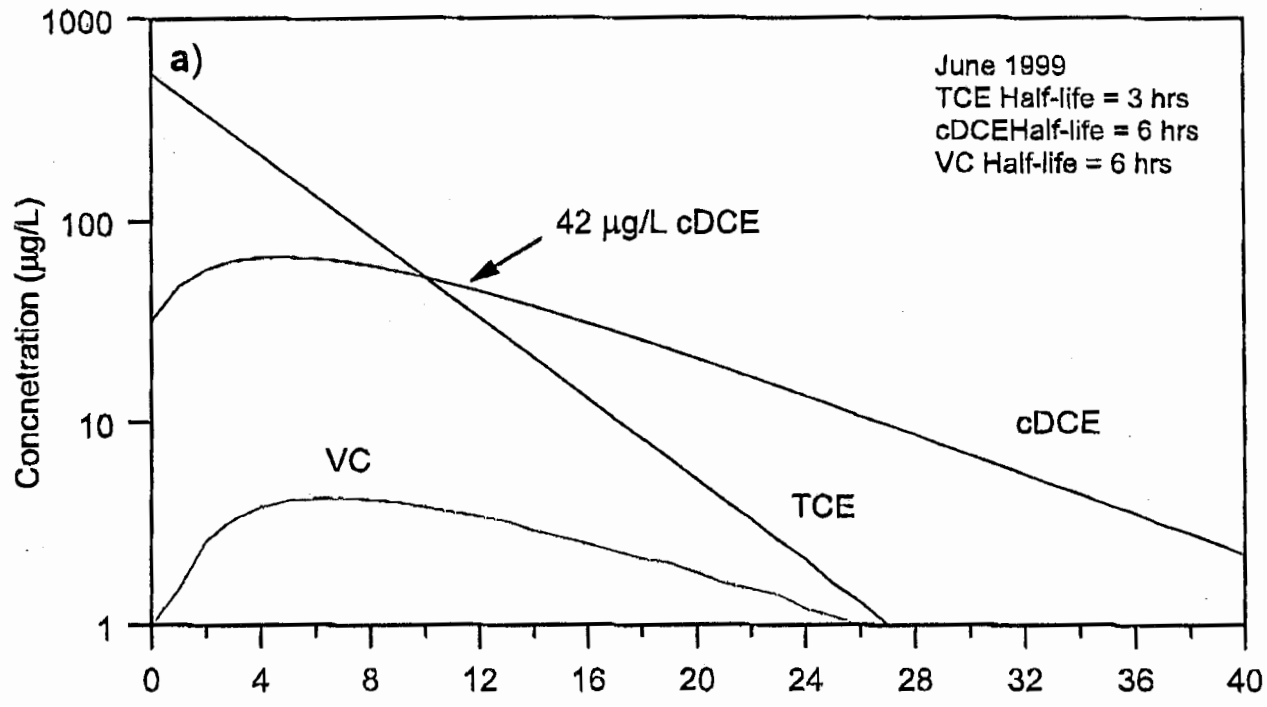


Figure. 4. Typical molar conversion for chlorinated ethenes.





*For demonstration only 3/14/00*

Figure 5. Simulation of VOC degradation based on the June 1999 monitoring results:  
a) typical half lives from database; b) half-life of cDCE increased 2.5 times.

## Porosity Loss Calculation Updates

These updates refer to the note on the bottom of page 5 of ETI's Memorandum of March 2, 2000.

Groundwater velocity = 0.73 ft/day - Average of groundwater velocities of Table 6-2.

$$\frac{0.73 \frac{\text{ft}}{\text{day}}}{1 \frac{\text{ft}}{\text{PV}}} \times 365 \frac{\text{day}}{\text{year}} = 266.5 \frac{\text{PV}}{\text{yr}}$$

The maximum difference between influent and effluent calcium concentration, 144.5mg/L was measured in September 1999 between MWT-7 and -8.

$$\frac{144.5 \frac{\text{mg}}{\text{L}}}{40 \frac{\text{mg}}{\text{mmol}}} = 3.61 \frac{\text{mmol}}{\text{L}}$$

$$\frac{0.0004 \text{L} \times 3.61 \frac{\text{mmol}}{\text{L}}}{\text{PV}} \times 266.5 \frac{\text{PV}}{\text{yr}} = 0.38 \frac{\text{mmol}}{\text{yr}}$$

$$\frac{0.38 \frac{\text{mmol}}{\text{yr}} \times 36.9 \frac{\text{cm}^3}{\text{mol}}}{1,000 \frac{\text{mmol}}{\text{mol}}} = 0.0140 \frac{\text{cm}^3}{\text{yr}}$$

$$\frac{0.0140 \frac{\text{cm}^3}{\text{yr}}}{0.4 \text{cm}^3} \times 100\% = 3.5\%$$

Based on this rate of porosity loss, design life of existing reactive wall is the following:

$$\frac{0.4 \text{cm}^3 - 0.15 \text{cm}^3}{0.0140 \frac{\text{cm}^3}{\text{yr}}} = 18 \text{yr}$$

**Calculations verified by ETI on 3/27/2000**



# Diffusion Samplers as an Inexpensive Approach to Monitoring VOCs in Ground Water

by Don A. Vroblesky and W. Thomas Hyde

## Abstract

**D**iffusion samplers installed in observation wells were found to be capable of yielding representative water samples for chlorinated volatile organic compounds. The samplers consisted of polyethylene bags containing deionized water and relied on diffusion of chlorinated volatile organic compounds through the polyethylene membrane. The known ability of polystyrene to transmit other volatile compounds, such as benzene and toluene, indicates that the samplers can be used for a variety of volatile organic compounds. In wells at the study area, the volatile organic compound concentrations in water samples obtained using the samplers without prior purging were similar to concentrations in water samples obtained from the respective wells using traditional purging and sampling approaches. The low cost associated with this approach makes it a viable option for monitoring large observation well networks for volatile organic compounds.

## Introduction

The typical approach to sampling observation wells for volatile organic compounds (VOCs) involves purging the wells of casing water prior to collecting the water quality sample. Often, the purging removes at least three casing volumes of water, or enough water until selected water quality parameters stabilize. Recent studies, however, suggest that removing three to five casing volumes of water prior to sampling, as suggested by the U.S. Environmental Protection Agency (EPA) (1986), is sometimes unnecessary and, in some cases, may produce undesirable effects (Gibs and Imbrigotta 1990; Powell and Puls 1993; Kearl et al. 1992; Barcelona et al. 1994). Moreover, increasing the purge volumes can increase the radius of aquifer influenced by the pumping, resulting in a sample that may represent an integration of differing water types. Thus, it often is desirable to minimize well purging prior to obtaining representative samples.

Data from recent investigations suggest that the water immediately adjacent to a well screen sometimes can be representative of aquifer water prior to purging. Robin and Gillham (1987) showed that ground water at their site moved through the screened portion of a well with little interaction or mixing with water in the overlying well casing. Powell and Puls (1993) used tracer studies to show that, for three of the four wells they examined, the water in the screened interval exchanged with formation water and did not

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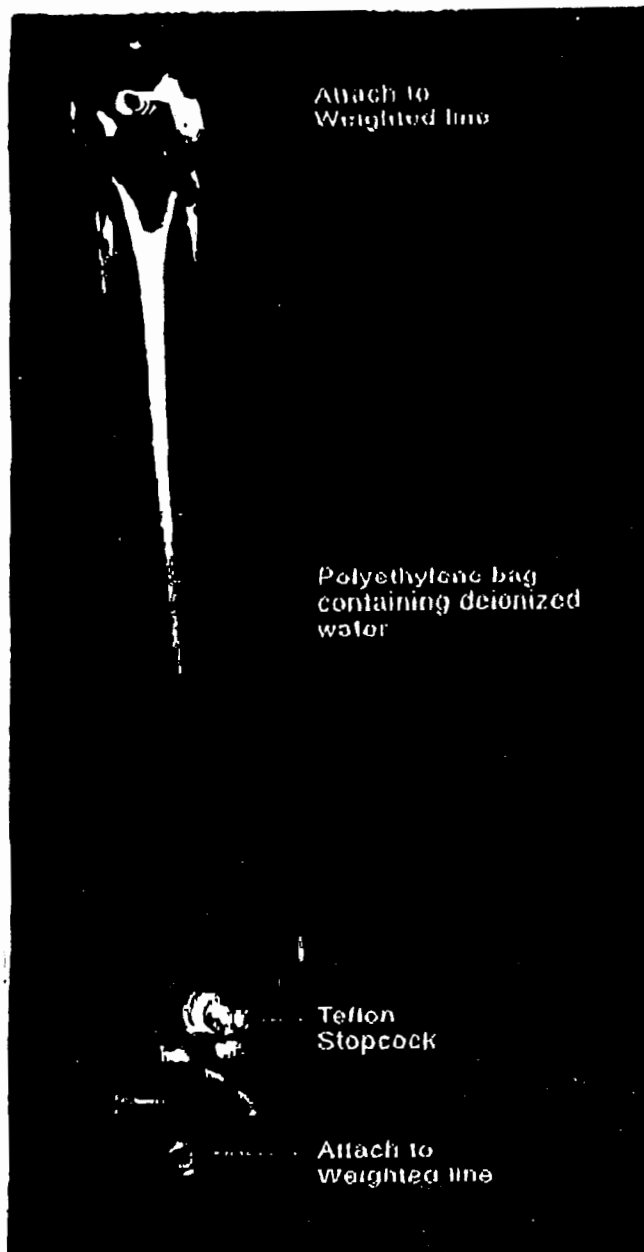


Figure 1. Downhole diffusion sampler.

significantly mix with overlying casing water unless disturbed. In the fourth well, Powell and Puls (1993) found that the casing was constantly replenished with formation water throughout its volume with little or no time available for stagnation of casing water. The studies implied that flow through the well across the screened interval was often horizontal and laminar and representative of formation water. Karl et al. (1992) used a downhole colloidal boreoscope to provide visual support of this hypothesis by showing advection of suspended sediment across the borehole. Thus, in a well with horizontal, laminar flow across the screened interval and little interaction or disturbance of the overlying water col-

umn, a sampling device in the screened interval potentially could be used to collect a representative sample while minimizing disturbance of the overlying water column in the borehole.

Alternative methods have been developed to obtain representative aquifer samples with minimal disturbance of the borehole water column. One method involves placing packers in the well or borehole to isolate specific intervals that can then be pumped (Oliverson et al. 1988; Kaminsky and Wylie 1995). Micropurging, an additional approach, uses dedicated pumps with intakes placed midway in the screened intervals. By pumping at a rate slow enough to eliminate drawdown in the borehole, representative samples of the aquifer can be obtained while minimizing disturbance of the overlying water column above the screened interval (Barcelona et al. 1994; Shanklin et al. 1995). These methods reduce the amount of purge water, but do not eliminate it. An approach that has the potential to eliminate purge water is the DMLS passive sampler (Kaplan et al. 1991). The sampler relies on movement of borehole solutes into proprietary dialysis coils containing distilled water. The coils are vortically separated by flexible seals to provide multilevel information on ground water quality.

The purpose of this paper is to present an inexpensive alternative method to allow routine monitoring of VOCs in ground water at observation wells. The method uses polyethylene bags as semipermeable membranes to allow diffusion of VOCs from the ground water into the water-filled bags. The study area for this investigation was a gas-turbine manufacturing facility in Greenville, South Carolina. The ground water beneath the facility was contaminated with chlorinated VOCs (CVOCs). The dominant constituents of the contamination were tetrachloroethene (PCE), trichloroethene (TCE), cis 1,2-dichloroethene (cis 1,2-DCE), trans 1,2-dichloroethene (trans 1,2-DCE), 1,1-dichloroethane (1,1-DCA), and vinyl chloride (VC). Contaminated ground water at the facility moves through both a fractured-rock aquifer and an overlying saprolitic zone. Diffusion samplers were tested in two wells open to a fractured-rock aquifer and in three wells screened in saprolite. Results obtained using the samplers were compared to results obtained using a submersible electric pump, a bladder pump, and bailer methods.

## Methodology

The diffusion samplers tested in this investigation were polyethylene bags containing deionized water. The ability of polyethylene to transmit CVOCs and aromatic VOCs, such as benzene and toluene, from a water phase to a vapor phase has been demonstrated in previous publications (Vroblesky et al. 1991, 1992, 1994, 1996; Karp 1993). The use of water in the polyethylene bags in this investigation simplifies the analyses by allowing water samples obtained from the diffusion samplers to be analyzed using the same methodology as

water samples collected directly from the well using traditional approaches.

In the testing period from October 1995 to January 1996, the diffusion samplers were extremely simple, consisting merely of sealable sandwich bags obtained from the local grocery store. The bags were placed in Teflon® screens and lowered down observation wells by means of strings. In late 1996, we fabricated elongated polyethylene sleeves with a Teflon valve attached to the bottom (Figure 1) and continued the tests. The volume of the polyethylene sleeves can be adjusted depending on the site-specific requirements, but a volume of approximately 300 mL was used during the testing involved in these experiments. With the exception of a test in Well PW-34C in January 1996, the water-filled bags contained no trapped air.

In the saprolite part of the aquifer, the diffusion samplers were placed within the screened interval of the wells (Table 1). In Well PW-34C, open to the fractured-rock part of the aquifer, placement of the diffusion samplers was determined based on geologic and geophysical logs of the wells. Heat-pulse flowmeter data indicated that water was moving vertically upward between fractures in Well PW-34C in response to pumpage at a nearby contaminated ground water removal well. Approximately 53 gal/min (200 L/min) of water were entering Well PW-34C through a fracture zone at the base of the hole approximately 179 feet (54.5 m) below land surface (bls) and exiting through two fractures at depths of 104.2 and 106 feet (31.8 and 32.3 m) bls (Idler 1994). The diffusion samplers in Well PW-34C were placed in the zone of moving water at a depth of 145 feet (44.2 m) bls.

Well WQ-40B also was open to the fractured-rock aquifer. The boring log for well WQ-40B indicated that fractures were present in the borehole at depths of 41.7 and 42.3 feet. The diffusion samplers were suspended in the vicinity of the fractures at a depth of about 42 feet.

The samplers were in place for periods ranging from 11 to 54 days. The correlation between samples recovered from the wellbores and the respective diffusion sampler implies that sufficient time had elapsed to allow equilibration of the diffusion samplers.

Recovery of the diffusion samplers consisted of

removing the samplers from the well by means of the attached strings and gently pouring water from the samplers into 40-mL glass sampling vials. The samples were then preserved with three drops of hydrochloric acid and capped with Teflon-lined septa. If aeration of a sample was suspected, or if bubbles were observed in a vial, the sample was discarded and a new sample was collected. The water samples were delivered to a private laboratory on the day of collection for analysis by EPA method 8260 (U.S. EPA 1986).

An additional approach to collecting samples was tested in Well PW-34C. A diffusion sampler containing two 40-mL uncapped glass sampling vials was also in Well PW-34C adjacent to the standard diffusion samplers (containing no sampling vials) during the equilibration period ending in October 1995. Upon recovery of the sampler, the vials were removed from the membrane, preserved with hydrochloric acid, and capped. The approach was intended to reduce volatilization loss from pouring the sample into the vials; however, as will be shown, the concentrations obtained by inclusion of vials within the membranes were lower than those obtained using other methods.

Results obtained using the diffusion samplers were compared to results obtained using a variety of standard water collection techniques. The techniques included sampling without prior purging of casing water using a Well Wizard bladder pump, purging and sampling with a Grundfos submersible pump, purging with a submersible pump and sampling with a bladder pump, sampling without purging using a point source bailer in a well where ground water is actively moving in the wellbore, and purging and sampling with bailers.

In August 1996, diffusion samplers were attached to the bottom of a bladder pump and the bladder pump was lowered to the target horizon in Well PW-34C. The pump and diffusion samplers remained undisturbed in the well for 34 days. Sample recovery consisted of first pumping three tubing and pump volumes of water from the well using the bladder pump at approximately 1 gal/min or less (3.785 L/min). Purging of casing water was not necessary because approximately 53 gal/min (200 L/min) of water were moving through the sampled interval. A water sample for VOCs then was collected

**Table 1**  
Well Construction and Sampling Data

Well Number	Sampler Installation Date	Sampler Recovery Date	Casing Diameter (Inches)	Sampler Depth (Feet bls)	Screened Interval (Feet bls)	Open Interval (Feet bls)	Aquifer Type
PW-34C	10/6/95	10/17/95	6	145	NA	37.5-179	Fractured Rock
PW-34C	12/8/95	1/11/96	6	145	NA	37.5-179	Fractured Rock
PW-34C	8/30/96	10/3/96	6	145	NA	37.5-179	Fractured Rock
WQ-40B	8/30/96	10/18/96	4	42	NA	38.2-58.9	Fractured Rock
WQ-67	12/8/95	1/31/96	2	19	13.75-23.95	NA	Saprolite
WQ-74R	12/8/95	1/11/96	2	37.5	29.2-39.2	NA	Saprolite
WQ-87	12/8/95	1/11/96	2	33	28.3-38.3	NA	Saprolite

bls: below land surface  
NA: not applicable

using the bladder pump. Immediately after collecting the bladder pump sample, the bladder pump and attached diffusion samplers were removed from the well, and water samples were recovered from the diffusion samplers.

Results obtained using the diffusion samplers also were compared to results obtained by purging and sampling with a Grundfos submersible pump as well as to sampling with a Well Wizard bladder pump after purging with a submersible pump. Diffusion samplers were placed adjacent to fractures in Well WQ-40B and allowed to equilibrate for 49 days. At the end of the equilibration period, the diffusion samplers were recovered and the water was transferred to sample bottles. After removing the diffusion samplers, a Grundfos submersible pump was lowered into the well and used to purge three casing volumes of water. Water samples for VOCs were then collected using the submersible pump at a pumping rate of less than 1 gal/min (3.785 L/min). The pump was then removed and replaced with a Well Wizard bladder pump. Water samples for VOCs were collected using the bladder pump at a pumping rate of

less than 1 gal/min (3.785 L/min).

Following recovery of the diffusion samplers in January 1996, Wells WQ-67, WQ-74AR, and WQ-87 were purged of three casing volumes of water using a bailer. Well PW-34C was not purged for reasons previously discussed. Water samples from the wells were obtained by lowering a point source bailer to the depth of the diffusion sampler. Upon recovery of the bailer, water samples were collected by slowly filling sample-rinsed glass 40-mL vials from a bottom-discharge bailer into the bottom of the vials. The vials were allowed to overflow several seconds, and the samples were then preserved with three drops of hydrochloric acid. Sample bottles were capped with Teflon-lined bottle caps. If aeration of a sample was suspected, or if bubbles were observed in a bottle, the sample was discarded, and a new sample was collected (U.S. EPA 1986).

Duplicate samples were collected from a single bailer of water at Well PW-34C during two sampling events: October 1995 and January 1996. Duplicate samples were collected from a single diffusion sampler in January 1996 at all sites.

**Table 2**  
Comparison of CVOC Concentrations from Submersible Electric Pump,  
Bladder Pump, and Diffusion Samplers

Well and Sample ID	Date	Sampling Method	PCB ( $\mu\text{g/L}$ )	TCE ( $\mu\text{g/L}$ )	c-1,2-DCE ( $\mu\text{g/L}$ )	t-1,2-DCE ( $\mu\text{g/L}$ )	1,1-DCA ( $\mu\text{g/L}$ )	VC ( $\mu\text{g/L}$ )
PW-34C 1C	10/3/96	Bladder Pump	806	1830	288	<5	8.5	41
PW-34C 1C (Repl.)	10/3/96	Bladder Pump	749	2170	310	8.9	8.5	41.6
PW-34C 2C	10/3/96	DS (3 Mil)	951	2170	267	<5	8.5	44.1
PW-34C 2C (Repl.)	10/3/96	DS (3 Mil)	1170	2520	302	<5	9	46.5
PW-34C 3C	10/3/96	DS (4 Mil)	896	2000	252	<5	7.4	41.8
PW-34C 3C (Repl.)	10/3/96	DS (4 Mil)	1300	2640	329	<5	7.7	44.9
WQ-40B 1D	10/18/96	Bladder Pump	129	148	1730	46.1	77.6	311
WQ-40B 1D (Repl.)	10/18/96	Bladder Pump	129	148	1170	46.6	77.9	178
WQ-40B 2D	10/18/96	Submersible Electric	132	146	1870	44.2	82.5	356
WQ-40B 2D (Repl.)	10/18/96	Submersible Electric	131	146	1850	43.4	83	343
WQ-40B 3D	10/18/96	DS (3 Mil)	141	159	1720	45.3	77.8	370
WQ-40B 3D (Repl.)	10/18/96	DS (3 Mil)	163	151	1450	41.3	68.9	273
WQ-40B 4D	10/18/96	DS (4 Mil)	143	163	1700	47.9	74.1	355
WQ-40B 4D (Repl.)	10/18/96	DS (4 Mil)	156	145	1590	42	66.1	290

PCB: Tetrachloroethene  
TCE: Trichloroethene  
c-1,2-DCE: cis 1,2-dichloroethene  
t-1,2-DCE: trans 1,2-dichloroethene  
1,1-DCA: 1,1-dichloroethane  
VC: Vinyl chloride  
Repl.: replicate

DS: Diffusion sampler method  
Bladder Pump: Well Wizard bladder pump  
Submersible Electric: Grundfos submersible electric pump  
 $\mu\text{g/L}$ : micrograms per liter  
3 Mil: Thickness of the polyethylene was 3 mil  
4 Mil: Thickness of the polyethylene was 4 mil

## Results and Discussion

Water chemistry results (Tables 2 and 3) showed that the wells used for this investigation contained water with a broad range in concentrations of CVOCs. Well PW-34C was open to a part of the aquifer containing high concentrations of CVOCs (>1000 µg/L of TCE), and Wells WQ-67 and WQ-74R were screened in uncontaminated parts of the aquifer. Well WQ-87 contained mid-range concentrations of CVOCs (approximately 350 to 400 µg/L of TCE). Well WQ-40B contained mid-range concentrations of TCE (approximately 145 to 159 µg/L), and relatively high concentrations of cis 1,2-DCE (approximately 1450 to 1870 µg/L).

In general, the CVOC concentrations in water obtained with the diffusion samplers prior to purging were similar to the CVOC concentrations in water

obtained by purging and sampling with a submersible electric pump and to those obtained by purging with a submersible electrical pump and sampling with a bladder pump (Figure 2). Average concentrations of detected CVOCs in the diffusion samplers differed from the average concentrations of the respective CVOCs obtained using the submersible electrical pump by only 9.1 percent in water from Well WQ-40B and by 11.5 percent from the average concentrations of the respective CVOCs obtained by sampling with a bladder pump after purging with a submersible pump in Well WQ-40B.

A comparison of the diffusion samplers and a bladder pump yielded similar results at Well PW-34C (Figure 3). The average concentrations of detected CVOCs in water from the diffusion samplers differed by 11.5 percent from the average concentrations of the

**Table 3**  
Comparison of CVOC Concentrations from Bailers and Diffusion Samplers

Well and Sample ID	Date	Sampling Method	PCE (µg/L)	TCE (µg/L)	c-1,2-DCE (µg/L)	t-1,2-DCE (µg/L)	1,1-DCA (µg/L)	VC (µg/L)
PW-34C 1A	10/17/95	Bailer	2000	2500	570	<40	<40	130
PW-34C 1A (Repl.)	10/17/95	Bailer	1870	2000	480	<40	<40	93
PW-34C 2A	10/17/95	DS	1900	2200	490	<40	<40	97
PW-34C 2A (Repl.)	10/17/95	DS	2000	2200	500	<40	<40	95
PW-34C 3A	10/17/95	DS	2000	2300	490	<40	<40	98
PW-34C 3A (Repl.)	10/17/95	Vial Test	710	770	170	<40	<40	<40
PW-34C 3A (Repl.)	10/17/95	Vial Test	830	940	220	<40	<40	<40
PW-34C 1B	1/11/96	Bailer	1400	2290	389	6.1	13.3	76
PW-34C 1B (Repl.)	1/11/96	Bailer	1830	2320	409	6.1	13.7	79
PW-34C 2B	1/11/96	DS with bubble	1510	2520	421	5.1	13.3	95
PW-34C 2B (Repl.)	1/11/96	DS with bubble	678	1240	490	5.3	12.1	89
PW-34C 3B	1/11/96	DS	1260	2070	290	6.4	12.2	56
PW-34C 3B (Repl.)	1/11/96	DS	1750	2230	396	6	13.1	54
WQ-67 4B	1/11/96	Bailer	<5	<5	<5	<5	<5	<10
WQ-67 5B	1/11/96	DS	<5	<5	<5	<5	<5	<10
WQ-67 5B (Repl.)	1/11/96	DS	<5	<5	<5	<5	<5	<10
WQ-74R 6B	1/11/96	Bailer	<5	<5	<5	<5	<5	<10
WQ-74R 7B	1/11/96	DS	<5	<5	<5	<5	<5	<10
WQ-74R 7B (Repl.)	1/11/96	DS	<5	<5	<5	<5	<5	<10
WQ-87 8B	1/11/96	Bailer	212	379	31	<5	<5	<10
WQ-87 9B	1/11/96	DS	187	389	34	<5	<5	<10
WQ-87 9B (Repl.)	1/11/96	DS	170	364	34	<5	<5	<10

PCE: Tetrachloroethene  
 TCE: Trichloroethene  
 c-1,2-DCE: cis 1,2-dichloroethene  
 t-1,2-DCE: trans 1,2-dichloroethene  
 1,1-DCA: 1,1-dichloroethane  
 VC: Vinyl chloride

Repl.: replicate  
 DS: Diffusion sampler method  
 DS with bubble: Diffusion sampler contained air bubble  
 Vial Test: Sample vials were within diffusion sampler during equilibration period  
 µg/L: micrograms per liter

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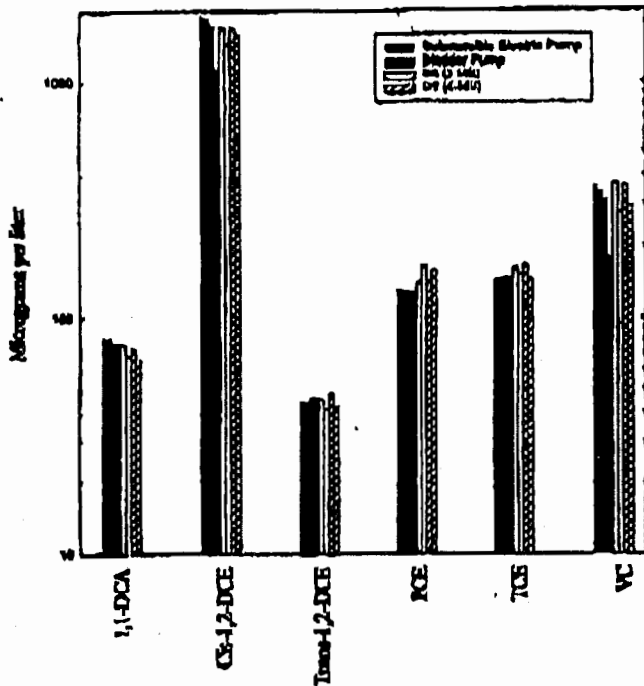


Figure 2. Comparison of samples obtained from 3-Mil and 4-Mil-thick downhole diffusion samplers (DS) to samples obtained by purging and sampling with a submersible pump and to samples obtained by purging with a submersible pump and sampling with a bladder pump in Well WQ-40B, August 1998.

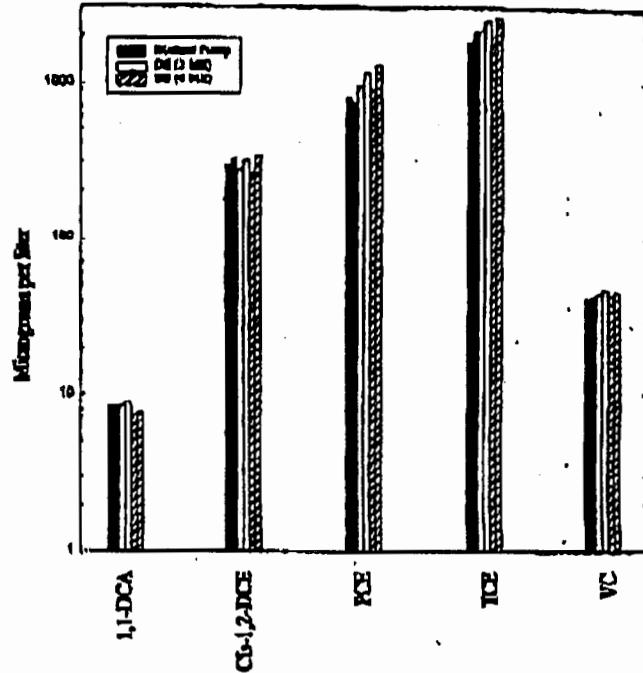


Figure 3. Comparison of samples obtained from 3-Mil and 4-Mil-thick downhole diffusion samplers (DS) to samples obtained from an in-place bladder pump with no purging in Well PW-34C, August 1996.

respective CVOCs obtained by sampling with the bladder pump from the same interval without purging. Differences in the concentrations of CVOCs between the 3-Mil-thick and 4-Mil-thick diffusion samplers were relatively minor (Figures 2 and 3).

Examination of individual CVOCs showed some variations between concentrations obtained with the diffusion samplers and concentrations obtained with the bladder pump. The average PCE concentration (1079 µg/L, standard deviation 163.5 µg/L for four samples) in diffusion samplers from Well PW-34C in October 1996 was approximately 28 percent higher than the average PCE concentration (777.5 µg/L, standard deviation 28.5 µg/L for two samples) obtained using the bladder pump. Likewise, the average TCE concentration (2332.5 µg/L, standard deviation 258.2 µg/L for four samples) in diffusion samplers was approximately 14 percent higher than average TCE concentration (2000 µg/L, standard deviation 170 µg/L for two samples) obtained using the bladder pump (Table 2). Obtaining a water sample with the bladder pump at 145-foot depth necessitated using a higher pump discharge pressure than needed for shallower wells. Thus, although the pumping rate was less than 1 gallon per minute, the discharge velocity of individual pulses from the bladder pump may have been high enough to allow VOC volatilization during sample collection. The higher concentrations of VOCs in the diffusion samplers relative to the bladder pump implies that, in such a situation, samples obtained using the dif-

fusion samplers may be more representative than those obtained using a bladder pump.

Similarly, in Well WQ-40B, the average PCE concentration (150.7 µg/L, standard deviation 9.1 µg/L for four samples) in water from the diffusion samplers was approximately 14.4 percent higher than the concentration (129 µg/L in two samples) obtained using the bladder pump and approximately 12.7 percent higher than the average concentration (131.5 µg/L, standard deviation 0.5 µg/L for two samples) obtained using the submersible pump (Table 2). The average TCE concentration in water from diffusion samplers in Well WQ-40B (154.4 µg/L, standard deviation 8 for four samples) was slightly higher than those obtained with the bladder pump (148 µg/L in two samples) and with the submersible pump (146 µg/L in two samples). Again, the higher concentrations obtained with the diffusion samplers suggest that this collection approach sometimes may provide more representative concentrations of PCE and TCE than water samples obtained by purging and sampling using bladder pumps or submersible pumps.

Because ground water samples for routine monitoring also are commonly obtained using bailer methods, the diffusion samplers were compared to bailers at wells in both supracrustal and fractured-rock wells. A comparison of results obtained in a test of the diffusion samplers in Well PW-34C showed that the concentrations of CVOCs in vials filled from the diffusion samplers closely matched the concentrations in water obtained

from a point source bailer (Table 3). Vinyl chloride, PCE, TCE, and cis 1,2-DCE concentrations from the diffusion samplers were within the range of concentrations detected in water from the bailer.

A test of an alternate approach, involving inclusion of two 40-mL uncapped glass sampling vials within the membrane, showed that the detected concentrations of CVOCs in water using this method (labeled "Vial Test" in Table 3) were substantially lower than those obtained from either the diffusion sampler or from the bailer methods of sample collection. It is possible that the glass vials, though open at one end, slowed down diffusion into the vials sufficiently to cause lower concentrations inside the vials than outside the vials. Thus, incorporation of the 40-mL glass sampling vials into the diffusion samplers is not practical.

The diffusion samplers again were tested in Well PW-34C in January 1996 (Table 3). During this test, a comparison was run to determine the effect of air bubbles in the diffusion samplers. Two diffusion samplers were installed in the well. One of the samplers (PW-34C 3B) contained no trapped air, and the second sampler (PW-34C 2B) contained an air bubble that constituted approximately one-third of the sampler volume. When the samplers were recovered after 34 days, neither sampler contained air bubbles. Because volatile compounds can diffuse out of the polyethylene bags as well as into them (Vroblesky and Robertson 1996), the trapped air apparently diffused out of the sampler, leaving only water. Of the two water samples recovered from the diffusion sampler to which an air bubble had been added, one sample (PW-34C 2B) closely matched the CVOC concentrations in water obtained by using a point source bailer and by using the diffusion samplers with no air bubbles (Table 3). The second sample [PW-34C 2B (Rep.)] from the diffusion sampler to which an air bubble had been added contained approximately half of the concentrations of PCE and TCE found in the first sample and in water samples from the point source bailer (Table 3). The variability in water collected from the same diffusion sampler implies that the lower concentrations in the second sample were caused by losses during transfer from the diffusion sampler to the sample bottle and not from losses within the diffusion sampler. The data imply that, although the presence of air bubbles in the diffusion samplers should be avoided, their presence apparently has little influence on concentrations of CVOCs after sufficient equilibration time.

The diffusion sampler method also was tested in Well WQ-87, screened in a part of the saprolite aquifer characterized by moderate concentrations of CVOCs (approximately 350 to 400 µg/L of TCE). Again, the concentrations of CVOCs detected in water recovered with the diffusion samplers closely corresponded with concentrations of CVOCs detected in water bailed from the well (Table 3). The average concentration in the diffusion samplers differed from the concentration in water obtained by the bailer by less than 2 percent for TCE and by 16 percent for PCE. These data showed that the samplers were capable of collecting a represen-

tative sample of mid-range concentrations of CVOCs in ground water.

Volatile organic compounds were not detected in water from background Wells WQ-67 and WQ-74R by either the bailer method or the diffusion samplers (Table 3). Thus, materials and deionized water used in the diffusion samplers did not contribute VOCs to the analyses.

### Conclusions

Previous investigations have shown that it generally is desirable to minimize well purging and well disturbance prior to collecting representative samples of ground water. Investigations also have shown that ground water in some wells flows through the open interval with little interaction or mixing with water in the overlying well casing. In such wells, the water in the screened interval appears to be representative of the surrounding ground water. This paper presents an inexpensive approach to sample the water for VOCs in the screened interval without disturbing the overlying water column. The method involves placing polyethylene bags that function as diffusion samplers adjacent to the screened or open interval of the borehole. Each diffusion sampler consists of deionized water enclosed by a polyethylene membrane. The membrane allows diffusion of the VOCs from the aquifer water into or back out of the deionized water. In simplest manifestation of the sampler, adequate water samples can be obtained by merely using sealable sandwich bags obtainable from grocery stores as the diffusion samplers.

The samplers were allowed to equilibrate in the borehole for a minimum of 11 days. The samplers were then recovered and transferred to 40-mL glass vials for transport to the laboratory. Laboratory analysis by EPA method 8260 showed that concentrations of CVOCs in water recovered from the diffusion samplers were similar to concentrations of the respective CVOCs obtained by: (1) purging and sampling with a submersible electric pump; (2) purging with a submersible electric pump and sampling with a bladder pump; (3) sampling with an in-place bladder pump without purging; (4) sampling without purging using a point source bailer in a well where ground water is actively moving in the wellbore; and (5) purging and sampling with a bailer. For some constituents, the average concentration was slightly higher in water obtained with the diffusion samplers than in water obtained with a submersible pump and with a bladder pump, implying that the diffusion samplers may provide a more representative sample in some situations. These data demonstrated that the diffusion samplers were capable of recovering a representative water sample for VOCs without the need to purge the wells tested at this site. To ensure transferability of this technique to other sites, an initial test period is recommended during which the diffusion sampler approach is compared to the routine method of sampling a particular well. Comparable results will indicate that the water in the open interval is representative of the formation

water, that the target compounds can efficiently diffuse into the samplers, and that the diffusion-sampler approach can be used to sample the well without the need to purge. In wells where the screen length is large relative to the sampler length, multiple samplers initially may be used to determine optimum sampler depth. The known ability of polyethylene to transmit other VOCs, such as benzene and toluene, indicate that the diffusion samplers can be used to monitor a variety of VOCs. The low cost associated with the diffusion samplers makes this a potentially viable approach to reducing monitoring costs of large observation well networks where the target compounds are organic compounds capable of diffusing into the samplers.

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## Disclaimer

Although the research described in this report has been funded wholly or in part by the U.S. EPA it has not been subjected to the Agency's peer and administration review and therefore may not necessarily reflect the view of the Agency, and no official endorsement may be inferred. Use of tradenames does not imply endorsement by the U.S. Government.

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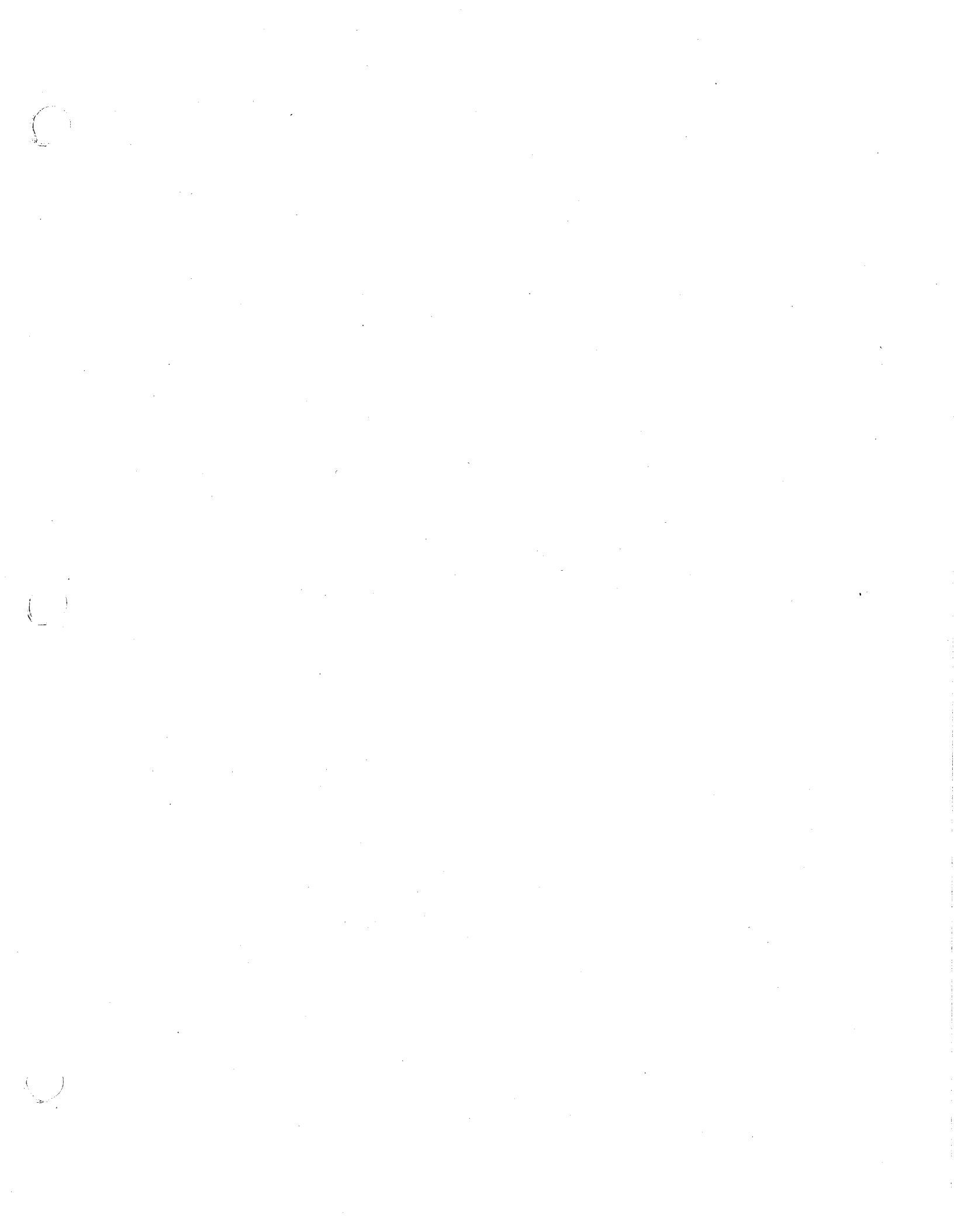
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**Email:** **aprzepiora@eti.ca**  
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**Pages:** **1 of 27**

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Anne:  
Attached is a table with HL values for waters similar  
to the Ash Landfill.  
Also attached are two papers with HL based on field  
results, one of them from a NY site. Let me know  
if this is sufficient.

Andrzej Przepiora

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**Table 1. Range of TCE and cDCE half-lives obtained from bench-scale column tests (25° C) using site waters with total VOC concentration <1,000 µg/L and low (<1,000 mg/L) TDS levels (ETI Database). The anticipated field half-lives are usually obtained by increasing the lab-derived values by a factor of 2 to 3.**

Iron Type	Laboratory TCE Half-life (hrs)					Laboratory cDCE Half-life (hrs)				
	No. tests	Mean	Min.	Max.	Std. dev	No. tests	Mean	Min.	Max.	Std. dev
Peerless	3	0.28	0.18	0.37	0.1	3	1.0	0.28	2.4	1.2

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## Performance evaluation of a permeable reactive barrier for remediation of dissolved chlorinated solvents in groundwater

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### Abstract

A pilot-scale permeable reactive barrier (PRB) consisting of granular iron was installed in May 1995 at an industrial facility in New York to evaluate the use of this technology for remediation of chlorinated volatile organic compounds (VOCs) in groundwater. The performance of the barrier was monitored over a 2-year period. Groundwater velocity through the barrier was determined using water level measurements, tracer tests, and in situ velocity measurements. While uncertainty in the measured groundwater velocity hampered interpretation of results, the VOC concentration data from wells in the PRB indicated that VOC degradation rates were similar to those anticipated from laboratory results. Groundwater and core analyses indicated that formation of carbonate precipitates occurred in the upgradient section of the iron zone, however, these precipitates did not appear to adversely affect system performance. There was no indication of microbial fouling of the system over the monitoring period. Based on the observed performance of the pilot, a full-scale iron PRB was installed at the site in December 1997. © 1999 Elsevier Science B.V. All rights reserved.

*Keywords:* Permeable reactive barrier; Volatile organic compound; Groundwater

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### 1. Introduction

Permeable reactive barriers (PRBs) containing granular iron have been installed at several commercial sites in the United States to degrade chlorinated volatile organic

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compounds (VOCs) in groundwater [1]. Although the results of laboratory studies conducted to determine reaction mechanisms have been widely disseminated [2,3], much less information has been published on the field-scale application of this technology.

One of the more complete performance records exists for a pilot-scale PRB installed in May 1995 at a former industrial facility in upstate New York. Past release of solvents at the site created a plume of trichloroethene (TCE) and related byproducts in the shallow sand aquifer at the site [4]. The water table at the site is about 1 m below ground level, and the aquifer is bounded by a clay layer at a depth of 4 to 5 m. Following encouraging results from laboratory treatability tests, the decision was made to proceed with a field demonstration.

The pilot-scale system installed at the site consisted of a funnel-and-gate located in an area of the plume containing the highest VOC concentrations. The gate section, 3.7 m long  $\times$  1.8 m wide (Fig. 1), was constructed by driving sealable sheet piling into the underlying aquitard at a depth of about 4.5 m. Native material was excavated and replaced with a center 0.9-m thick section of granular iron flanked by 0.5 m thick layer of pea gravel on both upgradient and downgradient sides. The purpose of the pea gravel

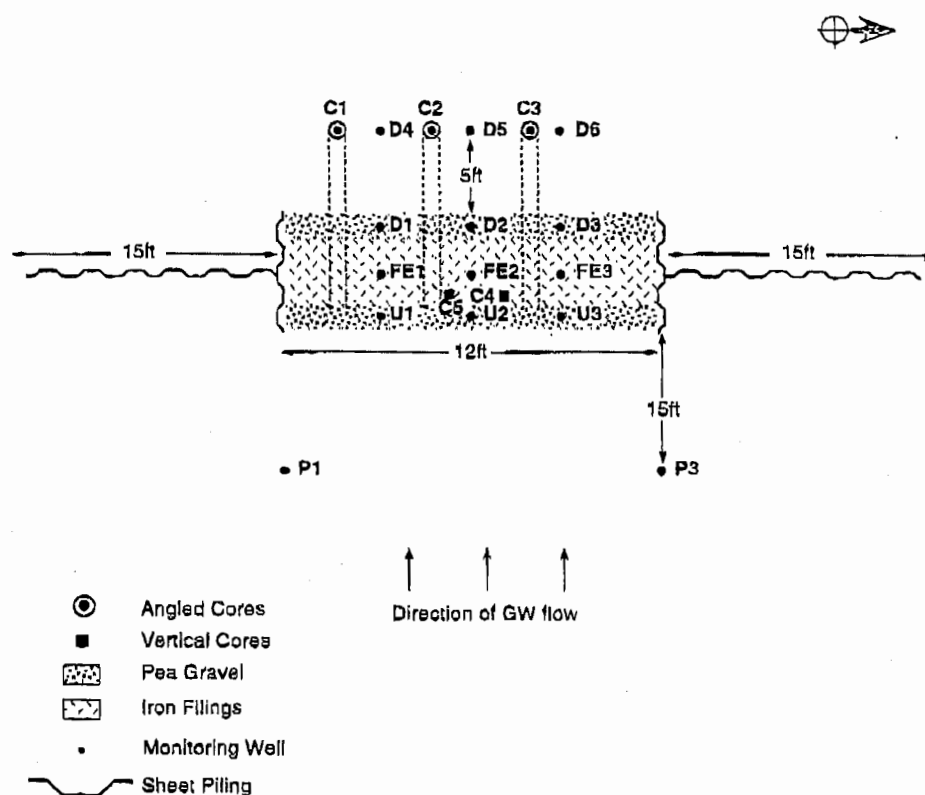


Fig. 1. Plan view of monitoring well and coring location, New York.



was to minimize the effects of high velocity layers in the aquifer by spreading flow vertically across the reactive zone; and to serve as locations for monitoring well placement. The piling on the long axis of the box was then removed to create a flow through reaction section or gate (Fig. 1). The gate section was flanked by funnels comprised of sealable-joint sheet piling extending 4.6 m laterally on either side, to a depth of 5 m. Modelling completed by Starr and Cherry [5] indicated that this configuration creates a larger upgradient capture zone relative to funnels angled more acutely to the gate. Monitoring wells shown in Fig. 1 were made of 2-in. diameter PVC, and screened across most of the saturated thickness of the iron, pea gravel or aquifer. The installation took about 10 days to complete.

## 2. Performance evaluation methods

### 2.1. Groundwater sampling

The monitoring wells were sampled monthly from June to December 1995 under auspices of the US EPA SITE Program [6]. Additional samples were collected in June 1997 immediately prior to coring activities. The number of wells sampled and analyses completed on the samples varied depending on the sampling event. Samples were collected using individual disposable teflon bailers for each sampling event and each well [7]. Analyses included the following [8]:

- VOCs using Method SW-846 8260A;
- Major anions including chloride (Method MCAWW 325.2), sulfate (Method MCAWW 375.4) and bicarbonate alkalinity (MCAWW 310.1);
- Metals (cations) by Method SW-846 3010/6010A;
- pH, redox potential ( $E_h$ ), dissolved oxygen, specific conductance, and temperature using field electrodes.

### 2.2. Groundwater velocity

Groundwater velocity is a critical parameter in evaluating PRB performance [9]. It enables calculation of field-scale VOC degradation rates and can also be used to estimate the plume capture zone upgradient of the PRB. Three methods of determining groundwater velocity were used during this evaluation:

- hydraulic head measurements;
- conservative tracer tests;
- in-well velocity meters.

### 2.3. Analyses of PRB cores

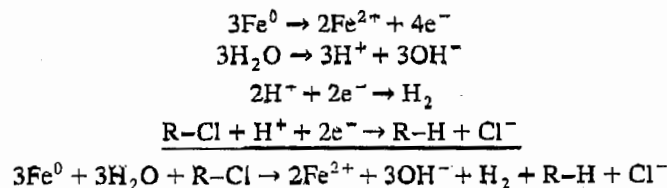
A drive point/piston sampler was used to obtain angle cores from the PRB in June 1997 [10]. Since laboratory studies had indicated that significant inorganic changes in aqueous chemistry occur near the upgradient interface, efforts were made to collect continuous core samples that passed from the upgradient interface into the iron zone. A

complete continuous angle core (Fig. 1) was obtained from the interface, and subdivided into 5 cm sections for analysis. Mineralogical analyses performed on the core samples included total carbonate using acid digestion, and surface mineralogical studies using electron dispersive X-ray (EDX), Raman spectroscopy, and scanning electron microscopy (SEM). Microbial enumerations and total lipid biomass determinations were also completed. Hydraulic conductivity values were calculated from laboratory permeameter tests on a second angled core.

### 3. Results and discussion

#### 3.1. Observed VOC degradation

Consistent trends in VOC concentration were observed throughout the monitoring period. The highest VOC concentrations over the first seven months of operation were observed in the center transect in the October sampling event (Table 1). A graph of TCE concentrations for the three transects of monitoring wells in the seventh month of operation is shown in Fig. 2. While upgradient VOC concentrations showed some variability, concentrations at or near the detection limit were reported at the midpoint of the iron. These declines in concentration of TCE and related compounds were interpreted to reflect the degradation of these VOCs by zero-valent iron, according to the following reaction [11], which considers only the presence of water, zero-valent iron and a chlorinated organic compound R-Cl:



Low to non-detectable VOC concentrations were maintained or increased slightly downgradient, likely due to incomplete flushing of the downgradient plume and/or desorption of VOCs from aquifer sediments.

Table 1  
Observed VOC concentrations along the center transect

Well location	Concentrations along center transect (mg/l)					
	TCE		cDCE		VC	
	October 1995	June 1997	October 1995	June 1997	October 1995	June 1997
Upgradient pea gravel	160	189	450	298	79	53
Midpoint of iron zone	< 1.0	2.0	2.0	< 7.8	< 1.0	< 0.7
Downgradient pea gravel	1.5	< 1.7	7.5	15	1.2	< 0.7

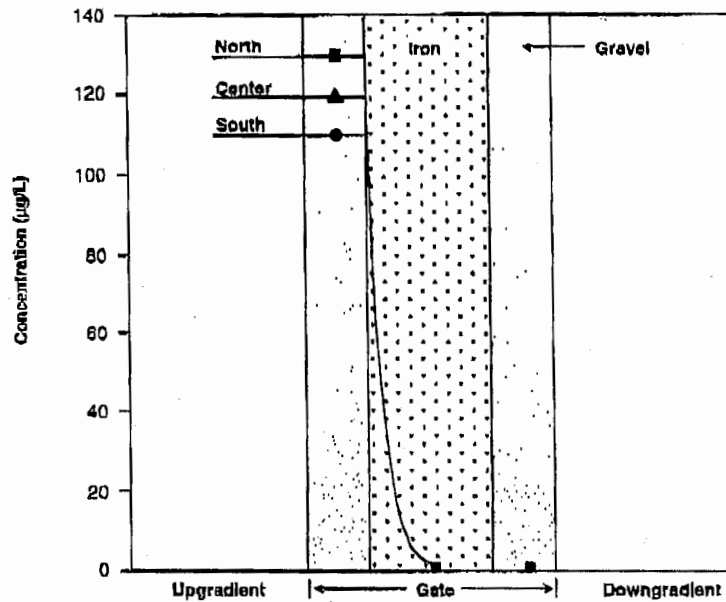


Fig. 2. TCE concentration in the seventh month of operation.

VOC degradation rates, the slope of concentration vs. time curves ( $k_1$  and  $k_2$  shown in Fig. 3) are commonly expressed in half-lives; the time required to reduce the concentration by 50%. Concentration vs. distance profiles from the monitoring wells were converted to concentration vs. time profiles using an estimate of groundwater velocity of 0.2 m/day (see Section 3.2) and compared to half-lives predicted from the

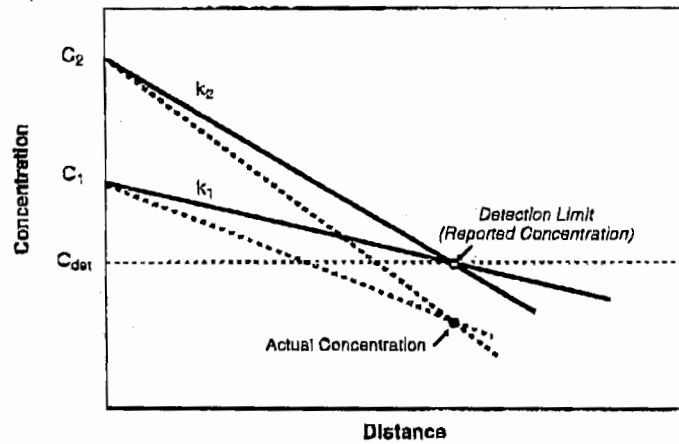


Fig. 3. Uncertainty in calculated degradation rates.

laboratory study (Table 2). Note that if a higher velocity is used in the calculation, the half-lives would be shorter.

It should be noted that the half-lives determined from the field data are conservative estimates of the actual half-lives since VOC concentrations of 1  $\mu\text{g}/\text{l}$  (the detection limit) were used for monitoring well concentrations in the middle of the iron zone. There is no way of knowing the distance at which the detection limit was actually reached (Fig. 3). As shown in Fig. 3, half-lives can also vary according to variations in the influent concentration. This effect is particularly apparent in the calculation of TCE half-lives, which are generally below 3 h at other field installations. In spite of the uncertainty, cDCE and vinyl chloride half-lives compare well with values predicted from laboratory studies.

### 3.2. System hydraulics

The three methods of determining groundwater velocity at the site produced estimated groundwater flow velocities in the treatment gate from 0.2 to 0.7 m/day (Table 3). These field measurements compared reasonably well with a velocity of 0.34 m/day and a capture zone of about 7.5 m predicted by a two-dimensional plan view particle tracking model of the system developed during system design. The model was based on groundwater velocities in the aquifer of about 0.2 m/day. The bromide tracer was injected into fully screened wells located in the upgradient pea gravel. To minimize hydraulic disturbance, only 9.5 l of tracer solution was added to each of the three wells, resulting in small pencil-like plumes emanating from each well. The tracer was detected in each of the wells in the iron zone, but only in one sample. This single detection indicated a groundwater velocity through the gate of about 0.36 to 0.49 m/day. Dilution of the bromide solution upon injection could have reduced the possibility of detection. Furthermore, because of the small dimensions of the tracer plumes, small deviations in groundwater flow direction away from the downgradient monitoring wells would result in intercepting only a small portion of the tracer or possibly missing it all together. Evidence of this has been observed in similar tracer tests [9,12].

Calculations using water table elevations are limited by the accuracy of measurement (small differences in water level elevations over short distances) and the uncertainty in hydraulic parameters (porosity and hydraulic conductivity of the iron). The in-well velocity meter gave velocity magnitudes that were in the range anticipated. Although the

Table 2  
Observed chlorinated volatile organic compound half-lives

VOC	Predicted half-life (h) <sup>a</sup> from laboratory studies	Half-life (h) from monitoring well data
TCE	0.4 to 1.1	< 4.0
cDCE	1.5 to 4.0	3.0 to 5.0
VC	2.0 to 6.0	5.0 to 10.0

<sup>a</sup>Rates at two velocities adjusted for temperature.

Table 3  
Groundwater flow velocity estimates in the treatment gate

Method of measurement	Groundwater flow velocity estimate
Groundwater flow model prediction; $\bar{v}_{\text{Aquifer}} = 0.2$ m/day	0.3 m/day
Hydraulic head measurements (June to December 1995)	< 0.2 to 0.4 m/day
Bromide tracer test (August 1996)	0.4 to 0.5 m/day
Velocity meter (September 1996)	0.2 m/day
Velocity meter; $\bar{v}_{\text{Aquifer}} = 0.1$ to 0.2 m/day (June 1997)	0.3 to 0.7 m/day

direction of velocity vectors obtained with the meter were somewhat variable, most showed flow in a westerly direction (through the system).

Laboratory permeameter tests performed on undisturbed angle core samples gave hydraulic conductivity values ranging from  $6 \times 10^{-2}$  to  $10^{-1}$  cm/s. These compare favourably with hydraulic conductivity values of  $5 \times 10^{-2}$  to  $10^{-1}$  cm/s for 'fresh' iron. Though this result is encouraging, the core materials were disturbed and therefore the results may not accurately reflect the in situ effect of precipitation on hydraulic conductivity.

### 3.3. Inorganic geochemistry

As groundwater moves through granular iron, the pH of the groundwater increases and the  $E_h$  decreases as a consequence of iron corrosion. As the pH increases, bicarbonate ( $\text{HCO}_3^-$ ) in solution converts to carbonate ( $\text{CO}_3^{2-}$ ) to buffer the pH increase:



The carbonate then combines with cations ( $\text{Ca}^{2+}$ ,  $\text{Fe}^{2+}$ ,  $\text{Mg}^{2+}$ , etc.) in solution to form mineral precipitates:



These reactions were reflected in the aqueous geochemical results throughout the monitoring period (Table 4). Results are shown from wells along the centre transect (Fig. 1). Results were very consistent both laterally across the wall and over time through the monitoring period. Upgradient groundwater was near neutral in pH and slightly aerobic, while at the midpoint of the iron the pH was generally between 9 and 10 and  $E_h$  of less than  $-300$  mV were common. Downgradient of the gate pH increased to background levels while the  $E_h$  of the groundwater remained slightly lower than in the aquifer upgradient of the gate. Declines in aqueous calcium, alkalinity and sulphate were observed throughout the test. Iron concentrations did not increase substantially over background, indicating rapid precipitation of the ferrous iron introduced into solution from corrosion of the iron material.

Results of the carbonate mineral determinations on the core samples are shown in Fig. 4 The maximum carbonate content of about 6%  $\text{CaCO}_3$  (6 g/100 g solid), obtained

Table 4  
Changes in inorganic chemistry along centre transect

Chemical parameter (unit)	Monitoring well location			
	U2	FE2	D2	D5
Ca (mg/l)	90.6	9.6	15.4	33.6
Fe (mg/l)	< 0.1	0.158	< 0.1	0.159
Mg (mg/l)	12.7	7.33	4.23	5.95
Mn (mg/l)	0.388	0.0574	0.195	0.174
K (mg/l)	1.93	1.86	1.02	< 1.0
Na (mg/l)	29.4	29.6	23.4	15.5
HCO <sub>3</sub> (mg/l)	291	47.8	56.5	Na
Cl (mg/l)	47.4	49.2	42.8	Na
SO <sub>4</sub> (mg/l)	17.2	< 5.0	< 5.0	Na
pH	7.39	9.46	8.56	7.06
E <sub>h</sub> (mV)	261	-459	-156	-16.5

from the sample nearest the upgradient interface, rapidly declines with distance with values of less than 1% beyond a distance of 15 cm.

The carbonate content present in the core samples and the changes in bicarbonate alkalinity observed in monitoring well samples were used to develop independent estimates of the mass of carbonate deposited in the iron zone over a 2-year period. The latter estimate is dependent on the assumed flow rate of groundwater passing through the treatment zone. At a flow velocity of 0.2 m/day, and a porosity of about 0.5 for the iron, about 76 m<sup>3</sup> (76,000 l) of groundwater passed through a 1 m<sup>2</sup> cross-sectional area of the gate prior to coring. The average decline in calcium concentration between wells in the upgradient iron zone and wells at the midpoint of the iron zone was about 80 mg/l. Using these data, about 15 kg of calcium carbonate would have been deposited in this 1 m<sup>2</sup> × 0.46 m long section of iron. The mass of carbonate estimated from core samples, obtained by approximating the area under the curve shown in Fig. 4, is about 15 kg. The agreement between these two values is remarkable, given the uncertainties involved in calculating each estimate.

Raman spectroscopy, SEM, and to a lesser extent EDX, confirmed the results of carbonate analyses. Examination of samples near the upgradient interface showed significant amounts of calcite and aragonite. Samples from sections of cores further downgradient showed less carbonate precipitates. Several randomly distributed iron oxides and oxyhydroxides were also detected. Calcite and aragonite were the predominant carbonate species observed, with only minor amounts of siderite (FeCO<sub>3</sub>). Green rusts, complex iron hydroxides containing both chloride, sulphate, and carbonate were observed on a few samples. No sulphide precipitates were observed in the core samples.

The precipitates did not appear to significantly affect system performance. Hydraulic conductivity measurements of core samples approached that of 'fresh' iron, and velocity measurements showed no trend upwards or downwards. Removal of VOCs was also consistent over the monitoring period, indicating no significant effects of precipitation on iron reactivity.

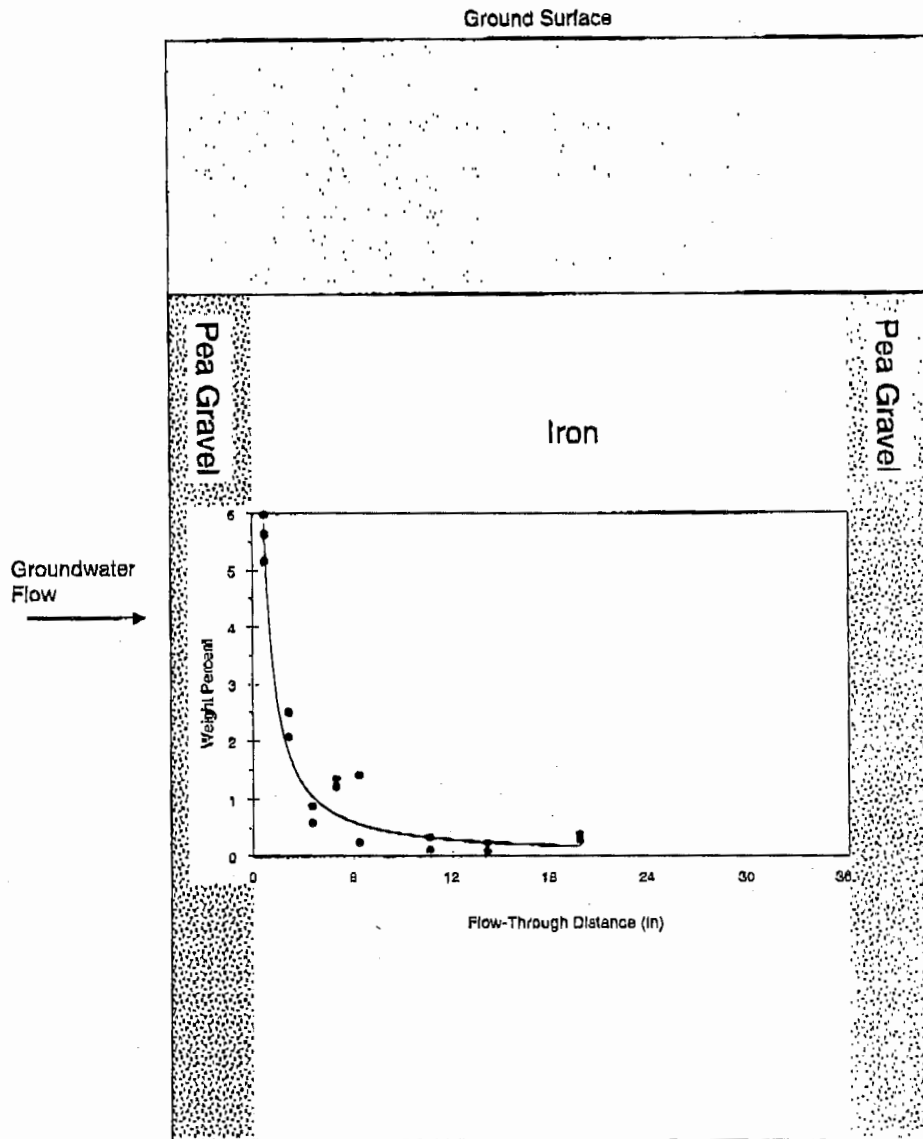


Fig. 4. Calcium carbonate equivalent, New York.

#### 3.4. Microbial activity

Data on microbial biomass and composition was obtained from groundwater samples collected in the iron zone, in upgradient and downgradient pea gravel zones, and in upgradient and downgradient aquifer monitoring wells for a 6-month period following

construction. The microbial populations in the groundwater samples from upgradient, iron and background zones appeared to be of similar size ( $10^3$  to  $10^4$  cells/g dry weight) and composition. The microbial biomass in the downgradient gravel and aquifer zones were of similar size but different composition explained by the changes in aqueous geochemistry on the downgradient side of the iron zone, including the production of hydrogen gas from the iron that supports the activity of many obligate anaerobic bacteria. The disappearance of sulphate in groundwater samples from the iron zone may indicate the establishment of a sulphate-reducing bacteria in this zone.

Each 5-cm section of the angle core was subjected to microbial analysis. Lipid biomass results from the iron zone core samples were in the order of  $10^6$  cells/g dry weight. Microbial enumerations in both the aerobic and anaerobic cultures developed from the iron zone cores ranged from less than the detection limit to  $10^4$  colony forming units (CFUs)/g wet weight after 28 days of growth [13]. No microbial films were noted on the samples during microscopic examination. The core data supported the lack of microbial growth observed in the groundwater samples from the iron zone.

### 3.5. Implications of pilot-scale performance to full-scale design

Based on the record of pilot-scale performance, the decision was made to proceed with a PRB for full-scale plume remediation at the site. Field-scale half-lives of 4.8, 5.1 and 9.4 h for TCE, cDCE and VC were used in a first order kinetic model to determine the required residence time in the full-scale PRB, together with assumed influent concentrations from recent sampling events and relevant New York state regulatory criteria. The amount of carbonate precipitate (6%) in the upgradient section was calculated to represent a porosity loss of about 10% over 2 years (i.e. a decrease in porosity from about 0.5 to 0.45). Based on this estimate there did not appear to be any need to include design features to remove carbonate precipitates. Periodic (every few years) scarification of the upgradient interface using augering equipment was considered to be a more practical alternative (if required).

The continuous wall configuration was chosen over a funnel-and-gate configuration because of lower construction costs. A continuous wall also minimized the potential for bypass around or beneath the system compared to a funnel-and-gate. The lower velocity through a unit cross-section of a continuous permeable zone, relative to the higher velocity created by funnelling water through a treatment gate, means that the rate of precipitation at the interface should be less in the continuous zone, leading potentially to a longer service life.

Following design, a 0.3-m thick continuous PRB was installed across the entire plume at the facility in December 1997. The pilot-scale PRB was destroyed during full-scale construction.

## 4. Conclusions

The 2-year evaluation of this pilot-scale system provides encouraging data with respect to the long term performance of iron PRBs for VOC remediation, particularly in view of the multi-year records from other sites which have produced similar results



[11,14]. Consistent VOC degradation was observed over the 2-year period. Microbial populations did not increase in the iron zone relative to the aquifer, and while mineral precipitates formed in the iron zone, they did not appear to represent an insurmountable limitation to the technology. One difficulty identified during the evaluation was that of accurately measuring groundwater velocity through a PRB; in-well meters may provide a reasonable means of measurement for minimal cost.

### Acknowledgements

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**For Presentation at the Air & Waste Management Association's 90th Annual Meeting & Exhibition, June 8-13, 1997, Toronto, Ontario, Canada**

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## **The Results of a Zero Valence Metal Reactive Wall Demonstration at Lowry AFB, Colorado**

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**Brian Myller**

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### **Abstract**

The Air Force Base Conversion Agency (AFBCA), in association with the Air Force Center for Environmental Excellence (AFCEE), hosted an innovative technology demonstration for implementation at Lowry AFB. Versar, Inc., Dames & Moore Group and EnviroMetal Technologies Inc. designed, constructed and monitored the treatment cell. The system was constructed in December 1995 and the monitoring results through June 1996 as well as the conclusions of the demonstration will be presented.

A 10-foot wide reactive iron section flanked by 14-foot-long sheet piling wing walls formed the funnel and gate system. Total influent concentrations of 1,400 µg/L consist of dissolved chlorinated compounds. The highest concentrations (1,000 µg/L) are as trichloroethene. The extensive use of monitoring wells gives an accurate picture of the physical and chemical conditions throughout the cell and provides definition of the processes that are causing the degradation of the chlorinated compounds. The parameters being measured in addition to the chlorinated compounds include Eh, pH, alkalinity, DO, conductivity, and turbidity. General anions, cations, methane, ethene, and ethane were also analyzed on a periodic schedule in a selected number of wells. Results during the six month period indicate complete degradation of the CAH's within the first several feet of entering the wall. A detailed analysis of the results will be presented.

### **Introduction**

This report describes the process, design, construction, and performance of a passive in-situ reactive wall installed at Lowry Air Force Base (LAFB) in Denver, Colorado. The purpose of this project is to demonstrate the applicability of iron reactive walls for groundwater remediation at United States Air Force (USAF) facilities. Funding for the project was provided by the Technology Transfer Division of the USAF Center for Environmental Excellence (AFCEE).

### **Process**

This section presents background information about the reactive-iron treatment process, including previous studies, chemical reactions, and other applications.

## Previous Studies

Iron reactive-wall technology relies on the ability of certain metals to degrade certain dissolved chlorinated organic compounds to non-toxic breakdown products. This process was documented in the early 1970s (Sweeny, 1973a) in patents which involved the use of metals to degrade certain pesticides. Researchers in Japan (Senzaki and Kumagi, 1988 and 1989; and Senzaki, 1991) also documented this process when they noted the degradation of tetrachloroethane and trichloroethene (TCE) in aqueous solutions exposed to iron powder. In 1990, researchers at the University of Waterloo (UW) Center for Groundwater Research in Ontario, Canada, observed this process during studies on the uptake of various compounds on various well casing materials (Gillham and O'Hannesin, 1991). These studies showed that concentrations of several chlorinated organic compounds decreased in the presence of mild steel and galvanized metal.

Following these observations, UW initiated research efforts to further evaluate the metal-enhanced degradation process and its capabilities. These research efforts involved a series of batch tests which showed that iron was relatively inexpensive and effective at degrading 14 chlorinated compounds, which include the most prevalent pollutants found in groundwater. This led to a series of column experiments wherein aqueous solutions of various chlorinated hydrocarbons were pumped through iron grindings. These experiments revealed that the degradation of chlorinated hydrocarbons could be effectively accomplished under dynamic flow conditions (Gillham et. al, 1993).

UW then emplaced iron grindings in a subsurface cell that intercepts and degrades TCE in groundwater (O'Hannesin and Gillham, 1992). The success of this first in situ permeable reactive wall led to several other successful installations, and, in turn, to this AFCEE demonstration at LAFB. Metal-enhanced degradation technology has also been successfully applied in the form of above-ground treatment canisters.

## Chemical Reactions

Several observations noted during this and previous studies provide insight regarding the metal-enhanced degradation reaction. These observations are listed below:

- Rates of degradation tend to increase as the degree of halogenation increases.
- Rates of degradation tend to increase as the surface area of iron increases.
- Eh declines significantly during degradation.
- pH generally increases from roughly 7 to about 9.5 during degradation.
- Intermediate breakdown products, which are produced in relatively small proportions, are also degraded.
- Rates of degradation are exponential.
- Bactericides do not significantly affect degradation rates.

These observations suggest that the chemical mechanism is first order, abiotic, and involves reductive dehalogenation, where:

- the iron oxidizes:  $2\text{Fe}^0 \rightarrow 2\text{Fe}^{2+} + 4\text{e}^-$
- the water dissociates:  $3\text{H}_2\text{O} \rightarrow 3\text{H}^+ + 3\text{OH}^-$
- hydrogen gas is produced:  $2\text{H} + 2\text{e}^- \rightarrow \text{H}_2$
- reductive dehalogenation occurs:  $\text{X} - \text{Cl} + \text{H}^+ + 2\text{e}^- \rightarrow \text{X} - \text{H} + \text{Cl}^-$

Collectively, this gives:



If dissociation of water is not a part of the degradation, the reaction can be written:



### Geologic Setting

The shallow geologic material beneath LAFB consists of a horizontal sequence of sedimentary units. The uppermost stratigraphic unit at LAFB consists of unconsolidated Quaternary alluvial deposits of the Piney Creek Alluvium. The thickness of these deposits ranges from less than 1 foot to over 60 feet (ft) (PES, 1995a). The Piney Creek Alluvium is composed primarily of heterogeneous and generally discontinuous sands, silts, and clays. Along the quarter mile of Westerly Creek downstream from the outfall source area, the land surface is covered with fill material up to 13 ft thick. Sand and gravel units are often present at the base of the Piney Creek Alluvium.

Beneath the Piney Creek Alluvium lies the eroded upper surface of the Denver Formation. The Denver Formation is Late Cretaceous to Paleocene in age and is composed primarily of silty claystone and sandy siltstone with thin discontinuous sand layers.

The Denver Formation is underlain by the Cretaceous Arapahoe Formation. This, and the deeper formations beneath LAFB, are not discussed further because they are too deep to have an effect on, or be effected by, the reactive treatment wall.

### Outfall Source Area Hydrology

The saturated thickness within alluvial material varies across the Outfall Source Area. The saturated thickness of the alluvium near Westerly Creek ranges from 2.5 to 16 ft while the saturated thickness in the northern portion of the site ranges from 2 to 8 ft. Water samples obtained at depths of over 10 ft below the inferred bedrock surface indicate that the upper portion of bedrock can also be saturated (PES, 1995b).

### Outfall Source Area Groundwater Chemistry

The highest observed detections of TCE occur adjacent to Westerly Creek in the vicinity of the storm-drain outfalls north of 6th Avenue. The highest concentration (107,925  $\mu\text{g}/\text{L}$  from sample CP-100) was observed immediately downstream of the outfall area in the lower portion of the alluvial aquifer. Samples from several other CPT locations adjacent to Westerly Creek and up to approximately 500 ft downstream (north) of the Outfall Source Area yielded TCE concentrations in excess of 10,000  $\mu\text{g}/\text{L}$ . These samples were also collected from the lower portion of the alluvial aquifer.

Bench-scale studies were performed to assess the ability of the permeable reactive media to degrade the contamination present in groundwater collected from the Outfall Source Area.

To summarize, the contaminant hydrogeology at the Outfall Source Area at LAFB offered the following conditions suitable for the demonstration:

- groundwater contaminated by halogenated organics
- contamination distributed at shallow depths
- relatively consistent groundwater flow patterns
- groundwater flow velocities sufficient to allow performance monitoring within a reasonable time-frame
- a low-permeability layer (Denver Formation) underlying the alluvial aquifer
- unconsolidated aquifer material (facilitating construction).

### **Residence-Time Calculations**

In order to assess the residence time needed for the reactive wall, the maximum detected TCE concentration (1,260  $\mu\text{g/L}$ ) was used as the influent concentration. Based on the results of bench-scale tests and other studies, a reactive section consisting of 100 percent iron was determined to provide the maximum rate of VOC degradation, while minimizing the required size and cost of the treatment cell.

The residence times needed to treat the identified constituents to maximum contaminant levels (MCLs) are presented in Table 1.0. The values were calculated using the above influent concentrations and half-lives measured in the bench-scale studies. Measured half-lives were increased by 2 and 3 times (2x and 3x) on Table 1.0 to account for declines in degradation rates due to field effects (mainly lower groundwater temperatures). These factors are based on results from other field tests. Because a half-life for VC could not be reliably determined during the bench-scale studies, a representative half-life for VC based on other studies conducted with groundwater exhibiting similar chemistry is used. Based upon this data and other assumptions a resident time of two days was selected for the design.

### **Reactive Wall Construction**

Construction of the reactive wall began November 16, 1995 and took approximately one month to construct. The reactive wall consisted of a 10-ft reactive wall section flanked by two 14-ft long wing walls.

### **Performance-Monitoring System**

The performance-monitoring system was designed to provide information regarding the groundwater-flow patterns and velocities, and chemical processes within and around the wall. This information was obtained using a monitoring-well network consisting of 34 wells. The locations of the wells were based on the results from the detailed subsurface characterization, the numerical model, and the residence-time calculations.

## Performance Evaluation

The performance of the reactive wall is evidenced by the distribution of physical and chemical parameters within and around the wall, and by variances in this distribution over time. The physical parameters evaluated include hydraulic conductivity and hydraulic potential. The chemical parameters evaluated include field parameters (pH, Eh, conductivity, temperature, alkalinity, and turbidity), laboratory-analyzed constituents (dissolved ethenes and ethanes, ethene and ethane gas, other organics, cations, and anions) and tracer-related analytes (bromide, potassium, and sodium). These parameters were measured within and around the wall during seven monthly sampling events.

### Field Parameters

Field parameter data, as well as all other chemical data, were collected during seven groundwater sampling events completed monthly from December 1995 through June 1996. The concentration-versus-distance graphs show the longitudinal distribution of chemical parameters along various laterally and vertically positioned cross sections within the wall. While individual concentration-versus-distance graphs reveal the distribution of chemical parameters in the longitudinal dimension, comparisons with other concentration-versus-distance graphs are used to assess chemical distributions in the lateral, vertical, and temporal dimensions.

With the exception of alkalinity, the field parameter data were collected within a closed system (YSI 6000®) involving a flow-through cell that contained the various parameter probes. Alkalinity was measured using a Hach® titration kit. The values represent conditions measured after purging the wells.

### Temperature, Oxidation-Reduction Potential, and pH

Figure 1.0 shows the Temperature, ORP, and pH measurements longitudinally through the wall along the center well-row (deep) during March 1996. Note that ORP drops significantly within the first foot of the filter rock and continues to drop within the iron. In contrast, pH rises from roughly 7 to nearly 10 within the iron. Temperature remains relatively consistent within the wall. This distribution is consistent with conditions present at other lateral and vertical locations within the wall.

The increase in pH values and decrease in ORP values with distance in the iron are also consistent with results of the laboratory treatability study and other in-situ reactive-wall installations. The reduction in ORP presumably reflects the oxidation of Fe<sub>0</sub> to ferrous iron; the increase in pH values seems to reflect the production of hydroxide.

### Alkalinity and Dissolved Oxygen

Figure 2.0 and center well-row (deep) shows the concentrations of alkalinity and DO measured longitudinally through the wall during April 1996. Total alkalinity decreases rapidly with distance into the wall; this behavior is consistent laterally and vertically within the wall. In contrast to alkalinity, DO concentrations decrease within the wall. This behavior may reflect seasonal influences on the DO concentrations in the groundwater, although the measured variations are very small with respect to the sensitivity of the measuring probe. This behavior is consistent at other lateral and vertical locations within the wall.

## Conductivity and Turbidity

Figure 3.0 shows the electric conductivity and turbidity measurements obtained longitudinally through the wall along the central well-row (shallow and deep) during April 1996. Electric conductivity and turbidity values drop within the wall. The drop in electrical conductivity likely reflects removal of alkalinity, calcium, etc., from solution.

### Summary of field parameter results:

- ORP drops significantly with distance into the wall, likely reflecting the oxidation of FeO to Fe<sup>+2</sup>
- pH rises with distance into the wall, until approximately 10, likely reflecting the production of OH<sup>-1</sup>
- Total alkalinity is consumed within the wall
- Field parameter conditions are relatively consistent in the lateral dimension within the wall
- With the exception of DO, field parameter conditions are relatively consistent temporally within the wall.

## Dissolved Ethenes

Figure 4.0 shows the longitudinal distribution of detected ethenes during April 1996 along the center well-row (deep). All four detected ethenes, including TCE, degrade to approximately their respective analytical quantitation limits after traveling less than one foot through the iron. Influent concentrations vary temporally as well. For example, incoming concentrations were over 1,000 µg/L in January 1996, but were less than 350 µg/L in June 1996. Again, the degradation behavior appears consistent, despite temporal variations in influent concentrations.

## Dissolved Ethanes

Figure 5.0 shows the longitudinal distribution of detected ethanes during April 1996 along the center well-row (deep). 1,1,1-trichloroethane (1,1,1-TCA) the most prevalent ethane, is degraded rapidly within the first foot of the iron. Concentrations of 1,1-dichloroethane (1,1-DCA), and 1,2-dichloroethane (1,2-DCA), are reduced more slowly. This probably reflects the tendency for less-chlorinated compounds to degrade slower, and/or the production of breakdown intermediates. This degradation behavior is relatively consistent laterally and vertically.

## De-chlorinated End Products

Consistent with the degradation of the ethenes and ethanes would be the production of de-chlorinated end products. Consequently, during the January 1996 sampling event, samples were collected and analyzed for ethene, ethane, and methane. Figure 6.0 shows that these end-products are produced at rates that inversely correlate with the degradation of the chlorinated compounds. Note that methane and a small amount of ethane were present in the upgradient groundwater. This, in addition to the presence of dissolved ethenes and ethanes, may reflect ambient degradation of the source products.

## Other Chlorinated Compounds

Of concern with the de-chlorination of ethanes and ethenes is the production of intermediate chlorinated breakdown products that could pose even greater risk to human health or the environment than the



source constituents. The degradation of VC to near the quantitation limit within the first foot prior to its complete degradation further into the iron. In all cases VC is degraded to the quantitation limit within the first 2 ft of the wall.

## Cations and Anions

Alkalinity, sulfate, and calcium appear to be consumed in the wall, while chloride appears to be produced. Other cations and anions appear to remain relatively unchanged. These conditions are consistent with those measured during the February and April 1996 sample events.

## Assessment

The following three factors assess the performance of the wall:

- groundwater velocity
- VOC degradation rates
- potential porosity losses.

## Groundwater Velocity

The groundwater velocity through the treatment system is the key parameter needed to assess rates of VOC degradation and mineral precipitation. Three independent methods of determining groundwater velocity were used during the course of the project:

- calculation using water elevation data and Darcy's Law
- use of an in-well heat-pulse flow meter
- use of a conservative tracer.

Estimates of groundwater flow velocity ranged from about 0.4 ft/day using in-situ flow meter to 1.4 ft/day (or higher) using the observed water table and estimated hydraulic conductivity values. It is quite likely that the velocity varies at the site in response to both seasonal variations and the water level in Westerly Creek. Given these values, a velocity of about 1 ft/day is used in the following calculations of VOC degradation rates and inorganic precipitation (clogging rates). The implications of this velocity estimate on these calculations is also discussed below.

## VOC Degradation Rates

As shown in graphs contained in the report, TCE and related compounds all declined to below regulatory MCLs within about 2 ft of travel distance in the granular iron zone. This decline was consistent throughout the seven-month monitoring period. Concentrations obtained in month seven were used to calculate first-order degradation rates of major VOCs. Concentrations measured in aquifer wells N1, N2, and N3 upgradient of the system were used as influent concentrations in these calculations. Half-lives were calculated using concentration-versus-distance profiles along each of the three parallel lines of wells in the direction of groundwater flow (i.e., the line of wells N1, R1 and R4, the line of wells N2, R2B, R5B, and R8B, and the line of wells N3, R3, R6, and R7). This is considered appropriate given the lateral variation in TCE concentration indicated in the upgradient wells.

Observed concentration-versus-distance profiles were converted to concentration-versus-time profiles using an estimated velocity of 1 ft/day. VOC half-lives were determined by fitting the first-order kinetic equation to the concentration versus time data. These results are shown in Table 2.0.

Several of the values listed in Table 2.0 were calculated using only two or three points (concentration values), with the last point being the reported detection limit for that compound. The use of a two-point curve (i.e., a straight line) causes a perfect goodness of fit or  $r^2$  value of 1.0 as shown in the table. The use of detection limits, especially coupled with low initial concentrations, causes an artificially high half-life (low degradation rate) to be calculated. In reality, the concentrations at this point are less than the detection limit (i.e., the compound has degraded past the detection limit). This effect is most pronounced in the rate constants calculated for compounds such as PCE and 1,1,1-TCA, but may also influence the half-lives reported for other compounds. Note that if the velocity was indeed higher than 1.4 ft/day, then degradation rates would also increase (i.e., the sample locations at a given distance would be reached in less time).

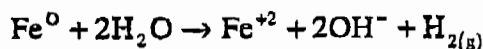
Taking this uncertainty into account, half-lives for TCE, the compound present in the highest concentration, are within the range of previous field values at other sites, and are also within the range of half-lives predicted from the bench-scale studies. As noted, a two- to three-time decrease in laboratory half-lives is normally observed due to the effect of lower groundwater temperatures on reaction rates. Using the half-life of 0.45 hours (hrs) measured in the laboratory, a half-life in the field of 0.9 to 1.35 hrs was predicted. Given these uncertainties, the two-point half-life of 2 hrs calculated using influent concentrations from N1 and N2 is similar to the predicted value. TCE half-lives calculated using data from months 5 and 6 (Table 2.0) suggest that TCE degradation rates were reasonably consistent throughout this time period.

The declines in 1,2-DCA concentrations are inconsistent with previous studies. Consequently, the declines may represent sampling/analytical artifacts rather than true degradation.

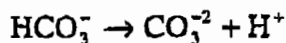
### Potential Porosity Loss

Consistent declines in dissolved calcium, and alkalinity occurred throughout the test period. As shown graphically, most of these declines occurred in the first one foot of reactive material. Potential porosity losses associated with this decline are assessed in this section, using influent geochemical data from well N2, and data from wells R2A and R2B.

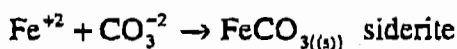
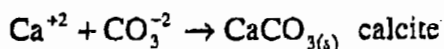
Declines in calcium, alkalinity, and increasing pH indicate that calcium carbonate (calcite), iron carbonate (siderite), and iron hydroxide precipitates were occurring in the iron. These precipitates occur in response to increasing pH due to corrosion of iron:



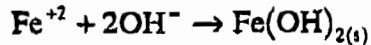
Bicarbonate ions in solution convert to carbonate ions to buffer this pH increase:



The carbonate ion then combines with cations in solution to form mineral precipitates:



More dissolved iron is introduced into solution due to corrosion than can be precipitated as siderite. As the pH increases, precipitation of iron hydroxide occurs.



### Summary of Potential Precipitation Effects

In summary, porosity losses in the reactive material could theoretically amount to about 13 to 14 percent of the original porosity per year, at least in the first year, based on field measurements to date of carbonate and hydroxide precipitate formation. This means a decrease in porosity from 0.4 to about 0.35. The values assume the concurrent precipitation of carbonate minerals and either magnetite or iron hydroxides. This rate of porosity loss may well decrease over time due to varying (decreasing) iron corrosion rates, and could also vary depending on temporal changes in the influent groundwater geochemistry and groundwater velocity.

### Cost Comparison

This section compares the costs for the demonstration reactive wall at LAFB with estimates of costs for other technologies. A comparison is also provided based on a fictitious full-scale application so that influences of scale on cost effectiveness can also be assessed.

### Demonstration Scale

The demonstration-scale cost comparison compares the costs for the performance obtained by the demonstration wall with estimates of the performance obtainable using pump-and-treat and air-sparging technologies. Pump-and-treat and air-sparge technologies were selected for this comparison because they represent, in lieu of the reactive wall, the most feasible conventional technologies for the site. To develop this comparison, designs for pump-and-treat and air-sparge systems were developed based on treating the same aquifer and chemistry that the reactive wall is treating. The following assumptions were made for these comparisons:

- Design engineering costs for all three technologies are assumed to be equal.
- Sampling and analysis costs for each technology are assumed to be equal, with the exception of air sparging, which includes the addition of air samples to the monitoring program. Costs for air sampling and analysis are included as operations and maintenance (O&M) costs with the air-sparging technology.
- A conservative refurbishing effort, involving the replacement of iron every 5 years, was incorporated into the reactive wall O&M costs.

To summarize, the cost comparisons are based on capital plus O&M costs.

Figure 7.0 shows the cumulative cost over time associated with each of the technologies as applied to the Lowry Reactive Wall. The costs represented during year one include the up-front capital costs; the remaining years reflect the O&M costs. A seven percent inflation rate is assumed. The point where the cumulative costs for the reactive wall become less than the cumulative costs associated with pump-and-treat and air sparge technologies occurs at 8 and 5 years, respectively.

## Full Scale

Figure 8.0 shows the cumulative cost over time associated with each of the technologies as applied to a fictitious full-scale application.

This full-scale application involves the following assumptions:

- Aquifer has 5,000 µg/L influent concentration (average) of TCE
- Capture width of plume is 500 ft
- Saturated thickness (also plume-capture height) is 15 ft
- Depth to water is 10 ft
- Hydraulic conductivity is 32 ft/day
- Hydraulic gradient is 0.03 ft/ft
- Porosity is 0.03
- Refurbishing effort involving replacement of iron is incorporated every 5 years
- Reactive wall is constructed using a continuous iron reactive section rather than a funnel-and-gate approach; the iron is excavated and emplaced using a single-pass trenching technique.

For the full-scale application, the point where the cumulative costs for the reactive wall become less than the cumulative costs associated with pump-and-treat and air-sparging technologies occurs at approximately 5 and 8 years, respectively.

## References

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2. Gillham, R.W., O'Hannesin, S.F., and Orth, S.W., 1993. Metal Enhanced Abiotic Degradation of Halogenated Aliphatics: Laboratory Tests and Field Trials. Presented at the 1993 HazMat Central Conference, Chicago, Illinois, March 9-11.
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5. **Parsons Engineering-Science, Inc. (PES). 1995b. US Air Force Environmental Restoration Program, Installation Restoration Program, Characterization of the Source and Extent of Trichloroethene and Related Compounds in Groundwater at the Fly Ash Disposal Area, Addendum to the Characterization Summary Informal Technical Information Report Landfill Zone, Fire Training Zone, Fly Ash Disposal Area. Volume I. Lowry Air Force Base, Colorado. March.**
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7. **Senzaki, T. and Y. Kumagai, 1989. Removal of organochloro compounds by reduction treatment (the second report) - treatment of trichloroethylene with iron powder. Kogyo Yosui 369, 19-24 (Japanese).**
8. **Sweeny, K.H., 1973a. Decomposition of halogenated organic compounds using metallic couples. United States Patent No. 3,737,384.**
9. **Versar, 1996b. Draft Final Source Area Remediation Implementation Plan. Prepared for US Air Force Environmental Restoration Program. December.**

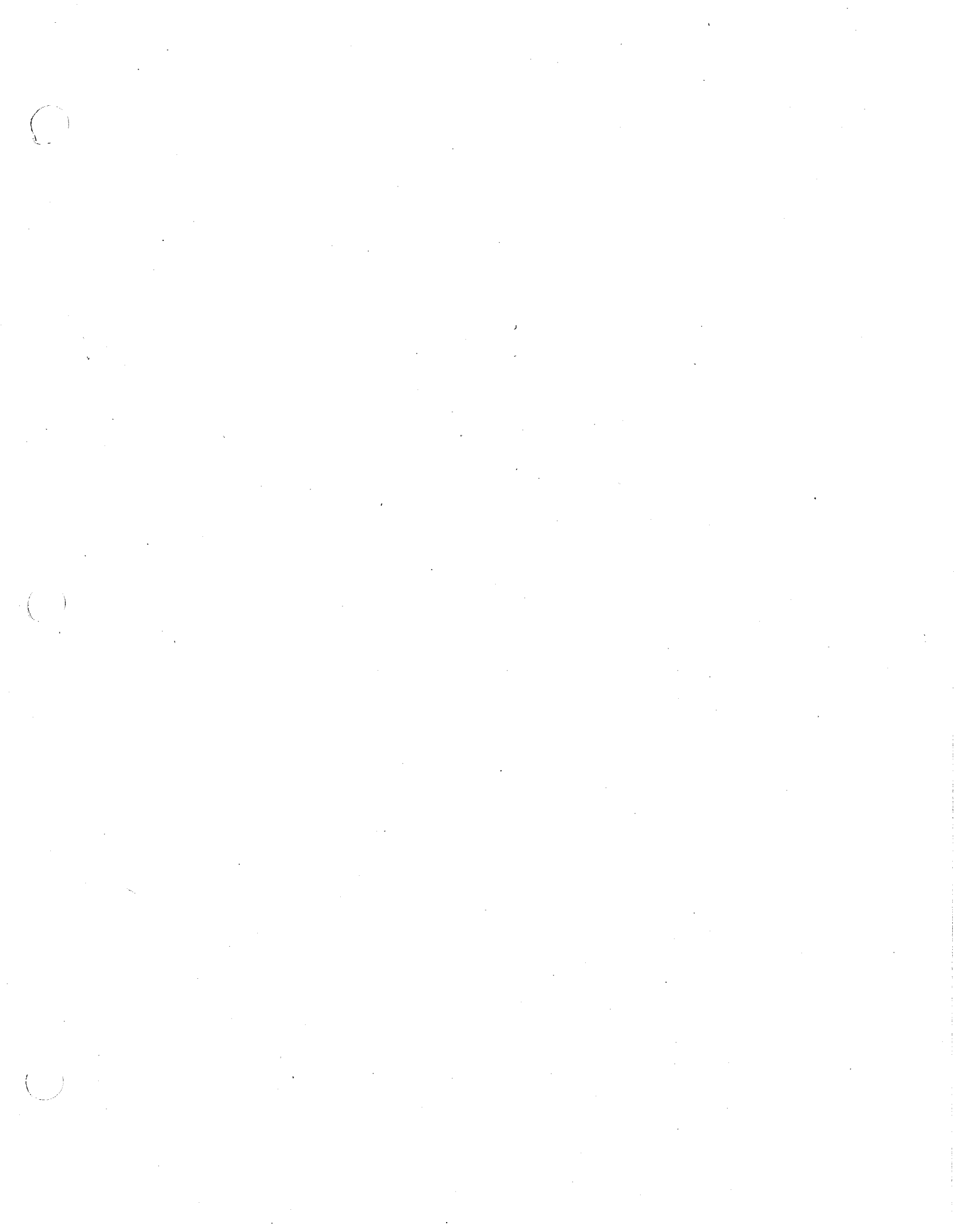
**Table 1.0. Required residence times for the in-situ pilot-scale treatment system.**

<b>Volatile Organic Compound</b>	<b>Estimated VOC Concentration Requiring Treatment (µg/L)</b>	<b>MCL (µg/L)</b>	<b>Half-Life (Hours)</b>	<b>Required Residence Time (Hours)</b>
TCE	1,260	5	0.45	3.6
			(2x) 0.9	7.2
			(3x) 1.35	10.8
cis-1,2-DCE	338	70	2.2	5.0
			(2x) 4.4	10.0
			(3x) 6.6	15.0
VC	65.5	2	3	15.1
			(2x) 6	30.2
			(3x) 9	45.3

**Table 2.0** Calculated trichloroethene and cis-1,2-dichloroethene half-lives.

Volatile Organic Compound	Laboratory Half-Life (hr)	Initial Conc. ( $\mu\text{g/L}$ )	Half-Life (hr)	$r^2$
<b>Month 5 Measurements</b>				
cDCE	2.20	208	4.79	0.97
		162	2.48	1.0
		162	9.38	.87
		190	8.43	.95
TCE	0.45	654	2.06	1.0
		613	2.07	1.0
		613	2.07	1.0
		754	4.04	1.0
<b>Month 6 Measurements</b>				
cDCE	2.20	177	4.90	0.95
		121	2.6	1.0
		121	9.49	1.0
		141	9.29	0.98
TCE	0.45	677	2.05	1.0
		531	2.11	1.0
		531	2.11	1.0
		625	4.13	1.0
<b>Month 7 Measurements</b>				
cDCE	2.20	192	4.85	1.00
		114	2.62	1.00
		114	9.52	0.98
		112	9.26	1.00
TCE	0.45	603	2.08	1.00
		393	2.19	1.00
		393	2.19	1.00
		314	4.52	0.89

\* value measured at this well was at detection limit







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Re: 31317.77

Pages: 1 of 12

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Anna,

Attached is the memo on hole-lives + a recent paper  
on lab test results.

Andrzej Przepiora

Original To Follow: Mail  Courier  No

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This transmission contains information that may contain confidential and/or legally privileged. It is intended for use only by the person to whom it is directed. If you have received this in error, please notify us by telephone immediately. Thank you.



**To:** Anna Fodor, Jackie Travers, Parsons Engineering Science, Fax: 781-401-2575

**From:** John Vogan, Andrzej Przepiora, EnviroMetal Technologies Inc.

**Date:** 24 March 200

**Re:** **Selection of the TCE and cDCE Half-Life Values Used in Residence Time Calculations for the Ash Landfill Site – 31317.88**

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Further to your request, ETI has provided below the rationale for the selection of VOC half-life values that were used in residence time determination for the iron permeable wall at the Ash Landfill Site (the site).

ETI memorandum of 29 October 1998 contained residence time requirements obtained based on VOC concentrations detected in five groundwater wells at the site and MCL cleanup targets (Table 1). Half-lives of 3 hrs for TCE and 6 hrs for cDCE and VC were used for the calculations (Table 1).

A laboratory test using the site groundwater was not conducted for the site. Instead, ETI database was used to obtain VOC half-life values expected at the site groundwater conditions. At the end of 1998, ETI database contained results from over 100 bench-scale column test in which different sources of iron and a wide variety of site groundwater were used. The decision to use the database-derived half-lives at the site was based on relatively low total VOC concentrations and typical values of inorganic parameters found at the site.

Table 2 lists the TCE and cDCE half-lives obtained from three bench-scale column test conducted with Peerless iron (the iron source used at the site) in which site groundwaters had VOC composition and concentrations and geochemical parameters similar to the contaminated groundwater at the site. Half-lives obtained from numerous other tests with other iron sources have produced similar results. Laboratory half-lives established at room

temperature (23° C) must be adjusted to the field groundwater temperature. Previous laboratory and field experience has shown that bench-scale half-lives should be increased to account for field effects including temperature. For example, if it is assumed that the operating (groundwater) temperature will not fall substantially below 10° C, it is reasonable to increase the effective half-lives by a factor of two. Note that even after the field adjustment is applied to the laboratory half-lives listed in Table 2, the values of 3 hrs for TCE and 6 hrs for cDCE appear conservative.

Field monitoring results from iron permeable barrier installations indicate that the VOC half-values detected in the field conditions correspond well to the adjusted half-lives obtained from bench scale tests. For example, half-lives calculated from the VOC monitoring of an iron permeable barrier installed in New York in 1995 ranged from 3 to 5 hrs for cDCE and were less than 4 hrs for TCE (Vogan et al., 1999). Half-lives determined based on field monitoring data from the iron reactive wall at Lowry AFB, CO ranged from 2 to 4 hrs for TCE and from 2.5 to 9.5 hrs for cDCE (Gallant and Myller, 1997). The field data would seem to support the TCE and cDCE half-lives used in the site design.

Recent research papers provide a summary of laboratory first-order degradation rates for granular iron materials (e.g. Tratnyek et al., 1998). The reported half-lives for chlorinated ethenes ranged from few minutes to several hours, depending on the source of iron and geochemical conditions of the groundwater, with half-life values of 0.5 hr (30 min.) and 4.8 hrs (290 min.) considered as representative for TCE and cDCE, respectively (Tratnyek et al., 1998). Note that most of the published laboratory data is based on column and batch experiments conducted with laboratory grade iron material which has different characteristics (i.e. surface area, size distribution) than commercial iron sources used in field installations. Data collected in ETI's laboratory database are from column tests conducted with commercial iron sources only, but the contained results are similar to these values.

If you have any questions regarding this memorandum, please contact us.

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**Table 1: Residence Time Requirements, Ash Landfill (From ETI memorandum of 29 October 1998)**

VOC	MCL (µg/L)	Half Lives (hr)	Well Location and Concentration						
			PT17		MW-28	MW-53	PT-24	MW-29	MW-27
TCE	5	3	260	190	35	4	7	5	nd
CDCE	5	6	53	17	53	51	140	150	nd
VC	2	6	14	--	--	--	--	--	nd
RT (hrs)			30	25	23	21	29	30	--
RT (days)			1.25	1.04	0.96	0.88	1.21	1.25	--

**Table 2: Range of TCE and cDCE half-lives obtained from bench-scale column tests (23° C) using site waters with total VOC concentration <1,000 µg/L and low (<1,000 mg/L) TDS levels (ETI Database).**

Iron Type	Laboratory TCE Half-life (hrs)					Laboratory cDCE Half-life (hrs)				
	No. tests	Mean	Min.	Max.	Std. dev	No. tests	Mean	Min.	Max.	Std. dev
Peerless	3	0.28	0.18	0.37	0.1	3	1.0	0.28	2.4	1.2

# Remediating Ground Water with Zero-Valent Metals: Chemical Considerations in Barrier Design

by Paul G. Tratnyek, Timothy L. Johnson, Michelle M. Scherer, and Gerald R. Eykholt

## Abstract

To gain perspective and insight into the performance of permeable reactive barriers containing granular iron metal, it is useful to compare the degradation kinetics of individual chlorinated solvents over a range of operating conditions. Pseudo first-order disappearance rate constants normalized to iron surface area concentration ( $k_{SA}$ ) recently have been reported for this purpose. This paper presents the results of further exploratory data analysis showing the extent to which variation in  $k_{SA}$  is due to initial halocarbon concentration, iron type, and other factors. To aid in preliminary design calculations, representative values of  $k_{SA}$  and a reactive transport model have been used to calculate the minimum barrier width needed for different ground water flow velocities and degrees of halocarbon conversion. Complete dechlorination of all degradation intermediates requires a wider treatment zone, but the effect is not simply additive because degradation occurs by sequential and parallel reaction pathways.

## Introduction

During the last several years, a great deal of progress has been made toward understanding the design and performance of in situ permeable treatment barriers using zero-valent metals (Gillham 1996; Tratnyek 1996). Much of this progress has come from laboratory experiments with halogenated aliphatic compounds and granular iron in well-mixed bottles or in homogeneously packed columns (recent examples include Orth and Gillham 1996; Roberts et al. 1996; Allen-King et al. 1997; Johnson et al. 1997). Kinetic data from these types of experiments are now quite abundant, and represent a wide range of experimental conditions. We recently reported a statistical analysis of the available data that identifies the factors that contribute most to variability in observed contaminant degradation rates (Johnson et al. 1996). The results show that most of the range in first-order disappearance rate constants is due to differences in the reactivity of individual chemical contaminants and the amount of reactive surface area on the iron particles. By using surface area normalized rate constants, it is possible to make generalizations about degradation rates by iron metal that apply over a wide range of laboratory conditions (Johnson et al. 1996). In this paper, we consider the effects of additional experimental variables and apply representative rate constants to a reactive transport model for degradation of contaminants by an in situ permeable treatment barrier.

## Surface Area Normalized Disappearance Kinetics

The most successful kinetic models for environmental degradation reactions are usually second order overall: first order in concentration of the substrate, P, and first order in concentration of each specific environmental reactant (Hoigné 1990). The parameters in this formulation are sufficiently general to be site independent, and yet are specific enough to be derived from available data. For degradation of a contaminant by a zero-valent metal, such a model can be written as

$$-\frac{d[P]}{dt} = k_{SA} \rho_a [P] \quad (1)$$

where  $k_{SA}$  is the specific reaction rate constant ( $L \text{ hr}^{-1} \text{ m}^{-2}$ );  $\rho_a$  is the concentration of iron surface area ( $\text{m}^2 \text{ L}^{-1}$  of solution); and P represents the reacting halocarbon (Johnson et al. 1996). In a particular system where  $\rho_a$  is known and constant,  $k_{SA}$  can be derived from  $k_{obs} = k_{SA} \rho_a$ , where  $k_{obs}$  is the observed pseudo first-order disappearance rate constant for P.

Values of  $k_{SA}$  recently have been compiled from all published data on the degradation of halogenated alkanes and alkenes in batch and column systems containing zero-valent iron (Johnson et al. 1996). The individual data (open circles in Figure 1) show that variability in reported values of  $k_{SA}$  for each individual halocarbon averages about one order of magnitude. The reasons for this variability have been discussed previously (Johnson et al. 1996), and are further elaborated below. It is important to note, however, that variability in  $k_{SA}$  for individual compounds is modest relative to the five orders of magnitude variability between the various halocarbons.

## Processes Contributing to Degradation

The kinetic model represented by Equation 1 is formulated to reflect only a single pathway of contaminant transformation. However, it now appears that the degradation of halocarbons by iron metal can be due to a variety of degradation pathways (Roberts et al. 1996). The various possibilities can be accommodated by expanding  $k_{SA}$  into the sum of rate constants for each individual degradation pathway. Thus, we can write

$$k_{SA} = k_{et} + k_{re} + k_{other} \quad (2)$$

where  $k_{et}$  represents hydrogenolysis by single electron transfer (Matheson and Tratnyek 1994);  $k_{re}$  represents reductive elimination by two electron transfer (Roberts et al. 1996); and  $k_{other}$  is included to accommodate other possibilities whose importance remains to be demonstrated (such as hydrogen atom transfer). The model (Figure 2) assumes that the rate of degradation is controlled by chemical reaction rather than adsorption (Burris et al. 1995; Allen-King et al. 1997; Campbell et al. 1997) or mass transport across the stagnant bound-

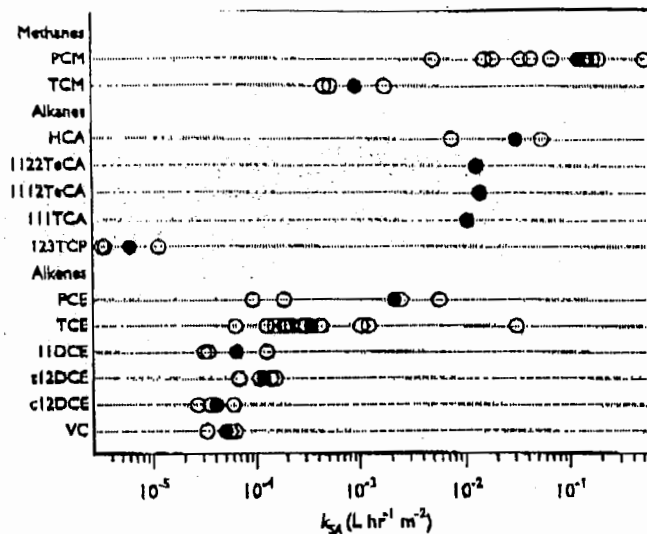


Figure 1. Representative values of  $k_{SA}$  (solid circles) for common chlorinated solvents, superimposed on the individual  $k_{SA}$  data from which the average values were derived (open circles). Batch-, regression-, and column-derived data are included. Representative data can be found in Table 1 and Johnson et al. 1996.

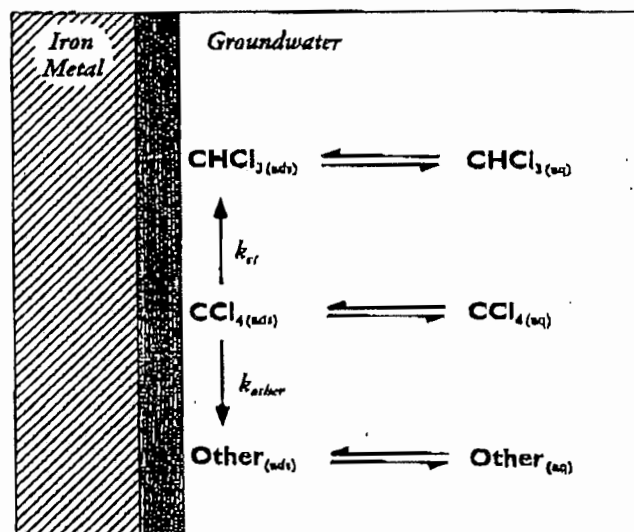


Figure 2. Conceptual model of parallel transformation processes that contribute to  $k_{SA}$  for reduction of a halocarbon at the surface of iron metal in aqueous systems. Rate constants reflect those defined in Equation 2. Reversible arrows indicate adsorption/desorption. The reductive elimination pathway is not shown.

ary layer (Scherer et al. 1997). Although experimental data are not yet available to quantify each of the terms in Equation 2 independently, the formulation does provide qualitative insight into degradation reactions occurring at the metal surface. For example, the relative contributions of the terms comprising  $k_{SA}$  will not only vary from compound to compound, but are also likely to be affected in compound-specific ways by experimental variables such as pH and precipitation of oxides, carbonates, or sulfides.

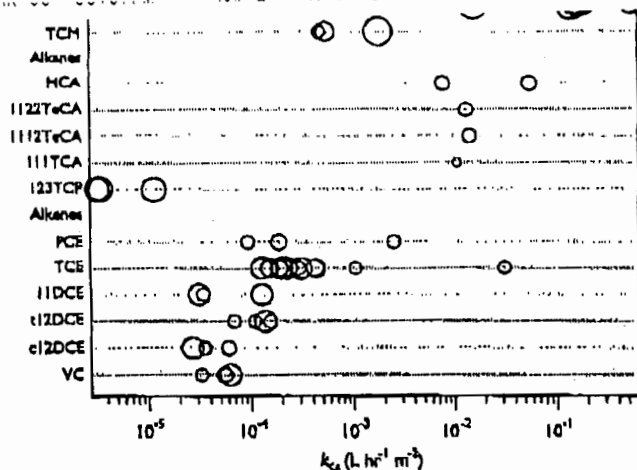


Figure 3. Effect of initial substrate concentration (represented by dot size) on the distribution of  $k_{SA}$  data for common chlorinated solvents. Individual points are the same as those represented as open circles in Figure 1.

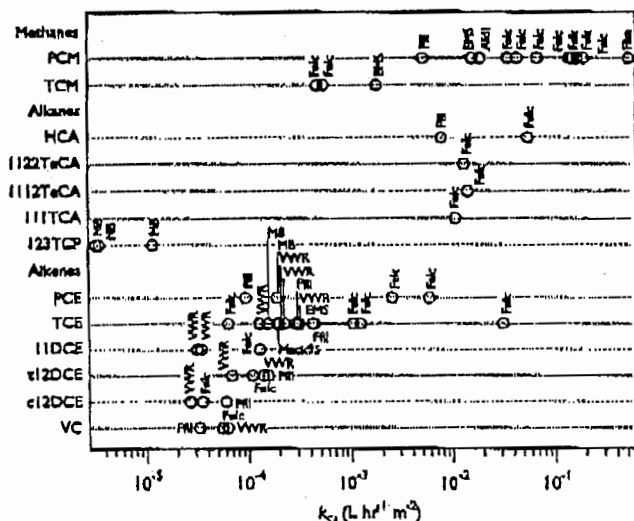


Figure 4. Effect of iron type (labels) used in degradation studies on the distribution of  $k_{SA}$  data for the major chlorinated solvents. Felc=Fisher electrolytic; Ffil=Fisher filings. Other label abbreviations can be found in Johnson et al. 1996.

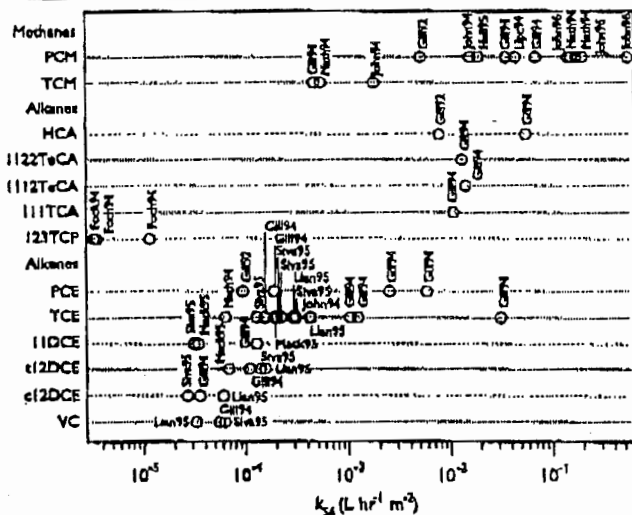


Figure 5. Effect of literature source (labels) on the distribution of  $k_{SA}$  data for the major chlorinated solvents. Labels abbreviate first author and year for the  $k_{SA}$  data found in the supporting material to Johnson et al. 1996.

## Kinetics

In addition to the primary effects of substrate and metal surface area (Equation 1), several other factors influence the kinetics of halocarbon degradation by iron. One factor that can be quantified using currently available data is the saturation of reactive surface area with increasing substrate concentration. When initial substrate concentration is increased up to 2.0 mM, under otherwise constant conditions, data from batch experiments exhibit the classical behavior of site-limited reaction kinetics (Scherer and Tratnyek 1995; Johnson et al. 1996; Johnson et al. 1997). A similar effect has been reported for degradation of PCE on zinc (Arnold and Roberts 1997). Despite this, the effect of initial substrate concentration is not discernible in the collective set of currently reported kinetic data (Figure 3). This suggests that a single value of  $k_{SA}$  should be adequate over the range of chlorinated solvent concentrations commonly encountered in ground water, although a more complex kinetic model may be necessary to accommodate highly contaminated water or laboratory systems containing small quantities of metal.

Metal "type" is the variable that is most commonly invoked to rationalize otherwise unexplained variability in degradation rates by iron. The  $\rho_s$  term in Equation 1 characterizes quantity of iron surface area, but does not address differences in the reactivity of the surface. Formally, the density of reactive sites can be factored out of  $\rho_s$  (Johnson et al. 1996), but there is little prospect that this can be done routinely for environmental applications. At present, the best we can do is treat iron type as a category variable and look for qualitative trends in the available data. Figure 4 represents such a comparison, but it does not reveal any trends in  $k_{SA}$ . There may be effects of iron type that eventually will be discerned from controlled experiments designed for this purpose, but Figure 4 suggests that the effect on  $k_{SA}$  is less pronounced than is widely assumed.

Other factors may influence  $k_{SA}$ , but their general significance is difficult to evaluate because detailed studies of each factor are not yet available. Some of these factors are experimental variables that are likely to vary in ways that correlate with the laboratory in which the data were measured (such as buffer formulation, treatment of the iron, and conditions of incubation). However, applying a source identifier as a category variable to the distribution of  $k_{SA}$  (Figure 5) reveals no obvious patterns in the data that can be used to explain the order of magnitude variability in literature values of  $k_{SA}$ . This does not mean that differences in laboratory protocols are not important, but it shows that their effects are modest relative to the range of reactivities exhibited by the different chlorinated solvents.

Since there is no immediate prospect of defining or measuring a more general descriptor than  $k_{SA}$ , we have calculated average values (Johnson et al. 1996) and reported them in Table 1. These rate constants are "typ-



**TABLE 1**  
**Representative Kinetic Data for Dehalogenation by Iron**

Halocarbon	Abbreviation	$k_{SA}^1$ (L m <sup>-2</sup> hr <sup>-1</sup> )	$t_{1/2}$ (min) <sup>2</sup> @ 1 m <sup>2</sup> mL <sup>-1</sup>	$t_{1/2}$ (min) <sup>2</sup> @ 3.5 m <sup>2</sup> mL <sup>-1</sup>
Tetrachloromethane	PCM	$1.2 \times 10^{-1}$	0.35	0.10
Trichloromethane	TCM	$9.2 \times 10^{-4}$	45	13
Tribromomethane	TBM	$1.7 \times 10^{-2}$	2.4	0.70
Hexachloroethane	HCA	$3.1 \times 10^{-2}$	1.3	0.38
1,1,2,2-tetrachloroethane	1122TeCA	$1.3 \times 10^{-2}$	3.2	0.91
1,1,1,2-tetrachloroethane	1112TeCA	$1.4 \times 10^{-2}$	3.0	0.85
1,1,1-trichloroethane	111TCA	$1.1 \times 10^{-2}$	3.8	1.1
1,2,3-trichloropropane	123TCP	$6.1 \times 10^{-6}$	6800	1900
Tetrachloroethene	PCE	$2.1 \times 10^{-3}$	20	5.7
Trichloroethene	TCE	$3.9 \times 10^{-4}$	110	30
1,1-dichloroethene	11DCE	$6.4 \times 10^{-5}$	650	190
trans-1,2-dichloroethene	t12DCE	$1.2 \times 10^{-4}$	350	99
cis-1,2-dichloroethene	c12DCE	$4.1 \times 10^{-5}$	1000	290
Vinyl chloride	VC	$5.0 \times 10^{-5}$	830	240

<sup>1</sup>Originally reported in Johnson et al. 1996.

<sup>2</sup>Derived from tabulated values of  $k_{SA}$ .

ical" in the sense that they reflect the whole range of disappearance rates reported (as of November 1996). As such, they are the best available input parameters for preliminary design calculations. Of course, final designs for a particular site should be based on values of  $k_{SA}$  determined in treatability tests done under site-specific conditions.

### Implications for Barrier Design

One of the most critical issues that must be considered in the design of permeable reactive barriers is selection of an appropriate barrier width (Gavaskar 1997; Suthersan 1997). The barrier width must provide sufficient contact time to ensure that contaminants are degraded to target levels. The necessary contact time is a function of the reactive surface area of the iron; degradation rate constants for the contaminants by iron; reaction pathways that lead to formation and degradation of hazardous reaction products; and the degree of contaminant degradation required to reduce effluent concentrations to regulatory limits. By modeling the net contribution of these four factors, it is possible to derive some quantitative guidelines for the preliminary design of reactive barriers.

Contaminant degradation rates are determined, in part, by first-order rate constants ( $k_{obs}$ ), which are equal to the product of  $k_{SA}$  for the particular contaminant and the surface area of iron per unit pore volume in the treatment zone (i.e.,  $\rho_a$  in Equation 1). While it is convenient to report kinetic data normalized to  $\rho_a = 1 \text{ m}^2 \text{ mL}^{-1}$  (Gillham and O'Hannesin 1994), iron treatment systems are often designed with  $\rho_a$  as high as  $3.5 \text{ m}^2 \text{ mL}^{-1}$ . Half-lives for the reduction of halocarbons by iron metal, calculated using both 3.5 and  $1.0 \text{ m}^2 \text{ mL}^{-1}$  for  $\rho_a$ , are shown in Table 1.

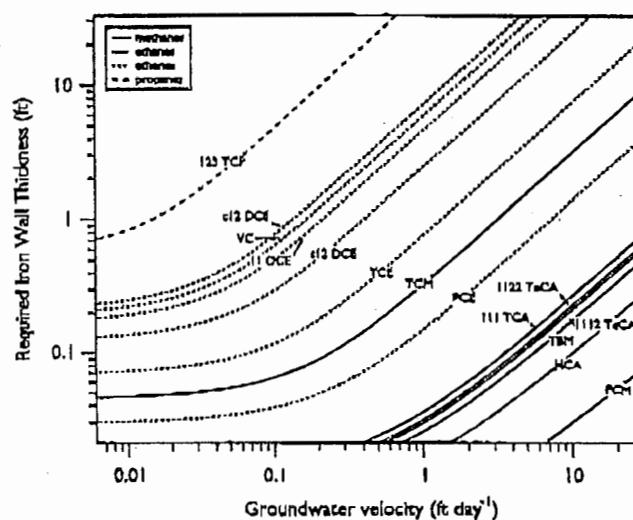


Figure 5. Preliminary barrier width design curves for thousand-fold reduction in parent halocarbon concentration as a function of groundwater velocity ( $v$ ). Curves are based on  $k_{SA}$  values in Table 1; iron surface area  $\rho_a = 1 \text{ m}^2 \text{ mL}^{-1}$ ; dispersion  $D = (0.001 \text{ ft}) \cdot v + (9.3 \times 10^{-4} \text{ ft}^2 \text{ d}^{-1})$ ; and the steady-state reactive transport model discussed in Eykholt and Sivavec 1995. The effects of parallel or sequential first-order reactions and changes in  $k_{SA}$  over time are not represented.

Half-lives for contaminant degradation can be related to contact time in a treatment zone by application of a reactive transport model. The general analytical solution of the advection-dispersion equation (van Genuchten 1981) considers transient, one-dimensional transport of a contaminant in a saturated column with simple boundary conditions, steady flow, Fickian dispersion, linear sorption, first-order degradation, and a zero-order source-sink term. In the following analysis of reactive transport in a permeable barrier, we have included only steady-state transport with first-order degradation

(no sorption and no other sources or sinks), using conservative values for velocity-dependent dispersion (Eykholt and Sivavec 1995). At higher velocities, the model converges to the steady-state solution for first-order reaction with plug flow, but the solution used here deviates substantially from this approximation at lower velocities.

Using this approach, the required width of an iron-bearing treatment zone can be calculated as a function of ground water flow rate for the various chlorinated solvents (Eykholt and Sivavec 1995). Figure 6 shows the calculated wall thickness for a thousandfold decrease in contaminant concentration as a function of ground water flow rate, using representative values of  $k_{SA}$  (Table 1) as input parameters for each halocarbon and assuming  $\rho_a = 1.0 \text{ m}^2 \text{ mL}^{-1}$ . Preliminary design widths ( $W_d$ ) for other degrees of conversion and values of  $\rho_a$  can be calculated with the following scaling relationship:

$$W_d = \frac{(1.0 \text{ m}^2 \text{ mL}^{-1})}{\rho_a} \frac{\log(C_0/C_d)}{3} W_{ref} \quad (3)$$

where  $C_d$  is the desired effluent concentration;  $C_0$  is the input concentration; and  $W_{ref}$  is the reference width obtained from Figure 6. Note that barrier widths are inversely proportional to  $\rho_a$  and to  $k_{SA}$  (reflected in  $W_{ref}$ ). Thus, barrier width must be doubled if treatability tests indicate a  $k_{SA}$  which is half of the corresponding value in Figure 6.

The calculation of an appropriate barrier width is more challenging for reactions involving parallel and sequential first-order reactions, such as the reduction of chlorinated ethenes to ethene (Roberts et al. 1996; Campbell et al. 1997). Where contaminant degradation leads to several possible products, the kinetics can be formulated in terms of branching ratios (i.e., the proportion of a degradation rate constant that goes to formation of each product). Unfortunately, few data are available from which branching ratios can be derived for degradation by zero-valent iron, and little is known about how much these ratios vary with operational conditions. Nevertheless, the simple model described above can be extended to illustrate the effects that parallel and sequential degradation pathways may have on barrier design.

The extended model, and its limitations, are illustrated in the following analysis for TCE and PCE. Good estimates are available for  $k_{SA}$  for TCE and PCE (Table 1). However, few data are available regarding the branching ratios for formation of the various products such as c12DCE, t12DCE, and 11DCE (by hydrogenolysis) and chloroacetylene (by  $\beta$ -elimination). Typically, as TCE degrades, the main chlorinated products are c12DCE and VC (Liang et al. 1997). The compound 11DCE may also be produced, but usually at concentrations an order of magnitude below c12DCE. Chloroacetylene is produced by elimination (Roberts et al. 1996), but it should degrade quickly to acetylene or VC. As ground water standards are usually most stringent for vinyl chloride, the formation and degradation

of this degradation product is particularly important to the design of permeable reactive barriers.

Thus, a simplified system of rate equations can be written for the degradation of PCE in terms of TCE, t12DCE, VC, chloroacetylene,  $f_\beta$  (the branching ratio for  $\beta$ -elimination of TCE to give chloroacetylene), and Ac (the combined concentrations of chloroacetylene and acetylene).

$$-\frac{d[\text{PCE}]}{\rho_a dt} = k_{SA,\text{PCE}}[\text{PCE}] \quad (4)$$

$$-\frac{d[\text{TCE}]}{\rho_a dt} = k_{SA,\text{TCE}}[\text{TCE}] - k_{SA,\text{PCE}}[\text{PCE}] \quad (5)$$

$$-\frac{d[\text{c12DCE}]}{\rho_a dt} = k_{SA,\text{c12DCE}}[\text{c12DCE}] - (1-f_\beta)k_{SA,\text{TCE}}[\text{TCE}] \quad (6)$$

$$-\frac{d[\text{Ac}]}{\rho_a dt} = k_{SA,\text{Ac}}[\text{Ac}] - f_\beta k_{SA,\text{TCE}}[\text{TCE}] \quad (7)$$

$$-\frac{d[\text{VC}]}{\rho_a dt} = k_{SA,\text{VC}}[\text{VC}] - k_{SA,\text{t12DCE}}[\text{t12DCE}] \quad (8)$$

An analytical solution set can be derived for the concentrations of all species in Equations 4 through 8 using Laplace transforms (Walas 1981). The solution can be used to make quantitative estimates of the barrier width necessary to treat each contaminant. Table 2 illustrates the result for the case where a thousandfold decrease in initial chlorinated ethene concentration is needed to reach the target effluent concentration of vinyl chloride. For this simulation,  $f_\beta = 0.75$  was used to simulate faster formation of Ac than c12DCE (Roberts et al. 1996), degradation of Ac was not considered, and rate constants for all other reactions were taken from Table 1.

The results in Table 2 show that barrier widths estimated only from degradation of PCE and TCE (as in Figure 6) are far less than the widths required when action levels for degradation products such as VC are considered. The width required to treat any input combination of chlorinated ethenes is never greater than that required for the same conversion of c12DCE, but is always greater than that required to treat an equivalent molar concentration of vinyl chloride. Therefore, a conservative approach to barrier design for mixtures of chlorinated ethenes (that does not require additional modeling) may be to choose a width of treatment zone greater than the width required if all chlorinated ethenes were present as c12DCE. To achieve the target effluent concentration of VC, barrier widths for c12DCE from Figure 6 should be increased by 20 percent. Substantially narrower treatment zones may suffice where ground water velocities are slower or the required degree of contaminant degradation is less (see Figure 6, Equation 3).

These design guidelines are based only on the analysis in Figure 6 and Table 2, so they do not incorporate

**Table 2**  
**Estimated Barrier Widths Required to Treat Mixtures of Chlorinated Ethenes**

Chlorinated Ethene Concentrations in the Influent Relative to Target Concentrations of Vinyl Chloride in the Effluent <sup>1</sup>				Estimate of Required Barrier Width (ft) <sup>2</sup>			
PCE	TCE	c12DCE	VC	$\rho_a = 1.0 \text{ m}^2 \text{ mL}^{-1}$		$\rho_a = 3.5 \text{ m}^2 \text{ mL}^{-1}$	
				of parent <sup>3</sup>	to VC	of parent	to VC
1000				0.1	7.0	0.03	2.0
	1000			0.7	7.0	0.2	2.0
		1000		7.0	8.4	2.0	2.4
			1000	5.8	5.8	1.7	1.7
	600	200	200		7.3		2.1
	800	200			7.4		2.1
	400	500	100		7.8		2.2
	200	800			8.2		2.3

<sup>1</sup>Based on molar concentrations.

<sup>2</sup>All calculations assume 1 ft d<sup>-1</sup> velocity and average rate constants ( $k_{SA}$ ) as in Table 1.

<sup>3</sup>For a thousandfold decrease in parent concentration only, as in Figure 6.

(statistical) uncertainty in rate constants or flow velocity. Using Monte Carlo modeling, we have recently shown that safety factors in barrier width ranging from two to six may be required to reduce the probability of exceeding the target effluent concentration to 5 percent (Eykholt 1997). This analysis assumed that ground water velocities vary log-normally with standard deviations ranging from 0.5 to three times the velocity, and that degradation reactions are independent (not sequential) with normally distributed rate constants having standard deviations that range from zero to 0.5 times the rate constant. While these safety factors may be generous, it is important to note that they apply to widths calculated from average values of velocity and rate constants. Realizing the impact of large variations in either parameter, some designers may choose to select widths based on expected extreme values.

The calculations presented here are based on average estimates of reaction rate constants and the assumption that reductive dechlorination is the primary degradation mechanism. Deviations from the model predictions are likely with longer exposure time due to the gradual passivation of iron surfaces by precipitates in the treatment zone. Predictions for sequential first-order processes are particularly vulnerable to changes in the mechanism or rate constants for less reactive constituents. However, these results do provide a quantitative basis for performing preliminary design calculations and should be useful in this capacity as long as they are followed by laboratory feasibility testing.

### Acknowledgments

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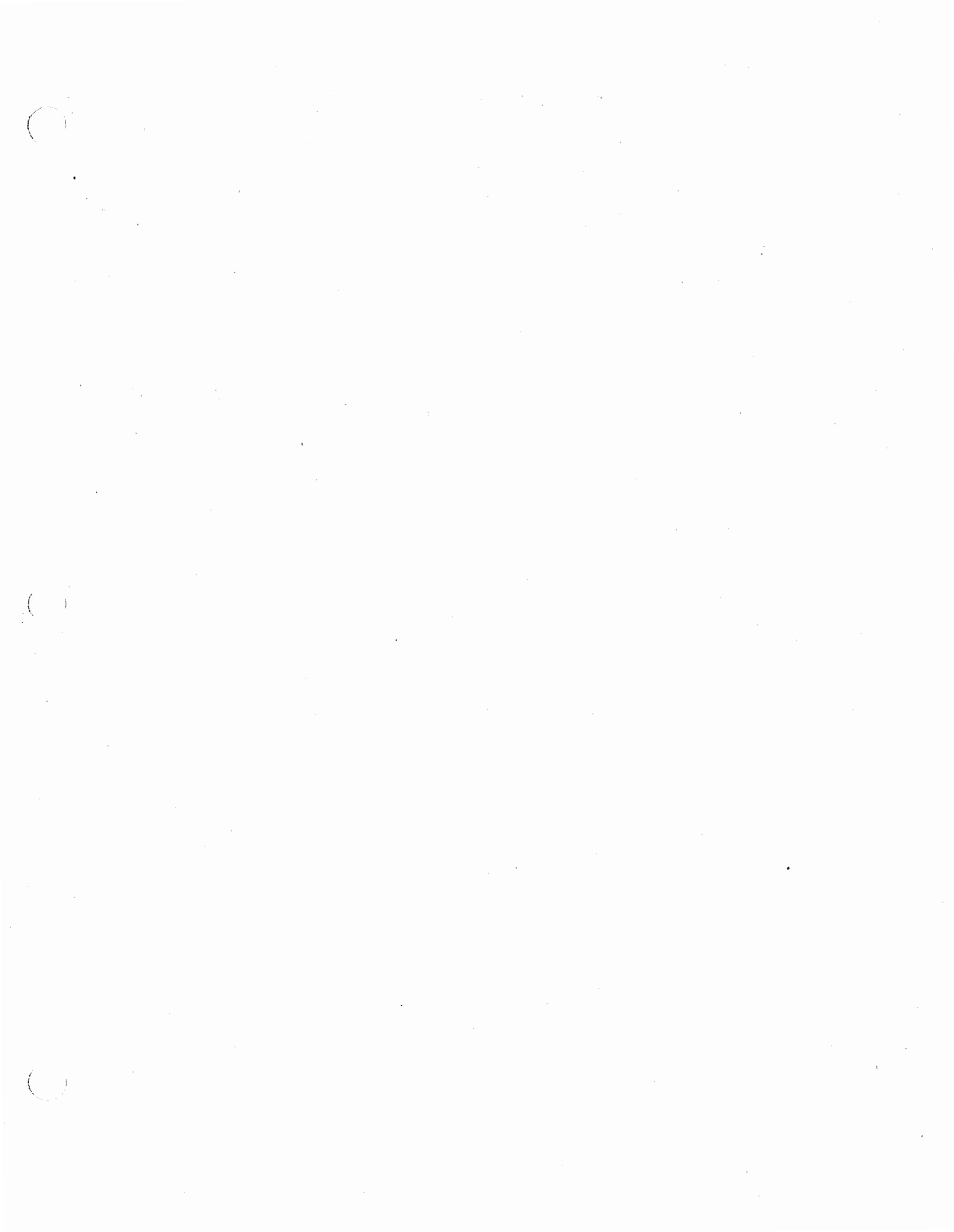
## Biographical Sketches

**Paul G. Tratnyek** is an associate professor in the Department of Environmental Science and Engineering at the Oregon Graduate Institute (P.O. Box 91000, Portland, OR 97291; e-mail: tratnyek@ese.ogi.edu). He received his Ph.D. from the Colorado School of Mines in 1987. Tratnyek served as a National Research Council postdoctoral fellow at the U.S. Environmental Protection Agency Laboratory in Athens, Georgia, during 1988 and as a research associate at the Swiss Federal Institute for Water Resources and Water Pollution Control (EAWAG) from 1989 to 1991. His research has involved remediation with zero-valent iron metal since he joined the University of Waterloo Solvents-in-Groundwater Research Programme in 1992.

**Timothy L. Johnson** is currently a postdoctoral associate at the Oregon Graduate Institute (Department of Environmental Science and Engineering, P.O. Box 91000, Portland, OR 97291) studying the effects of ligands on dechlorination by zero-valent iron. He was a DOE energy research fellow from 1993 to 1995 and received an AGWSE graduate student fellowship in 1994.

**Michelle M. Scherer** is currently a doctoral candidate at the Oregon Graduate Institute (Department of Environmental Science and Engineering, P.O. Box 91000, Portland, OR 97291) using electrochemical techniques to probe the reaction of chlorinated solvents with zero-valent iron. Scherer has an M.S. in environmental engineering from the University of Connecticut and received an AGWSE graduate student fellowship in 1995.

**Gerald R. Eykholt** is assistant professor in the Department of Civil and Environmental Engineering at the University of Wisconsin, Madison (Madison, WI 53706). His prior position was as staff scientist at General Electric Corporate Research and Development, Schenectady, New York. Eykholt received his M.S. and Ph.D. degrees from the University of Texas, Austin.





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## Memorandum

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**To:** Anna Fodor, Parsons Engineering Science, Inc. Fax: 781-401-2575

**From:** Andrzej Przepiora, John Vogan, EnviroMetal Technologies Inc.

**Date:** 20 April 2000

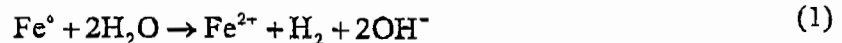
**Re:** **Anticipated Iron Lifetime and O&M Requirements for a Permeable Reactive Barrier Located at Ash Landfill, Romulus, NY – 31317.77**

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Further to your request, EnviroMetal Technologies Inc. (ETI) performed the following calculations to determine the theoretical lifetime of granular iron in an additional permeable reactive barrier (PRB) designed for VOC treatment at Ash Landfill, Romulus, NY. Also included is a response to your recent enquiry about long-term iron PRB operation and maintenance.

The calculations are based on measured iron corrosion rates with water, volatile organic compound (VOC) degradation and oxidation by dissolved oxygen (DO). To simplify the calculations, iron loss due to corrosion is calculated for a representative "unit" volume of iron wall with a face surface area of 1 cm<sup>2</sup> and a thickness equal to the PRB thickness (2.1 ft or 64 cm in the PRB located in the vicinity of the source zone). Iron porosity of 0.5, iron bulk density of 2.6 g/cm<sup>3</sup> (162 lb/ft<sup>3</sup>), a maximum dissolved oxygen (DO) concentration in groundwater of 7.8 mg/L and a groundwater velocity of 0.4 ft/day were assumed for the calculations.

When iron is exposed to water containing dissolved VOCs, several reactions occur which corrode or "consume" the iron. One reaction is the iron corrosion reaction by water to produce hydrogen and hydroxide ions.

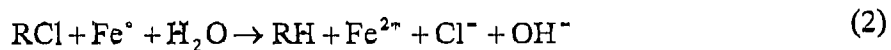


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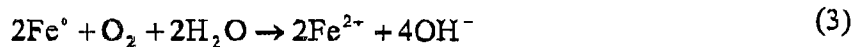
For the purpose of this calculation, this reaction is assumed to be independent of groundwater flow rate (velocity) through the iron (i.e. it will occur whether "fresh" groundwater is entering the system or not). By equating the measured hydrogen gas production rate to the rate of iron corrosion in the laboratory, corrosion rates for granular iron have been determined to be 0.05 mmol/kg Fe/day (Reardon, 1997). Using the molecular weight of iron (55.9 g/mol), 0.05 mmol is equivalent to 2.8 mg of iron. If each day, 2.8 mg of each kg of iron are converted from Fe to Fe<sup>2+</sup>, then in the representative cell containing 166.4 g of iron (64 cm × 1 cm<sup>2</sup> × 2.6 g/cm<sup>3</sup>) about 0.47 mg (166.4 g ÷ 1,000 g × 2.8 mg) of iron would be consumed each day in this reaction.

Iron corrosion is not the only iron consuming reaction occurring in these systems. Iron also serves as the electron donor in the reduction of chlorinated VOCs. This reaction can be represented by the equation:



The amount of iron consumed in this reaction is dependent on the mass flux of VOCs entering the PRB. From equation (2) 1 mol of iron is consumed for 1 mol of chloride released into solution. For a PRB located in the vicinity of the source zone, 1L of water containing about 10 mg/L TCE (C<sub>2</sub>HCl<sub>3</sub>) (0.076 mmols) would consume 12.7 mg (0.228 mmols) of iron. At a groundwater flow velocity of 0.43 ft/day, about 0.2 pore volumes passes each day through a 2.1-ft (64 cm) thick cell, equating to about 0.006 L (0.2 × 0.5 × 64 cm × 1 cm<sup>2</sup> ÷ 1,000 cm<sup>3</sup>/L) of groundwater. Therefore, about 0.08 mg of iron (12.8 mg/L × 0.006 L) would be corroded each day in the representative cell due to the reaction presented in equation (2).

A third reaction that consumes iron is the aerobic reaction with DO.



The amount of iron corrosion in this reaction is dependent on the mass flux of DO entering the PRB. From the reaction, 2 mols of iron are consumed for 1 mol of DO. Based on data from well MW-45, 1 L of water containing 7.8 mg/L (0.244 mmol) of DO will consume 27.3

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mg of iron. At this rate, about 0.16 mg ( $27.3 \text{ mg/L} \times 0.006 \text{ L}$ ) of iron a day would be corroded in this reaction in the representative cell.

The cumulative rate of iron consumption in the representative cell due to corrosion reactions represented in equations (1), (2) and (3) equals 0.71 mg/day ( $0.47 \text{ mg/day} + 0.08 \text{ mg/day} + 0.16 \text{ mg/day}$ ). Therefore in the representative cell containing 166.4 g of iron, it would take about 642 years ( $166,400 \text{ mg} \div 0.71 \text{ mg/day} \div 365 \text{ days/yr}$ ) to consume all iron material at this rate.

Similar calculation were performed for the other two proposed walls; the middle wall (groundwater velocity of 0.43 ft/day, wall thickness of 1.2 ft, DO = 3.9 mg/L, TCE = 0.53 mg/L) and the downgradient wall (groundwater velocity of 1.23 ft/day, wall thickness of 2.1 ft, DO = 1.8 mg/L, TCE = 0.10 mg/L). The theoretical lifetimes of iron in these two walls are 695 and 756 years, respectively.

Although there is some uncertainty in the above calculations and the groundwater flux conditions that may exist decades in the future, it seems reasonable to expect the iron in the PRB to last for many decades.

The major factor affecting O&M costs is the possible need for periodic rejuvenation of iron sections affected by precipitates. The precipitates (if significant) will form in a narrow zone at the upgradient aquifer/iron interface. Rejuvenation therefore could be as simple as agitating the upgradient face of the iron every few (i.e. 7 to 10) years with an auger to restore the permeability of this material. Cost of this procedure may be in the order of \$5 to \$7 per  $\text{ft}^2$ .

This periodic O&M requirement should be included in long-term cost models for the technology. The rise in pH as a result of corrosion of the iron typically causes the precipitation of carbonate minerals such as calcium carbonate and iron carbonate (siderite), and at pH values in the range of 9 to 10, iron will precipitate as iron hydroxide. Concern has been expressed regarding the potential for these precipitates to reduce the activity of the iron and/or to reduce the permeability through pore clogging. Experience to date indicates calcium carbonate to represent by far the largest volume of precipitates, and also indicates that precipitates have only minor effect on the activity of the iron.



Recent core analyses from pilot-scale systems in New York and Colorado revealed porosity losses in the upgradient few inches of iron in the range of 10% of the initial porosity, with losses declining sharply over the first foot to below 2% (Vogan et al., 1998). These porosity losses were calculated based on carbonate analyses of iron material retrieved by coring the treatment zone. The porosity loss measured in the core samples was consistent with that predicted on the basis of changes in the inorganic water chemistry. Assuming an initial porosity of 0.5, the porosity after 18 months (Colorado) to 2 years (New York) in the first few inches of the iron zones had declined to about 0.45. Concurrent field data (VOC and groundwater velocity measurements) indicated that system hydraulics and iron reactivity had not been adversely affected by the precipitates. Based on groundwater monitoring data, a porosity loss of 0.35% a year was calculated for an iron PRB at a site in Colorado (McMahon et al., 1999). A commercial system in Sunnyvale, CA (Szerdy et al., 1996) has also been performing consistently for over 5 years. Groundwater at this site exhibits TDS in the range of 1,000 to 3,500 mg/L. No significant precipitates were observed in cores from an in situ reactive wall at the University of Waterloo Borden test site two and four years after it was installed (O'Hannesin and Gillham, 1998). This wall performed consistently over a 5 year period, with the expectation that it would continue to perform for at least another five years with no maintenance.

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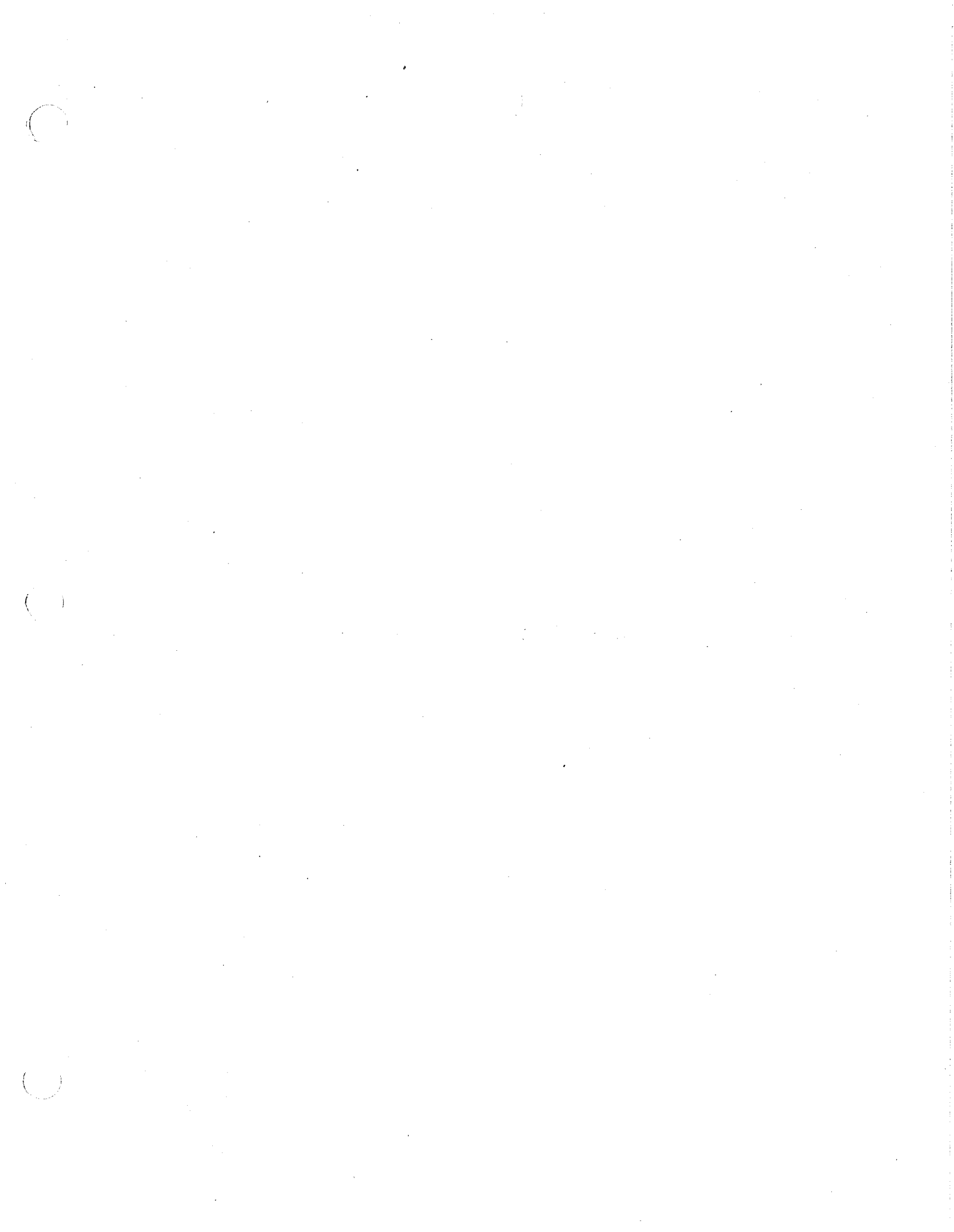
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## Memorandum

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**To:** Michael Duchesneau, Parsons Engineering Science, Inc. Fax: 781-401-2575

**From:** John Vogan, Andrzej Przepiora, EnviroMetal Technologies Inc.

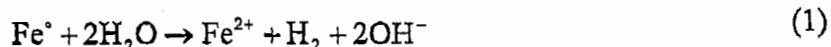
**Date:** 20 May 2000

**Re:** **Anticipated Amount of Hydrogen Gas Generation in a Permeable Reactive Barrier Located at Ash Landfill, Romulus, NY - 31317.77**

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Further to our recent discussions, EnviroMetal Technologies Inc. (ETI) performed the following calculations to determine the theoretical amount of hydrogen generated in the permeable reactive barrier (PRB) at Ash Landfill, Romulus, NY.

Hydrogen gas is produced during iron corrosion reaction by water:



Laboratory experiments with commercial iron indicated that the hydrogen gas production in this reaction is 0.05 mmol/kg Fe/day (Reardon, 1997).

For the purposes of the calculations, we have made the following assumptions:

- A unit length of the wall (1 ft wide × 10 ft high × 0.5 ft thick) contains 5 ft<sup>3</sup> of iron,
- A long-term H<sub>2</sub> gas production rate is 0.05 mmol H<sub>2</sub>/kg Fe/day,
- Iron bulk density is 160 lbs/ft<sup>3</sup> and porosity is 0.4,
- Solubility of H<sub>2</sub> equals 0.019 L/L of groundwater (Dean, 1985),
- Groundwater flow velocity is 1 ft/day.

Based on the iron density of 160 lbs/ft<sup>3</sup>, about 800 lbs (363 kg) is contained in the 5 ft<sup>3</sup> iron zone. Therefore, the amount of H<sub>2</sub> formed during corrosion in this iron zone equals 20 mmol

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H<sub>2</sub>/day (363 kg × 0.05 mmol/kg Fe/day). Since at standard pressure and temperature 1 mol of H<sub>2</sub> occupies 22.441 L, about 0.45 L/day of hydrogen is formed in the 5 ft<sup>3</sup> iron zone.

Based on the assumed groundwater velocity of 1 ft/day, about 2 ft<sup>3</sup>/day (56.6 L/day) of water moves through the 5 ft<sup>3</sup> iron zone (1 ft/day × 10 ft × 0.5 ft × 0.4). Based on H<sub>2</sub> gas solubility, the maximum amount of H<sub>2</sub> gas dissolved in that amount of water equals about 1.1 L/day (56.6 L/day × 0.019 L/L), and therefore all of the H<sub>2</sub> generated in the iron zone (0.45 L/day) should theoretically remain in the dissolved phase (no free H<sub>2</sub> gas).

The generated hydrogen will undoubtedly influence microbial population as the iron-treated water moves into the downgradient aquifer. Monitoring results from iron PRBs provide an indirect evidence of increased microbial activity directly downgradient of the iron zone. For example, Warner et al. 1998 reported methane levels in downgradient aquifer wells 6-fold higher than those measured in the upgradient wells, indicating increased methanogenesis. Similar increases in methane levels were observed in the monitoring wells downgradient of an iron PRB in Elizabeth City, NC (EPA, 1999). However, we (or our EPA contacts) are not aware of any published data concerning quantification of hydrogen-related microbial activity downgradient of an iron PRB.

Our literature database includes a few references dealing with microbiological hydrogen consumption and dehalogenation (see the attached list). Sample published H<sub>2</sub> microbial consumption rates are as follows:

- low H<sub>2</sub>-gas consumption rate=0.13 mole/hr/g<sub>bacteria(dry weight)</sub>=3.12 mole/day/g<sub>bacteria(dry weight)</sub> (Ahring and Westermann, 1987); and
- high H<sub>2</sub>-gas consumption rate=0.43 mole/hr/g<sub>bacteria(dry weight)</sub>=10.32 mole/day/g<sub>bacteria(dry weight)</sub> (Zehnder et al., 1981).

We are currently checking with researchers active in this area to see if any unpublished data can be made available concerning microbial activity downgradient of a PRB. We will forward any information we can in this regard as soon as possible.

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#### Microbial References:

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Smatlak, C.R., Gossett, J.M., and Zinder, S.H., 1996. Comparative Kinetics of hydrogen utilization for reductive dechlorination of tetrachloroethene and methanogenesis in an anaerobic enrichment culture. *Environ. Sci. Technol.* 30:2850-2858.

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Appendix E  
Groundwater Monitoring and Modeling at the Ash Landfill

- Modeling for Remedial Design for Continuous Reactive Wall Scenarios at the Ash Landfill, Seneca Army Depot Activity
- Groundwater Chemical Results Round 1 Groundwater Monitoring Ash Landfill Remedial Design, Seneca Army Depot Activity, Romulus, NY
- Groundwater Chemical Results Round 2 Groundwater Monitoring Ash Landfill Remedial Design, Seneca Army Depot Activity, Romulus, NY
- Ash Landfill 1998 Third Quarter Groundwater Monitoring Indicator Parameters

## Technical Memorandum

To: Ash Landfill Remedial Design Project File  
From: Ko-Hui Liu and Paul Feshbach-Meriney  
Date: June 6, 2000  
Re: Modeling for Remedial Design for Continuous Treatment Wall Scenarios at the Ash Landfill Ash, Seneca Army Depot Activity

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### INTRODUCTION

This memorandum presents the results of groundwater flow and solute transport modeling that evaluated four designs of additional continuous, zero-valent (reactive) iron walls at the Ash Landfill. The additional walls will supplement the existing iron wall that was installed on the site in 1998. The designs (scenarios) evaluated were as follows:

1. Scenario 1 – One additional cut-off trench installed perpendicular to the direction of groundwater flow;
2. Scenario 2 – Two additional cut-off trenches installed perpendicular to the direction of groundwater flow;
3. Scenario 3 – V-trench and parallel trench configuration; and
4. Scenario 4 – Multiple parallel trenches and single cut-off trench.

Prior to evaluating the reactive iron wall designs, a three-dimensional numerical groundwater flow model was developed for the site. The numerical model was based on conceptual hydrogeologic model that was first developed during previous modeling of the site (Parsons, 1996). The conceptual model was refined in the area of the Ash Landfill site for this evaluation, and translated into a steady-state, numerical groundwater flow model. The steady-state flow model was calibrated until a reasonable match to long-term water levels was made. A solute transport model was then developed. The solute transport model was calibrated to the observed concentrations in the plume, prior to the Removal Action at the Ash Landfill. Then, the calibrated model was used to evaluate the four design scenarios using the most recent chemical data as starting concentrations (of total chlorinated ethenes), and affects of matrix-controlled diffusion of the chlorinated ethenes, for the predictive simulations. Finally, the model was run using the scenario with the best overall performance (Scenario 2), and it included the affect of increased biodegradation due to hydrogen addition to the aquifer system from the reactions in the iron wall. This last model scenario provided the best estimate of the clean-up time for the plume of chlorinated ethenes at the site.

The groundwater modeling was conducted using MODFLOW<sup>win32</sup> [MODFLOW (McDonald and Harbough, 1984)]. The solute transport simulations were conducted using the MT3DMS solute transport model (Zheng and Wang, 1998). Both models are well-known, well-documented, public domain models. The model data were managed in Microsoft Excel and Golden Software's Surfer Version 6. ESI's Groundwater Vistas pre- and post-processing software (ESI, 1998) was used to develop the model and evaluate the modeling results. The modeling results were exported to ESRI's Arcview 3.1 GIS software for preparation of the figures for this report.

## **GROUNDWATER FLOW MODEL**

The groundwater flow model consisted of four layers, one for the till/weathered shale aquifer, and three other layers for the competent shale. The model had a dimension of 122 x 353 cells. The model cells were set at 25 feet within the area of the Ash Landfill site, but these cells were later refined during solute transport to simulate the reactive iron walls. Model boundaries were set at large distances from the Ash Landfill site (**Figure 1**). Seneca Lake was a constant head boundary to the west, the topographic (and groundwater) divide along Route 96 was a no-flow boundary to the east, and streamline no-flow boundaries were used for the northern and southern boundaries of the model.

### **Model Calibration**

Calibration of an existing four-layer steady-state groundwater flow model was accomplished by adjusting hydraulic conductivity zones in the upper three layers and recharge in layer 1. Initially, conductivity zones were established based on hydrostratigraphic determinations made during the previous modeling (Parsons, 1996). Then, in selected locations of the upper three layers of the model, the conductivity values were further adjusted, however, the range of adjustments were within an order of magnitude established using field measurements during the RI. In addition, zones of regional net recharge were established on the top of layer 1 to reflect the relative amount of recharge based on the slope of the ground surface. The recharge zones were also adjusted based on the presence of landfilled areas and wetlands. A large roadside drainage ditch along North-South Baseline Road was simulated using model drains, which removed water at the western end of the Ash Landfill. The steady-state model was calibrated when the simulated water levels reasonably matched the long-term water level targets. Simulated groundwater contours are shown in Attachment A. Statistically, the model was considered to have been calibrated when the absolute mean error (average of the absolute value of the differences between the observed and simulated water levels) was 10% or less of the difference in water level across the modeled area. The actual calibrated error was 1.8%. The water balance error for the model was approximately 0.3 %.

### **Refined Groundwater Flow Grid and Establishing Treatment Walls**

Prior to establishing the reactive iron walls in the model, the grid in the area of the proposed walls was refined. This allowed the narrow walls to be simulated, and increased the hydraulic head and concentration resolution of the modeling results. To refine the grid, the 25-ft grid spaces of the steady-state flow model were adjusted to a regularly spaced grid size of 3.1 ft, which is the approximate width of a typical excavator bucket, and the anticipated width of the final reactive walls. Beyond this area, the grid expanded by roughly 1.5 times. The refined flow model had a dimension of 310 x 632 cells. Then the four reactive iron wall scenarios were established in four separate flow models. The reactive walls were established in layer 1 and they consisted of elongate zones with a hydraulic conductivity of  $7.4 \times 10^{-3}$  cm/sec (or 20.97 ft/day), which is based on laboratory permeability testing of the iron/sand mixture in existing reactive iron wall. Steady-state groundwater flow head solutions were obtained first for each scenario and then transient groundwater flow simulations were subsequently conducted to generate the input files required by MT3DMS.

## **SOLUTE TRANSPORT MODEL**

The solute transport modeling evaluated the effectiveness of the four reactive iron wall scenarios and evaluated the potential for the portion of the plume that exists downgradient of the existing



reactive iron wall to adversely impact the wells at the Farm House. In these evaluations, the solute transport model simulated the movement of the total chlorinated ethenes plume as TCE; multispecies transport was not simulated for this project.

The MT3DMS computer code was selected to simulate contaminant transport. MT3DMS includes the standard finite-difference method, several mixed Eulerian-lagrangian methods, and a third-order TVD method with a universal flux limiter. These solution options treat the dispersion, sink/source and reaction terms in exactly the same fashion, using the block-centered finite-difference method, either explicitly or implicitly. They differ; however, in the way the advection term is solved. In this simulation, the Generalized Conjugate Gradient Solver package was selected, and the implicit upstream finite difference method was used to solve the advection term without any stability constraints.

### Calibration

Prior to simulating the reactive wall scenarios, the transport model was calibrated. The model was calibrated by simulating the plume migration from constant sources in the former source areas at the Ash Landfill, without the presence of the continuous reactive walls. The time of the initial release was estimated to be 30 years. The constant sources were based on the chemical concentrations measured in the plume source areas prior the Removal Action. Two of the sources were represented by the total chlorinated ethene concentrations in MW44 (132,360 µg/l) and in PT18 (13,953 µg/l) (Figure 1-1, Parsons 1996). During the calibration process, one additional point source was established between MW44 and PT18. A distribution coefficient ( $K_d$ ) of 0.0752 ml/g was used for the model calibration. It was calculated using site-specific organic carbon data (foc of 0.0008) for the till matrix and a literature-derived  $K_{oc}$  (94 ml/g), which is the geometric mean for TCE as cited by EPA (1996). This revised  $K_d$  for TCE is different from the one used in previous Ash Landfill model (Parsons 1996), which was a literature-derived value of 0.013 ml/g. Using the revised  $K_d$ , and bulk density and porosity data, a retardation factor of 1.9 was calculated for TCE in the till/weathered shale aquifer at the Ash Landfill site, which is consistent with the TCE retardation factor of 2.2 calculated by Mehran et al. (1987) and within the range cited by Wilson et al. (1981) of 1.5 to 2.0. Other parameters such as longitudinal, transverse, and vertical dispersivity were adopted from the previous modeling effort.

The biodegradation rate constant ( $k$ ) was considered to be the most uncertain variable that controlled the plume configuration and, therefore, it was the parameter that was adjusted for calibration. The  $k$  value was obtained from the resultant of natural log of 2 divided by a half-life of the TCE. A half-life of 875 days ( $k = 0.00079/\text{day}$ ) resulted in a simulated plume that was most similar to the total chlorinated ethene plume prior to the Removal Action (Figure 1-1, Parson ES, 1996). A  $k$  value of 0.00079/day is consistent with the range of values cited in *Anerobic Biodegradation of Organic Chemicals in Groundwater: A Summary of Field and Laboratory Studies* (API 1997). This report cites a lower limit equal to 0.00014/day (half-life of 4950 days), which is the lowest measured field value, to 0.0025/day (half life of 277 days), which is the mean value for the field/in situ microcosm data set cited in the report.

### Transport Modeling Results

#### **Evaluation of Treatment Wall Designs**

Four separate solute transport models were established using the initial calibrated solute transport model as a framework for each reactive wall scenario (**Figure 2**). The model scenarios used initial total chlorinated ethene (as TCE) plume concentrations that were based on October 1999

chemical sampling results. Total chlorinated ethenes were calculated by adding the molar concentrations of the individual chlorinated ethene compounds (PCE, TCE, 1,2-DCE, and VC), and converting the total molar concentration back to a weight concentration (equivalent to TCE). Then, the initial plume concentration array for the model scenarios were generated in SURFER using the converted chemical data and a krigging method with an exponential variogram model.

The chemical reaction parameters defined for the model were based on site-specific data, bench-scale testing, and literature. The half life (and k) in the aquifer was previously established during model calibration, however, a different half-life was used in the cells that simulated the reactive walls. In the walls, a half-life of 6 hours (0.25 days) was used, which is an empirical value for zero-valent iron based on several years of bench-scale, chemical column testing by EnviroMetal Technologies, Inc. (March 20, 2000).

While advective transport, retardation and biodegradation of chemicals are all considered in the solute transport model, matrix-controlled diffusion was identified as an important factor in evaluating the effectiveness of the scenarios and clean-up times for the plume. Long-term diffusion of chemicals (e.g., TCE, 1,2-DCE, and VC) from the aquifer matrix was considered to be a significant factor at the site due to the presence of the till aquifer, which has a relatively high silt and clay content. To approximate the effects of the matrix-controlled diffusion on clean-up times in the simulations, the Kd of the aquifer matrix was adjusted up by two times the value that was used to calibrate the transport model in a zone that extended from the existing wall to just beyond the eastern plume boundary. This adjustment that was based on TCE adsorption and desorption studies cited by Olsen and Davis, 1990. During the simulation, the result was an increase in the mass of chemical solute adsorbed to the solid phase relative to the mass of solute in the liquid phase in the aquifer. This, in effect, accounted for the additional flushing of pore water that would ultimately be needed to remove the dissolved chemicals sorbed to the solid phase. Analytical data collected during the treatability study of the existing iron wall provides further support for the importance of chemical diffusion from the till matrix when assessing clean-up times at the Ash Landfill site.

The table below presents generalized descriptive results from the modeling that can be used to compare the relative effectiveness of the four treatment wall scenarios (**Attachment A**).

Scenario	Approximate Total Length of Reaction Walls (feet)	Comments
1	1,400	The two cut-off walls effectively divided the plume in half and the plume had to move a relatively large distance to be treated by the walls. This configuration was not as effective as other scenarios (2 and 3) in reducing, in a timely manner, the zone of elevated concentrations downgradient of the southern portion of the Ash Landfill.
2	2,000	The three cut-off walls segmented the plume and minimized the travel distances needed before treatment in the walls. The walls were effective in reducing the large plume to relatively small impact areas. The wall immediately east of North South Baseline Road was effective in cutting off the plume to allow the portion of the plume at the depot boundary to be treated in a relatively short period of time.

3	1,900	The "V" wall was effective in cutting off the high concentration portion of the plume, however, the wall parallel to groundwater flow did little to treat the plume. The drawback to this configuration is that the plume immediately beyond the "V" had to move the entire distance to the existing wall before being treated. This resulted in a relatively long treatment time for most of the plume.
4	2,700	The parallel walls isolated the plume into zones and treat plume on the edges of these zones in the immediate vicinity of the wall, but they did not significantly induce groundwater to flow toward them. Ultimately, the cut-off wall at the downgradient end of the parallel walls performed most of the treatment. This scenario required the plume to move a relatively large distance before being treated.

Note:

\* This range of years was based on visual observation of plume maps with a 5-year time series cycle.

Based on the results of the simulations using the four continuous reactive wall scenarios, the following general observations were made:

1. All four reactive wall scenarios were effective in capturing and treating the on-site plume.
2. The continuous reactive walls do not significantly affect the hydraulic heads around them and, therefore, the wall systems rely on natural gradients to move the plume toward them.
3. In general, cut-off walls installed perpendicular to the plume movement perform better than walls installed parallel to the long axis of the plume. The parallel walls do not significantly induce groundwater (and the plume) to flow toward them and, thus, treatment times for parallel walls are relative long, unless a perpendicular wall is also installed to directly intercept the plume. The regional westerly direction of groundwater flow dominates over any local hydraulic influence from these parallel walls.
4. Configurations with a reactive iron wall installed immediately east of North-South Baseline Road (Scenarios 2 and 4) were effective in cutting off the movement of upgradient portion of the plume. This resulted in a reduction in the plume concentrations at the depot boundary within a relatively quick time frame compared to the other scenarios.

While it is clear that, at the Ash Landfill site, cut-off walls perform better than "V" wall or walls installed parallel to the flow of the plume, the last factor to consider in estimating the clean-up time for the site is the effect that chemical reactions in the wall have on "natural" degradation rates in the aquifer. Specifically, the effects of increased delivery of dissolved hydrogen to the aquifer system from the reactions in the wall. Chemical data from wells downgradient of the existing iron wall indicate that dissolved hydrogen concentrations range from 0.026 µg/L (12.9 nM/L) to >0.101 µg/L (>50 nM/L). The increase in hydrogen generated by the wall would undoubtedly influence microbial populations as the iron-treated water moves into the downgradient aquifer (ETI, May 2000). This would, in effect, increase the rate of biodegradation in the aquifer by stimulating the microbes. The hydrogen is rapidly used as an electron donor by naturally-occurring bacteria to achieve reductive dechlorination of chlorinated ethenes in the subsurface.

The effect of hydrogen addition from reactive iron walls has not been widely studied due to the fact that in-situ reactive iron walls are a relative new and innovative technology and the long-term field data are not available to date. However, it is widely accepted that hydrogen (an electron donor) is a key factor governing dechlorination. Recently published laboratory results of long term column studies at (>1 year) at Rice University indicate the potential for stimulating and sustaining dechlorination activity through direct hydrogen addition (Fisher et. al, undated).

To estimate effect that hydrogen would have on the half-life of TCE in the aquifer at the Ash Landfill, we examined the rate of decay for TCE in a commingled, dissolved plume containing TCE and BTEX at a site at the Plattsburgh Airforce Base in Plattsburgh, New York (Wiedemeier, et al., 1996). At this site, reductive dechlorination supported by fuel hydrocarbons (BTEX) is described as one of the chemical environments in the dissolved plume that results in increased hydrogen in the aquifer, among other geochemical changes. Hydrogen concentrations of up to 0.023  $\mu\text{g/L}$  (11.3 nM) were measured in this portion of the plume at Plattsburgh. In this area of the plume, the first-order biodegradation rate constant for TCE ranged from 0.0033/day to 0.0010/day, which corresponds to half lives of 210 days and 630 days, respectively. The biodegradation rate for DCE was also within this range. These rates reflect the increased degradation due to the presence of BTEX as a primary substrate and the resulting addition of hydrogen to the aquifer system. Similarly, at the Ash Landfill, hydrogen is produced during the iron corrosion reaction by water in the wall and it is released to downgradient portions of the aquifer. While the methods by which dissolved hydrogen is produced in the Plattsburgh and Ash Landfill systems are different, the net effect is an increase in availability of hydrogen to be used by the microbial population in the reductive dechlorination of TCE.

Dissolved hydrogen concentrations above 0.010  $\mu\text{g/L}$  (5 nM/L) indicate that the dominant terminal electron-accepting process in the aquifer system is methanogenesis Wiedemeier (1996). At the Ash Landfill the dissolved hydrogen concentrations downgradient of the existing permeable reactive iron wall are between 0.026  $\mu\text{g/L}$  (12.9 nM/L) and >0.101  $\mu\text{g/L}$  (>50 nM/L), which provides support for the predominance of methanogenesis as the dominant electron-accepting process. The presence of increased methane concentrations downgradient of the wall at the Ash Landfill also indicates that methanogenesis is an active process at the site.

Based on the available groundwater chemical data, it is important that the estimate of clean-up time at the Ash Landfill consider the potential benefits of long-term hydrogen addition from the reactive walls. Therefore, the final model scenario combined the Scenario 2 wall configuration, which had the best overall performance, with an estimate of the effect of hydrogen addition to the zones between the reactive walls. This scenario also included the effect of adding carbon in areas upgradient of the easternmost wall, near the former source area at the Ash Landfill, which when degraded by microbes would produce hydrogen. The effect of the increase hydrogen in the aquifer was simulated in the model by setting the half-life for the biodegradation term to 437 days (0.0015/day), which is one-half of the value established under "natural" dechlorination conditions (877 days) at the site. The estimate of 437 days is consistent with the range of first-order biodegradation rates established at the commingled TCE and BTEX plume in Plattsburgh noted in the discussion above.

The results of the model simulation using the Scenario 2 wall configuration (three cut-off trenches) and the effects of both matrix-controlled diffusion and hydrogen addition (i.e., zones of increase dechlorination) indicated that that the plume of total chlorinated ethenes would be remediated in about 15 years (**Figure 3**).

### **Impact on Farm House Wells**

To evaluate the potential for the plume to impact the wells at the downgradient Farm House, the solute transport model simulation evaluated the movement of the portion of the plume beyond the existing trench using the Scenario 2 wall configuration described above. It is important to note that down gradient of the existing trench the simulation used the same  $K_d$  value that was used to calibrate the transport model, since the intent was to determine the forward movement of the

plume and not the effects of long term, matrix-controlled diffusion on clean-up time. The initial plume concentrations were, again, based on October 1999 results that were converted to TCE equivalents. During this simulation, two downgradient monitoring points were established in the model to record the changes in concentration over time. Monitoring Point 1 was located at the mid-point between the Farm House and the Depot boundary, and Monitoring Point 2 was located at the Farm House (**Figure 4**).

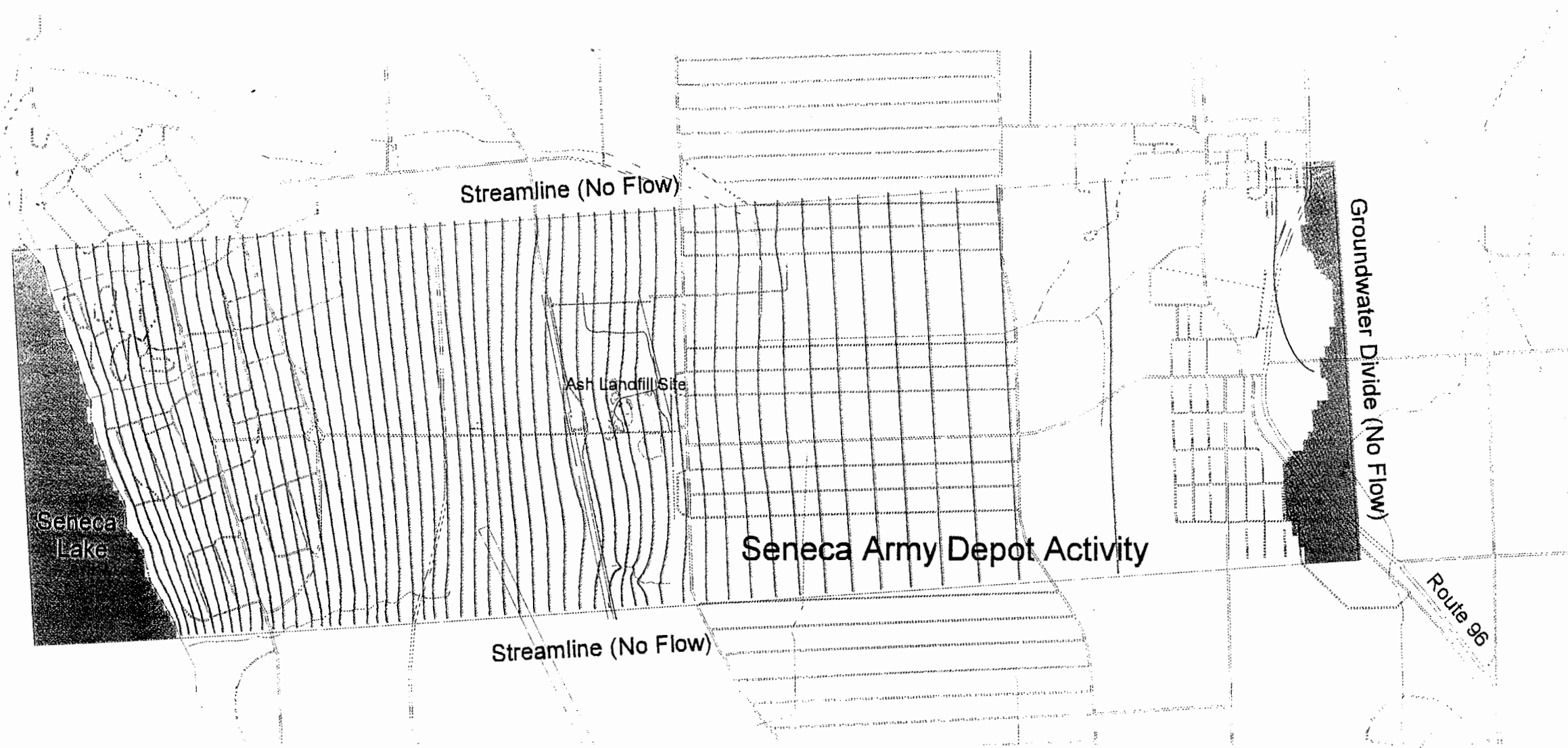
The results of the simulation showed that a slug of the plume would continue to move beyond the existing reactive iron wall, however, the concentrations within the slug were degraded as they moved farther downgradient of the existing wall. The simulation predicted that a maximum concentration of approximately 0.2  $\mu\text{g/L}$  (total chlorinated ethenes) would reach Monitoring Point 1 in approximately 25 years. At the Farm House, the results indicated that the maximum concentration would be approximately two orders of magnitude less than this ( $\sim 0.008 \mu\text{g/L}$ ) in about 40 years (**Figure 5**). The plume of total chlorinated ethenes is expected to move in the till/weathered shale aquifer at about one half the average pore-water velocity based on a retardation factor of 1.9, which was established earlier.

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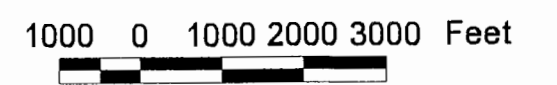
# ATTACHMENT A

## Figures



Simulated Groundwater Contour (5 foot interval)  
Contours begin at 460 feet near Seneca Lake and end at 740 feet near Route 96)

- Constant Head Zone at Seneca Lake
- No Flow Zone



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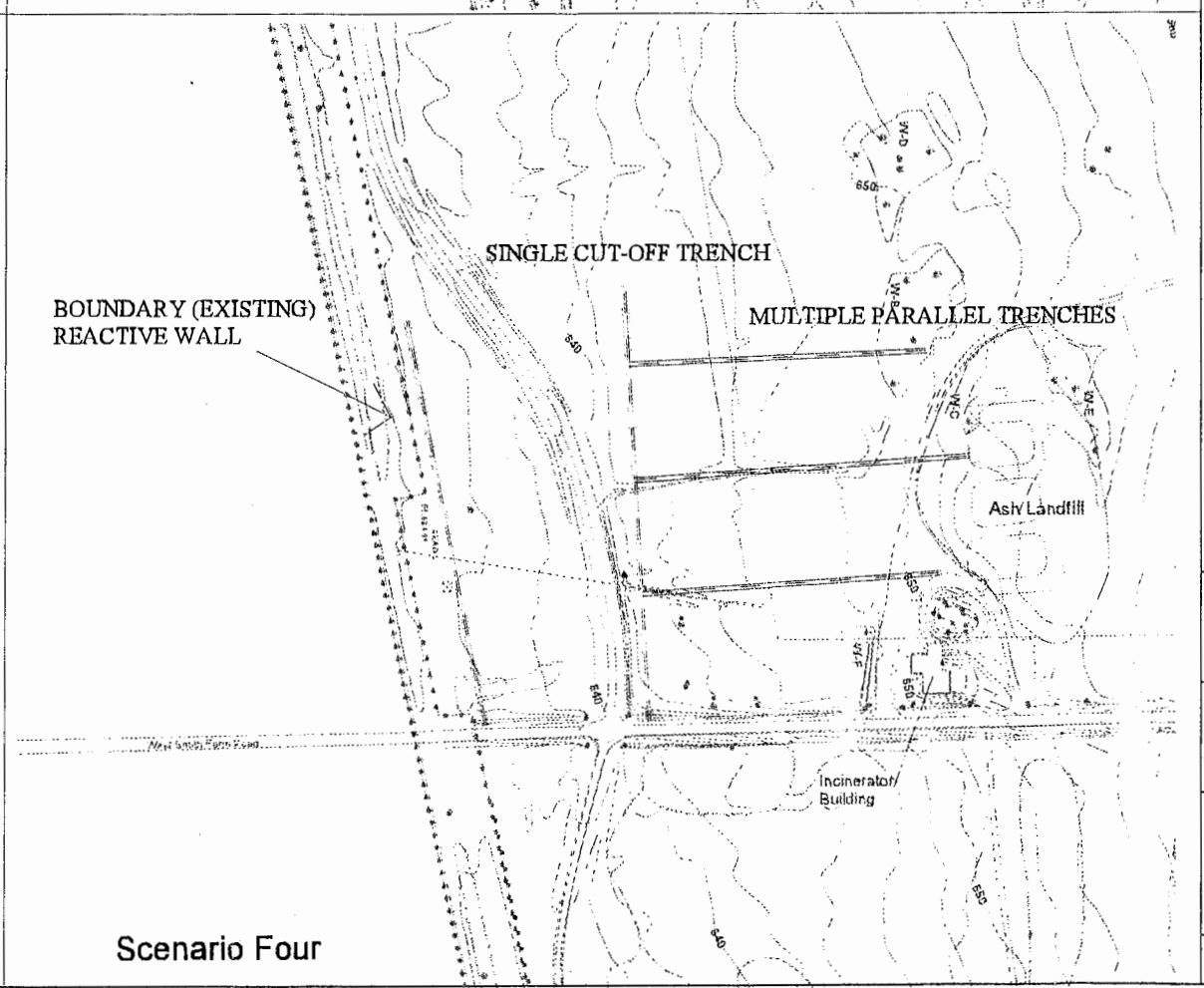
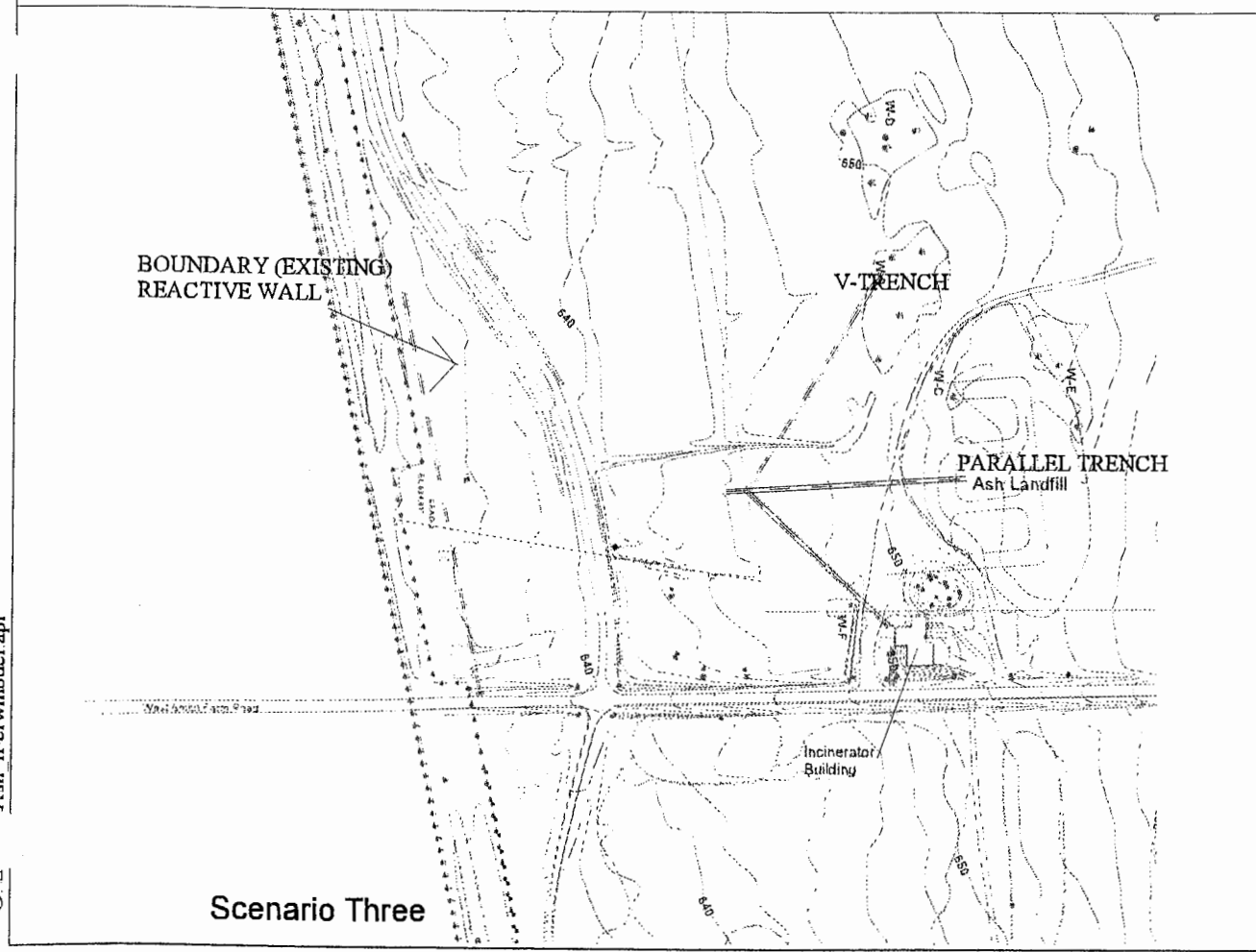
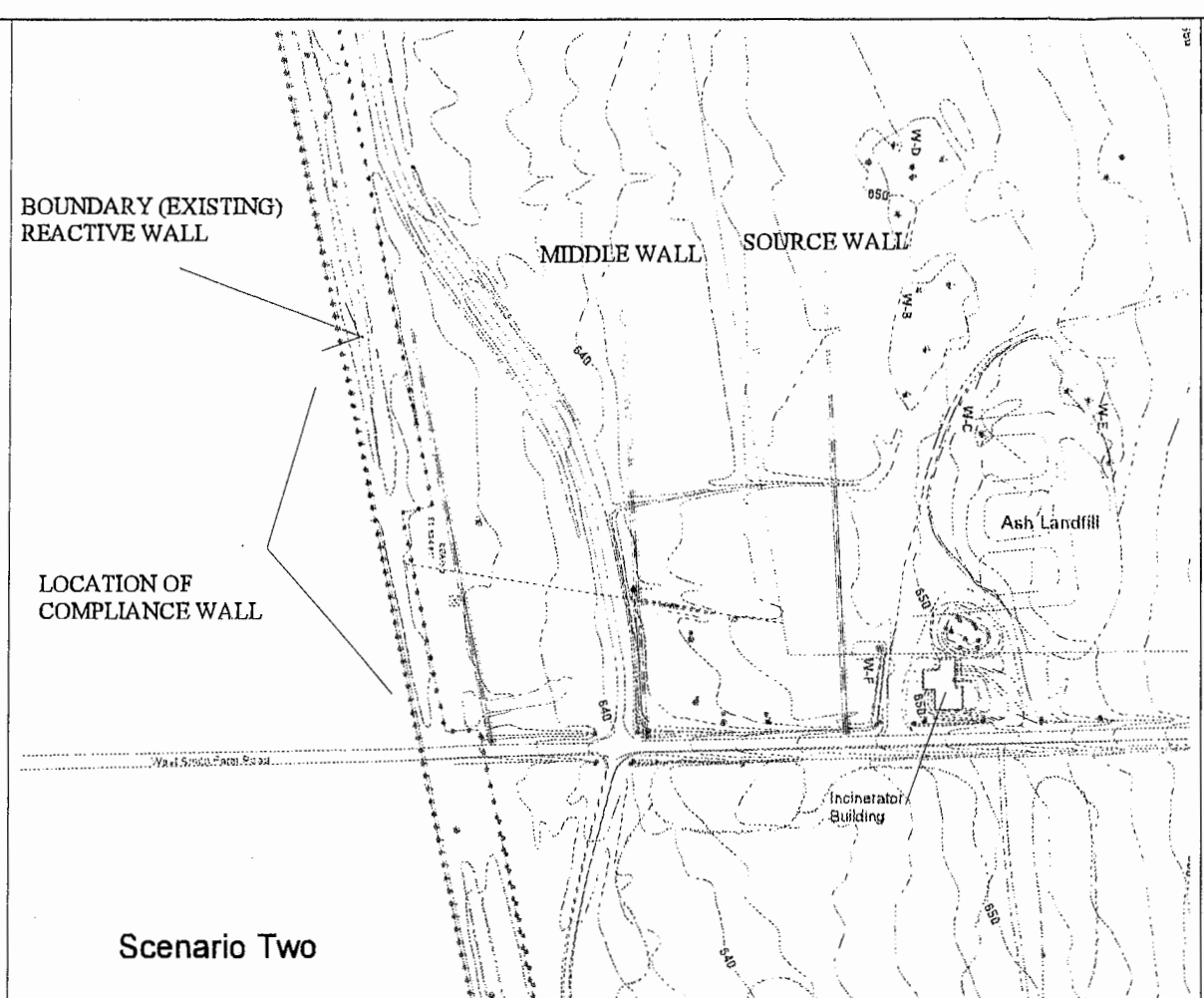
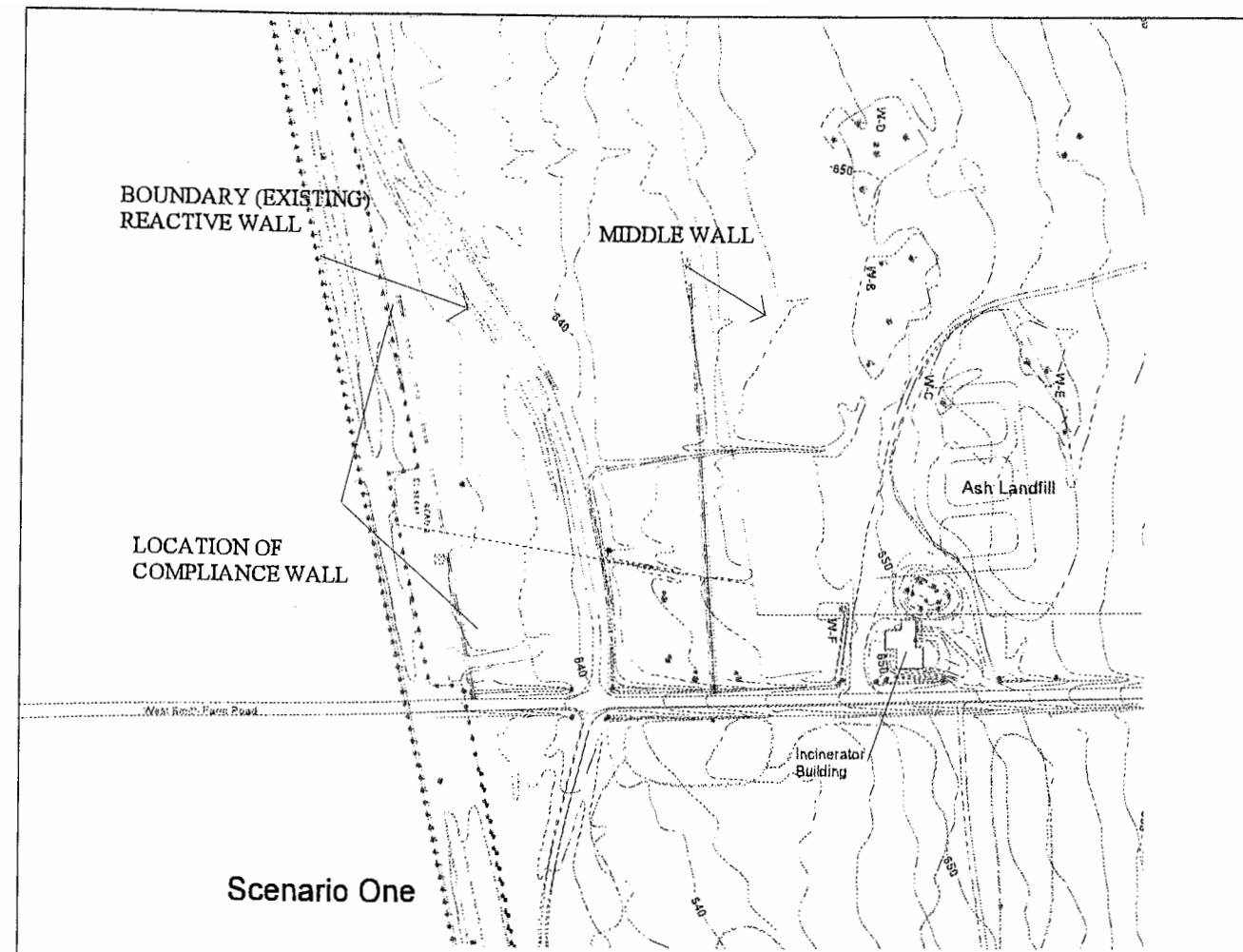
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**Seneca Army Depot Activity**  
Ash Landfill Remedial Design

Figure 1  
Model Boundary Conditions and  
Simulated Groundwater Contours

Scale: As shown April 2000





Reactive Iron Wall



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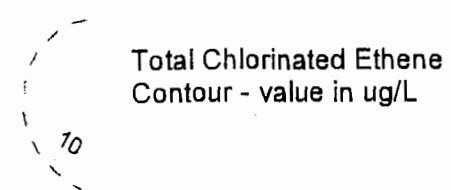
**SENECA ARMY DEPOT ACTIVITY**  
 Ash Landfill Remedial Design

**FIGURE 2**  
 Layout of Continuous Iron  
 Wall Scenarios One Through Four

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Reactive Iron Wall



Notes:

- 1) Matrix controlled diffusion is primary factor controlling clean-up time for plume.  $K_d$  increased by 2 times to simulate these matrix effects.
- 2) Hydrogen addition to aquifer occurs from chemical reactions in walls and from hydrogen point sources upgradient of the easternmost reactive wall. To simulate effects of hydrogen addition and increased microbial degradation, half-life of total ethenes divided by 2.

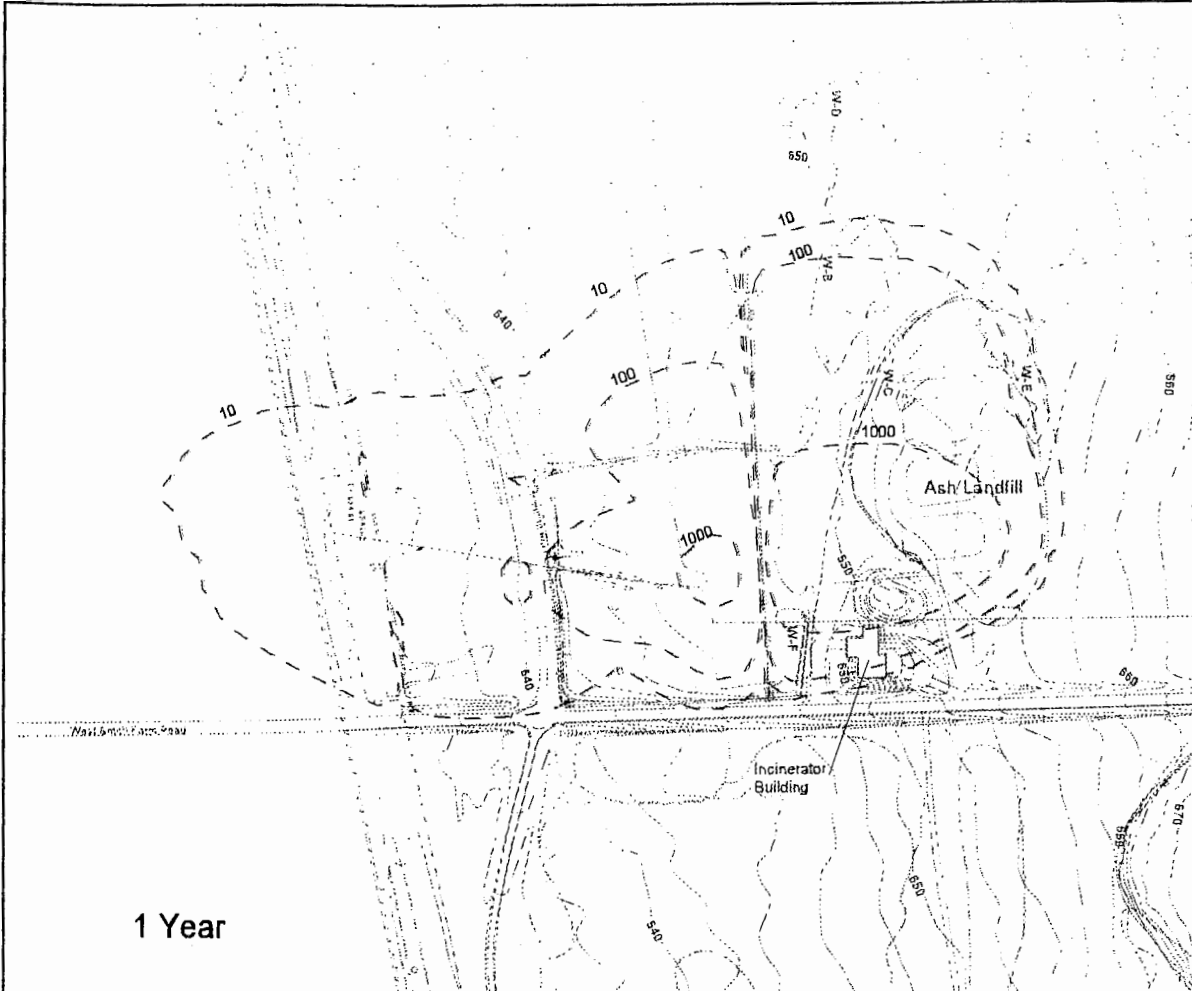


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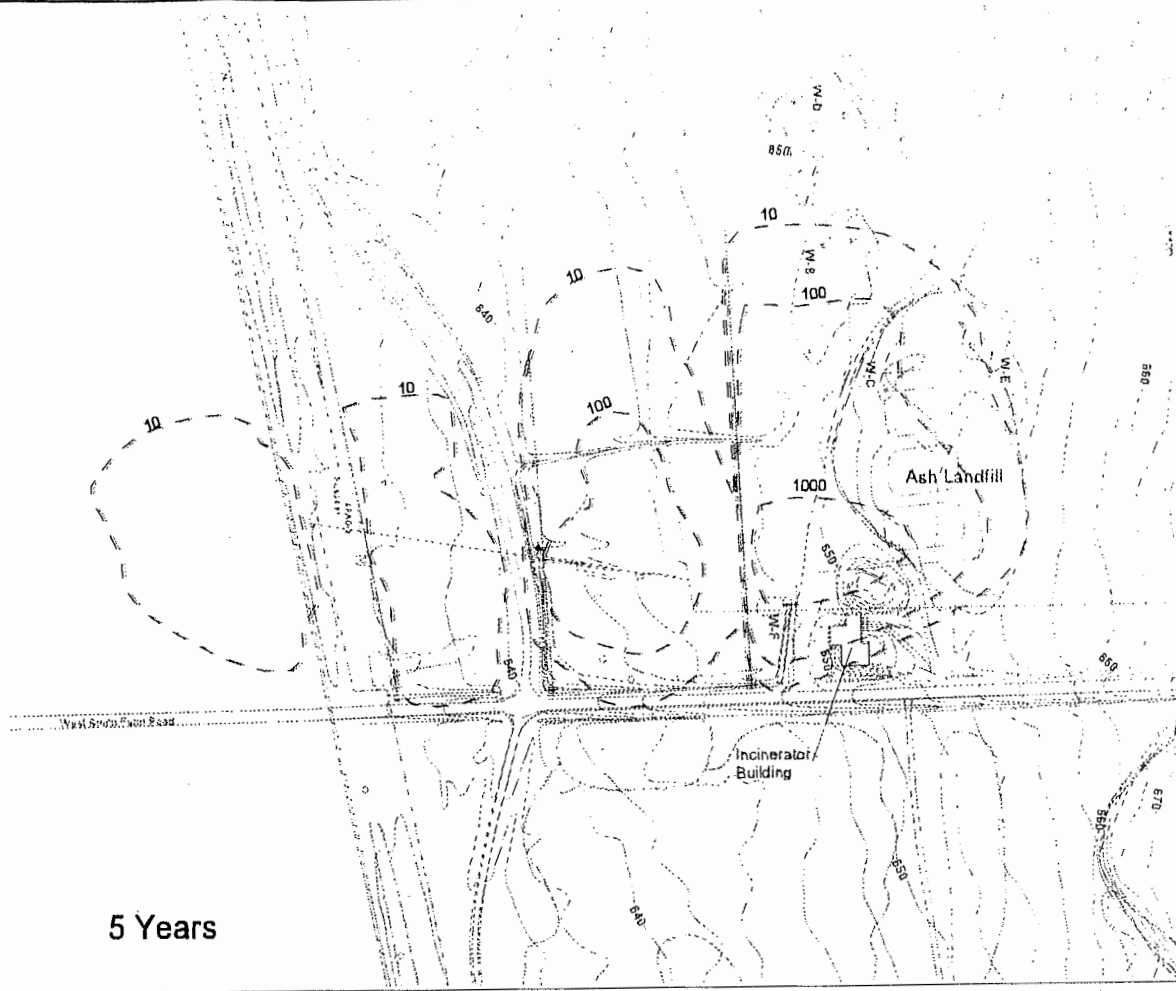
**Seneca Army Depot Activity**  
**Ash Landfill Remedial Design**

**Figure 3**  
**Reactive Iron Wall Scenario 2**

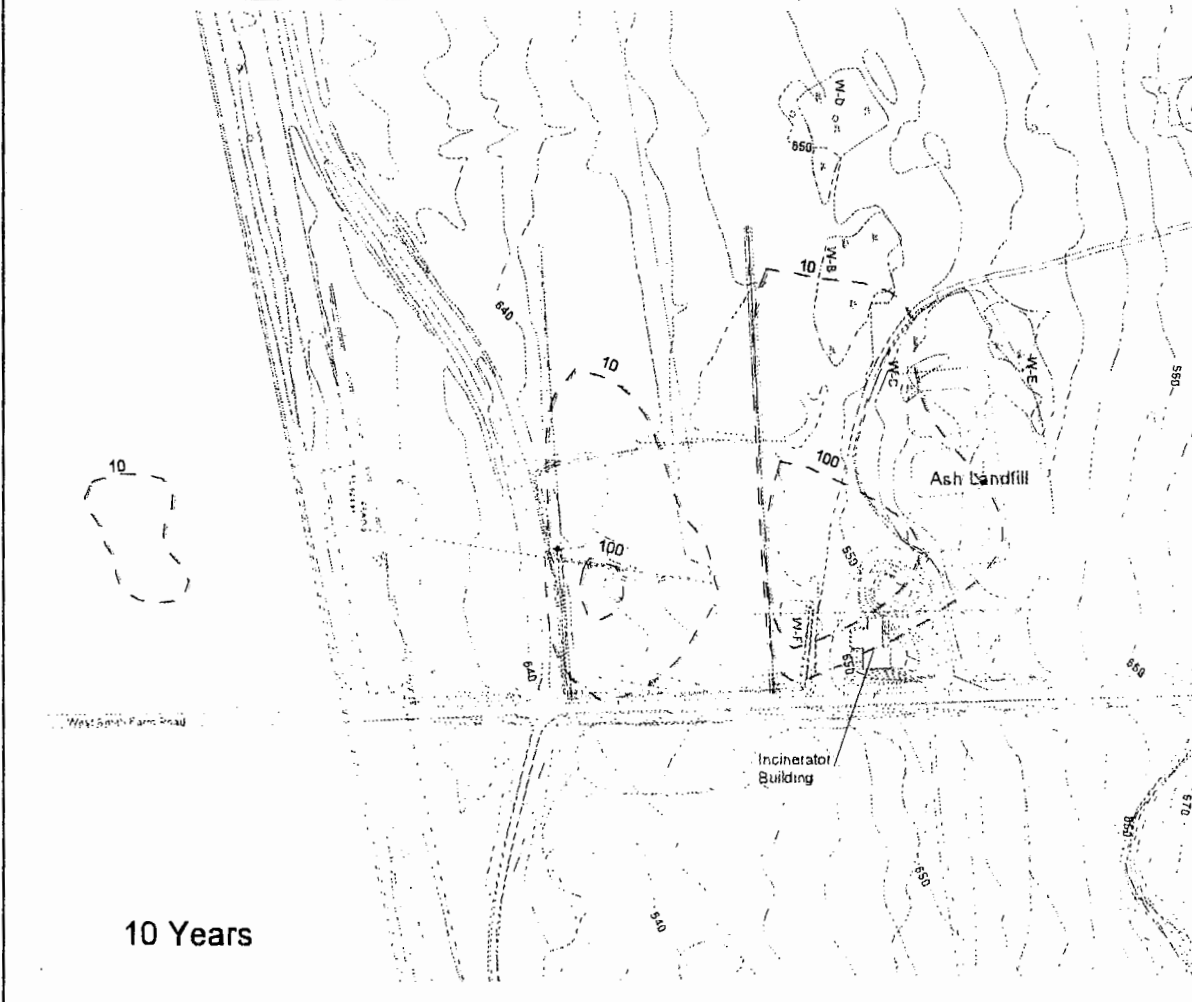
Scale: As shown April 2000



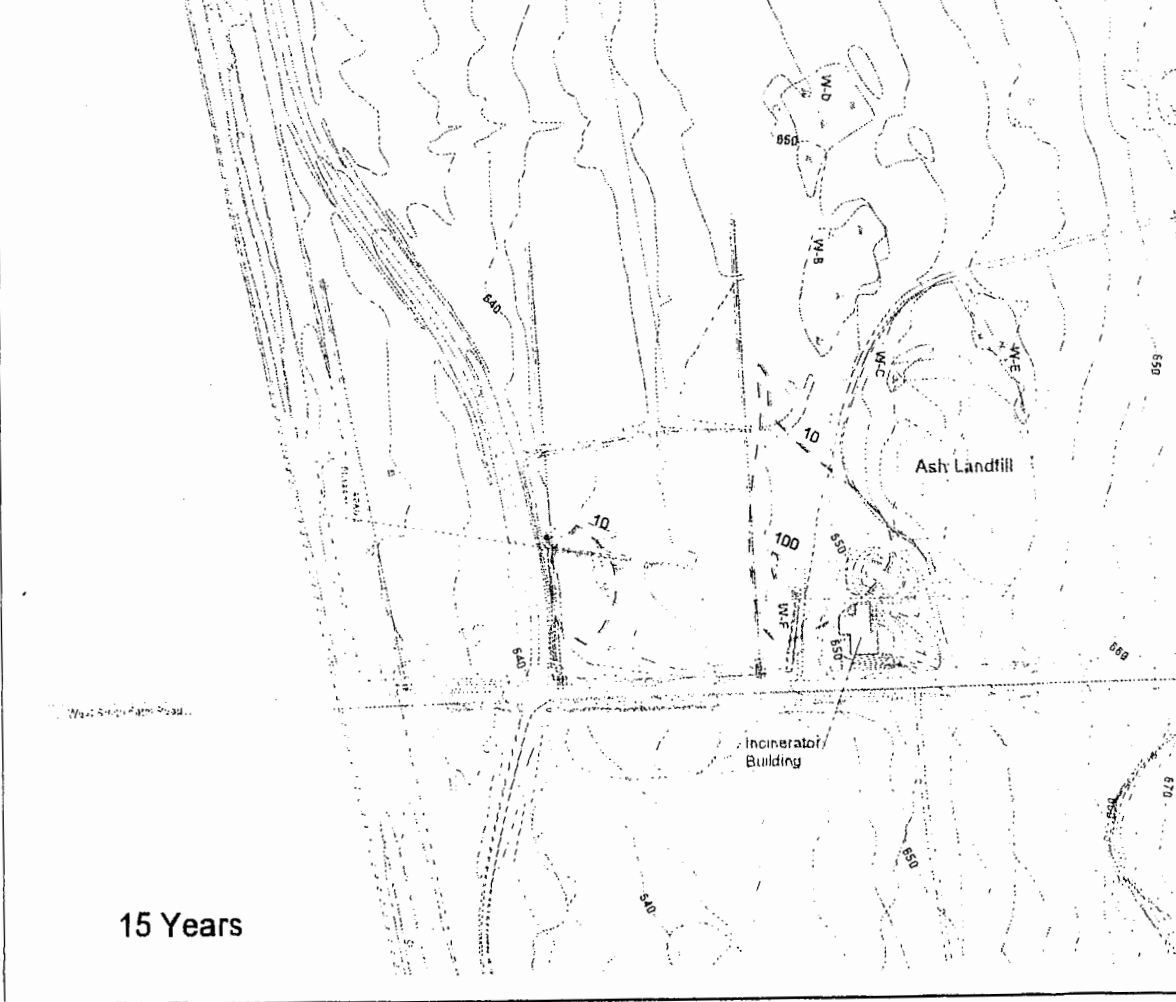
1 Year



5 Years



10 Years



15 Years

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Reactive Iron Wall

Total Chlorinated Ethene Contour - value in ug/L



Monitoring Point for Concentration During Transport Model

Notes:

- 1) Matrix controlled diffusion is primary factor controlling clean-up time for plume.  $K_d$  increased by 2 times to simulate these matrix effects.
- 2) Hydrogen addition to aquifer occurs from chemical reactions in walls and from hydrogen point sources upgradient of the easternmost reactive wall. To simulate effects of hydrogen addition and increased microbial degradation, half-life of total ethenes divided by 2.

400 0 400 800 Feet

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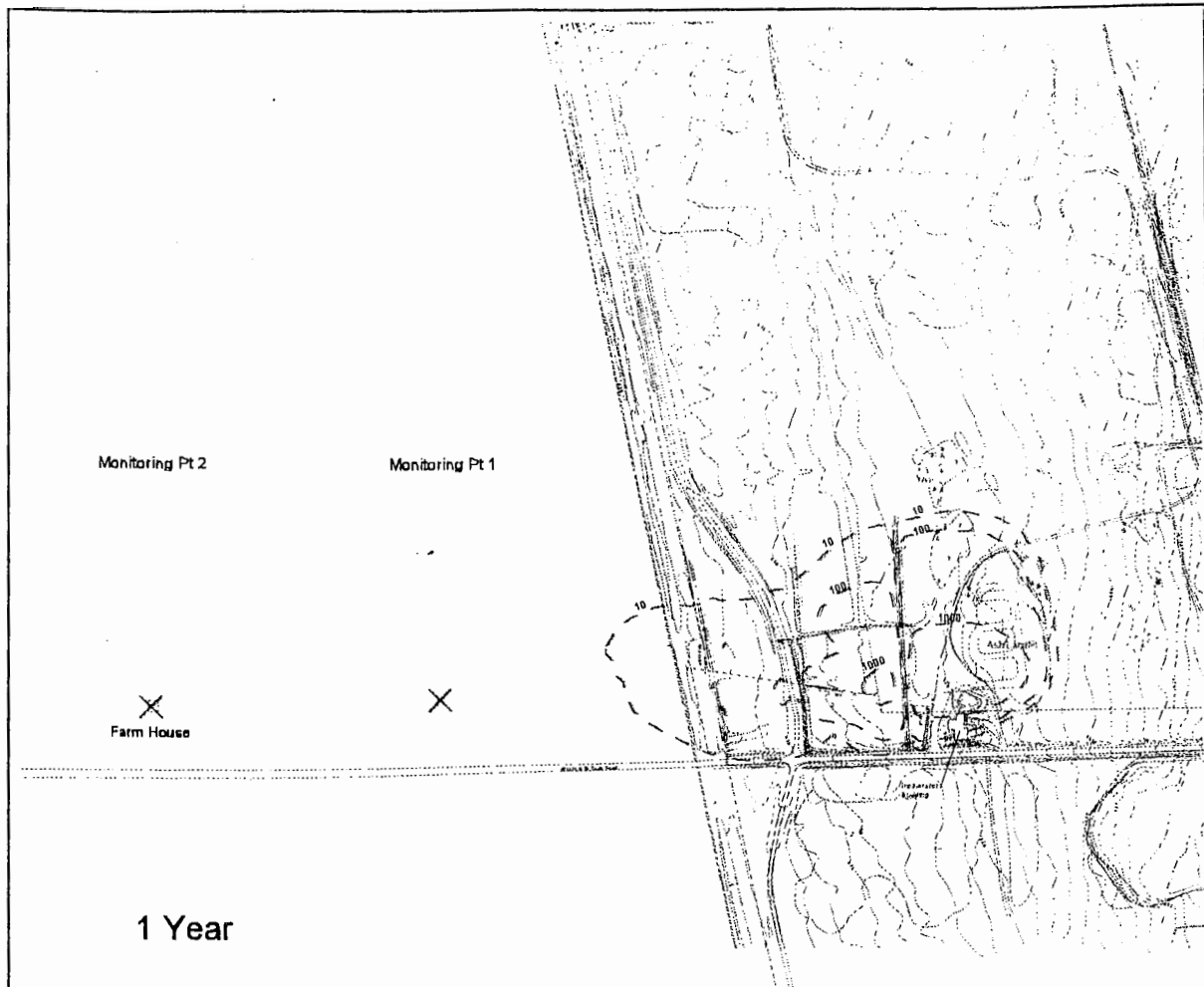
**Seneca Army Depot Activity**  
Ash Landfill Remedial Design

Figure 4  
Reactive Iron Wall Scenario 2  
with Monitoring Points

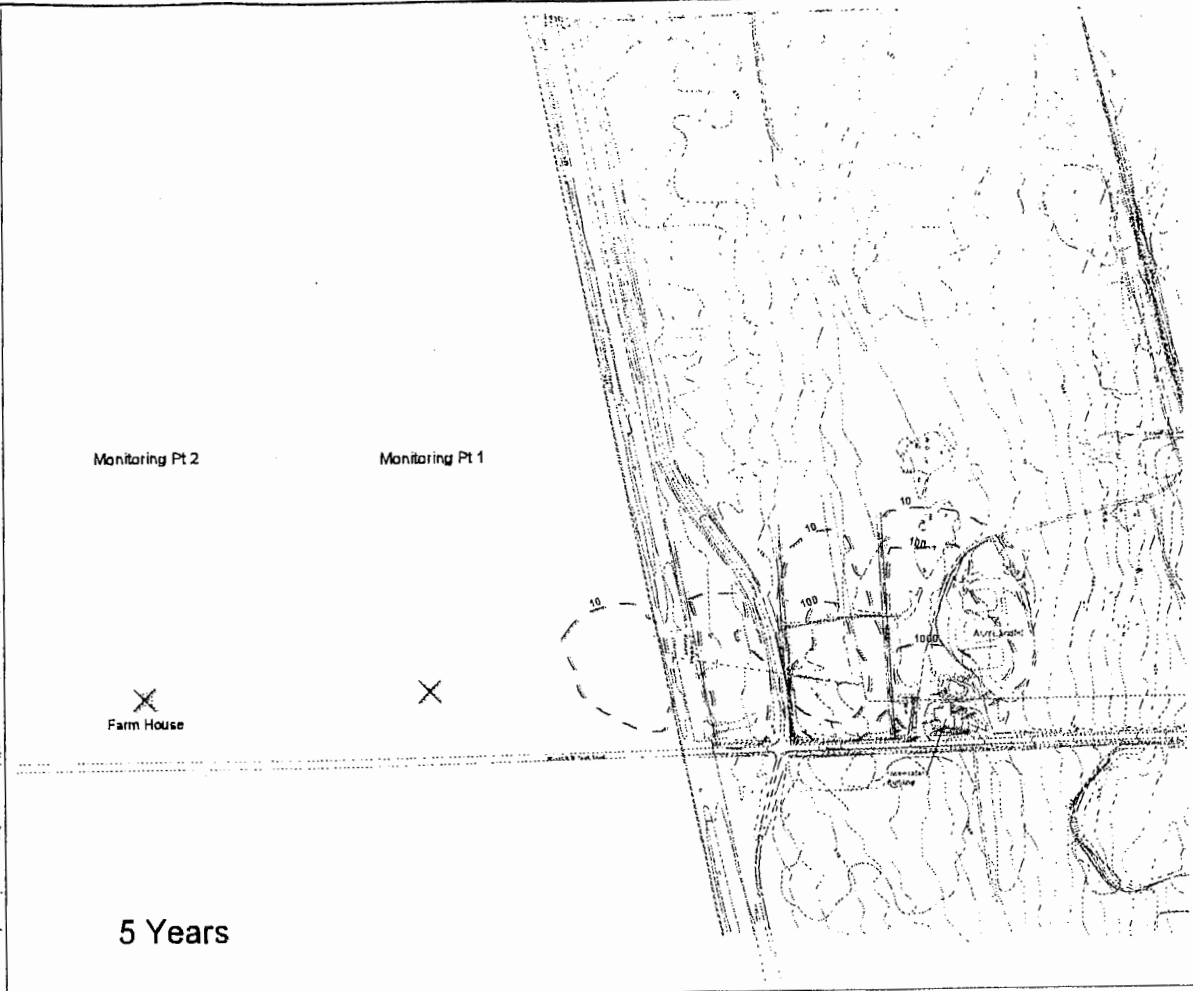
Scale: As shown

April 2000

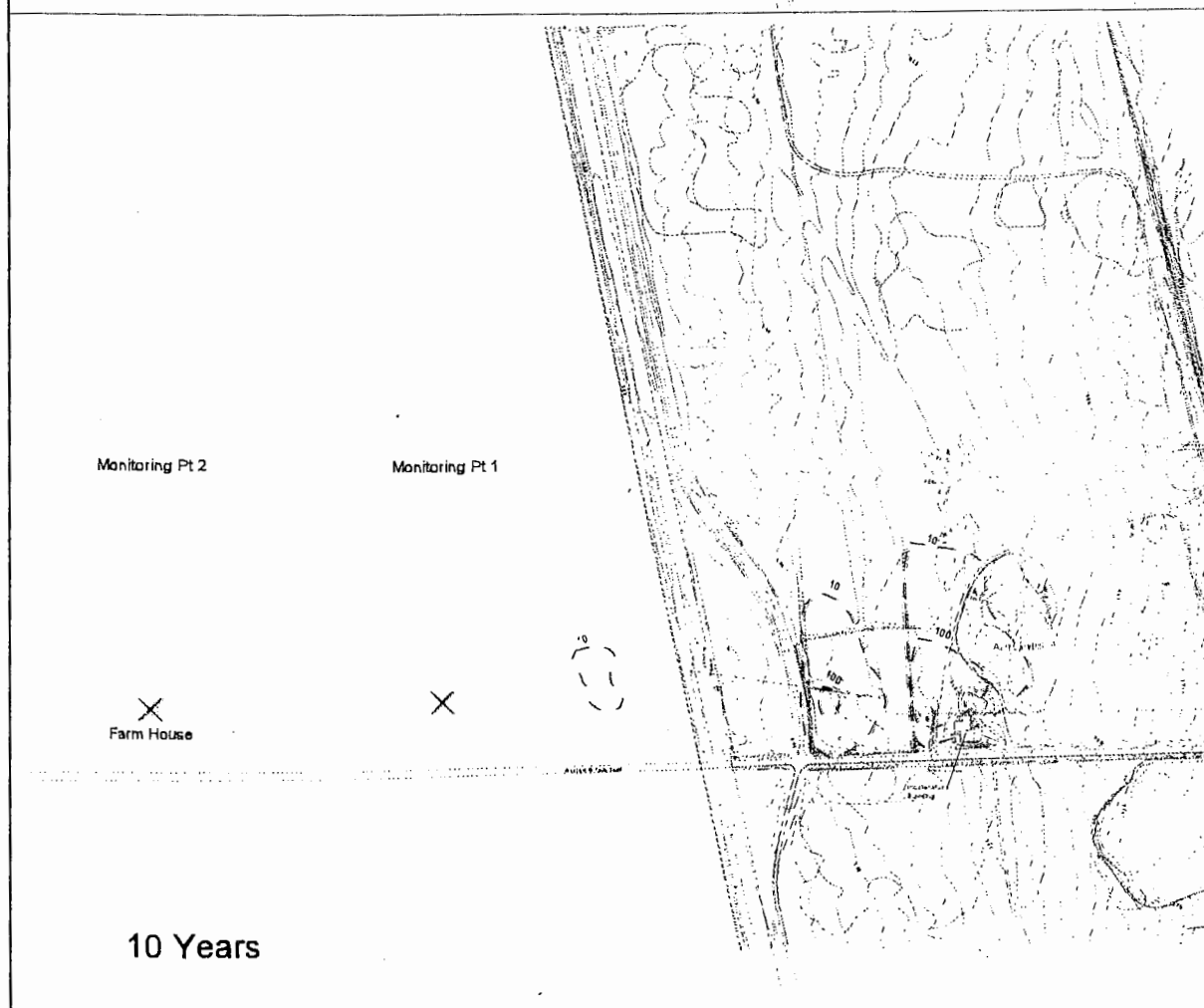
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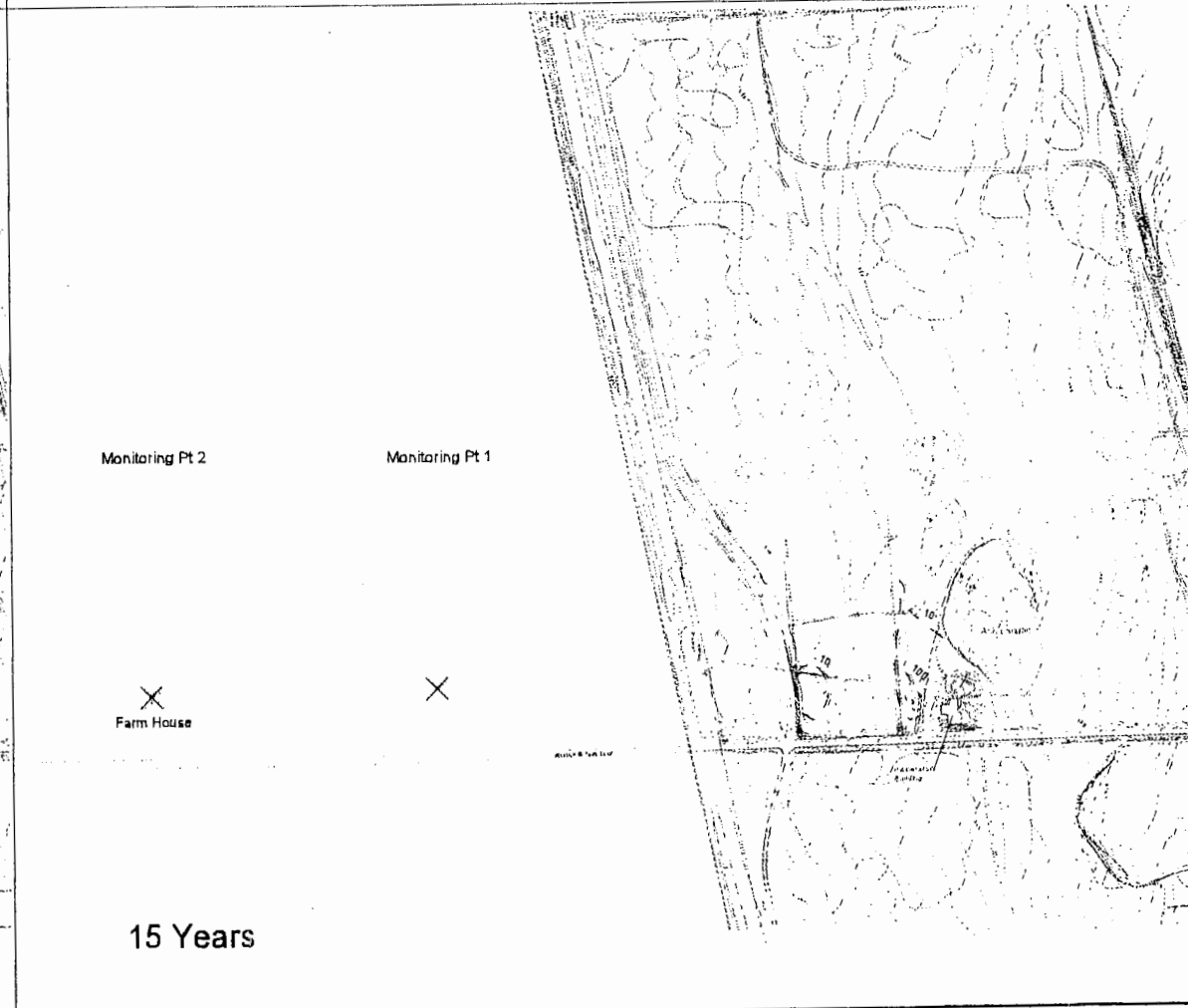
1 Year



5 Years

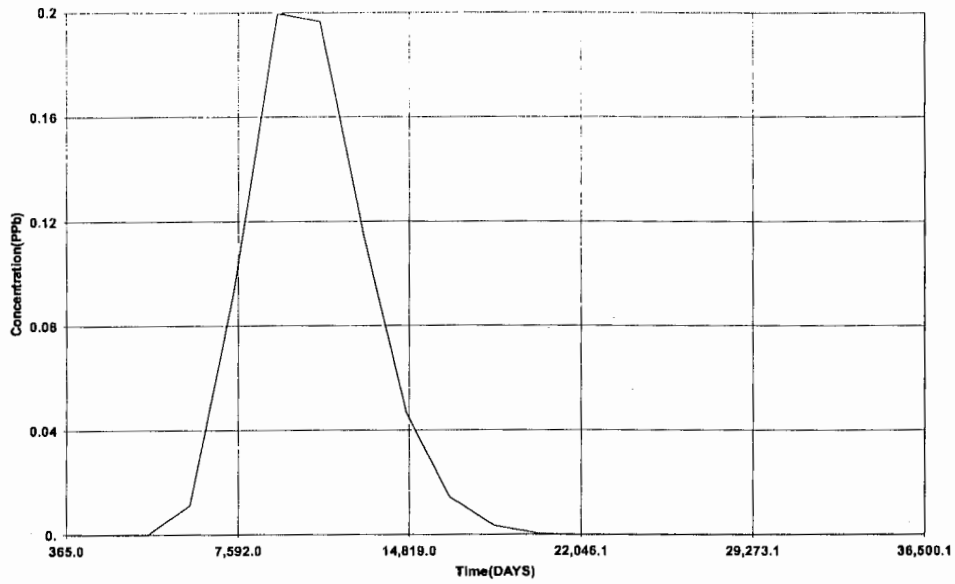


10 Years

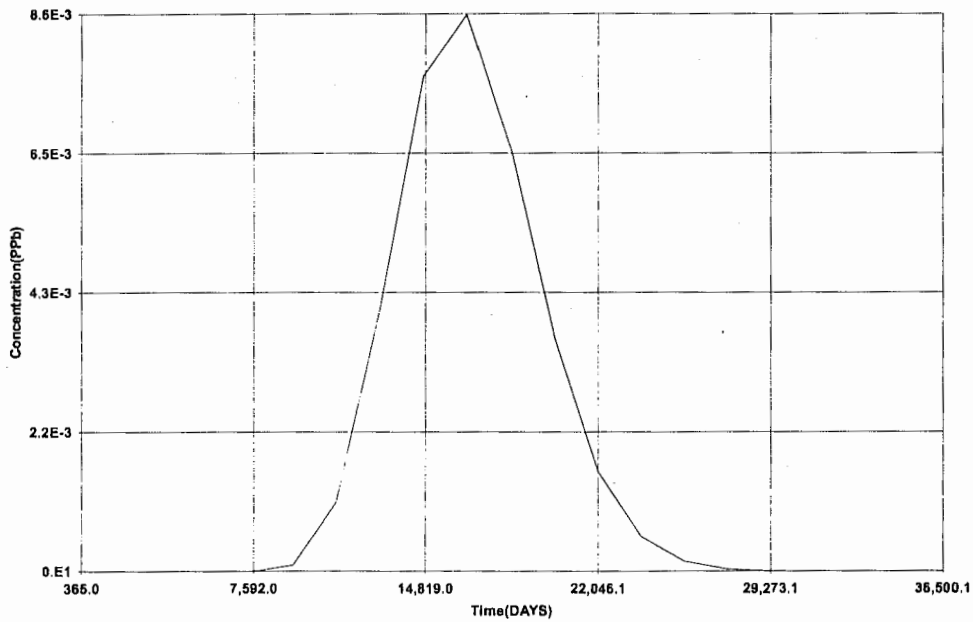


15 Years


### Monitoring Point 1 - Upgradient of Farm House



### Monitoring Point 2 - At Farm House



Note: Results are based on Scenario 2

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<small>CLIENT/PROJECT TITLE</small> <b>Seneca Army Depot Activity</b> Ash Landfill Remedial Design	
<small>DEPT</small> ENVIRONMENTAL ENGINEERING	<small>DWG NO</small>
<b>Figure 5</b> <b>Total Chlorinated Ethene</b> <b>Concentration Profiles at</b> <b>Monitoring Points 1 and 2</b>	
<small>SCALE</small> NA	<small>DATE</small> April 2000

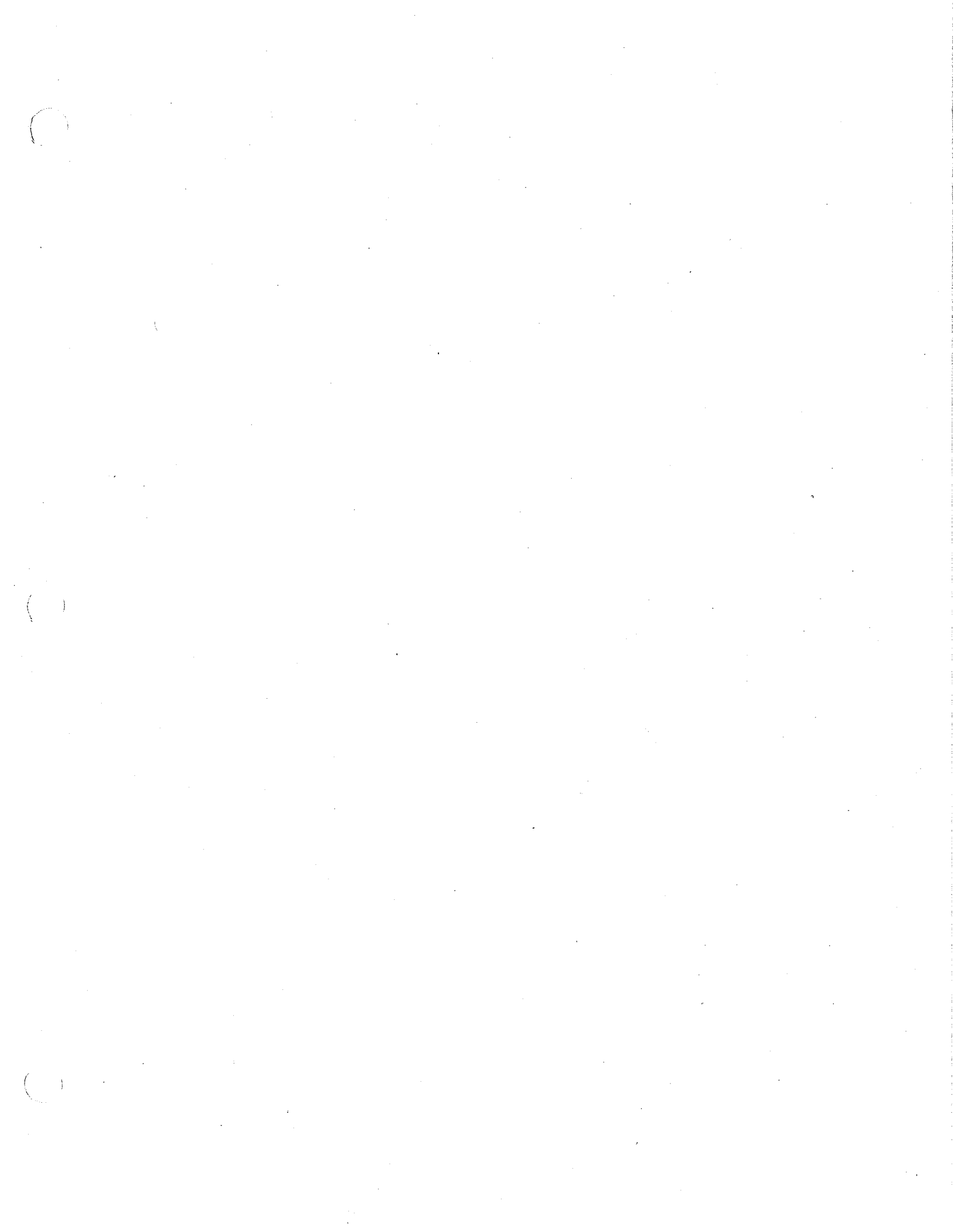


TABLE 1  
GROUND WATER CHEMICAL RESULTS  
ROUND 1 GROUNDWATER MONITORING  
ASH REMEDIAL DESIGN  
SENECA ARMY DEPOT ACTIVITY ROMULUS, NY

				ASH LANDFILL BN-S	ASH LANDFILL FH-D	ASH LANDFILL FH-S	ASH LANDFILL MW-12A	ASH LANDFILL MW-27				
				GROUND WATER	GROUND WATER	GROUND WATER	GROUND WATER	GROUND WATER				
				ARD2038	ARD2036	ARD2037	ARD2047	ARD2030				
				0	0	0	11	10				
				0	0	0	11	10				
				19-Oct-99	19-Oct-99	19-Oct-99	21-Oct-99	19-Oct-99				
				SA	SA	SA	SA	SA				
				ASH REMEDIAL DES	ASH REMEDIAL DES	ASH REMEDIAL DES	ASH REMEDIAL DES	ASH REMEDIAL DES				
				1	1	1	1	1				
PARAMETER	UNIT	MAXIMUM	FREQUENCY OF DETECTION	NYSDEC CLASS GA STD.	NUMBER ABOVE STD.	NUMBER OF DETECTS	NUMBER OF ANALYSES	N	N	N	N	N
<b>VOLATILE ORGANICS</b>												
1,1,1-Trichloroethane	UG/L	1	2%	5	0	1	55	10 U	10 U	10 U	73 U	10 U
1,1,2,2-Tetrachloroethane	UG/L	0	0%	5	0	0	55	10 U	10 U	10 U	73 U	10 U
1,1,2-Trichloroethane	UG/L	0	0%	5	0	0	55	10 U	10 U	10 U	73 U	10 U
1,1-Dichloroethane	UG/L	9	2%	5	1	1	55	10 U	10 U	10 U	73 U	10 U
1,1-Dichloroethene	UG/L	0	0%	5	0	0	55	10 U	10 U	10 U	73 U	10 U
1,2-Dichloroethane	UG/L	4	4%	5	0	2	55	10 U	10 U	10 U	73 U	10 U
1,2-Dichloroethene (total)	UG/L	1100	27%	5	14	15	55	10 U	10 U	10 U	940	10 U
1,2-Dichloropropane	UG/L	0	0%	5	0	0	55	10 U	10 U	10 U	73 U	10 U
Acetone	UG/L	2	4%		0	2	55	10 UJ	10 UJ	10 UJ	73 UJ	10 UJ
Benzene	UG/L	0	0%	0.7	0	0	55	10 U	10 U	10 U	73 U	10 U
Bromodichloromethane	UG/L	0	0%		0	0	55	10 U	10 U	10 U	73 U	10 U
Bromoform	UG/L	0	0%		0	0	55	10 U	10 U	10 U	73 U	10 U
Carbon disulfide	UG/L	0	0%		0	0	55	10 U	10 U	10 U	73 U	10 U
Carbon tetrachloride	UG/L	0	0%	5	0	0	55	10 U	10 U	10 U	73 U	10 U
Chlorobenzene	UG/L	0	0%	5	0	0	55	10 U	10 U	10 U	73 U	10 U
Chlorodibromomethane	UG/L	0	0%		0	0	55	10 U	10 U	10 U	73 U	10 U
Chloroethane	UG/L	0	0%	5	0	0	55	10 U	10 U	10 U	73 U	10 U
Chloroform	UG/L	74	2%	7	1	1	55	10 U	10 U	10 U	73 U	10 U
Cis-1,3-Dichloropropene	UG/L	0	0%	5	0	0	55	10 U	10 U	10 U	73 U	10 U
Ethyl benzene	UG/L	0	0%	5	0	0	55	10 U	10 U	10 U	73 U	10 U
Methyl bromide	UG/L	0	0%		0	0	55	10 U	10 U	10 U	73 U	10 U
Methyl butyl ketone	UG/L	0	0%		0	0	55	10 UJ	10 UJ	10 UJ	73 U	10 UJ
Methyl chloride	UG/L	0	0%	5	0	0	55	10 U	10 U	10 U	73 U	10 U
Methyl ethyl ketone	UG/L	0	0%	50	0	0	55	10 UJ	10 UJ	10 UJ	73 U	10 UJ
Methyl isobutyl ketone	UG/L	0	0%		0	0	55	10 UJ	10 UJ	10 UJ	73 U	10 UJ
Methylene chloride	UG/L	0	0%	5	0	0	55	10 U	10 U	10 U	73 U	10 U
Styrene	UG/L	0	0%		0	0	55	10 U	10 U	10 U	73 U	10 U
Tetrachloroethene	UG/L	0	0%	5	0	0	55	10 U	10 U	10 U	73 U	10 U
Toluene	UG/L	0	0%	5	0	0	55	10 U	10 U	10 U	73 U	10 U
Total Xylenes	UG/L	0	0%	5	0	0	55	10 U	10 U	10 U	73 U	10 U

TABLE 1  
GROUND WATER CHEMICAL RESULTS  
ROUND 1 GROUNDWATER MONITORING  
ASH REMEDIAL DESIGN  
SENECA ARMY DEPOT ACTIVITY ROMULUS, NY

FACILITY										ASH LANDFILL	ASH LANDFILL	ASH LANDFILL	ASH LANDFILL	ASH LANDFILL	
LOCATION ID										BN-S	FH-D	FH-S	MW-12A	MW-27	
MATRIX										GROUND WATER	GROUND WATER	GROUND WATER	GROUND WATER	GROUND WATER	
SAMPLE ID										ARD2038	ARD2036	ARD2037	ARD2047	ARD2030	
DEPTH TO TOP OF SAMPLE										0	0	0	11	10	
DEPTH TO BOTTOM OF SAMPLE										0	0	0	11	10	
SAMPLE DATE										19-Oct-99	19-Oct-99	19-Oct-99	21-Oct-99	19-Oct-99	
QC CODE										SA	SA	SA	SA	SA	
STUDY ID			FREQUENCY	NYSDEC	NUMBER	NUMBER	NUMBER			ASH REMEDIAL DES	ASH REMEDIAL DES	ASH REMEDIAL DES	ASH REMEDIAL DES	ASH REMEDIAL DES	
SAMPLE ROUND			OF	CLASS GA	ABOVE	OF	OF			1	1	1	1	1	
PARAMETER	UNIT	MAXIMUM	DETECTION	STD.	STD.	DETECTS	ANALYSES	N		N		N	N	N	
Trans-1,3-Dichloropropene	UG/L	0	0%	5	0	0	55		10 U		10 U		10 U	73 U	10 U
Trichloroethene	UG/L	9100	27%	5	10	15	55		10 U		10 U		10 U	340	10 U
Vinyl chloride	UG/L	180	5%	2	2	3	55		10 U		10 U		10 U	11 J	10 U
<b>METALS</b>															
Aluminum	UG/L	2600	65%		0	34	52							56.2 J	1130
Antimony	UG/L	3	2%		0	1	52							2.7 U	2.7 U
Arsenic	UG/L	7	23%	25	0	12	52							1.9 U	1.9 U
Barium	UG/L	176	98%	1000	0	51	52							32.8 J	47.5 J
Beryllium	UG/L	0.66	10%		0	5	52							0.2 U	0.2 U
Cadmium	UG/L	0	0%	10	0	0	52							0.3 U	0.3 U
Calcium	UG/L	268000	98%		0	51	52							268000	83200
Chromium	UG/L	5.6	15%	50	0	8	52							0.9 U	0.9 U
Cobalt	UG/L	8.4	4%		0	2	52							2.5 U	2 U
Copper	UG/L	6.1	10%	200	0	5	52							1.7 U	1.7 U
Cyanide	UG/L	0	0%	100	0	0	52							5 U	5 U
Iron	UG/L	11600	67%	300	14	35	52							155 J	1130
Lead	UG/L	5.4	10%	25	0	5	52							1.2 U	1.1 J
Magnesium	UG/L	47100	98%		0	51	52							38400	10800
Manganese	UG/L	3140	83%	300	7	43	52							528	102
Mercury	UG/L	0.2	12%	2	0	6	52							0.1 U	0.1 U
Nickel	UG/L	5.6	12%		0	6	52							1.7 U	1.7 U
Potassium	UG/L	18400	98%		0	51	52							6100	2640 J
Selenium	UG/L	2.6	2%	10	0	1	52							2.4 U	2.4 U
Silver	UG/L	0	0%	50	0	0	52							1.6 U	1.6 U
Sodium	UG/L	142000	98%	20000	27	51	52							74000	28600
Thallium	UG/L	10.8	19%		0	10	52							2.9 U	2.7 U
Vanadium	UG/L	4.5	6%		0	3	52							1.5 U	1.5 U
Zinc	UG/L	134	81%	300	0	42	52							6.5 J	5.2 J

TABLE 1  
GROUND WATER CHEMICAL RESULTS  
ROUND 1 GROUNDWATER MONITORING  
ASH REMEDIAL DESIGN  
SENECA ARMY DEPOT ACTIVITY ROMULUS, NY

FACILITY				ASH LANDFILL													
LOCATION ID				MW-28			MW-29			MW-30		MW-31		MW-32			
MATRIX				GROUND WATER			GROUND WATER			GROUND WATER		GROUND WATER		GROUND WATER			
SAMPLE ID				ARD2044			ARD2056			ARD2028		ARD2003		ARD2029			
DEPTH TO TOP OF SAMPLE				9			11			9.5		9.8		10			
DEPTH TO BOTTOM OF SAMPLE				9			11			9.5		9.8		10			
SAMPLE DATE				21-Oct-99			22-Oct-99			19-Oct-99		08-Oct-99		19-Oct-99			
QC CODE				SA			SA			SA		SA		SA			
STUDY ID				FREQUENCY			NYSDEC			NUMBER		NUMBER		NUMBER			
SAMPLE ROUND				OF			CLASS GA			ABOVE		OF		OF			
PARAMETER				DETECTION			STD.			STD.		DETECTS		ANALYSES			
UNIT				MAXIMUM			N			1		1		1			
<b>VOLATILE ORGANICS</b>																	
1,1,1-Trichloroethane	UG/L	1	2%	5	0	1	55	10	U	1	J	10	U	10	UJ	10	U
1,1,2,2-Tetrachloroethane	UG/L	0	0%	5	0	0	55	10	U	10	U	10	U	10	UJ	10	U
1,1,2-Trichloroethane	UG/L	0	0%		0	0	55	10	U	10	U	10	U	10	UJ	10	U
1,1-Dichloroethane	UG/L	9	2%	5	1	1	55	10	U	10	U	10	U	10	UJ	10	U
1,1-Dichloroethene	UG/L	0	0%	5	0	0	55	10	U	10	U	10	U	10	UJ	10	U
1,2-Dichloroethane	UG/L	4	4%	5	0	2	55	10	U	10	U	10	U	10	UJ	10	U
1,2-Dichloroethene (total)	UG/L	1100	27%	5	14	15	55	19	U	110	U	10	U	10	UJ	10	U
1,2-Dichloropropane	UG/L	0	0%	5	0	0	55	10	U	10	U	10	U	10	UJ	10	U
Acetone	UG/L	2	4%		0	2	55	10	UJ	10	UJ	10	UJ	10	UJ	10	UJ
Benzene	UG/L	0	0%	0.7	0	0	55	10	U	10	U	10	U	10	UJ	10	U
Bromodichloromethane	UG/L	0	0%		0	0	55	10	U	10	U	10	U	10	UJ	10	U
Bromoform	UG/L	0	0%		0	0	55	10	U	10	U	10	U	10	UJ	10	U
Carbon disulfide	UG/L	0	0%		0	0	55	10	U	10	U	10	U	10	UJ	10	U
Carbon tetrachloride	UG/L	0	0%	5	0	0	55	10	U	10	U	10	U	10	UJ	10	U
Chlorobenzene	UG/L	0	0%	5	0	0	55	10	U	10	U	10	U	10	UJ	10	U
Chlorodibromomethane	UG/L	0	0%		0	0	55	10	U	10	U	10	U	10	UJ	10	U
Chloroethane	UG/L	0	0%	5	0	0	55	10	U	10	U	10	U	10	UJ	10	U
Chloroform	UG/L	74	2%	7	1	1	55	10	U	10	U	10	U	10	UJ	10	U
Cis-1,3-Dichloropropene	UG/L	0	0%	5	0	0	55	10	U	10	U	10	U	10	UJ	10	U
Ethyl benzene	UG/L	0	0%	5	0	0	55	10	U	10	U	10	U	10	UJ	10	U
Methyl bromide	UG/L	0	0%		0	0	55	10	U	10	U	10	U	10	UJ	10	U
Methyl butyl ketone	UG/L	0	0%		0	0	55	10	U	10	U	10	UJ	10	UJ	10	UJ
Methyl chloride	UG/L	0	0%	5	0	0	55	10	U	10	U	10	U	10	UJ	10	U
Methyl ethyl ketone	UG/L	0	0%	50	0	0	55	10	U	10	U	10	UJ	10	UJ	10	UJ
Methyl isobutyl ketone	UG/L	0	0%		0	0	55	10	U	10	U	10	UJ	10	UJ	10	UJ
Methylene chloride	UG/L	0	0%	5	0	0	55	10	U	10	U	10	U	10	UJ	10	U
Styrene	UG/L	0	0%		0	0	55	10	U	10	U	10	U	10	UJ	10	U
Tetrachloroethene	UG/L	0	0%	5	0	0	55	10	U	10	U	10	U	10	UJ	10	U
Toluene	UG/L	0	0%	5	0	0	55	10	U	10	U	10	U	10	UJ	10	U
Total Xylenes	UG/L	0	0%	5	0	0	55	10	U	10	U	10	U	10	UJ	10	U



TABLE 1  
GROUND WATER CHEMICAL RESULTS  
ROUND 1 GROUNDWATER MONITORING  
ASH REMEDIAL DESIGN  
SENECA ARMY DEPOT ACTIVITY ROMULUS, NY

FACILITY	LOCATION ID	MATRIX	SAMPLE ID	DEPTH TO TOP OF SAMPLE	DEPTH TO BOTTOM OF SAMPLE	SAMPLE DATE	QC CODE	STUDY ID	FREQUENCY OF DETECTION	NYSDEC CLASS GA STD.	NUMBER ABOVE STD.	NUMBER OF DETECTS	NUMBER OF ANALYSES	ASH LANDFILL MW-28	ASH LANDFILL MW-29	ASH LANDFILL MW-30	ASH LANDFILL MW-31	ASH LANDFILL MW-32	
														GROUND WATER	GROUND WATER	GROUND WATER	GROUND WATER	GROUND WATER	
														ARD2044	ARD2056	ARD2028	ARD2003	ARD2029	
														9	11	9.5	9.8	10	
														9	11	9.5	9.8	10	
														21-Oct-99	22-Oct-99	19-Oct-99	08-Oct-99	19-Oct-99	
														SA	SA	SA	SA	SA	
														ASH REMEDIAL DES	ASH REMEDIAL DES	ASH REMEDIAL DES	ASH REMEDIAL DES	ASH REMEDIAL DES	
														1	1	1	1	1	
														N	N	N	N	N	
Trans-1,3-Dichloropropene	UG/L	0	0%	5	0	0	55	10	U				55	10	U			10	U
Trichloroethene	UG/L	9100	27%	5	10	15	55	21	J				55	3	J			10	UJ
Vinyl chloride	UG/L	180	5%	2	2	3	55	10	U				55	10	U			10	UJ
<b>METALS</b>																			
Aluminum	UG/L	2600	65%		0	34	52	21.1	J				52	173	J			106	J
Antimony	UG/L	3	2%		0	1	52	2.7	U				52	2.7	U			2.7	U
Arsenic	UG/L	7	23%	25	0	12	52	1.9	U				52	1.9	U			1.9	U
Barium	UG/L	176	98%	1000	0	51	52	43.8	J				52	67.9	J			46.8	J
Beryllium	UG/L	0.66	10%		0	5	52	0.2	U				52	0.2	U			0.2	UJ
Cadmium	UG/L	0	0%	10	0	0	52	0.3	U				52	0.3	U			0.3	UJ
Calcium	UG/L	268000	98%		0	51	52	112000					52	164000				112000	
Chromium	UG/L	5.6	15%	50	0	8	52	0.9	U				52	0.9	U			0.9	UJ
Cobalt	UG/L	8.4	4%		0	2	52	2.5	U				52	2.5	U			2	U
Copper	UG/L	6.1	10%	200	0	5	52	1.7	U				52	1.7	U			1.9	UJ
Cyanide	UG/L	0	0%	100	0	0	52	5	U				52	5	U			5	UJ
Iron	UG/L	11600	67%	300	14	35	52	28.8	J				52	442	J			109	UJ
Lead	UG/L	5.4	10%	25	0	5	52	1	U				52	1	U			1.2	UJ
Magnesium	UG/L	47100	98%		0	51	52	12100					52	18900				11600	J
Manganese	UG/L	3140	83%	300	7	43	52	1.3	J				52	2.6	J			17.1	J
Mercury	UG/L	0.2	12%	2	0	6	52	0.1	U				52	0.1	U			0.1	UJ
Nickel	UG/L	5.6	12%		0	6	52	1.7	U				52	1.7	U			2.6	UJ
Potassium	UG/L	18400	98%		0	51	52	1220	J				52	1680	J			2760	J
Selenium	UG/L	2.6	2%	10	0	1	52	2.4	U				52	2.4	U			2.8	UJ
Silver	UG/L	0	0%	50	0	0	52	1.6	U				52	1.6	U			1.6	UJ
Sodium	UG/L	142000	98%	20000	27	51	52	8770					52	22900				15800	J
Thallium	UG/L	10.8	19%		0	10	52	4.4	J				52	2.9	U			2.9	UJ
Vanadium	UG/L	4.5	6%		0	3	52	1.5	U				52	1.5	U			3.2	UJ
Zinc	UG/L	134	81%	300	0	42	52	2.1	J				52	2.5	J			2	J

TABLE 1  
GROUND WATER CHEMICAL RESULTS  
ROUND 1 GROUNDWATER MONITORING  
ASH REMEDIAL DESIGN  
SENECA ARMY DEPOT ACTIVITY ROMULUS, NY

FACILITY									ASH LANDFILL	ASH LANDFILL	ASH LANDFILL	ASH LANDFILL	ASH LAN
LOCATION ID									MW-33	MW-34	MW-35D	MW-36	MW-36
MATRIX									GROUND WATER	GROUND WATER	GROUND WATER	GROUND WATER	GROUND
SAMPLE ID									ARD2020	ARD2021	ARD2043	ARD2041	ARD2040
DEPTH TO TOP OF SAMPLE									9.79	12.5	44	10	10
DEPTH TO BOTTOM OF SAMPLE									9.79	12.5	44	10	10
SAMPLE DATE									12-Oct-99	12-Oct-99	20-Oct-99	20-Oct-99	20-Oct-99
QC CODE									SA	SA	SA	DU	SA
STUDY ID			FREQUENCY	NYSDEC	NUMBER	NUMBER	NUMBER	ASH REMEDIAL DESIGN	ASH REMEDIAL DESI	ASH REMEDIAL DES	ASH REMEDIAL DES	ASH REM	ASH REM
SAMPLE ROUND			OF	CLASS GA	ABOVE	OF	OF	1	1	1	1	1	1
PARAMETER	UNIT	MAXIMUM	DETECTION	STD.	STD.	DETECTS	ANALYSES	N	N	N	N	N	N
<b>VOLATILE ORGANICS</b>													
1,1,1-Trichloroethane	UG/L	1	2%	5	0	1	55	10 U	10 U	10 U	10 U	10 U	10
1,1,2,2-Tetrachloroethane	UG/L	0	0%	5	0	0	55	10 U	10 U	10 U	10 U	10 U	10
1,1,2-Trichloroethane	UG/L	0	0%		0	0	55	10 U	10 U	10 U	10 U	10 U	10
1,1-Dichloroethane	UG/L	9	2%	5	1	1	55	10 U	10 U	10 U	10 U	10 U	10
1,1-Dichloroethene	UG/L	0	0%	5	0	0	55	10 U	10 U	10 U	10 U	10 U	10
1,2-Dichloroethane	UG/L	4	4%	5	0	2	55	10 U	10 U	10 U	10 U	10 U	10
1,2-Dichloroethene (total)	UG/L	1100	27%	5	14	15	55	10 U	10 U	10 U	10 U	10 U	10
1,2-Dichloropropane	UG/L	0	0%	5	0	0	55	10 U	10 U	10 U	10 U	10 U	10
Acetone	UG/L	2	4%		0	2	55	10 U	10 U	10 UJ	10 UJ	10 UJ	10
Benzene	UG/L	0	0%	0.7	0	0	55	10 U	10 U	10 U	10 U	10 U	10
Bromodichloromethane	UG/L	0	0%		0	0	55	10 U	10 U	10 U	10 U	10 U	10
Bromoform	UG/L	0	0%		0	0	55	10 U	10 U	10 U	10 U	10 U	10
Carbon disulfide	UG/L	0	0%		0	0	55	10 U	10 U	10 U	10 U	10 U	10
Carbon tetrachloride	UG/L	0	0%	5	0	0	55	10 U	10 U	10 U	10 U	10 U	10
Chlorobenzene	UG/L	0	0%	5	0	0	55	10 U	10 U	10 U	10 U	10 U	10
Chlorodibromomethane	UG/L	0	0%		0	0	55	10 U	10 U	10 U	10 U	10 U	10
Chloroethane	UG/L	0	0%	5	0	0	55	10 U	10 U	10 U	10 U	10 U	10
Chloroform	UG/L	74	2%	7	1	1	55	10 U	10 U	10 U	10 U	10 U	10
Cis-1,3-Dichloropropene	UG/L	0	0%	5	0	0	55	10 U	10 U	10 U	10 U	10 U	10
Ethyl benzene	UG/L	0	0%	5	0	0	55	10 U	10 U	10 U	10 U	10 U	10
Methyl bromide	UG/L	0	0%		0	0	55	10 U	10 U	10 U	10 U	10 U	10
Methyl butyl ketone	UG/L	0	0%		0	0	55	10 U	10 U	10 UJ	10 UJ	10 UJ	10
Methyl chloride	UG/L	0	0%	5	0	0	55	10 U	10 U	10 U	10 U	10 U	10
Methyl ethyl ketone	UG/L	0	0%	50	0	0	55	10 U	10 U	10 UJ	10 UJ	10 UJ	10
Methyl isobutyl ketone	UG/L	0	0%		0	0	55	10 U	10 U	10 UJ	10 UJ	10 UJ	10
Methylene chloride	UG/L	0	0%	5	0	0	55	10 U	10 U	10 U	10 U	10 U	10
Styrene	UG/L	0	0%		0	0	55	10 U	10 U	10 U	10 U	10 U	10
Tetrachloroethene	UG/L	0	0%	5	0	0	55	10 U	10 U	10 U	10 U	10 U	10
Toluene	UG/L	0	0%	5	0	0	55	10 U	10 U	10 U	10 U	10 U	10
Total Xylenes	UG/L	0	0%	5	0	0	55	10 U	10 U	10 U	10 U	10 U	10

TABLE 1  
GROUND WATER CHEMICAL RESULTS  
ROUND 1 GROUND WATER MONITORING  
ASH REMEDIAL DESIGN  
SENECA ARMY DEPOT ACTIVITY ROMULUS, NY

FACILITY	ASH LANDFILL															
LOCATION ID	MW-33		MW-34		MW-35D		MW-36		ASH LAN							
MATRIX	GROUND WATER		GROUND WATER		GROUND WATER		GROUND WATER		GROUND							
SAMPLE ID	ARD2020		ARD2021		ARD2043		ARD2041		ARD2040							
DEPTH TO TOP OF SAMPLE	9.79		12.5		44		10		10							
DEPTH TO BOTTOM OF SAMPLE	9.79		12.5		44		10		10							
SAMPLE DATE	12-Oct-99		12-Oct-99		20-Oct-99		20-Oct-99		20-Oct-99							
QC CODE	SA		SA		SA		DU		SA							
STUDY ID	FREQUENCY		NYSDEC		NUMBER		NUMBER		NUMBER							
SAMPLE ROUND	OF	CLASS GA	ABOVE	OF	OF	OF	OF	OF	OF	OF						
PARAMETER	UNIT	MAXIMUM	DETECTION	STD.	STD.	DETECTS	ANALYSES	N	1	1	1	1	1			
Trans-1,3-Dichloropropene	UG/L	0	0%	5	0	0	55	10	U	10	U	10	U	10		
Trichloroethene	UG/L	9100	27%	5	10	15	55	10	U	10	U	10	U	10		
Vinyl chloride	UG/L	180	5%	2	2	3	55	10	U	10	U	10	U	10		
<b>METALS</b>																
Aluminum	UG/L	2600	65%		0	34	52	89.3	J	82	J	42	J	14.3	U	24
Antimony	UG/L	3	2%		0	1	52	2.7	U	2.7	U	2.7	U	2.7	U	2.7
Arsenic	UG/L	7	23%	25	0	12	52	1.9	U	1.9	U	3.6	J	2.2	J	3.2
Barium	UG/L	176	98%	1000	0	51	52	36.1	J	82.6	J	102	J	68.4	J	66.9
Beryllium	UG/L	0.66	10%		0	5	52	0.2	U	0.2	U	0.2	U	0.2	U	0.2
Cadmium	UG/L	0	0%	10	0	0	52	0.3	U	0.3	U	0.3	U	0.3	U	0.3
Calcium	UG/L	268000	98%		0	51	52	106000		49900		19400		114000		108000
Chromium	UG/L	5.6	15%	50	0	8	52	0.9	U	0.9	U	0.9	U	0.9	U	0.93
Cobalt	UG/L	8.4	4%		0	2	52	2	U	2	U	2.5	U	2.5	U	2.5
Copper	UG/L	6.1	10%	200	0	5	52	1.7	U	1.7	U	1.7	U	1.7	U	1.7
Cyanide	UG/L	0	0%	100	0	0	52	5	U	5	U	5	U	5	U	5
Iron	UG/L	11600	67%	300	14	35	52	81.7	J	142	J	66.9	J	25.4	U	25.4
Lead	UG/L	5.4	10%	25	0	5	52	1	U	1	U	1	U	1	U	1
Magnesium	UG/L	47100	98%		0	51	52	11200		11200		6010		16700		16500
Manganese	UG/L	3140	83%	300	7	43	52	6.3	J	54.4	J	37.6	J	23.1	J	20.7
Mercury	UG/L	0.2	12%	2	0	6	52	0.1	U	0.1	U	0.1	U	0.2	J	0.1
Nickel	UG/L	5.6	12%		0	6	52	1.7	U	1.7	U	1.7	U	1.7	U	1.7
Potassium	UG/L	18400	98%		0	51	52	1710	J	2450	J	1820	J	1830	J	1850
Selenium	UG/L	2.6	2%	10	0	1	52	2.4	U	2.4	U	2.4	U	2.4	U	2.4
Silver	UG/L	0	0%	50	0	0	52	1.6	U	1.6	U	1.6	U	1.6	U	1.6
Sodium	UG/L	142000	98%	20000	27	51	52	16000		63100		95900		32600		32600
Thallium	UG/L	10.8	19%		0	10	52	2.7	U	2.7	U	2.9	U	2.9	U	2.9
Vanadium	UG/L	4.5	6%		0	3	52	1.5	U	1.5	U	1.5	U	1.5	U	1.5
Zinc	UG/L	134	81%	300	0	42	52	1.6	U	2.5	J	3.7	J	3.7	J	4.2

TABLE 1  
GROUND WATER CHEMICAL RESULTS  
ROUND 1 GROUNDWATER MONITORING  
ASH REMEDIAL DESIGN  
SENECA ARMY DEPOT ACTIVITY ROMULUS, NY

FACILITY									FILL					
LOCATION ID									ASH LANDFILL	ASH LANDFILL	ASH LANDFILL	ASH LANDFILL	ASH LANDFILL	ASH LANDFILL
MATRIX									MW-37	MW-38D	MW-39	MW-40		
SAMPLE ID									GROUND WATER	GROUND WATER	GROUND WATER	GROUND WATER		
DEPTH TO TOP OF SAMPLE									ARD2017	ARD2015	ARD2007	ARD2008		
DEPTH TO BOTTOM OF SAMPLE									11	20	9.5		12	
SAMPLE DATE									11	20	9.5		12	
QC CODE									11-Oct-99	11-Oct-99	09-Oct-99		09-Oct-99	
STUDY ID			FREQUENCY	NYSDEC	NUMBER	NUMBER	NUMBER	DIAL DES	SA	SA	SA	SA	SA	
SAMPLE ROUND			OF	CLASS GA	ABOVE	OF	OF	ASH REMEDIAL DES	ASH REMEDIAL DES	ASH REMEDIAL DES	ASH REMEDIAL DES	ASH REMEDIAL DES	ASH REMEDIAL DESIGN	
PARAMETER	UNIT	MAXIMUM	DETECTION	STD.	STD.	DETECTS	ANALYSES	1	1	1	1	1	1	
VOLATILE ORGANICS														
1,1,1-Trichloroethane	UG/L	1	2%	5	0	1	55 U	10 U	10 U	10 U	10 U	10 U	10 U	
1,1,2,2-Tetrachloroethane	UG/L	0	0%	5	0	0	55 U	10 U	10 U	10 U	10 U	10 U	10 U	
1,1,2-Trichloroethane	UG/L	0	0%	5	0	0	55 U	10 U	10 U	10 U	10 U	10 U	10 U	
1,1-Dichloroethane	UG/L	9	2%	5	1	1	55 U	10 U	10 U	10 U	10 U	10 U	10 U	
1,1-Dichloroethene	UG/L	0	0%	5	0	0	55 U	10 U	10 U	10 U	10 U	10 U	10 U	
1,2-Dichloroethane	UG/L	4	4%	5	0	2	55 U	10 U	10 U	10 U	10 U	10 U	10 U	
1,2-Dichloroethene (total)	UG/L	1100	27%	5	14	15	55 U	10 U	10 U	10 U	10 U	10 U	10 U	
1,2-Dichloropropane	UG/L	0	0%	5	0	0	55 U	10 U	10 U	10 U	10 U	10 U	10 U	
Acetone	UG/L	2	4%		0	2	55 UJ	10 U	10 U	10 U	10 U	10 U	10 U	
Benzene	UG/L	0	0%	0.7	0	0	55 U	10 U	10 U	10 U	10 U	10 U	10 U	
Bromodichloromethane	UG/L	0	0%		0	0	55 U	10 U	10 U	10 U	10 U	10 U	10 U	
Bromoform	UG/L	0	0%		0	0	55 U	10 U	10 U	10 U	10 U	10 U	10 U	
Carbon disulfide	UG/L	0	0%		0	0	55 U	10 U	10 U	10 U	10 U	10 U	10 U	
Carbon tetrachloride	UG/L	0	0%	5	0	0	55 U	10 U	10 U	10 U	10 U	10 U	10 U	
Chlorobenzene	UG/L	0	0%	5	0	0	55 U	10 U	10 U	10 U	10 U	10 U	10 U	
Chlorodibromomethane	UG/L	0	0%		0	0	55 U	10 U	10 U	10 U	10 U	10 U	10 U	
Chloroethane	UG/L	0	0%	5	0	0	55 U	10 U	10 U	10 U	10 U	10 U	10 U	
Chloroform	UG/L	74	2%	7	1	1	55 U	10 U	10 U	10 U	10 U	10 U	10 U	
Cis-1,3-Dichloropropene	UG/L	0	0%	5	0	0	55 U	10 U	10 U	10 U	10 U	10 U	10 U	
Ethyl benzene	UG/L	0	0%	5	0	0	55 U	10 U	10 U	10 U	10 U	10 U	10 U	
Methyl bromide	UG/L	0	0%		0	0	55 U	10 U	10 U	10 U	10 U	10 U	10 U	
Methyl butyl ketone	UG/L	0	0%		0	0	55 UJ	10 U	10 U	10 U	10 U	10 U	10 U	
Methyl chloride	UG/L	0	0%	5	0	0	55 U	10 U	10 U	10 U	10 U	10 U	10 U	
Methyl ethyl ketone	UG/L	0	0%	50	0	0	55 UJ	10 U	10 U	10 U	10 U	10 U	10 U	
Methyl isobutyl ketone	UG/L	0	0%		0	0	55 UJ	10 U	10 U	10 U	10 U	10 U	10 U	
Methylene chloride	UG/L	0	0%	5	0	0	55 U	10 U	10 U	10 U	10 U	10 U	10 U	
Styrene	UG/L	0	0%		0	0	55 U	10 U	10 U	10 U	10 U	10 U	10 U	
Tetrachloroethene	UG/L	0	0%	5	0	0	55 U	10 U	10 U	10 U	10 U	10 U	10 U	
Toluene	UG/L	0	0%	5	0	0	55 U	10 U	10 U	10 U	10 U	10 U	10 U	
Total Xylenes	UG/L	0	0%	5	0	0	55 U	10 U	10 U	10 U	10 U	10 U	10 U	

TABLE 1  
GROUND WATER CHEMICAL RESULTS  
ROUND 1 GROUNDWATER MONITORING  
ASH REMEDIAL DESIGN  
SENECA ARMY DEPOT ACTIVITY ROMULUS, NY

								FILL	ASH LANDFILL	ASH LANDFILL	ASH LANDFILL	ASH LANDFILL
								MW-37	MW-38D	MW-39	MW-40	
								ATER	GROUND WATER	GROUND WATER	GROUND WATER	GROUND WATER
								ARD2017	ARD2015	ARD2007	ARD2008	
								11	20	9.5	12	
								11	20	9.5	12	
								11-Oct-99	11-Oct-99	09-Oct-99	09-Oct-99	
								SA	SA	SA	SA	
STUDY ID	FREQUENCY			NYSDEC	NUMBER	NUMBER	NUMBER	DIAL DES	ASH REMEDIAL DES	ASH REMEDIAL DES	ASH REMEDIAL DES	ASH REMEDIAL DESIGN
SAMPLE ROUND	UNIT	MAXIMUM	DETECTION	CLASS GA	ABOVE	OF	OF	1	1	1	1	
PARAMETER	UNIT	MAXIMUM	DETECTION	STD.	STD.	DETECTS	ANALYSES	N	N	N	N	
Trans-1,3-Dichloropropene	UG/L	0	0%	5	0	0	55 U	10 U	10 U	10 U	10 U	
Trichloroethene	UG/L	9100	27%	5	10	15	55 U	10 U	10 U	10 U	10 U	
Vinyl chloride	UG/L	180	5%	2	2	3	55 U	10 U	10 U	10 U	10 U	
<b>METALS</b>												
Aluminum	UG/L	2600	65%		0	34	52 J	69.6 J	16.3 U	16.3 U	71.2 J	
Antimony	UG/L	3	2%		0	1	52 U	4.9 U	4.9 U	4.9 U	4.9 U	
Arsenic	UG/L	7	23%	25	0	12	52 J	3.7 U	4.5 J	3.7 U	3.7 U	
Barium	UG/L	176	98%	1000	0	51	52 J	58.3 J	164 J	39.2 J	69.8 J	
Beryllium	UG/L	0.66	10%		0	5	52 U	0.2 U	0.2 U	0.2 U	0.2 U	
Cadmium	UG/L	0	0%	10	0	0	52 U	0.7 U	0.7 U	0.7 U	0.7 U	
Calcium	UG/L	268000	98%		0	51	52	97600	91200	92300	99200	
Chromium	UG/L	5.6	15%	50	0	8	52 J	0.9 U	0.9 U	0.9 U	0.9 U	
Cobalt	UG/L	8.4	4%		0	2	52 U	2.5 U	2.5 U	2.5 U	2.5 U	
Copper	UG/L	6.1	10%	200	0	5	52 U	1.9 U	1.9 U	1.9 U	1.9 U	
Cyanide	UG/L	0	0%	100	0	0	52 U	5 U	5 U	5 U	5 U	
Iron	UG/L	11600	67%	300	14	35	52 U	61.4 J	172	14.7 U	14.7 U	
Lead	UG/L	5.4	10%	25	0	5	52 U	1.2 U	1.2 U	1.2 U	1.2 U	
Magnesium	UG/L	47100	98%		0	51	52	13400	16500	11800	10600	
Manganese	UG/L	3140	83%	300	7	43	52	12 J	143	0.9 U	0.9 U	
Mercury	UG/L	0.2	12%	2	0	6	52 UJ	0.1 U	0.1 U	0.1 U	0.1 U	
Nickel	UG/L	5.6	12%		0	6	52 U	2.6 U	2.6 U	4.6 J	2.6 U	
Potassium	UG/L	18400	98%		0	51	52 J	1120 J	7100	2430 J	1720 J	
Selenium	UG/L	2.6	2%	10	0	1	52 U	2.8 U	2.8 U	2.8 U	2.8 U	
Silver	UG/L	0	0%	50	0	0	52 U	1.6 U	1.6 U	1.6 U	1.6 U	
Sodium	UG/L	142000	98%	20000	27	51	52	9360	5580	8040	13600	
Thallium	UG/L	10.8	19%		0	10	52 U	2.9 U	2.9 U	2.9 UJ	2.9 UJ	
Vanadium	UG/L	4.5	6%		0	3	52 U	3.2 U	3.2 U	3.2 U	3.2 U	
Zinc	UG/L	134	81%	300	0	42	52 J	7.7 J	18.6 J	9.5 J	5 J	

TABLE 1  
GROUND WATER CHEMICAL RESULTS  
ROUND 1 GROUNDWATER MONITORING  
ASH REMEDIAL DESIGN  
SENECA ARMY DEPOT ACTIVITY ROMULUS, NY

FACILITY									ASH LANDFILL	ASH LANDFILL	ASH LANDFILL	ASH LANDFILL	ASH LANDFI
LOCATION ID									MW-41D	MW-42D	MW-43	MW-44A	MW-45
MATRIX									GROUND WATER	GROUND WATER	GROUND WATER	GROUND WATER	GROUND W
SAMPLE ID									ARD2001	ARD2053	ARD2049	ARD2050	ARD2054
DEPTH TO TOP OF SAMPLE									32	38	7	12	7.8
DEPTH TO BOTTOM OF SAMPLE									32	38	7	12	7.8
SAMPLE DATE									08-Oct-99	22-Oct-99	22-Oct-99	22-Oct-99	22-Oct-99
QC CODE									SA	SA	SA	SA	SA
STUDY ID									ASH REMEDIAL DESIG	ASH REMEDIAL DES	ASH REMEDIAL DES	ASH REMEDIAL DES	ASH REMEDI
SAMPLE ROUND									1	1	1	1	1
PARAMETER	UNIT	MAXIMUM	FREQUENCY OF DETECTION	NYSDEC CLASS GA STD.	NUMBER ABOVE STD.	NUMBER OF DETECTS	NUMBER OF ANALYSES	N	N	N	N	N	
<b>VOLATILE ORGANICS</b>													
1,1,1-Trichloroethane	UG/L	1	2%	5	0	1	55	10 UJ	10 U	10 U	55 U	10	
1,1,2,2-Tetrachloroethane	UG/L	0	0%	5	0	0	55	10 UJ	10 U	10 U	55 U	10	
1,1,2-Trichloroethane	UG/L	0	0%		0	0	55	10 UJ	10 U	10 U	55 U	10	
1,1-Dichloroethane	UG/L	9	2%	5	1	1	55	10 UJ	10 U	10 U	9 J	10	
1,1-Dichloroethene	UG/L	0	0%	5	0	0	55	10 UJ	10 U	10 U	55 U	10	
1,2-Dichloroethane	UG/L	4	4%	5	0	2	55	10 UJ	10 U	10 U	55 U	10	
1,2-Dichloroethene (total)	UG/L	1100	27%	5	14	15	55	10 UJ	10 U	10 U	690	10	
1,2-Dichloropropane	UG/L	0	0%	5	0	0	55	10 UJ	10 U	10 U	55 U	10	
Acetone	UG/L	2	4%		0	2	55	10 UJ	10 UJ	10 UJ	55 UJ	10	
Benzene	UG/L	0	0%	0.7	0	0	55	10 UJ	10 U	10 U	55 U	10	
Bromodichloromethane	UG/L	0	0%		0	0	55	10 UJ	10 U	10 U	55 U	10	
Bromoform	UG/L	0	0%		0	0	55	10 UJ	10 U	10 U	55 U	10	
Carbon disulfide	UG/L	0	0%		0	0	55	10 UJ	10 U	10 U	55 U	10	
Carbon tetrachloride	UG/L	0	0%	5	0	0	55	10 UJ	10 U	10 U	55 U	10	
Chlorobenzene	UG/L	0	0%	5	0	0	55	10 UJ	10 U	10 U	55 U	10	
Chlorodibromomethane	UG/L	0	0%		0	0	55	10 UJ	10 U	10 U	55 U	10	
Chloroethane	UG/L	0	0%	5	0	0	55	10 UJ	10 U	10 U	55 U	10	
Chloroform	UG/L	74	2%	7	1	1	55	10 UJ	10 U	10 U	55 U	10	
Cis-1,3-Dichloropropene	UG/L	0	0%	5	0	0	55	10 UJ	10 U	10 U	55 U	10	
Ethyl benzene	UG/L	0	0%	5	0	0	55	10 UJ	10 U	10 U	55 U	10	
Methyl bromide	UG/L	0	0%		0	0	55	10 UJ	10 U	10 U	55 U	10	
Methyl butyl ketone	UG/L	0	0%		0	0	55	10 UJ	10 U	10 U	55 U	10	
Methyl chloride	UG/L	0	0%	5	0	0	55	10 UJ	10 U	10 U	55 U	10	
Methyl ethyl ketone	UG/L	0	0%	50	0	0	55	10 UJ	10 U	10 U	55 U	10	
Methyl isobutyl ketone	UG/L	0	0%		0	0	55	10 UJ	10 U	10 U	55 U	10	
Methylene chloride	UG/L	0	0%	5	0	0	55	10 UJ	10 U	10 U	55 U	10	
Styrene	UG/L	0	0%		0	0	55	10 UJ	10 U	10 U	55 U	10	
Tetrachloroethene	UG/L	0	0%	5	0	0	55	10 UJ	10 U	10 U	55 U	10	
Toluene	UG/L	0	0%	5	0	0	55	10 UJ	10 U	10 U	55 U	10	
Total Xylenes	UG/L	0	0%	5	0	0	55	10 UJ	10 U	10 U	55 U	10	

TABLE 1  
GROUND WATER CHEMICAL RESULTS  
ROUND 1 GROUNDWATER MONITORING  
ASH REMEDIAL DESIGN  
SENECA ARMY DEPOT ACTIVITY ROMULUS, NY

FACILITY	LOCATION ID	MATRIX	SAMPLE ID	DEPTH TO TOP OF SAMPLE	DEPTH TO BOTTOM OF SAMPLE	SAMPLE DATE	QC CODE	STUDY ID	SAMPLE ROUND	PARAMETER	UNIT	MAXIMUM	FREQUENCY OF DETECTION	NYSDEC CLASS GA STD.	NUMBER ABOVE STD.	NUMBER OF DETECTS	NUMBER OF ANALYSES	ASH LANDFILL MW-41D GROUND WATER ARD2001	ASH LANDFILL MW-42D GROUND WATER ARD2053	ASH LANDFILL MW-43 GROUND WATER ARD2049	ASH LANDFILL MW-44A GROUND WATER ARD2050	ASH LANDFILL MW-45 GROUND WATER ARD2054			
																		08-Oct-99	22-Oct-99	22-Oct-99	22-Oct-99	22-Oct-99			
																		SA	SA	SA	SA	SA			
																		ASH REMEDIAL DESIG 1	ASH REMEDIAL DES 1	ASH REMEDIAL DES 1	ASH REMEDIAL DES 1	ASH REMEDI 1			
																		N	N	N	N	N			
Trans-1,3-Dichloropropene	UG/L	0	0%	5	0	0	55	10	UJ	10	U	55	10	UJ	10	U	10	U	10	U	55	U	10		
Trichloroethene	UG/L	9100	27%	5	10	15	55	10	UJ	10	U	10	U	10	U	10	U	10	U	10	U	26	J	10	
Vinyl chloride	UG/L	180	5%	2	2	3	55	10	UJ	10	U	10	U	10	U	10	U	10	U	10	U	180	J	10	
<b>METALS</b>																									
Aluminum	UG/L	2600	65%		0	34	52	16.3	UJ	14.3	U	40.2	J	14.3	U	14.7	U	14.3	U	14.7	U	14.7	J	14.7	
Antimony	UG/L	3	2%		0	1	52	4.9	UJ	3	J	2.7	U	2.7	U	2.7	U	2.7	U	2.7	U	2.7	J	2.7	
Arsenic	UG/L	7	23%	25	0	12	52	3.7	UJ	1.9	U	1.9	U	1.9	U	1.9	U	1.9	U	1.9	U	1.9	J	1.9	
Barium	UG/L	176	98%	1000	0	51	52	66.3	J	79.1	J	48.3	J	52.9	J	44.5	J	48.3	J	52.9	J	52.9	J	44.5	
Beryllium	UG/L	0.66	10%		0	5	52	0.2	UJ	0.2	U	0.2	U	0.2	U	0.2	U	0.2	U	0.2	U	0.2	J	0.2	
Cadmium	UG/L	0	0%	10	0	0	52	0.7	UJ	0.3	U	0.3	U	0.3	U	0.3	U	0.3	U	0.3	U	0.3	J	0.3	
Calcium	UG/L	268000	98%		0	51	52	86700	J	62600	J	112000	J	236000	J	100000	J	62600	J	112000	J	236000	J	100000	
Chromium	UG/L	5.6	15%	50	0	8	52	0.9	UJ	0.9	U	0.9	U	1.3	J	0.9	U	0.9	U	1.3	J	1.3	J	0.9	
Cobalt	UG/L	8.4	4%		0	2	52	2.5	UJ	2.5	U	2.5	U	2.5	U	2.5	U	2.5	U	2.5	U	2.5	J	2.5	
Copper	UG/L	6.1	10%	200	0	5	52	1.9	UJ	1.7	U	2	J	1.7	U	1.7	U	1.7	U	2	J	1.7	J	1.7	
Cyanide	UG/L	0	0%	100	0	0	52	5	UJ	5	U	5	U	5	U	5	U	5	U	5	U	5	J	5	
Iron	UG/L	11600	67%	300	14	35	52	14.7	UJ	58.6	J	57.2	J	82.6	J	25.4	J	14.7	UJ	58.6	J	57.2	J	82.6	J
Lead	UG/L	5.4	10%	25	0	5	52	1.2	UJ	1	U	1	U	1	U	1	U	1.2	UJ	1	U	1	U	1	U
Magnesium	UG/L	47100	98%		0	51	52	31100	J	28600	J	9700	J	43400	J	11000	J	31100	J	28600	9700	J	43400	J	11000
Manganese	UG/L	3140	83%	300	7	43	52	252	J	88	J	0.4	U	1250	J	0.44	J	252	J	88	0.4	U	1250	J	0.44
Mercury	UG/L	0.2	12%	2	0	6	52	0.1	UJ	0.1	U	0.1	U	0.1	U	0.1	U	0.1	UJ	0.1	U	0.1	U	0.1	
Nickel	UG/L	5.6	12%		0	6	52	2.6	UJ	1.7	U	1.7	U	1.7	U	1.7	U	2.6	UJ	1.7	U	1.7	U	1.7	
Potassium	UG/L	18400	98%		0	51	52	3520	J	3230	J	1140	J	18400	J	1050	J	3520	J	3230	1140	J	18400	J	1050
Selenium	UG/L	2.6	2%	10	0	1	52	2.8	UJ	2.4	U	2.4	U	2.4	U	2.4	U	2.8	UJ	2.4	U	2.4	U	2.4	
Silver	UG/L	0	0%	50	0	0	52	1.6	UJ	1.6	U	1.6	U	1.6	U	1.6	U	1.6	UJ	1.6	U	1.6	U	1.6	
Sodium	UG/L	142000	98%	20000	27	51	52	35500	J	14300	J	13200	J	78100	J	7400	J	35500	J	14300	13200	J	78100	J	7400
Thallium	UG/L	10.8	19%		0	10	52	2.9	UJ	2.9	U	4.6	J	8.3	J	2.9	U	2.9	UJ	2.9	U	4.6	J	8.3	
Vanadium	UG/L	4.5	6%		0	3	52	3.2	UJ	1.5	U	1.5	U	1.5	U	1.5	U	3.2	UJ	1.5	U	1.5	U	1.5	
Zinc	UG/L	134	81%	300	0	42	52	4.8	J	2.5	J	2.6	J	5.3	J	3.3	J	4.8	J	2.5	J	2.6	J	5.3	

TABLE 1  
GROUND WATER CHEMICAL RESULTS  
ROUND 1 GROUNDWATER MONITORING  
ASH REMEDIAL DESIGN  
SENECA ARMY DEPOT ACTIVITY ROMULUS, NY

FACILITY	LOCATION ID	MATRIX	SAMPLE ID	DEPTH TO TOP OF SAMPLE	DEPTH TO BOTTOM OF SAMPLE	SAMPLE DATE	QC CODE	STUDY ID	FREQUENCY OF DETECTION	NYSDEC CLASS GA STD.	NUMBER ABOVE STD.	NUMBER OF DETECTS	NUMBER OF ANALYSES	L DESIG	ASH REMEDIAL DESIGN	ASH REMEDIAL DES	ASH REMEDIAL DES	ASH REMEDIAL DES	
															1	1	1	1	
PARAMETER	UNIT	MAXIMUM	DETECTION											N	N	N	N		
<b>VOLATILE ORGANICS</b>																			
1,1,1-Trichloroethane	UG/L	1	2%	5	0	1	55	U						10	U	10	U	10	U
1,1,2,2-Tetrachloroethane	UG/L	0	0%	5	0	0	55	U						10	U	10	U	10	U
1,1,2-Trichloroethane	UG/L	0	0%		0	0	55	U						10	U	10	U	10	U
1,1-Dichloroethane	UG/L	9	2%	5	1	1	55	U						10	U	10	U	10	U
1,1-Dichloroethene	UG/L	0	0%	5	0	0	55	U						10	U	10	U	10	U
1,2-Dichloroethane	UG/L	4	4%	5	0	2	55	U						10	U	10	U	10	U
1,2-Dichloroethene (total)	UG/L	1100	27%	5	14	15	55	U						73	U	10	U	10	U
1,2-Dichloropropane	UG/L	0	0%	5	0	0	55	U						10	U	10	U	10	U
Acetone	UG/L	2	4%		0	2	55	UJ						10	UJ	10	UJ	10	U
Benzene	UG/L	0	0%	0.7	0	0	55	U						10	U	10	U	10	U
Bromodichloromethane	UG/L	0	0%		0	0	55	U						10	U	10	U	10	U
Bromoform	UG/L	0	0%		0	0	55	U						10	U	10	U	10	U
Carbon disulfide	UG/L	0	0%		0	0	55	U						10	U	10	U	10	U
Carbon tetrachloride	UG/L	0	0%	5	0	0	55	U						10	U	10	U	10	U
Chlorobenzene	UG/L	0	0%	5	0	0	55	U						10	U	10	U	10	U
Chlorodibromomethane	UG/L	0	0%		0	0	55	U						10	U	10	U	10	U
Chloroethane	UG/L	0	0%	5	0	0	55	U						10	U	10	U	10	U
Chloroform	UG/L	74	2%	7	1	1	55	U						10	U	10	U	10	U
Cis-1,3-Dichloropropene	UG/L	0	0%	5	0	0	55	U						10	U	10	U	10	U
Ethyl benzene	UG/L	0	0%	5	0	0	55	U						10	U	10	U	10	U
Methyl bromide	UG/L	0	0%		0	0	55	U						10	U	10	U	10	U
Methyl butyl ketone	UG/L	0	0%		0	0	55	UJ						10	UJ	10	UJ	10	U
Methyl chloride	UG/L	0	0%	5	0	0	55	U						10	U	10	U	10	U
Methyl ethyl ketone	UG/L	0	0%	50	0	0	55	U						10	UJ	10	UJ	10	U
Methyl isobutyl ketone	UG/L	0	0%		0	0	55	U						10	UJ	10	UJ	10	U
Methylene chloride	UG/L	0	0%	5	0	0	55	U						10	U	10	U	10	U
Styrene	UG/L	0	0%		0	0	55	U						10	U	10	U	10	U
Tetrachloroethene	UG/L	0	0%	5	0	0	55	U						10	U	10	U	10	U
Toluene	UG/L	0	0%	5	0	0	55	U						10	U	10	U	10	U
Total Xylenes	UG/L	0	0%	5	0	0	55	U						10	U	10	U	10	U



TABLE 1  
GROUND WATER CHEMICAL RESULTS  
ROUND 1 GROUNDWATER MONITORING  
ASH REMEDIAL DESIGN  
SENECA ARMY DEPOT ACTIVITY ROMULUS, NY

FACILITY											L	ASH LANDFILL	ASH LANDFILL	ASH LANDFILL	ASH LANDFILL	
LOCATION ID												MW-46	MW-47	MW-48	MW-49D	
MATRIX											ER	GROUND WATER	GROUND WATER	GROUND WATER	GROUND WATER	
SAMPLE ID												ARD2009	ARD2032	ARD2012	ARD2011	
DEPTH TO TOP OF SAMPLE												10.5	9.5	10	26	
DEPTH TO BOTTOM OF SAMPLE												10.5	9.5	10	26	
SAMPLE DATE												10-Oct-99	19-Oct-99	10-Oct-99	10-Oct-99	
QC CODE												SA	SA	SA	SA	
STUDY ID												ASH REMEDIAL DESIGN	ASH REMEDIAL DES	ASH REMEDIAL DES	ASH REMEDIAL DES	
SAMPLE ROUND												1	1	1	1	
PARAMETER	UNIT	MAXIMUM	FREQUENCY OF DETECTION	NYSDEC CLASS GA STD.	NUMBER ABOVE STD.	NUMBER OF DETECTS	NUMBER OF ANALYSES	L DESIG	N	N	N	N				
Trans-1,3-Dichloropropene	UG/L	0	0%	5	0	0	55	U	10	U	10	U	10	U	10	U
Trichloroethene	UG/L	9100	27%	5	10	15	55	U	57	U	10	U	10	U	4	J
Vinyl chloride	UG/L	180	5%	2	2	3	55	U	1	J	10	U	10	U	10	U
<b>METALS</b>																
Aluminum	UG/L	2600	65%		0	34	52	J	124	J	25.1	J	16.3	U	16.3	U
Antimony	UG/L	3	2%		0	1	52	U	4.9	UJ	2.7	U	4.9	UJ	4.9	UJ
Arsenic	UG/L	7	23%	25	0	12	52	U	3.7	U	1.9	U	3.7	U	3.7	U
Barium	UG/L	176	98%	1000	0	51	52	J	71.4	J	48.3	J	45.2	J	115	J
Beryllium	UG/L	0.66	10%		0	5	52	U	0.23	J	0.2	U	0.2	U	0.2	U
Cadmium	UG/L	0	0%	10	0	0	52	U	0.7	U	0.3	U	0.7	U	0.7	U
Calcium	UG/L	268000	98%		0	51	52		129000		110000		104000		100000	
Chromium	UG/L	5.6	15%	50	0	8	52	U	0.9	U	0.9	U	0.9	U	0.9	U
Cobalt	UG/L	8.4	4%		0	2	52	U	2.5	U	2	U	2.5	U	2.5	U
Copper	UG/L	6.1	10%	200	0	5	52	U	1.9	U	1.7	U	1.9	U	1.9	U
Cyanide	UG/L	0	0%	100	0	0	52	U	5	U	5	U	5	U	5	U
Iron	UG/L	11600	67%	300	14	35	52	U	1330	J	14.7	U	14.7	U	250	J
Lead	UG/L	5.4	10%	25	0	5	52	U	1.2	U	1	U	1.2	U	1.2	U
Magnesium	UG/L	47100	98%		0	51	52		17800		12000		12500		23200	
Manganese	UG/L	3140	83%	300	7	43	52	J	570		0.9	U	1.2	J	125	
Mercury	UG/L	0.2	12%	2	0	6	52	U	0.1	U	0.1	U	0.1	U	0.1	U
Nickel	UG/L	5.6	12%		0	6	52	U	2.6	U	1.7	U	2.6	U	2.6	U
Potassium	UG/L	18400	98%		0	51	52	J	2690	J	992	J	1870	J	1820	J
Selenium	UG/L	2.6	2%	10	0	1	52	U	2.8	U	2.4	U	2.8	U	2.8	U
Silver	UG/L	0	0%	50	0	0	52	U	1.6	U	1.6	U	1.6	U	1.6	U
Sodium	UG/L	142000	98%	20000	27	51	52		10100		9240		8490		8220	
Thallium	UG/L	10.8	19%		0	10	52	U	2.9	U	2.7	U	2.9	U	2.9	U
Vanadium	UG/L	4.5	6%		0	3	52	U	3.2	U	1.5	U	3.2	U	3.2	U
Zinc	UG/L	134	81%	300	0	42	52	J	1.8	U	1.6	J	1.8	U	1.8	U

TABLE 1  
GROUND WATER CHEMICAL RESULTS  
ROUND 1 GROUNDWATER MONITORING  
ASH REMEDIAL DESIGN  
SENECA ARMY DEPOT ACTIVITY ROMULUS, NY

FACILITY LOCATION ID									ASH LANDFILL MW-50D	ASH LANDFILL MW-51D	ASH LANDFILL MW-52D	ASH LANDFILL MW-53	ASH LAN MW-54D
MATRIX									GROUND WATER	GROUND WATER	GROUND WATER	GROUND WATER	GROUND
SAMPLE ID									ARD2010	ARD2033	ARD2034	ARD2055	ARD2023
DEPTH TO TOP OF SAMPLE									50	28	50	11.5	25
DEPTH TO BOTTOM OF SAMPLE									50	28	50	11.5	25
SAMPLE DATE									10-Oct-99	19-Oct-99	19-Oct-99	22-Oct-99	13-Oct-99
QC CODE									SA	SA	SA	SA	SA
STUDY ID									ASH REMEDIAL DESI	ASH REMEDIAL DESI	ASH REMEDIAL DESIGN	ASH REMEDIAL DESIGN	ASH REM
SAMPLE ROUND			FREQUENCY OF DETECTION	NYSDEC CLASS GA STD.	NUMBER ABOVE STD.	NUMBER OF DETECTS	NUMBER OF ANALYSES		1	1	1	1	1
PARAMETER	UNIT	MAXIMUM						N	N	N	N	N	N
<b>VOLATILE ORGANICS</b>													
1,1,1-Trichloroethane	UG/L	1	2%	5	0	1	55	10 U	10 U	10 U	10 U	10 U	10
1,1,2,2-Tetrachloroethane	UG/L	0	0%	5	0	0	55	10 U	10 U	10 U	10 U	10 U	10
1,1,2-Trichloroethane	UG/L	0	0%	0	0	0	55	10 U	10 U	10 U	10 U	10 U	10
1,1-Dichloroethane	UG/L	9	2%	5	1	1	55	10 U	10 U	10 U	10 U	10 U	10
1,1-Dichloroethene	UG/L	0	0%	5	0	0	55	10 U	10 U	10 U	10 U	10 U	10
1,2-Dichloroethane	UG/L	4	4%	5	0	2	55	10 U	10 U	10 U	10 U	10 U	10
1,2-Dichloroethene (total)	UG/L	1100	27%	5	14	15	55	10 U	10 U	10 U	15	10 U	2
1,2-Dichloropropane	UG/L	0	0%	5	0	0	55	10 U	10 U	10 U	10 U	10 U	10
Acetone	UG/L	2	4%	0	0	2	55	10 U	10 UJ	2 J	10 UJ	10 UJ	10
Benzene	UG/L	0	0%	0.7	0	0	55	10 U	10 U	10 U	10 U	10 U	10
Bromodichloromethane	UG/L	0	0%	0	0	0	55	10 U	10 U	10 U	10 U	10 U	10
Bromoform	UG/L	0	0%	0	0	0	55	10 U	10 U	10 U	10 U	10 U	10
Carbon disulfide	UG/L	0	0%	0	0	0	55	10 U	10 U	10 U	10 U	10 U	10
Carbon tetrachloride	UG/L	0	0%	5	0	0	55	10 U	10 U	10 U	10 U	10 U	10
Chlorobenzene	UG/L	0	0%	5	0	0	55	10 U	10 U	10 U	10 U	10 U	10
Chlorodibromomethane	UG/L	0	0%	0	0	0	55	10 U	10 U	10 U	10 U	10 U	10
Chloroethane	UG/L	0	0%	5	0	0	55	10 U	10 U	10 U	10 U	10 U	10
Chloroform	UG/L	74	2%	7	1	1	55	10 U	10 U	10 U	10 U	10 U	10
Cis-1,3-Dichloropropene	UG/L	0	0%	5	0	0	55	10 U	10 U	10 U	10 U	10 U	10
Ethyl benzene	UG/L	0	0%	5	0	0	55	10 U	10 U	10 U	10 U	10 U	10
Methyl bromide	UG/L	0	0%	0	0	0	55	10 U	10 U	10 U	10 U	10 U	10
Methyl butyl ketone	UG/L	0	0%	0	0	0	55	10 U	10 UJ	10 UJ	10 UJ	10 U	10
Methyl chloride	UG/L	0	0%	5	0	0	55	10 U	10 U	10 U	10 U	10 U	10
Methyl ethyl ketone	UG/L	0	0%	50	0	0	55	10 U	10 UJ	10 UJ	10 UJ	10 U	10
Methyl isobutyl ketone	UG/L	0	0%	0	0	0	55	10 U	10 UJ	10 UJ	10 UJ	10 U	10
Methylene chloride	UG/L	0	0%	5	0	0	55	10 U	10 U	10 U	10 U	10 U	10
Styrene	UG/L	0	0%	0	0	0	55	10 U	10 U	10 U	10 U	10 U	10
Tetrachloroethene	UG/L	0	0%	5	0	0	55	10 U	10 U	10 U	10 U	10 U	10
Toluene	UG/L	0	0%	5	0	0	55	10 U	10 U	10 U	10 U	10 U	10
Total Xylenes	UG/L	0	0%	5	0	0	55	10 U	10 U	10 U	10 U	10 U	10

TABLE 1  
GROUND WATER CHEMICAL RESULTS  
ROUND 1 GROUNDWATER MONITORING  
ASH REMEDIAL DESIGN  
SENECA ARMY DEPOT ACTIVITY ROMULUS, NY

FACILITY										ASH LANDFILL	ASH LANDFILL	ASH LANDFILL	ASH LANDFILL	ASH LAN	
LOCATION ID										MW-50D	MW-51D	MW-52D	MW-53	MW-54D	
MATRIX										GROUND WATER	GROUND WATER	GROUND WATER	GROUND WATER	GROUND	
SAMPLE ID										ARD2010	ARD2033	ARD2034	ARD2055	ARD2023	
DEPTH TO TOP OF SAMPLE										50	28	50	11.5	25	
DEPTH TO BOTTOM OF SAMPLE										50	28	50	11.5	25	
SAMPLE DATE										10-Oct-99	19-Oct-99	19-Oct-99	22-Oct-99	13-Oct-99	
QC CODE										SA	SA	SA	SA	SA	
STUDY ID										ASH REMEDIAL DESI	ASH REMEDIAL DESI	ASH REMEDIAL DESIGN	ASH REMEDIAL DESIGN	ASH REM	
SAMPLE ROUND										1	1	1	1	1	
PARAMETER	UNIT	MAXIMUM	FREQUENCY OF DETECTION	NYSDEC CLASS GA STD.	NUMBER ABOVE STD.	NUMBER OF DETECTS	NUMBER OF ANALYSES	N	1	N	1	N	1	N	1
Trans-1,3-Dichloropropene	UG/L	0	0%		5	0	0	55	10 U	10 U	10 U	10 U	10 U	10	10
Trichloroethene	UG/L	9100	27%		5	10	15	55	10 U	10 U	10 U	2 J	10	10	10
Vinyl chloride	UG/L	180	5%		2	2	3	55	10 U	10 U	10 U	10 U	10 U	10	10
<b>METALS</b>															
Aluminum	UG/L	2600	65%			0	34	52	22.7 J	20.2 J	2350	14.3 U	14.3	14.3	14.3
Antimony	UG/L	3	2%			0	1	52	4.9 UU	2.7 U	2.7 U	2.7 U	2.7 U	2.7	2.7
Arsenic	UG/L	7	23%	25		0	12	52	3.7 U	1.9 U	1.9 U	3.9 J	1.9	1.9	1.9
Barium	UG/L	176	98%	1000		0	51	52	107 J	125 J	64.7 J	71 J	134	134	134
Beryllium	UG/L	0.66	10%			0	5	52	0.46 J	0.2 U	0.2 U	0.2 U	0.2 U	0.2	0.2
Cadmium	UG/L	0	0%	10		0	0	52	0.7 U	0.3 U	0.3 U	0.3 U	0.3	0.3	0.3
Calcium	UG/L	268000	98%			0	51	52	49700	85400	5920	165000	82000	82000	82000
Chromium	UG/L	5.6	15%	50		0	8	52	0.9 U	0.9 U	0.9 U	0.9 U	0.9	0.9	0.9
Cobalt	UG/L	8.4	4%			0	2	52	2.5 U	2 U	2 U	2.5 U	2	2	2
Copper	UG/L	6.1	10%	200		0	5	52	1.9 U	1.7 U	1.9 J	1.7 U	1.7	1.7	1.7
Cyanide	UG/L	0	0%	100		0	0	52	5 U	5 U	5 U	5 U	5	5	5
Iron	UG/L	11600	67%	300	14	35	52	52	348 J	56.2 J	2310	25.4 U	28.7	28.7	28.7
Lead	UG/L	5.4	10%	25		0	5	52	1.2 U	1 U	2.6 J	1 U	1	1	1
Magnesium	UG/L	47100	98%			0	51	52	22400	13500	2180 J	20100	24600	24600	24600
Manganese	UG/L	3140	83%	300	7	43	52	52	87.4	42.5	39.3	0.4 U	127	127	127
Mercury	UG/L	0.2	12%	2		0	6	52	0.1 U	0.1 U	0.1 U	0.1 U	0.1	0.1	0.1
Nickel	UG/L	5.6	12%			0	6	52	2.6 U	1.7 U	2.7 J	1.7 U	1.7	1.7	1.7
Potassium	UG/L	18400	98%			0	51	52	2270 J	1350 J	1570 J	1690 J	2570	2570	2570
Selenium	UG/L	2.6	2%	10		0	1	52	2.8 U	2.6 J	2.4 U	2.4 U	2.4	2.4	2.4
Silver	UG/L	0	0%	50		0	0	52	1.6 U	1.6 U	1.6 U	1.6 U	1.6	1.6	1.6
Sodium	UG/L	142000	98%	20000	27	51	52	52	20900	26300	102000	24100	23300	23300	23300
Thallium	UG/L	10.8	19%			0	10	52	2.9 U	2.7 U	2.7 U	2.9 U	2.7	2.7	2.7
Vanadium	UG/L	4.5	6%			0	3	52	3.2 U	1.5 U	3.3 J	1.5 U	1.5	1.5	1.5
Zinc	UG/L	134	81%	300		0	42	52	1.8 U	2.9 J	6.9 J	2.5 J	1.8	1.8	1.8

TABLE 1  
GROUND WATER CHEMICAL RESULTS  
ROUND 1 GROUNDWATER MONITORING  
ASH REMEDIAL DESIGN  
SENECA ARMY DEPOT ACTIVITY ROMULUS, NY

FACILITY									FILL						
LOCATION ID									ASH LANDFILL	ASH LANDFILL	ASH LANDFILL	ASH LANDFILL	ASH LANDFILL	ASH LAN	
MATRIX									MW-55D	MW-56	MW-57D	MW-58D	MW-59		
SAMPLE ID									GROUND WATER	GROUND WATER	GROUND WATER	GROUND WATER	GROUND		
DEPTH TO TOP OF SAMPLE									ARD2022	ARD2035	ARD2039	ARD2042	ARD2005		
DEPTH TO BOTTOM OF SAMPLE									50	6	25	48	8		
SAMPLE DATE									50	6	25	48	8		
QC CODE									13-Oct-99	20-Oct-99	20-Oct-99	20-Oct-99	09-Oct-99		
STUDY ID									SA	SA	SA	SA	SA		
SAMPLE ROUND			FREQUENCY	NYSDEC	NUMBER	NUMBER	NUMBER	DIAL DES	ASH REMEDIAL DES	ASH REMEDIAL DES	ASH REMEDIAL DES	ASH REMEDIAL DES	ASH REM		
PARAMETER	UNIT	MAXIMUM	OF	CLASS GA	ABOVE	OF	OF		1	1	1	1	1		
			DETECTION	STD.	STD.	DETECTS	ANALYSES		N	N	N	N	N		
<b>VOLATILE ORGANICS</b>															
1,1,1-Trichloroethane	UG/L	1	2%	5	0	1	55 U		10 U	10 U	10 U	10 U	10 U		10
1,1,2,2-Tetrachloroethane	UG/L	0	0%	5	0	0	55 U		10 U	10 U	10 U	10 U	10 U		10
1,1,2-Trichloroethane	UG/L	0	0%		0	0	55 U		10 U	10 U	10 U	10 U	10 U		10
1,1-Dichloroethane	UG/L	9	2%	5	1	1	55 U		10 U	10 U	10 U	10 U	10 U		10
1,1-Dichloroethene	UG/L	0	0%	5	0	0	55 U		10 U	10 U	10 U	10 U	10 U		10
1,2-Dichloroethane	UG/L	4	4%	5	0	2	55 U		10 U	10 U	10 U	10 U	10 U		10
1,2-Dichloroethene (total)	UG/L	1100	27%	5	14	15	55 J		10 U	10 U	10 U	10 U	10 U		10
1,2-Dichloropropane	UG/L	0	0%	5	0	0	55 U		10 U	10 U	10 U	10 U	10 U		10
Acetone	UG/L	2	4%		0	2	55 U		10 U	10 UJ	10 UJ	10 UJ	10 UJ		10
Benzene	UG/L	0	0%	0.7	0	0	55 U		10 U	10 U	10 U	10 U	10 U		10
Bromodichloromethane	UG/L	0	0%		0	0	55 U		10 U	10 U	10 U	10 U	10 U		10
Bromoform	UG/L	0	0%		0	0	55 U		10 U	10 U	10 U	10 U	10 U		10
Carbon disulfide	UG/L	0	0%		0	0	55 U		10 U	10 U	10 U	10 U	10 U		10
Carbon tetrachloride	UG/L	0	0%	5	0	0	55 U		10 U	10 U	10 U	10 U	10 U		10
Chlorobenzene	UG/L	0	0%	5	0	0	55 U		10 U	10 U	10 U	10 U	10 U		10
Chlorodibromomethane	UG/L	0	0%		0	0	55 U		10 U	10 U	10 U	10 U	10 U		10
Chloroethane	UG/L	0	0%	5	0	0	55 U		10 U	10 U	10 U	10 U	10 U		10
Chloroform	UG/L	74	2%	7	1	1	55 U		10 U	10 U	10 U	10 U	10 U		10
Cis-1,3-Dichloropropene	UG/L	0	0%	5	0	0	55 U		10 U	10 U	10 U	10 U	10 U		10
Ethyl benzene	UG/L	0	0%	5	0	0	55 U		10 U	10 U	10 U	10 U	10 U		10
Methyl bromide	UG/L	0	0%		0	0	55 U		10 U	10 U	10 U	10 U	10 U		10
Methyl butyl ketone	UG/L	0	0%		0	0	55 U		10 U	10 UJ	10 UJ	10 UJ	10 UJ		10
Methyl chloride	UG/L	0	0%	5	0	0	55 U		10 U	10 U	10 U	10 U	10 U		10
Methyl ethyl ketone	UG/L	0	0%	50	0	0	55 U		10 U	10 UJ	10 UJ	10 UJ	10 UJ		10
Methyl isobutyl ketone	UG/L	0	0%		0	0	55 U		10 U	10 UJ	10 UJ	10 UJ	10 UJ		10
Methylene chloride	UG/L	0	0%	5	0	0	55 U		10 U	10 U	10 U	10 U	10 U		10
Styrene	UG/L	0	0%		0	0	55 U		10 U	10 U	10 U	10 U	10 U		10
Tetrachloroethene	UG/L	0	0%	5	0	0	55 U		10 U	10 U	10 U	10 U	10 U		10
Toluene	UG/L	0	0%	5	0	0	55 U		10 U	10 U	10 U	10 U	10 U		10
Total Xylenes	UG/L	0	0%	5	0	0	55 U		10 U	10 U	10 U	10 U	10 U		10

TABLE 1  
GROUND WATER CHEMICAL RESULTS  
ROUND 1 GROUNDWATER MONITORING  
ASH REMEDIAL DESIGN  
SENECA ARMY DEPOT ACTIVITY ROMULUS, NY

FACILITY	LOCATION ID	MATRIX	SAMPLE ID	DEPTH TO TOP OF SAMPLE	DEPTH TO BOTTOM OF SAMPLE	SAMPLE DATE	QC CODE	STUDY ID	SAMPLE ROUND	PARAMETER	UNIT	MAXIMUM	FREQUENCY OF DETECTION	NYSDEC CLASS GA STD.	NUMBER ABOVE STD.	NUMBER OF DETECTS	NUMBER OF ANALYSES	DIAL DES	ASH REMEDIAL DES	ASH REMEDIAL DES	ASH REMEDIAL DES	ASH REMEDIAL DES	ASH REMEDIAL DES			
																			FILL	ASH LANDFILL	ASH LANDFILL	ASH LANDFILL	ASH LANDFILL	ASH LAN		
																				MW-55D	MW-56	MW-57D	MW-58D	MW-59		
																			ATER	GROUND WATER	GROUND WATER	GROUND WATER	GROUND WATER	GROUND		
																				ARD2022	ARD2035	ARD2039	ARD2042	ARD2005		
																				50	6	25	48	8		
																				50	6	25	48	8		
																				13-Oct-99	20-Oct-99	20-Oct-99	20-Oct-99	09-Oct-99		
																				SA	SA	SA	SA	SA		
																				ASH REMEDIAL DES	ASH REMEDIAL DES	ASH REMEDIAL DES	ASH REMEDIAL DES	ASH REM		
																				1	1	1	1	1		
																				N	N	N	N	N		
										Trans-1,3-Dichloropropene	UG/L	0	0%	5	0	0	55	U	10	U	10	U	10	U	10	
										Trichloroethene	UG/L	9100	27%	5	10	15	55	U	10	U	10	U	10	U	10	
										Vinyl chloride	UG/L	180	5%	2	2	3	55	U	10	U	10	U	10	U	10	
										<b>METALS</b>																
										Aluminum	UG/L	2600	65%		0	34	52	U	1160		160	J	688	2400	21.9	
										Antimony	UG/L	3	2%		0	1	52	U	2.7	U	2.7	U	2.7	U	4.9	
										Arsenic	UG/L	7	23%	25	0	12	52	U	1.9	U	1.9	U	1.9	U	3.7	
										Barium	UG/L	176	98%	1000	0	51	52	J	61.9	J	44.5	J	62.1	J	121	
										Beryllium	UG/L	0.66	10%		0	5	52	U	0.2	U	0.2	U	0.2	U	0.2	
										Cadmium	UG/L	0	0%	10	0	0	52	U	0.3	U	0.3	U	0.3	U	0.7	
										Calcium	UG/L	268000	98%		0	51	52	J	2440	J	104000		3130	J	4110	199000
										Chromium	UG/L	5.6	15%	50	0	8	52	U	0.9	U	0.9	U	1.9	J	4.5	0.9
										Cobalt	UG/L	8.4	4%		0	2	52	U	2	U	2.5	U	2.5	U	2.5	
										Copper	UG/L	6.1	10%	200	0	5	52	U	1.7	U	1.7	U	1.7	U	2.2	1.9
										Cyanide	UG/L	0	0%	100	0	0	52	U	5	U	5	U	5	U	5	
										Iron	UG/L	11600	67%	300	14	35	52	J	1050		149	J	853	J	3200	14.7
										Lead	UG/L	5.4	10%	25	0	5	52	U	1.5	J	1	U	1.9	J	1.2	
										Magnesium	UG/L	47100	98%		0	51	52	J	781	J	12500		842	J	1350	47100
										Manganese	UG/L	3140	83%	300	7	43	52	J	16.9	J	12.3	J	3.2	J	35.3	0.9
										Mercury	UG/L	0.2	12%	2	0	6	52	U	0.1	U	0.1	U	0.1	U	0.1	
										Nickel	UG/L	5.6	12%		0	6	52	U	1.7	U	1.7	U	1.7	U	3.4	2.6
										Potassium	UG/L	18400	98%		0	51	52	J	1120	J	1630	J	1150	J	1740	2610
										Selenium	UG/L	2.6	2%	10	0	1	52	U	2.4	U	2.4	U	2.4	U	2.4	2.8
										Silver	UG/L	0	0%	50	0	0	52	U	1.6	U	1.6	U	1.6	U	1.6	1.6
										Sodium	UG/L	142000	98%	20000	27	51	52	J	118000		18800		133000		142000	36200
										Thallium	UG/L	10.8	19%		0	10	52	U	2.7	J	2.9	U	2.9	U	2.9	2.9
										Vanadium	UG/L	4.5	6%		0	3	52	U	1.5	U	1.5	U	1.5	U	4.1	3.2
										Zinc	UG/L	134	81%	300	0	42	52	J	15.7	J	3.7	J	7.1	J	8.9	2.5

TABLE 1  
GROUND WATER CHEMICAL RESULTS  
ROUND 1 GROUNDWATER MONITORING  
ASH REMEDIAL DESIGN  
SENECA ARMY DEPOT ACTIVITY ROMULUS, NY

FACILITY				FILL					ASH LANDFILL		ASH LANDFILL		ASH LANDFILL		ASH LANDFILL	
LOCATION ID									MW-60		PT-10		PT-11		PT-15	
MATRIX				ATER					GROUND WATER		GROUND WATER		GROUND WATER		GROUND WATER	
SAMPLE ID									ARD2004		ARD2002		ARD2006		ARD2031	
DEPTH TO TOP OF SAMPLE									8.5		40		18		18.5	
DEPTH TO BOTTOM OF SAMPLE									8.5		40		18		18.5	
SAMPLE DATE									09-Oct-99		08-Oct-99		10-Oct-99		20-Oct-99	
QC CODE									SA		SA		SA		SA	
STUDY ID									ASH REMEDIAL DES		ASH REMEDIAL DES		ASH REMEDIAL DESIGN		ASH REMEDIAL DES	
SAMPLE ROUND				FREQUENCY OF DETECTION					1		1		1		1	
PARAMETER				UNIT					N		N		N		N	
<b>VOLATILE ORGANICS</b>																
1,1,1-Trichloroethane	UG/L	1	2%	5	0	1	55	U	10	U	10	UJ	10	U	10	U
1,1,2,2-Tetrachloroethane	UG/L	0	0%	5	0	0	55	U	10	U	10	UJ	10	U	10	U
1,1,2-Trichloroethane	UG/L	0	0%		0	0	55	U	10	U	10	UJ	10	U	10	U
1,1-Dichloroethane	UG/L	9	2%	5	1	1	55	U	10	U	10	UJ	10	U	10	U
1,1-Dichloroethene	UG/L	0	0%	5	0	0	55	U	10	U	10	UJ	10	U	10	U
1,2-Dichloroethane	UG/L	4	4%	5	0	2	55	U	10	U	10	UJ	10	U	10	U
1,2-Dichloroethene (total)	UG/L	1100	27%	5	14	15	55	U	10	U	10	UJ	10	U	10	U
1,2-Dichloropropane	UG/L	0	0%	5	0	0	55	U	10	U	10	UJ	10	U	10	U
Acetone	UG/L	2	4%		0	2	55	U	10	U	10	UJ	10	U	10	UJ
Benzene	UG/L	0	0%	0.7	0	0	55	U	10	U	10	UJ	10	U	10	U
Bromodichloromethane	UG/L	0	0%		0	0	55	U	10	U	10	UJ	10	U	10	U
Bromoform	UG/L	0	0%		0	0	55	U	10	U	10	UJ	10	U	10	U
Carbon disulfide	UG/L	0	0%		0	0	55	U	10	U	10	UJ	10	U	10	U
Carbon tetrachloride	UG/L	0	0%	5	0	0	55	U	10	U	10	UJ	10	U	10	U
Chlorobenzene	UG/L	0	0%	5	0	0	55	U	10	U	10	UJ	10	U	10	U
Chlorodibromomethane	UG/L	0	0%		0	0	55	U	10	U	10	UJ	10	U	10	U
Chloroethane	UG/L	0	0%	5	0	0	55	U	10	U	10	UJ	10	U	10	U
Chloroform	UG/L	74	2%	7	1	1	55	U	10	U	10	UJ	10	U	10	U
Cis-1,3-Dichloropropene	UG/L	0	0%	5	0	0	55	U	10	U	10	UJ	10	U	10	U
Ethyl benzene	UG/L	0	0%	5	0	0	55	U	10	U	10	UJ	10	U	10	U
Methyl bromide	UG/L	0	0%		0	0	55	U	10	U	10	UJ	10	U	10	U
Methyl butyl ketone	UG/L	0	0%		0	0	55	U	10	U	10	UJ	10	U	10	UJ
Methyl chloride	UG/L	0	0%	5	0	0	55	U	10	U	10	UJ	10	U	10	U
Methyl ethyl ketone	UG/L	0	0%	50	0	0	55	U	10	U	10	UJ	10	U	10	UJ
Methyl isobutyl ketone	UG/L	0	0%		0	0	55	U	10	U	10	UJ	10	U	10	UJ
Methylene chloride	UG/L	0	0%	5	0	0	55	U	10	U	10	UJ	10	U	10	U
Styrene	UG/L	0	0%		0	0	55	U	10	U	10	UJ	10	U	10	U
Tetrachloroethene	UG/L	0	0%	5	0	0	55	U	10	U	10	UJ	10	U	10	U
Toluene	UG/L	0	0%	5	0	0	55	U	10	U	10	UJ	10	U	10	U
Total Xylenes	UG/L	0	0%	5	0	0	55	U	10	U	10	UJ	10	U	10	U

TABLE 1  
GROUND WATER CHEMICAL RESULTS  
ROUND 1 GROUNDWATER MONITORING  
ASH REMEDIAL DESIGN  
SENECA ARMY DEPOT ACTIVITY ROMULUS, NY

FACILITY				FILL				ASH LANDFILL				ASH LANDFILL				ASH LANDFILL				ASH LANDFILL			
LOCATION ID				ATER				MW-60				PT-10				PT-11				PT-15			
MATRIX				GROUND WATER				GROUND WATER				GROUND WATER				GROUND WATER							
SAMPLE ID				ARD2004				ARD2002				ARD2006				ARD2031							
DEPTH TO TOP OF SAMPLE				8.5				40				18				18.5							
DEPTH TO BOTTOM OF SAMPLE				8.5				40				18				18.5							
SAMPLE DATE				09-Oct-99				08-Oct-99				10-Oct-99				20-Oct-99							
QC CODE				SA				SA				SA				SA							
STUDY ID				ASH REMEDIAL DES				ASH REMEDIAL DES				ASH REMEDIAL DESIGN				ASH REMEDIAL DES							
SAMPLE ROUND				1				1				1				1							
PARAMETER				UNIT				UNIT				UNIT				UNIT							
MAXIMUM				DETECTION				DETECTION				DETECTION				DETECTION							
FREQUENCY OF DETECTION				NYSDEC CLASS GA STD.				NUMBER ABOVE STD.				NUMBER OF DETECTS				NUMBER OF ANALYSES							
Trans-1,3-Dichloropropene	UG/L	0	0%	5	0	0	55	U	N	10	U	N	10	UJ	N	10	U	N	10	U			
Trichloroethene	UG/L	9100	27%	5	10	15	55	U	N	10	U	N	10	UJ	N	10	U	N	10	U			
Vinyl chloride	UG/L	180	5%	2	2	3	55	U	N	10	U	N	10	UJ	N	10	U	N	10	U			
<b>METALS</b>																							
Aluminum	UG/L	2600	65%		0	34	52	J	N	16.3	U	N	16.3	UJ	N	340		N	2600				
Antimony	UG/L	3	2%		0	1	52	U	N	4.9	U	N	4.9	UJ	N	2.7	U	N	2.7	U			
Arsenic	UG/L	7	23%	25	0	12	52	U	N	3.7	U	N	4.7	J	N	1.9	U	N	3	J			
Barium	UG/L	176	98%	1000	0	51	52	J	N	46.6	J	N	176	J	N	86.6	J	N	119	J			
Beryllium	UG/L	0.66	10%		0	5	52	U	N	0.66	J	N	0.2	UJ	N	0.2	U	N	0.2	U			
Cadmium	UG/L	0	0%	10	0	0	52	U	N	0.7	U	N	0.7	UJ	N	0.3	U	N	0.3	U			
Calcium	UG/L	268000	98%		0	51	52		N	114000		N	81200	J	N	92000		N	92000				
Chromium	UG/L	5.6	15%	50	0	8	52	U	N	0.9	U	N	0.9	UJ	N	0.9	U	N	5.6	J			
Cobalt	UG/L	8.4	4%		0	2	52	U	N	2.5	U	N	2.5	UJ	N	2	U	N	8.4	J			
Copper	UG/L	6.1	10%	200	0	5	52	U	N	1.9	U	N	1.9	UJ	N	1.7	U	N	6.1	J			
Cyanide	UG/L	0	0%	100	0	0	52	U	N	5	U	N	5	UJ	N	5	U	N	5	U			
Iron	UG/L	11600	67%	300	14	35	52	U	N	14.7	U	N	21.8	J	N	457		N	4410	J			
Lead	UG/L	5.4	10%	25	0	5	52	U	N	1.2	U	N	1.2	UJ	N	1	U	N	5.4				
Magnesium	UG/L	47100	98%		0	51	52		N	16400		N	33300	J	N	31900		N	22100				
Manganese	UG/L	3140	83%	300	7	43	52	U	N	1.8	J	N	105	J	N	38.1		N	259				
Mercury	UG/L	0.2	12%	2	0	6	52	U	N	0.1	U	N	0.1	UJ	N	0.1	U	N	0.1	U			
Nickel	UG/L	5.6	12%		0	6	52	U	N	2.6	U	N	2.6	UJ	N	1.7	U	N	5.6	J			
Potassium	UG/L	18400	98%		0	51	52	J	N	2320	J	N	2560	J	N	3160	J	N	3460	J			
Selenium	UG/L	2.6	2%	10	0	1	52	U	N	2.8	U	N	2.8	UJ	N	2.4	U	N	2.8	U			
Silver	UG/L	0	0%	50	0	0	52	U	N	1.6	U	N	1.6	UJ	N	1.6	U	N	1.6	U			
Sodium	UG/L	142000	98%	20000	27	51	52		N	19900		N	33500	J	N	19700		N	27600				
Thallium	UG/L	10.8	19%		0	10	52	UJ	N	2.9	UJ	N	2.9	UJ	N	2.7	UJ	N	3.3	J			
Vanadium	UG/L	4.5	6%		0	3	52	U	N	3.2	U	N	3.2	UJ	N	1.5	U	N	4.5	J			
Zinc	UG/L	134	81%	300	0	42	52	J	N	1.8	U	N	1.8	UJ	N	9.5	J	N	34.1				

TABLE 1  
GROUND WATER CHEMICAL RESULTS  
ROUND 1 GROUNDWATER MONITORING  
ASH REMEDIAL DESIGN  
SENECA ARMY DEPOT ACTIVITY ROMULUS, NY

FACILITY									ASH LANDFILL	ASH LANDFILL	ASH LANDFILL	ASH LANDFILL	ASH LAN
LOCATION ID									PT-16	PT-16	PT-17	PT-18	PT-19
MATRIX									GROUND WATER	GROUND WATER	GROUND WATER	GROUND WATER	GROUND
SAMPLE ID									ARD2014	ARD2013	ARD2027	ARD2048	ARD2018
DEPTH TO TOP OF SAMPLE									10	10	10.5	11.1	10.5
DEPTH TO BOTTOM OF SAMPLE									10	10	10.5	11.1	10.5
SAMPLE DATE									11-Oct-99	11-Oct-99	18-Oct-99	21-Oct-99	11-Oct-99
QC CODE									DU	SA	SA	SA	SA
STUDY ID			FREQUENCY	NYSDEC	NUMBER	NUMBER	NUMBER	ASH REMEDIAL DES	ASH REMEDIAL DESI	ASH REMEDIAL DESIG	ASH REMEDIAL DESIG	ASH REMEDIAL DES	ASH REM
SAMPLE ROUND			OF	CLASS GA	ABOVE	OF	OF	1	1	1	1	1	1
PARAMETER	UNIT	MAXIMUM	DETECTION	STD.	STD.	DETECTS	ANALYSES	N	N	N	N	N	N
<b>VOLATILE ORGANICS</b>													
1,1,1-Trichloroethane	UG/L	1	2%	5	0	1	55	10 U	10 U	10 UJ	540 U	540 U	10
1,1,2,2-Tetrachloroethane	UG/L	0	0%	5	0	0	55	10 U	10 U	10 UJ	540 U	540 U	10
1,1,2-Trichloroethane	UG/L	0	0%		0	0	55	10 U	10 U	10 UJ	540 U	540 U	10
1,1-Dichloroethane	UG/L	9	2%	5	1	1	55	10 U	10 U	10 UJ	540 U	540 U	10
1,1-Dichloroethene	UG/L	0	0%	5	0	0	55	10 U	10 U	10 UJ	540 U	540 U	10
1,2-Dichloroethane	UG/L	4	4%	5	0	2	55	10 U	10 U	10 UJ	540 U	540 U	10
1,2-Dichloroethene (total)	UG/L	1100	27%	5	14	15	55	10 U	10 U	16 J	1100	540 U	10
1,2-Dichloropropane	UG/L	0	0%	5	0	0	55	10 U	10 U	10 UJ	540 U	540 U	10
Acetone	UG/L	2	4%		0	2	55	10 U	10 U	10 UJ	540 UJ	540 U	10
Benzene	UG/L	0	0%	0.7	0	0	55	10 U	10 U	10 UJ	540 U	540 U	10
Bromodichloromethane	UG/L	0	0%		0	0	55	10 U	10 U	10 UJ	540 U	540 U	10
Bromoform	UG/L	0	0%		0	0	55	10 U	10 U	10 UJ	540 U	540 U	10
Carbon disulfide	UG/L	0	0%		0	0	55	10 U	10 U	10 UJ	540 U	540 U	10
Carbon tetrachloride	UG/L	0	0%	5	0	0	55	10 U	10 U	10 UJ	540 U	540 U	10
Chlorobenzene	UG/L	0	0%	5	0	0	55	10 U	10 U	10 UJ	540 U	540 U	10
Chlorodibromomethane	UG/L	0	0%		0	0	55	10 U	10 U	10 UJ	540 U	540 U	10
Chloroethane	UG/L	0	0%	5	0	0	55	10 U	10 U	10 UJ	540 U	540 U	10
Chloroform	UG/L	74	2%	7	1	1	55	10 U	10 U	10 UJ	74 J	540 U	10
Cis-1,3-Dichloropropene	UG/L	0	0%	5	0	0	55	10 U	10 U	10 UJ	540 U	540 U	10
Ethyl benzene	UG/L	0	0%	5	0	0	55	10 U	10 U	10 UJ	540 U	540 U	10
Methyl bromide	UG/L	0	0%		0	0	55	10 U	10 U	10 UJ	540 U	540 U	10
Methyl butyl ketone	UG/L	0	0%		0	0	55	10 U	10 U	10 UJ	540 U	540 U	10
Methyl chloride	UG/L	0	0%	5	0	0	55	10 U	10 U	10 UJ	540 U	540 U	10
Methyl ethyl ketone	UG/L	0	0%	50	0	0	55	10 U	10 U	10 UJ	540 U	540 U	10
Methyl isobutyl ketone	UG/L	0	0%		0	0	55	10 U	10 U	10 UJ	540 U	540 U	10
Methylene chloride	UG/L	0	0%	5	0	0	55	10 U	10 U	10 UJ	540 U	540 U	10
Styrene	UG/L	0	0%		0	0	55	10 U	10 U	10 UJ	540 U	540 U	10
Tetrachloroethene	UG/L	0	0%	5	0	0	55	10 U	10 U	10 UJ	540 U	540 U	10
Toluene	UG/L	0	0%	5	0	0	55	10 U	10 U	10 UJ	540 U	540 U	10
Total Xylenes	UG/L	0	0%	5	0	0	55	10 U	10 U	10 UJ	540 U	540 U	10



TABLE 1  
GROUND WATER CHEMICAL RESULTS  
ROUND 1 GROUNDWATER MONITORING  
ASH REMEDIAL DESIGN  
SENECA ARMY DEPOT ACTIVITY ROMULUS, NY

FACILITY	ASH LANDFILL											
LOCATION ID	PT-16		PT-16		PT-17		PT-18		PT-19			
MATRIX	GROUND WATER		GROUND WATER		GROUND WATER		GROUND WATER		GROUND			
SAMPLE ID	ARD2014		ARD2013		ARD2027		ARD2048		ARD2018			
DEPTH TO TOP OF SAMPLE	10		10		10.5		11.1		10.5			
DEPTH TO BOTTOM OF SAMPLE	10		10		10.5		11.1		10.5			
SAMPLE DATE	11-Oct-99		11-Oct-99		18-Oct-99		21-Oct-99		11-Oct-99			
QC CODE	DU		SA		SA		SA		SA			
STUDY ID	FREQUENCY		NYSDEC	NUMBER	NUMBER	NUMBER	ASH REMEDIAL DES	ASH REMEDIAL DESI	ASH REMEDIAL DESIG	ASH REMEDIAL DES	ASH REM	
SAMPLE ROUND	UNIT	MAXIMUM	OF	CLASS GA	ABOVE	OF	OF	1	1	1	1	
PARAMETER	UNIT	MAXIMUM	DETECTION	STD.	STD.	DETECTS	ANALYSES	N	N	N	N	
Trans-1,3-Dichloropropene	UG/L	0	0%	5	0	0	55	10 U	10 U	10 UJ	540 U	10
Trichloroethene	UG/L	9100	27%	5	10	15	55	10 U	10 U	110 J	9100	10
Vinyl chloride	UG/L	180	5%	2	2	3	55	10 U	10 U	10 UJ	540 U	10
<b>METALS</b>												
Aluminum	UG/L	2600	65%		0	34	52	16.3 U	16.3 U	198 J	51.6 J	184
Antimony	UG/L	3	2%		0	1	52	4.9 U	4.9 UJ	2.7 UJ	2.7 U	4.9
Arsenic	UG/L	7	23%	25	0	12	52	4.4 J	3.7 U	1.9 UJ	3.7 J	7
Barium	UG/L	176	98%	1000	0	51	52	40.6 J	44.5 J	50.5 J	50.3 J	173
Beryllium	UG/L	0.66	10%		0	5	52	0.57 J	0.2 U	0.2 UJ	0.2 U	0.46
Cadmium	UG/L	0	0%	10	0	0	52	0.7 U	0.7 U	0.3 UJ	0.3 U	0.7
Calcium	UG/L	268000	98%		0	51	52	95500	100000	105000 J	224000	202000
Chromium	UG/L	5.6	15%	50	0	8	52	0.9 U	0.9 U	0.9 UJ	0.93 J	1.3
Cobalt	UG/L	8.4	4%		0	2	52	2.5 U	2.5 U	2 UJ	2.5 U	3.2
Copper	UG/L	6.1	10%	200	0	5	52	1.9 U	1.9 U	1.7 UJ	1.7 U	3.8
Cyanide	UG/L	0	0%	100	0	0	52	5 U	5 U	5 UJ	5 U	5
Iron	UG/L	11600	67%	300	14	35	52	14.7 U	14.7 U	243 J	199 J	11600
Lead	UG/L	5.4	10%	25	0	5	52	1.2 U	1.2 U	1 UJ	1.2 U	1.2
Magnesium	UG/L	47100	98%		0	51	52	11500	12400	10200 J	27900	25700
Manganese	UG/L	3140	83%	300	7	43	52	7.3 J	3.7 J	12.2 J	471	3140
Mercury	UG/L	0.2	12%	2	0	6	52	0.1 U	0.15 J	0.1 UJ	0.16 J	0.16
Nickel	UG/L	5.6	12%		0	6	52	2.6 U	2.6 U	1.7 UJ	1.8 J	2.6
Potassium	UG/L	18400	98%		0	51	52	1050 J	1160 J	1230 J	4470 J	8270
Selenium	UG/L	2.6	2%	10	0	1	52	2.8 U	2.8 U	2.4 UJ	2.4 U	2.8
Silver	UG/L	0	0%	50	0	0	52	1.6 U	1.6 U	1.6 UJ	1.6 U	1.6
Sodium	UG/L	142000	98%	20000	27	51	52	7140	7780	20000 J	58600	28900
Thallium	UG/L	10.8	19%		0	10	52	2.9 U	2.9 U	2.7 UJ	4.2 J	10.8
Vanadium	UG/L	4.5	6%		0	3	52	3.2 U	3.2 U	1.5 UJ	1.5 U	3.2
Zinc	UG/L	134	81%	300	0	42	52	1.8 U	2.9 J	2.3 J	134	4.4

TABLE 1  
GROUND WATER CHEMICAL RESULTS  
ROUND 1 GROUNDWATER MONITORING  
ASH REMEDIAL DESIGN  
SENECA ARMY DEPOT ACTIVITY ROMULUS, NY

FACILITY				FILL				ASH LANDFILL			
LOCATION ID				PT-20				PT-20			
MATRIX				GROUND WATER				GROUND WATER			
SAMPLE ID				ARD2026				ARD2025			
DEPTH TO TOP OF SAMPLE				10				10			
DEPTH TO BOTTOM OF SAMPLE				10				17.5			
SAMPLE DATE				18-Oct-99				18-Oct-99			
QC CODE				DU				SA			
STUDY ID				ASH REMEDIAL DES				ASH REMEDIAL DESIG			
SAMPLE ROUND				1				1			
PARAMETER				N				N			
UNIT	MAXIMUM	FREQUENCY OF DETECTION	NYSDEC CLASS GA STD.	NUMBER ABOVE STD.	NUMBER OF DETECTS	NUMBER OF ANALYSES	DIAL DES	ASH REMEDIAL DES	ASH REMEDIAL DESIG	ASH REMEDIAL DESIGN	ASH REMEDIAL DES
<b>VOLATILE ORGANICS</b>											
1,1,1-Trichloroethane	UG/L	1	2%	5	0	1	55 U	10 UJ	10 UJ	10 U	10 U
1,1,2,2-Tetrachloroethane	UG/L	0	0%	5	0	0	55 U	10 UJ	10 UJ	10 U	10 U
1,1,2-Trichloroethane	UG/L	0	0%	5	0	0	55 U	10 UJ	10 UJ	10 U	10 U
1,1-Dichloroethane	UG/L	9	2%	5	1	1	55 U	10 UJ	10 UJ	10 U	10 U
1,1-Dichloroethene	UG/L	0	0%	5	0	0	55 U	10 UJ	10 UJ	10 U	10 U
1,2-Dichloroethane	UG/L	4	4%	5	0	2	55 U	10 UJ	10 UJ	2 J	4 J
1,2-Dichloroethene (total)	UG/L	1100	27%	5	14	15	55 U	28 J	29 J	16	88
1,2-Dichloropropane	UG/L	0	0%	5	0	0	55 U	10 UJ	10 UJ	10 U	10 U
Acetone	UG/L	2	4%	5	0	2	55 U	10 UJ	10 UJ	10 UJ	10 UJ
Benzene	UG/L	0	0%	0.7	0	0	55 U	10 UJ	10 UJ	10 U	10 U
Bromodichloromethane	UG/L	0	0%	5	0	0	55 U	10 UJ	10 UJ	10 U	10 U
Bromoform	UG/L	0	0%	5	0	0	55 U	10 UJ	10 UJ	10 U	10 U
Carbon disulfide	UG/L	0	0%	5	0	0	55 U	10 UJ	10 UJ	10 U	10 U
Carbon tetrachloride	UG/L	0	0%	5	0	0	55 U	10 UJ	10 UJ	10 U	10 U
Chlorobenzene	UG/L	0	0%	5	0	0	55 U	10 UJ	10 UJ	10 U	10 U
Chlorodibromomethane	UG/L	0	0%	5	0	0	55 U	10 UJ	10 UJ	10 U	10 U
Chloroethane	UG/L	0	0%	5	0	0	55 U	10 UJ	10 UJ	10 U	10 U
Chloroform	UG/L	74	2%	7	1	1	55 U	10 UJ	10 UJ	10 U	10 U
Cis-1,3-Dichloropropene	UG/L	0	0%	5	0	0	55 U	10 UJ	10 UJ	10 U	10 U
Ethyl benzene	UG/L	0	0%	5	0	0	55 U	10 UJ	10 UJ	10 U	10 U
Methyl bromide	UG/L	0	0%	5	0	0	55 U	10 UJ	10 UJ	10 U	10 U
Methyl butyl ketone	UG/L	0	0%	5	0	0	55 U	10 UJ	10 UJ	10 U	10 U
Methyl chloride	UG/L	0	0%	5	0	0	55 U	10 UJ	10 UJ	10 U	10 U
Methyl ethyl ketone	UG/L	0	0%	50	0	0	55 U	10 UJ	10 UJ	10 U	10 U
Methyl isobutyl ketone	UG/L	0	0%	5	0	0	55 U	10 UJ	10 UJ	10 U	10 U
Methylene chloride	UG/L	0	0%	5	0	0	55 U	10 UJ	10 UJ	10 U	10 U
Styrene	UG/L	0	0%	5	0	0	55 U	10 UJ	10 UJ	10 U	10 U
Tetrachloroethene	UG/L	0	0%	5	0	0	55 U	10 UJ	10 UJ	10 U	10 U
Toluene	UG/L	0	0%	5	0	0	55 U	10 UJ	10 UJ	10 U	10 U
Total Xylenes	UG/L	0	0%	5	0	0	55 U	10 UJ	10 UJ	10 U	10 U

TABLE 1  
GROUND WATER CHEMICAL RESULTS  
ROUND 1 GROUNDWATER MONITORING  
ASH REMEDIAL DESIGN  
SENECA ARMY DEPOT ACTIVITY ROMULUS, NY

FACILITY									FILL	ASH LANDFILL	ASH LANDFILL	ASH LANDFILL	ASH LANDFILL
LOCATION ID									PT-20	PT-20	PT-21A	PT-22	PT-22
MATRIX									GROUND WATER	GROUND WATER	GROUND WATER	GROUND WATER	GROUND WATER
SAMPLE ID									ARD2026	ARD2025	ARD2046	ARD2045	ARD2045
DEPTH TO TOP OF SAMPLE									10	10	17.5	11.3	11.3
DEPTH TO BOTTOM OF SAMPLE									10	10	17.5	11.3	11.3
SAMPLE DATE									18-Oct-99	18-Oct-99	21-Oct-99	21-Oct-99	21-Oct-99
QC CODE									DU	SA	SA	SA	SA
STUDY ID			FREQUENCY	NYSDEC	NUMBER	NUMBER	NUMBER	DIAL DES	ASH REMEDIAL DES	ASH REMEDIAL DESIG	ASH REMEDIAL DESIGN	ASH REMEDIAL DES	ASH REMEDIAL DES
SAMPLE ROUND			OF	CLASS GA	ABOVE	OF	OF		1	1	1	1	1
PARAMETER	UNIT	MAXIMUM	DETECTION	STD.	STD.	DETECTS	ANALYSES	N	N	N	N	N	N
Trans-1,3-Dichloropropene	UG/L	0	0%	5	0	0	55 U	10 UJ	10 UJ	10 U	10 U	10 U	10 U
Trichloroethene	UG/L	9100	27%	5	10	15	55 U	36 J	36 J	6 J	74	74	74
Vinyl chloride	UG/L	180	5%	2	2	3	55 U	10 UJ	10 UJ	10 U	10 U	10 U	10 U
<b>METALS</b>													
Aluminum	UG/L	2600	65%		0	34	52 J	14.3 UJ	14.3 UJ	14.3 U	30.3 J	30.3 J	30.3 J
Antimony	UG/L	3	2%		0	1	52 U	2.7 UJ	2.7 UJ	2.7 U	2.7 U	2.7 U	2.7 U
Arsenic	UG/L	7	23%	25	0	12	52 J	1.9 UJ	1.9 UJ	2.2 J	1.9 U	1.9 U	1.9 U
Barium	UG/L	176	98%	1000	0	51	52 J	81.1 J	5.6 UJ	56.9 J	77.5 J	77.5 J	77.5 J
Beryllium	UG/L	0.66	10%		0	5	52 J	0.2 UJ	0.2 UJ	0.2 U	0.2 U	0.2 U	0.2 U
Cadmium	UG/L	0	0%	10	0	0	52 U	0.3 UJ	0.3 UJ	0.3 U	0.3 U	0.3 U	0.3 U
Calcium	UG/L	268000	98%		0	51	52	159000 J	124 UJ	191000	236000	236000	236000
Chromium	UG/L	5.6	15%	50	0	8	52 J	0.9 UJ	0.9 UJ	0.9 U	0.9 U	0.9 U	0.9 U
Cobalt	UG/L	8.4	4%		0	2	52 J	2 UJ	2 UJ	2.5 U	2.5 U	2.5 U	2.5 U
Copper	UG/L	6.1	10%	200	0	5	52 J	1.7 UJ	1.7 UJ	1.7 U	1.7 U	1.7 U	1.7 U
Cyanide	UG/L	0	0%	100	0	0	52 U	5 UJ	5 UJ	5 U	5 U	5 U	5 U
Iron	UG/L	11600	67%	300	14	35	52	14.7 UJ	14.7 UJ	556 J	58.4 J	58.4 J	58.4 J
Lead	UG/L	5.4	10%	25	0	5	52 U	1 UJ	1 UJ	1 U	1 U	1 U	1 U
Magnesium	UG/L	47100	98%		0	51	52	16200 J	134 UJ	36200	28500	28500	28500
Manganese	UG/L	3140	83%	300	7	43	52	3.3 J	0.9 UJ	503	37.1	37.1	37.1
Mercury	UG/L	0.2	12%	2	0	6	52 J	0.12 J	0.1 UJ	0.1 U	0.1 U	0.1 U	0.1 U
Nickel	UG/L	5.6	12%		0	6	52 U	1.7 UJ	1.7 UJ	1.7 U	1.7 U	1.7 U	1.7 U
Potassium	UG/L	18400	98%		0	51	52	2050 J	261 UJ	8560	1990 J	1990 J	1990 J
Selenium	UG/L	2.6	2%	10	0	1	52 U	2.4 UJ	2.4 UJ	2.4 U	2.4 U	2.4 U	2.4 U
Silver	UG/L	0	0%	50	0	0	52 U	1.6 UJ	1.6 UJ	1.6 U	1.6 U	1.6 U	1.6 U
Sodium	UG/L	142000	98%	20000	27	51	52	24800 J	875 UJ	41300	59400	59400	59400
Thallium	UG/L	10.8	19%		0	10	52	2.7 UJ	2.7 UJ	5.1 J	3.9 J	3.9 J	3.9 J
Vanadium	UG/L	4.5	6%		0	3	52 U	1.5 UJ	1.5 UJ	1.5 U	1.5 U	1.5 U	1.5 U
Zinc	UG/L	134	81%	300	0	42	52 J	2.4 J	1.6 UJ	4.2 J	5.3 J	5.3 J	5.3 J

TABLE 1  
GROUND WATER CHEMICAL RESULTS  
ROUND 1 GROUNDWATER MONITORING  
ASH REMEDIAL DESIGN  
SENECA ARMY DEPOT ACTIVITY ROMULUS, NY

FACILITY										ASH LANDFILL	ASH LANDFILL	ASH LANDFILL	ASH LANDFILL
LOCATION ID										PT-23	PT-24	PT-25	PT-26
MATRIX										GROUND WATER	GROUND WATER	GROUND WATER	GROUND WATER
SAMPLE ID										ARD2016	ARD2000	ARD2019	ARD2057
DEPTH TO TOP OF SAMPLE										12	10.4	11.5	13.5
DEPTH TO BOTTOM OF SAMPLE										12	10.4	11.5	13.5
SAMPLE DATE										11-Oct-99	07-Oct-99	12-Oct-99	27-Oct-99
QC CODE										SA	SA	SA	SA
STUDY ID										ASH REMEDIAL DESIG	ASH REMEDIAL DES	ASH REMEDIAL DES	ASH REMEDIAL DESIGN
SAMPLE ROUND										1	1	1	1
PARAMETER	UNIT	MAXIMUM	FREQUENCY OF DETECTION	NYSDEC CLASS STD.	NUMBER ABOVE STD.	NUMBER OF DETECTS	NUMBER OF ANALYSES	N	N	N	N		
<b>VOLATILE ORGANICS</b>													
1,1,1-Trichloroethane	UG/L	1	2%	5	0	1	55	10 U	10 UJ	10 U	10 U		
1,1,2,2-Tetrachloroethane	UG/L	0	0%	5	0	0	55	10 U	10 UJ	10 U	10 U		
1,1,2-Trichloroethane	UG/L	0	0%		0	0	55	10 U	10 UJ	10 U	10 U		
1,1-Dichloroethane	UG/L	9	2%	5	1	1	55	10 U	10 UJ	10 U	10 U		
1,1-Dichloroethene	UG/L	0	0%	5	0	0	55	10 U	10 UJ	10 U	10 U		
1,2-Dichloroethane	UG/L	4	4%	5	0	2	55	10 U	10 UJ	10 U	10 U		
1,2-Dichloroethene (total)	UG/L	1100	27%	5	14	15	55	10 U	86 J	10 U	10 U		
1,2-Dichloropropane	UG/L	0	0%	5	0	0	55	10 U	10 UJ	10 U	10 U		
Acetone	UG/L	2	4%		0	2	55	10 U	10 UJ	10 U	10 UJ		
Benzene	UG/L	0	0%	0.7	0	0	55	10 U	10 UJ	10 U	10 U		
Bromodichloromethane	UG/L	0	0%		0	0	55	10 U	10 UJ	10 U	10 U		
Bromoform	UG/L	0	0%		0	0	55	10 U	10 UJ	10 U	10 U		
Carbon disulfide	UG/L	0	0%		0	0	55	10 U	10 UJ	10 U	10 U		
Carbon tetrachloride	UG/L	0	0%	5	0	0	55	10 U	10 UJ	10 U	10 U		
Chlorobenzene	UG/L	0	0%	5	0	0	55	10 U	10 UJ	10 U	10 U		
Chlorodibromomethane	UG/L	0	0%		0	0	55	10 U	10 UJ	10 U	10 U		
Chloroethane	UG/L	0	0%	5	0	0	55	10 U	10 UJ	10 U	10 U		
Chloroform	UG/L	74	2%	7	1	1	55	10 U	10 UJ	10 U	10 U		
Cis-1,3-Dichloropropene	UG/L	0	0%	5	0	0	55	10 U	10 UJ	10 U	10 U		
Ethyl benzene	UG/L	0	0%	5	0	0	55	10 U	10 UJ	10 U	10 U		
Methyl bromide	UG/L	0	0%		0	0	55	10 U	10 UJ	10 U	10 U		
Methyl butyl ketone	UG/L	0	0%		0	0	55	10 U	10 UJ	10 U	10 U		
Methyl chloride	UG/L	0	0%	5	0	0	55	10 U	10 UJ	10 U	10 U		
Methyl ethyl ketone	UG/L	0	0%	50	0	0	55	10 U	10 UJ	10 U	10 UJ		
Methyl isobutyl ketone	UG/L	0	0%		0	0	55	10 U	10 UJ	10 U	10 U		
Methylene chloride	UG/L	0	0%	5	0	0	55	10 U	10 UJ	10 U	10 U		
Styrene	UG/L	0	0%		0	0	55	10 U	10 UJ	10 U	10 U		
Tetrachloroethene	UG/L	0	0%	5	0	0	55	10 U	10 UJ	10 U	10 U		
Toluene	UG/L	0	0%	5	0	0	55	10 U	10 UJ	10 U	10 U		
Total Xylenes	UG/L	0	0%	5	0	0	55	10 U	10 UJ	10 U	10 U		

TABLE 1  
GROUND WATER CHEMICAL RESULTS  
ROUND 1 GROUNDWATER MONITORING  
ASH REMEDIAL DESIGN  
SENECA ARMY DEPOT ACTIVITY ROMULUS, NY

FACILITY								ASH LANDFILL		ASH LANDFILL		ASH LANDFILL		ASH LANDFILL	
LOCATION ID								PT-23		PT-24		PT-25		PT-26	
MATRIX								GROUND WATER		GROUND WATER		GROUND WATER		GROUND WATER	
SAMPLE ID								ARD2016		ARD2000		ARD2019		ARD2057	
DEPTH TO TOP OF SAMPLE								12		10.4		11.5		13.5	
DEPTH TO BOTTOM OF SAMPLE								12		10.4		11.5		13.5	
SAMPLE DATE								11-Oct-99		07-Oct-99		12-Oct-99		27-Oct-99	
QC CODE								SA		SA		SA		SA	
STUDY ID								ASH REMEDIAL DESIG		ASH REMEDIAL DES		ASH REMEDIAL DES		ASH REMEDIAL DESIGN	
SAMPLE ROUND				FREQUENCY		NYSDEC		NUMBER		NUMBER		NUMBER		NUMBER	
PARAMETER		UNIT		OF		CLASS GA		ABOVE		OF		OF		OF	
		MAXIMUM		DETECTION		STD.		STD.		DETECTS		ANALYSES		N	
Trans-1,3-Dichloropropene	UG/L	0	0%	5	0	0	55	10	U	10	UJ	10	U	10	U
Trichloroethene	UG/L	9100	27%	5	10	15	55	10	U	4	J	10	U	10	U
Vinyl chloride	UG/L	180	5%	2	2	3	55	10	U	10	UJ	10	U	10	U
<b>METALS</b>															
Aluminum	UG/L	2600	65%		0	34	52	357		16.3	UJ	41.9	J	96.2	J
Antimony	UG/L	3	2%		0	1	52	4.9	U	4.9	UJ	2.7	U	2.7	U
Arsenic	UG/L	7	23%	25	0	12	52	3.9	J	3.7	UJ	1.9	U	1.9	U
Barium	UG/L	176	98%	1000	0	51	52	52.9	J	41.3	J	29.2	J	58.2	J
Beryllium	UG/L	0.66	10%		0	5	52	0.2	U	0.2	UJ	0.2	U	0.2	U
Cadmium	UG/L	0	0%	10	0	0	52	0.7	U	0.7	UJ	0.3	U	0.3	U
Calcium	UG/L	268000	98%		0	51	52	104000		101000	J	77200		36900	
Chromium	UG/L	5.6	15%	50	0	8	52	0.9	U	0.9	UJ	0.9	U	1.2	J
Cobalt	UG/L	8.4	4%		0	2	52	2.5	U	2.5	UJ	2	U	2.5	U
Copper	UG/L	6.1	10%	200	0	5	52	1.9	U	1.9	UJ	1.7	U	1.7	U
Cyanide	UG/L	0	0%	100	0	0	52	5	U	5	UJ	5	U	5	U
Iron	UG/L	11600	67%	300	14	35	52	413		14.7	UJ	27.8	J	191	J
Lead	UG/L	5.4	10%	25	0	5	52	1.2	U	1.2	UJ	1	U	1	U
Magnesium	UG/L	47100	98%		0	51	52	12700		11400	J	8130		14000	
Manganese	UG/L	3140	83%	300	7	43	52	146		0.9	UJ	0.9	U	82.2	
Mercury	UG/L	0.2	12%	2	0	6	52	0.1	U	0.1	UJ	0.15	J	0.1	U
Nickel	UG/L	5.6	12%		0	6	52	2.6	U	2.6	UJ	1.7	U	1.7	U
Potassium	UG/L	18400	98%		0	51	52	2220	J	1510	J	1050	J	2680	J
Selenium	UG/L	2.6	2%	10	0	1	52	2.8	U	2.8	UJ	2.4	U	2.4	U
Silver	UG/L	0	0%	50	0	0	52	1.6	U	1.6	UJ	1.6	U	1.6	U
Sodium	UG/L	142000	98%	20000	27	51	52	10600		10200	J	10800		91100	
Thallium	UG/L	10.8	19%		0	10	52	2.9	U	2.9	UJ	2.7	U	5.5	J
Vanadium	UG/L	4.5	6%		0	3	52	3.2	U	3.2	UJ	1.5	U	1.5	U
Zinc	UG/L	134	81%	300	0	42	52	5.9	J	1.8	UJ	1.9	J	2.8	J

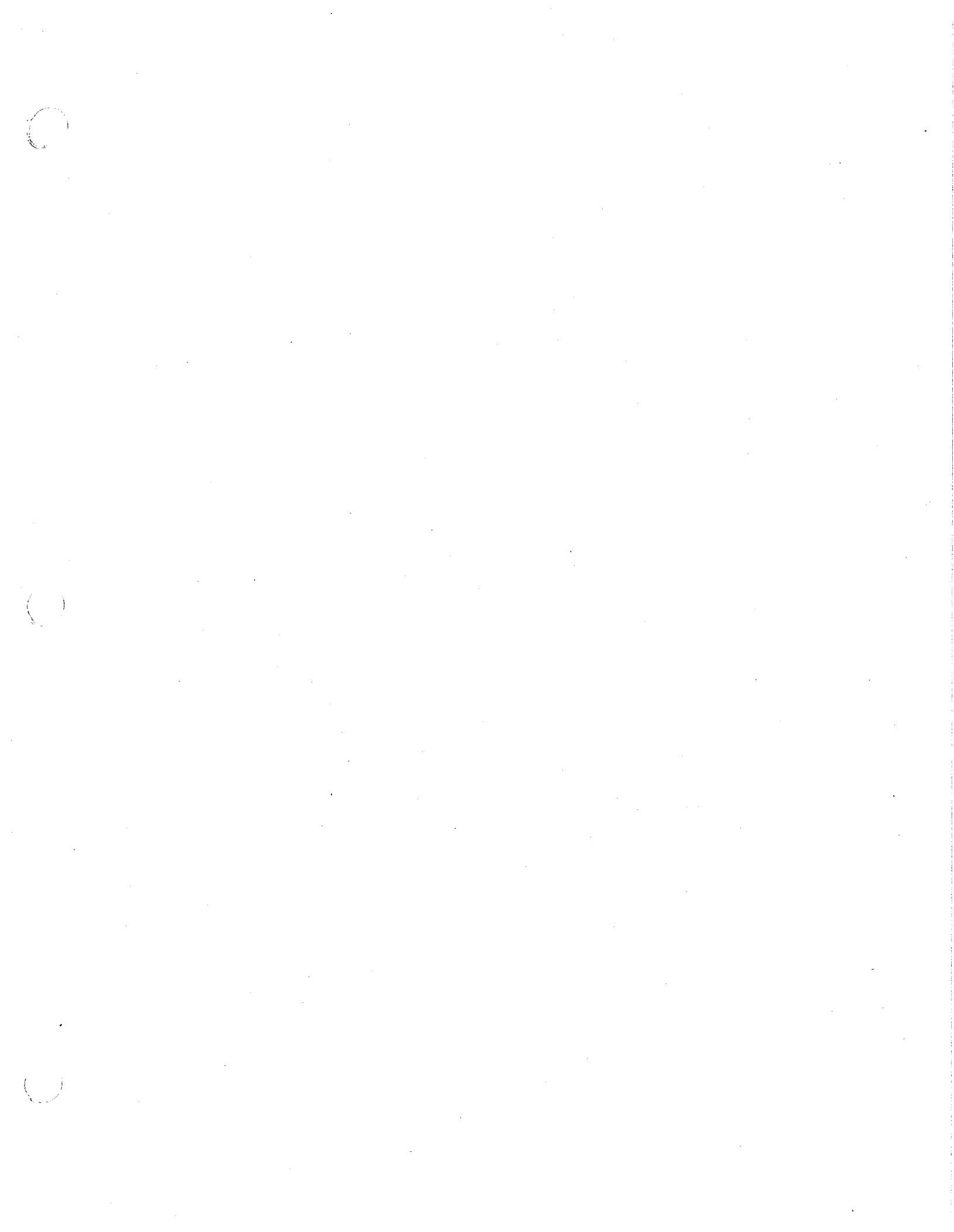


TABLE 2  
GROUND WATER CHEMICAL RESULTS  
ROUND 2 GROUND WATER MONITORING  
ASH REMEDIAL DESIGN  
SENECA ARMY DEPOT ACTIVITY ROMULUS, NY

FACILITY								ASH LANDFILL	ASH LANDFILL	ASH LANDFILL	ASH LANDFILL	ASH LANDFILL
LOCATION ID								BN-S	FH-D	FH-S	MW-12A	MW-27
MATRIX								GROUND WATER	GROUND WATER	GROUND WATER	GROUND WATER	GROUND WATER
SAMPLE ID								ARD2141	ARD2140	ARD2139	ARD2152	ARD2132
DEPTH TO TOP OF SAMPLE								0	0	0	12	10
DEPTH TO BOTTOM OF SAMPLE								0	0	0	12	10
SAMPLE DATE								01/19/2000	01/19/2000	01/19/2000	01/21/2000	01/10/2000
QC CODE								SA	SA	SA	SA	SA
STUDY ID			FREQUENCY	NYSDEC	NUMBER	NUMBER	NUMBER	ASH REMEDIAL DESIG	ASH REMEDIAL DESI	ASH REMEDIAL DESI	ASH REMEDIAL DESI	ASH REMEDIAL DESIG
SAMPLE ROUND			OF	CLASS GA	ABOVE	OF	OF	2	2	2	2	2
PARAMETER	UNIT	MAXIMUM	DETECTION	STD.	STD.	DETECTS	ANALYSES	N	N	N	N	N
<b>VOLATILE ORGANICS</b>												
1,1,1-Trichloroethane	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	58 U	1 U
1,1,2,2-Tetrachloroethane	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	58 U	1 U
1,1,2-Trichloroethane	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	58 U	1 U
1,1-Dichloroethane	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	58 U	1 U
1,1-Dichloroethene	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	58 U	1 U
1,2,4-Trichlorobenzene	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	58 U	1 U
1,2-Dibromo-3-chloropropane	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	58 U	1 U
1,2-Dibromoethane	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	58 U	1 U
1,2-Dichlorobenzene	UG/L	0	0%	4.7	0	0	54	1 U	1 U	1 U	58 U	1 U
1,2-Dichloroethane	UG/L	3	2%	5	0	1	54	1 U	1 U	1 U	58 U	1 U
1,2-Dichloropropane	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	58 U	1 U
1,3-Dichlorobenzene	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	58 U	1 U
1,4-Dichlorobenzene	UG/L	0	0%	4.7	0	0	54	1 U	1 U	1 U	58 U	1 U
Acetone	UG/L	1	4%	5	0	2	54	5 UJ	1 J	5 UJ	290 R	5 UJ
Benzene	UG/L	0	0%	0.7	0	0	54	1 U	1 U	1 U	58 U	1 U
Bromochloromethane	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	58 U	1 U
Bromodichloromethane	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	58 U	1 U
Bromoform	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	58 U	1 U
Carbon disulfide	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	58 U	1 U
Carbon tetrachloride	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	58 U	1 U
Chlorobenzene	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	58 U	1 U
Chlorodibromomethane	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	58 U	1 U
Chloroethane	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	58 U	1 U
Chloroform	UG/L	0	0%	7	0	0	54	1 U	1 U	1 U	58 U	1 U
Cis-1,2-Dichloroethene	UG/L	980	28%	5	14	15	54	1 U	1 U	1 U	980	1 U
Cis-1,3-Dichloropropene	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	58 U	1 U
Ethyl benzene	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	58 U	1 U
Methyl bromide	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	58 U	1 U
Methyl butyl ketone	UG/L	0	0%	5	0	0	54	5 U	5 U	5 U	290 UJ	5 U
Methyl chloride	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	58 U	1 U
Methyl ethyl ketone	UG/L	0	0%	50	0	0	54	5 U	5 U	5 U	290 U	5 UJ
Methyl isobutyl ketone	UG/L	0	0%	5	0	0	54	5 U	5 U	5 U	290 U	5 U
Methylene chloride	UG/L	0	0%	5	0	0	54	2 U	2 U	2 U	120 U	2 U
Styrene	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	58 U	1 U
Tetrachloroethene	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	58 U	1 U
Toluene	UG/L	2	6%	5	0	3	54	1 U	1 U	1 U	58 U	1 U

TABLE 2  
GROUND WATER CHEMICAL RESULTS  
ROUND 2 GROUNDWATER MONITORING  
ASH REMEDIAL DESIGN  
SENECA ARMY DEPOT ACTIVITY ROMULUS, NY

FACILITY				ASH LANDFILL		ASH LANDFILL		ASH LANDFILL		ASH LANDFILL		ASH LANDFILL	
LOCATION ID				BN-S		FH-D		FH-S		MW-12A		MW-27	
MATRIX				GROUND WATER		GROUND WATER		GROUND WATER		GROUND WATER		GROUND WATER	
SAMPLE ID				ARD2141		ARD2140		ARD2139		ARD2152		ARD2132	
DEPTH TO TOP OF SAMPLE				0		0		0		12		10	
DEPTH TO BOTTOM OF SAMPLE				0		0		0		12		10	
SAMPLE DATE				01/19/2000		01/19/2000		01/19/2000		01/21/2000		01/10/2000	
QC CODE				SA		SA		SA		SA		SA	
STUDY ID				ASH REMEDIAL DESIG		ASH REMEDIAL DESI		ASH REMEDIAL DESI		ASH REMEDIAL DESI		ASH REMEDIAL DESIG	
SAMPLE ROUND				2		2		2		2		2	
PARAMETER	UNIT	MAXIMUM	DETECTION	NYSDEC CLASS GA STD.	NUMBER ABOVE STD.	NUMBER OF DETECTS	NUMBER OF ANALYSES	N	N	N	N	N	N
Total Xylenes	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	58 U	1 U	1 U
Trans-1,2-Dichloroethene	UG/L	2	4%	5	0	2	54	1 U	1 U	1 U	58 U	1 U	1 U
Trans-1,3-Dichloropropene	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	58 U	1 U	1 U
Trichloroethene	UG/L	760	28%	5	8	15	54	1 U	1 U	1 U	760	1 U	1 U
Vinyl chloride	UG/L	25	2%	2	1	1	54	1 U	1 U	1 U	58 U	1 U	1 U
<b>METALS</b>													
Aluminum	UG/L	7700	49%		0	25	51				34.4 UJ		443 J
Antimony	UG/L	4.5	12%		0	6	51				5.4 U		2.2 U
Arsenic	UG/L	5	22%	25	0	11	51				2.4 U		2.5 U
Barium	UG/L	173	100%	1000	0	51	51				24.2 J		40.6 J
Beryllium	UG/L	0.26	14%		0	7	51				0.6 U		0.1 U
Cadmium	UG/L	0.35	2%	10	0	1	51				0.2 U		0.2 U
Calcium	UG/L	391000	100%		0	51	51				240000		92900
Chromium	UG/L	4.1	14%	50	0	7	51				1 U		1 U
Cobalt	UG/L	2	6%		0	3	51				3.5 U		1.3 U
Copper	UG/L	14.6	33%	200	0	17	51				1.6 U		2.2 J
Cyanide	UG/L	0	0%	100	0	0	51				10 U		10 U
Iron	UG/L	6350	63%	300	14	32	51				42.8 J		347 J
Lead	UG/L	3.8	10%	25	0	5	51				1 U		1.3 U
Magnesium	UG/L	85900	100%		0	51	51				38000		9390
Manganese	UG/L	344	100%	300	2	51	51				196		24
Mercury	UG/L	0.14	2%	2	0	1	51				0.1 U		0.1 U
Nickel	UG/L	6.2	10%		0	5	51				4.2 U		1.7 U
Potassium	UG/L	25600	100%		0	51	51				4480 J		1610 J
Selenium	UG/L	3	2%	10	0	1	51				2.2 U		2.2 U
Silver	UG/L	2.8	2%	50	0	1	51				1 UJ		1.3 UJ
Sodium	UG/L	175000	90%	20000	23	46	51				60800 J		26500
Thallium	UG/L	7.4	6%		0	3	51				3.2 U		3.2 UJ
Vanadium	UG/L	10.8	8%		0	4	51				2.8 U		1.8 U
Zinc	UG/L	1620	100%	300	1	51	51				2 J		7.9 J



TABLE 2  
GROUND WATER CHEMICAL RESULTS  
ROUND 2 GROUNDWATER MONITORING  
ASH REMEDIAL DESIGN  
SENECA ARMY DEPOT ACTIVITY ROMULUS, NY

FACILITY				ASH LANDFILL				ASH LANDFILL				ASH LANDFILL				ASH LANDFILL																																			
LOCATION ID				MW-28				MW-29				MW-30				MW-31																																			
MATRIX				GROUND WATER				GROUND WATER				GROUND WATER				GROUND WATER																																			
SAMPLE ID				ARD2146				ARD2148				ARD2129				ARD2115				ARD2114																															
DEPTH TO TOP OF SAMPLE				8.5				9.5				8.5				8.5				8.5																															
DEPTH TO BOTTOM OF SAMPLE				8.5				9.5				8.5				8.5				8.5																															
SAMPLE DATE				01/20/2000				01/20/2000				01/09/2000				01/09/2000				01/09/2000																															
QC CODE				SA				SA				DU				SA				SA																															
STUDY ID				FREQUENCY				NYSDEC				NUMBER				NUMBER				NUMBER																															
SAMPLE ROUND				OF				CLASS GA				ABOVE				OF				OF																															
PARAMETER				UNIT				MAXIMUM				DETECTION				STD.				STD.				DETECTS				ANALYSES				N				N				N				N				N			
<b>VOLATILE ORGANICS</b>																																																			
1,1,1-Trichloroethane	UG/L	0	0%	5	0	0	54	1	U	4	U	1	U	1	U	1	U	1	U																																
1,1,2,2-Tetrachloroethane	UG/L	0	0%	5	0	0	54	1	U	4	U	1	UJ	1	UJ	1	UJ	1	U																																
1,1,2-Trichloroethane	UG/L	0	0%	5	0	0	54	1	U	4	U	1	U	1	U	1	U	1	U																																
1,1-Dichloroethane	UG/L	0	0%	5	0	0	54	1	U	4	U	1	U	1	U	1	U	1	U																																
1,1-Dichloroethene	UG/L	0	0%	5	0	0	54	1	U	4	U	1	U	1	U	1	U	1	UJ																																
1,2,4-Trichlorobenzene	UG/L	0	0%	5	0	0	54	1	U	4	U	1	U	1	U	1	U	1	U																																
1,2-Dibromo-3-chloropropane	UG/L	0	0%	5	0	0	54	1	U	4	U	1	U	1	U	1	U	1	U																																
1,2-Dibromoethane	UG/L	0	0%	5	0	0	54	1	U	4	U	1	U	1	U	1	U	1	U																																
1,2-Dichlorobenzene	UG/L	0	0%	4.7	0	0	54	1	U	4	U	1	U	1	U	1	U	1	U																																
1,2-Dichloroethane	UG/L	3	2%	5	0	1	54	1	U	4	U	1	U	1	U	1	U	1	U																																
1,2-Dichloropropane	UG/L	0	0%	5	0	0	54	1	U	4	U	1	U	1	U	1	U	1	U																																
1,3-Dichlorobenzene	UG/L	0	0%	5	0	0	54	1	U	4	U	1	U	1	U	1	U	1	U																																
1,4-Dichlorobenzene	UG/L	0	0%	4.7	0	0	54	1	U	4	U	1	U	1	U	1	U	1	U																																
Acetone	UG/L	1	4%	5	0	2	54	5	R	19	R	5	UJ	5	U	5	U	5	U																																
Benzene	UG/L	0	0%	0.7	0	0	54	1	U	4	U	1	U	1	U	1	U	1	U																																
Bromochloromethane	UG/L	0	0%	5	0	0	54	1	U	4	U	1	U	1	U	1	U	1	U																																
Bromodichloromethane	UG/L	0	0%	5	0	0	54	1	U	4	U	1	U	1	U	1	U	1	U																																
Bromoform	UG/L	0	0%	5	0	0	54	1	U	4	U	1	U	1	U	1	U	1	U																																
Carbon disulfide	UG/L	0	0%	5	0	0	54	1	U	4	U	1	U	1	U	1	U	1	U																																
Carbon tetrachloride	UG/L	0	0%	5	0	0	54	1	U	4	U	1	U	1	U	1	U	1	U																																
Chlorobenzene	UG/L	0	0%	5	0	0	54	1	U	4	U	1	U	1	U	1	U	1	U																																
Chlorodibromomethane	UG/L	0	0%	5	0	0	54	1	U	4	U	1	U	1	U	1	U	1	U																																
Chloroethane	UG/L	0	0%	5	0	0	54	1	U	4	U	1	U	1	U	1	U	1	U																																
Chloroform	UG/L	0	0%	7	0	0	54	1	U	4	U	1	UJ	1	U	1	U	1	U																																
Cis-1,2-Dichloroethene	UG/L	980	28%	5	14	15	54	19	U	72	U	1	U	1	U	1	U	1	U																																
Cis-1,3-Dichloropropene	UG/L	0	0%	5	0	0	54	1	U	4	U	1	U	1	U	1	U	1	U																																
Ethyl benzene	UG/L	0	0%	5	0	0	54	1	U	4	U	1	U	1	U	1	U	1	U																																
Methyl bromide	UG/L	0	0%	5	0	0	54	1	U	4	U	1	UJ	1	U	1	U	1	U																																
Methyl butyl ketone	UG/L	0	0%	5	0	0	54	5	UJ	19	UJ	5	U	5	U	5	U	5	U																																
Methyl chloride	UG/L	0	0%	5	0	0	54	1	U	4	U	1	UJ	1	U	1	U	1	U																																
Methyl ethyl ketone	UG/L	0	0%	50	0	0	54	5	U	19	U	5	UJ	5	U	5	U	5	U																																
Methyl isobutyl ketone	UG/L	0	0%	5	0	0	54	5	U	19	U	5	U	5	U	5	U	5	U																																
Methylene chloride	UG/L	0	0%	5	0	0	54	2	U	8	U	2	U	2	U	2	U	2	U																																
Styrene	UG/L	0	0%	5	0	0	54	1	U	4	U	1	U	1	U	1	U	1	U																																
Tetrachloroethene	UG/L	0	0%	5	0	0	54	1	U	4	U	1	U	1	U	1	U	1	U																																
Toluene	UG/L	2	6%	5	0	3	54	1	U	4	U	1	U	1	U	1	U	1	U																																

TABLE 2  
GROUND WATER CHEMICAL RESULTS  
ROUND 2 GROUNDWATER MONITORING  
ASH REMEDIAL DESIGN  
SENECA ARMY DEPOT ACTIVITY ROMULUS, NY

FACILITY				ASH LANDFILL					ASH LANDFILL					ASH LANDFILL					ASH LANDFILL					ASH LANDFILL				
LOCATION ID				MW-28					MW-29					MW-30					MW-30					MW-31				
MATRIX				GROUND WATER					GROUND WATER					GROUND WATER					GROUND WATER					GROUND WATER				
SAMPLE ID				ARD2146					ARD2148					ARD2129					ARD2115					ARD2114				
DEPTH TO TOP OF SAMPLE				8.5					9.5					8.5					8.5					8.5				
DEPTH TO BOTTOM OF SAMPLE				8.5					9.5					8.5					8.5					8.5				
SAMPLE DATE				01/20/2000					01/20/2000					01/09/2000					01/09/2000					01/09/2000				
QC CODE				SA					SA					DU					SA					SA				
STUDY ID				ASH REMEDIAL DESI					ASH REMEDIAL DESI					ASH REMEDIAL DESI					ASH REMEDIAL DESI					ASH REMEDIAL DESI				
SAMPLE ROUND				2					2					2					2					2				
PARAMETER	UNIT	MAXIMUM	DETECTION	NYSDEC CLASS GA STD.	NUMBER ABOVE STD.	NUMBER OF DETECTS	NUMBER OF ANALYSES	N	U	J	UJ	N	U	J	UJ	N	U	J	UJ	N	U	J	UJ	N	U	J	UJ	
Total Xylenes	UG/L	0	0%	5	0	0	54	1	U			4	U			1	U			1	U			1	U			
Trans-1,2-Dichloroethene	UG/L	2	4%	5	0	2	54	1	U			4	U			1	U			1	U			1	U			
Trans-1,3-Dichloropropene	UG/L	0	0%	5	0	0	54	1	U			4	U			1	U			1	U			1	U			
Trichloroethene	UG/L	760	28%	5	8	15	54	20	J			2	J			0.7	J			1	U			1	U			
Vinyl chloride	UG/L	25	2%	2	1	1	54	1	U			4	U			1	UJ			1	U			1	UJ			
<b>METALS</b>																												
Aluminum	UG/L	7700	49%		0	25	51	123	J			98	J			15.5	UJ			15.5	UJ			833	J			
Antimony	UG/L	4.5	12%		0	6	51	2.2	U			2.2	U			2.2	U			2.2	U			2.2	U			
Arsenic	UG/L	5	22%	25	0	11	51	2.5	U			4.1	J			2.5	U			2.4	U			2.5	U			
Barium	UG/L	173	100%	1000	0	51	51	45.1	J			64.1	J			37.6	J			38	J			34	J			
Beryllium	UG/L	0.26	14%		0	7	51	0.1	U			0.1	U			0.1	U			0.1	U			0.1	U			
Cadmium	UG/L	0.35	2%	10	0	1	51	0.2	U			0.2	U			0.2	U			0.2	U			0.2	U			
Calcium	UG/L	391000	100%		0	51	51	126000				173000				94900				99300				82700				
Chromium	UG/L	4.1	14%	50	0	7	51	1	U			1	U			1.2	J			1	U			1.8	J			
Cobalt	UG/L	2	6%		0	3	51	1.3	U			1.3	U			1.3	U			1.3	U			1.3	U			
Copper	UG/L	14.6	33%	200	0	17	51	1.9	U			5.2	J			1.6	U			1.6	U			1.6	U			
Cyanide	UG/L	0	0%	100	0	0	51	10	U			10	U			10	U			10	U			10	U			
Iron	UG/L	6350	63%	300	14	32	51	150				98.6	J			63.7	J			20.3	UJ			647	J			
Lead	UG/L	3.8	10%	25	0	5	51	1	U			1	U			1.3	U			1.3	U			1.3	U			
Magnesium	UG/L	85900	100%		0	51	51	13500				20800				14000				14500				10800				
Manganese	UG/L	344	100%	300	2	51	51	4.6	J			7.6	J			1.8	J			1.5	J			16.9				
Mercury	UG/L	0.14	2%	2	0	1	51	0.1	U			0.1	U			0.1	U			0.1	U			0.1	U			
Nickel	UG/L	6.2	10%		0	5	51	1.7	U			1.7	U			1.7	U			1.7	U			1.7	U			
Potassium	UG/L	25600	100%		0	51	51	607	J			594	J			1930	J			1830	J			1210	J			
Selenium	UG/L	3	2%	10	0	1	51	2.2	U			2.2	U			3	J			2.5	U			2.5	U			
Silver	UG/L	2.8	2%	50	0	1	51	1.3	UJ			1.3	UJ			1	UJ			1	UJ			1	UJ			
Sodium	UG/L	175000	90%	20000	23	46	51	8210	U			20900	U			13200				12300				11400				
Thallium	UG/L	7.4	6%		0	3	51	3.2	UJ			3.2	UJ			3.2	U			6.2	J			3.6	U			
Vanadium	UG/L	10.8	8%		0	4	51	1.8	U			1.8	U			1.8	U			1.8	U			1.8	U			
Zinc	UG/L	1620	100%	300	1	51	51	3.9	J			5.2	J			4.3	J			5	J			6.4	J			

TABLE 2  
GROUND WATER CHEMICAL RESULTS  
ROUND 2 GROUNDWATER MONITORING  
ASH REMEDIAL DESIGN  
SENECA ARMY DEPOT ACTIVITY ROMULUS, NY

FACILITY									ASH LANDFILL	ASH LANDFILL	ASH LANDFILL	ASH LANDFILL	ASH LANDFILL
LOCATION ID									MW-32	MW-33	MW-34	MW-35D	MW-36
MATRIX									GROUND WATER	GROUND WATER	GROUND WATER	GROUND WATER	GROUND WATER
SAMPLE ID									ARD2119	ARD2118	ARD2117	ARD2127	ARD2124
DEPTH TO TOP OF SAMPLE									8.5	8.5	15	45	12
DEPTH TO BOTTOM OF SAMPLE									8.5	8.5	15	45	12
SAMPLE DATE									01/09/2000	01/09/2000	01/09/2000	01/11/2000	01/11/2000
QC CODE									SA	SA	SA	SA	SA
STUDY ID			FREQUENCY	NYSDEC	NUMBER	NUMBER	NUMBER	ASH REMEDIAL DESI	ASH REMEDIAL DESI	ASH REMEDIAL DESI	ASH REMEDIAL DESI	ASH REMEDIAL DESI	
SAMPLE ROUND			OF	CLASS GA	ABOVE	OF	OF	2	2	2	2	2	
PARAMETER	UNIT	MAXIMUM	DETECTION	STD.	STD.	DETECTS	ANALYSES	N	N	N	N	N	
<b>VOLATILE ORGANICS</b>													
1,1,1-Trichloroethane	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	1 U	1 U	
1,1,2,2-Tetrachloroethane	UG/L	0	0%	5	0	0	54	1 UJ	1 U	1 UJ	1 UJ	1 U	
1,1,2-Trichloroethane	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	1 U	1 U	
1,1-Dichloroethane	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	1 U	1 U	
1,1-Dichloroethene	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	1 U	1 U	
1,2,4-Trichlorobenzene	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	1 U	1 U	
1,2-Dibromo-3-chloropropane	UG/L	0	0%		0	0	54	1 U	1 U	1 U	1 U	1 U	
1,2-Dibromoethane	UG/L	0	0%		0	0	54	1 U	1 U	1 U	1 U	1 U	
1,2-Dichlorobenzene	UG/L	0	0%	4.7	0	0	54	1 U	1 U	1 U	1 U	1 U	
1,2-Dichloroethane	UG/L	3	2%	5	0	1	54	1 U	1 U	1 U	1 U	1 U	
1,2-Dichloropropane	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	1 U	1 U	
1,3-Dichlorobenzene	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	1 U	1 U	
1,4-Dichlorobenzene	UG/L	0	0%	4.7	0	0	54	1 U	1 U	1 U	1 U	1 U	
Acetone	UG/L	1	4%		0	2	54	5 UJ	5 U	5 UJ	5 UJ	5 U	
Benzene	UG/L	0	0%	0.7	0	0	54	1 U	1 U	1 U	1 U	1 U	
Bromochloromethane	UG/L	0	0%		0	0	54	1 U	1 U	1 U	1 U	1 U	
Bromodichloromethane	UG/L	0	0%		0	0	54	1 U	1 U	1 U	1 U	1 U	
Bromoform	UG/L	0	0%		0	0	54	1 U	1 U	1 U	1 U	1 U	
Carbon disulfide	UG/L	0	0%		0	0	54	1 U	1 U	1 U	1 U	1 U	
Carbon tetrachloride	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	1 U	1 U	
Chlorobenzene	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	1 U	1 U	
Chlorodibromomethane	UG/L	0	0%		0	0	54	1 U	1 U	1 U	1 U	1 U	
Chloroethane	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	1 U	1 U	
Chloroform	UG/L	0	0%	7	0	0	54	1 UJ	1 U	1 UJ	1 UJ	1 U	
Cis-1,2-Dichloroethene	UG/L	980	28%	5	14	15	54	1 U	1 U	1 U	1 U	1 U	
Cis-1,3-Dichloropropene	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	1 U	1 U	
Ethyl benzene	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	1 U	1 U	
Methyl bromide	UG/L	0	0%		0	0	54	1 UJ	1 U	1 UJ	1 UJ	1 U	
Methyl butyl ketone	UG/L	0	0%		0	0	54	5 U	5 U	5 U	5 U	5 U	
Methyl chloride	UG/L	0	0%	5	0	0	54	1 UJ	1 U	1 UJ	1 UJ	1 U	
Methyl ethyl ketone	UG/L	0	0%	50	0	0	54	5 UJ	5 U	5 UJ	5 UJ	5 U	
Methyl isobutyl ketone	UG/L	0	0%		0	0	54	5 U	5 U	5 U	5 U	5 U	
Methylene chloride	UG/L	0	0%	5	0	0	54	2 U	2 U	2 U	2 U	2 U	
Styrene	UG/L	0	0%		0	0	54	1 U	1 U	1 U	1 U	1 U	
Tetrachloroethene	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	1 U	1 U	
Toluene	UG/L	2	6%	5	0	3	54	1 U	1 U	1 U	1 U	2	

TABLE 2  
GROUND WATER CHEMICAL RESULTS  
ROUND 2 GROUNDWATER MONITORING  
ASH REMEDIAL DESIGN  
SENECA ARMY DEPOT ACTIVITY ROMULUS, NY

				ASH LANDFILL	ASH LANDFILL	ASH LANDFILL	ASH LANDFILL	ASH LANDFILL					
FACILITY				MW-32	MW-33	MW-34	MW-35D	MW-36					
LOCATION ID				GROUND WATER	GROUND WATER	GROUND WATER	GROUND WATER	GROUND WATER					
MATRIX				ARD2119	ARD2118	ARD2117	ARD2127	ARD2124					
SAMPLE ID				8.5	8.5	15	45	12					
DEPTH TO TOP OF SAMPLE				8.5	8.5	15	45	12					
DEPTH TO BOTTOM OF SAMPLE													
SAMPLE DATE				01/09/2000	01/09/2000	01/09/2000	01/11/2000	01/11/2000					
QC CODE				SA	SA	SA	SA	SA					
STUDY ID				ASH REMEDIAL DESI	ASH REMEDIAL DESI	ASH REMEDIAL DESI	ASH REMEDIAL DESI	ASH REMEDIAL DESI					
SAMPLE ROUND				2	2	2	2	2					
PARAMETER	UNIT	MAXIMUM	DETECTION	FREQUENCY OF	NYSDEC CLASS GA	NUMBER ABOVE	NUMBER OF	NUMBER OF	N	N	N	N	N
				OF	STD.	STD.	DETECTS	ANALYSES					
Total Xylenes	UG/L	0	0%	5	5	0	0	54	1 U	1 U	1 U	1 U	1 U
Trans-1,2-Dichloroethene	UG/L	2	4%	5	5	0	2	54	1 U	1 U	1 U	1 U	1 U
Trans-1,3-Dichloropropene	UG/L	0	0%	5	5	0	0	54	1 U	1 U	1 U	1 U	1 U
Trichloroethene	UG/L	760	28%	5	5	8	15	54	1 U	1 U	1 U	1 U	1 U
Vinyl chloride	UG/L	25	2%	2	2	1	1	54	1 UJ	1 U	1 UJ	1 UJ	1 U
<b>METALS</b>													
Aluminum	UG/L	7700	49%			0	25	51	118 J	15.5 UJ	55.5 J	91.8 J	20.3 J
Antimony	UG/L	4.5	12%			0	6	51	2.2 U	2.2 U	2.2 U	3.6 J	2.2 U
Arsenic	UG/L	5	22%	25	25	0	11	51	2.5 U	2.5 U	2.5 U	3.2 J	2.5 U
Barium	UG/L	173	100%	1000	1000	0	51	51	41.3 J	34.2 J	96.7 J	82.9 J	54.7 J
Beryllium	UG/L	0.26	14%			0	7	51	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Cadmium	UG/L	0.35	2%	10	10	0	1	51	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
Calcium	UG/L	391000	100%			0	51	51	102000	97500	75800	14400	107000
Chromium	UG/L	4.1	14%	50	50	0	7	51	1 U	1 U	1 U	1 U	1 U
Cobalt	UG/L	2	6%			0	3	51	1.3 U	1.3 U	1.3 U	1.3 U	1.3 U
Copper	UG/L	14.6	33%	200	200	0	17	51	1.6 U	1.7 J	1.6 U	1.9 U	1.9 U
Cyanide	UG/L	0	0%	100	100	0	0	51	10 U	10 U	10 U	10 U	10 U
Iron	UG/L	6350	63%	300	300	14	32	51	158 J	20.3 UJ	203 J	97.8 J	20.3 UJ
Lead	UG/L	3.8	10%	25	25	0	5	51	1.3 U	1.3 J	1.3 U	1.4 J	1.3 U
Magnesium	UG/L	85900	100%			0	51	51	13800	11100	13300	4690 J	15900
Manganese	UG/L	344	100%	300	300	2	51	51	12.3 J	2.2 J	39.7	44.4	41.1
Mercury	UG/L	0.14	2%	2	2	0	1	51	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Nickel	UG/L	6.2	10%			0	5	51	1.7 U	1.7 U	1.8 J	1.7 U	1.7 U
Potassium	UG/L	25600	100%			0	51	51	1980 J	630 J	1730 J	1650 J	1250 J
Selenium	UG/L	3	2%	10	10	0	1	51	2.5 U	2.5 U	2.5 U	2.2 U	2.2 U
Silver	UG/L	2.8	2%	50	50	0	1	51	1 UJ	1 UJ	1 UJ	1.3 UJ	1.3 UJ
Sodium	UG/L	175000	90%	20000	20000	23	46	51	18100	15800	41200	107000	29300
Thallium	UG/L	7.4	6%			0	3	51	3.2 U	3.2 U	3.2 U	3.2 U	3.2 U
Vanadium	UG/L	10.8	8%			0	4	51	1.8 U	1.8 U	1.8 U	1.8 U	1.8 U
Zinc	UG/L	1620	100%	300	300	1	51	51	5.1 J	4.6 J	19.1 J	6.4 J	5.4 J

TABLE 2  
GROUND WATER CHEMICAL RESULTS  
ROUND 2 GROUNDWATER MONITORING  
ASH REMEDIAL DESIGN  
SENECA ARMY DEPOT ACTIVITY ROMULUS, NY

				ASH LANDFILL	ASH LANDFILL	ASH LANDFILL	ASH LANDFILL	ASH LANDFILL				
FACILITY				MW-37	MW-38D	MW-39	MW-40	MW-41D				
LOCATION ID				GROUND WATER	GROUND WATER	GROUND WATER	GROUND WATER	GROUND WATER				
MATRIX				ARD2120	ARD2122	ARD2102	ARD2108	ARD2100				
SAMPLE ID												
DEPTH TO TOP OF SAMPLE				11.5	20	9.5	12	32				
DEPTH TO BOTTOM OF SAMPLE				11.5	20	9.5	12	32				
SAMPLE DATE				01/10/2000	01/10/2000	01/06/2000	01/07/2000	01/06/2000				
QC CODE				SA	SA	SA	SA	SA				
STUDY ID				ASH REMEDIAL DESI	ASH REMEDIAL DESI	ASH REMEDIAL DESI	ASH REMEDIAL DESI	ASH REMEDIAL DESI				
SAMPLE ROUND				2	2	2	2	2				
PARAMETER	UNIT	MAXIMUM	FREQUENCY OF DETECTION	NYSDEC CLASS GA STD.	NUMBER ABOVE STD.	NUMBER OF DETECTS	NUMBER OF ANALYSES	N	N	N	N	N
<b>VOLATILE ORGANICS</b>												
1,1,1-Trichloroethane	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	1 U	1 U
1,1,2,2-Tetrachloroethane	UG/L	0	0%	5	0	0	54	1 U	1 UJ	1 U	1 U	1 U
1,1,2-Trichloroethane	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	1 U	1 U
1,1-Dichloroethane	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	1 U	1 U
1,1-Dichloroethene	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	1 U	1 U
1,2,4-Trichlorobenzene	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	1 U	1 U
1,2-Dibromo-3-chloropropane	UG/L	0	0%		0	0	54	1 U	1 U	1 U	1 U	1 U
1,2-Dibromoethane	UG/L	0	0%		0	0	54	1 U	1 U	1 U	1 U	1 U
1,2-Dichlorobenzene	UG/L	0	0%	4.7	0	0	54	1 U	1 U	1 U	1 U	1 U
1,2-Dichloroethane	UG/L	3	2%	5	0	1	54	1 U	1 U	1 U	1 U	1 U
1,2-Dichloropropane	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	1 U	1 U
1,3-Dichlorobenzene	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	1 U	1 U
1,4-Dichlorobenzene	UG/L	0	0%	4.7	0	0	54	1 U	1 U	1 U	1 U	1 U
Acetone	UG/L	1	4%		0	2	54	5 U	5 UJ	5 UJ	5 U	5 UJ
Benzene	UG/L	0	0%	0.7	0	0	54	1 U	1 U	1 U	1 U	1 U
Bromochloromethane	UG/L	0	0%		0	0	54	1 U	1 U	1 U	1 U	1 U
Bromodichloromethane	UG/L	0	0%		0	0	54	1 U	1 U	1 U	1 U	1 U
Bromoform	UG/L	0	0%		0	0	54	1 U	1 U	1 U	1 U	1 U
Carbon disulfide	UG/L	0	0%		0	0	54	1 U	1 U	1 U	1 U	1 U
Carbon tetrachloride	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	1 U	1 U
Chlorobenzene	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	1 U	1 U
Chlorodibromomethane	UG/L	0	0%		0	0	54	1 U	1 U	1 U	1 U	1 U
Chloroethane	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	1 U	1 U
Chloroform	UG/L	0	0%	7	0	0	54	1 U	1 UJ	1 U	1 U	1 U
Cis-1,2-Dichloroethene	UG/L	980	28%	5	14	15	54	1 U	1 U	1 U	1 U	1 U
Cis-1,3-Dichloropropene	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	1 U	1 U
Ethyl benzene	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	1 U	1 U
Methyl bromide	UG/L	0	0%		0	0	54	1 U	1 UJ	1 U	1 U	1 U
Methyl butyl ketone	UG/L	0	0%		0	0	54	5 U	5 U	5 UJ	5 U	5 UJ
Methyl chloride	UG/L	0	0%	5	0	0	54	1 U	1 UJ	1 U	1 U	1 U
Methyl ethyl ketone	UG/L	0	0%	50	0	0	54	5 U	5 UJ	5 UJ	5 U	5 UJ
Methyl isobutyl ketone	UG/L	0	0%		0	0	54	5 U	5 U	5 U	5 U	5 U
Methylene chloride	UG/L	0	0%	5	0	0	54	2 U	2 U	2 U	2 U	2 U
Styrene	UG/L	0	0%		0	0	54	1 U	1 U	1 U	1 U	1 U
Tetrachloroethene	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	1 U	1 U
Toluene	UG/L	2	6%	5	0	3	54	1 U	1 U	1 U	1 U	1 U

TABLE 2  
GROUND WATER CHEMICAL RESULTS  
ROUND 2 GROUNDWATER MONITORING  
ASH REMEDIAL DESIGN  
SENECA ARMY DEPOT ACTIVITY ROMULUS, NY

FACILITY				ASH LANDFILL				ASH LANDFILL				ASH LANDFILL				ASH LANDFILL							
LOCATION ID				MW-37				MW-38D				MW-39				MW-40				MW-41D			
MATRIX				GROUND WATER				GROUND WATER				GROUND WATER				GROUND WATER							
SAMPLE ID				ARD2120				ARD2122				ARD2102				ARD2108				ARD2100			
DEPTH TO TOP OF SAMPLE				11.5				20				9.5				12				32			
DEPTH TO BOTTOM OF SAMPLE				11.5				20				9.5				12				32			
SAMPLE DATE				01/10/2000				01/10/2000				01/06/2000				01/07/2000				01/06/2000			
QC CODE				SA				SA				SA				SA				SA			
STUDY ID				ASH REMEDIAL DESI				ASH REMEDIAL DESI				ASH REMEDIAL DESI				ASH REMEDIAL DESI				ASH REMEDIAL DESI			
SAMPLE ROUND				2				2				2				2				2			
PARAMETER	UNIT	MAXIMUM	DETECTION	NYSDEC CLASS GA STD.	NUMBER ABOVE STD.	NUMBER OF DETECTS	NUMBER OF ANALYSES	N	U	J	N	U	J	N	U	J	N	U	J				
Total Xylenes	UG/L	0	0%	5	0	0	54		1	U		1	U		1	U		1	U				
Trans-1,2-Dichloroethene	UG/L	2	4%	5	0	2	54		1	U		1	U		1	U		1	U				
Trans-1,3-Dichloropropene	UG/L	0	0%	5	0	0	54		1	U		1	U		1	U		1	U				
Trichloroethene	UG/L	760	28%	5	8	15	54		1	U		1	U		1	U		1	U				
Vinyl chloride	UG/L	25	2%	2	1	1	54		1	U		1	UJ		1	U		1	U				
<b>METALS</b>																							
Aluminum	UG/L	7700	49%		0	25	51		395	J		80.4	J		15.5	UJ		15.5	UJ				
Antimony	UG/L	4.5	12%		0	6	51		2.2	U		2.2	U		2.2	U		2.2	U				
Arsenic	UG/L	5	22%	25	0	11	51		2.5	U		3.1	J		2.5	U		2.5	U				
Barium	UG/L	173	100%	1000	0	51	51		54.9	J		170	J		37	J		69.2	J				
Beryllium	UG/L	0.26	14%		0	7	51		0.1	U		0.1	U		0.12	J		0.1	U				
Cadmium	UG/L	0.35	2%	10	0	1	51		0.2	U		0.2	U		0.2	U		0.2	U				
Calcium	UG/L	391000	100%		0	51	51		95000			95900			94400			96800					
Chromium	UG/L	4.1	14%	50	0	7	51		1	U		1	U		1	U		2.9	J				
Cobalt	UG/L	2	6%		0	3	51		1.3	U		1.3	U		1.3	U		1.3	U				
Copper	UG/L	14.6	33%	200	0	17	51		1.9	U		1.9	U		1.6	U		1.7	J				
Cyanide	UG/L	0	0%	100	0	0	51		10	U		10	U		10	U		10	U				
Iron	UG/L	6350	63%	300	14	32	51		498	J		595	J		20.3	UJ		20.3	UJ				
Lead	UG/L	3.8	10%	25	0	5	51		1.3	U		1.3	U		1.3	U		1.3	U				
Magnesium	UG/L	85900	100%		0	51	51		12800			15800			12700			11100					
Manganese	UG/L	344	100%	300	2	51	51		53.1			251			1.2	J		1.8	J				
Mercury	UG/L	0.14	2%	2	0	1	51		0.1	U		0.1	U		0.1	U		0.1	U				
Nickel	UG/L	6.2	10%		0	5	51		1.7	U		1.7	U		1.7	U		1.7	U				
Potassium	UG/L	25600	100%		0	51	51		895	J		7990			1680	J		1340	J				
Selenium	UG/L	3	2%	10	0	1	51		2.2	U		2.2	U		2.5	U		2.5	U				
Silver	UG/L	2.8	2%	50	0	1	51		1.3	UJ		1.3	UJ		1	UJ		1	UJ				
Sodium	UG/L	175000	90%	20000	23	46	51		10400			6750			7400			13900					
Thallium	UG/L	7.4	6%		0	3	51		3.2	UJ		3.2	UJ		3.2	U		3.2	U				
Vanadium	UG/L	10.8	8%		0	4	51		1.8	U		1.8	U		1.8	U		1.8	U				
Zinc	UG/L	1620	100%	300	1	51	51		13.8	J		7.5	J		11.2	J		9.1	J				

TABLE 2  
GROUND WATER CHEMICAL RESULTS  
ROUND 2 GROUNDWATER MONITORING  
ASH REMEDIAL DESIGN  
SENECA ARMY DEPOT ACTIVITY ROMULUS, NY

FACILITY								ASH LANDFILL	ASH LANDFILL	ASH LANDFILL	ASH LANDFILL	ASH LANDFILL
LOCATION ID								MW-42D	MW-43	MW-44A	MW-45	MW-46
MATRIX								GROUND WATER	GROUND WATER	GROUND WATER	GROUND WATER	GROUND WATER
SAMPLE ID								ARD2109	ARD2103	ARD2155	ARD2112	ARD2113
DEPTH TO TOP OF SAMPLE								38	6.5	12	7.5	9.5
DEPTH TO BOTTOM OF SAMPLE								38	6.5	12	7.5	9.5
SAMPLE DATE								01/07/2000	01/06/2000	01/22/2000	01/08/2000	01/08/2000
QC CODE								SA	SA	SA	SA	SA
STUDY ID								ASH REMEDIAL DESI	ASH REMEDIAL DESI	ASH REMEDIAL DESI	ASH REMEDIAL DESI	ASH REMEDIAL DESI
SAMPLE ROUND								2	2	2	2	2
PARAMETER	UNIT	MAXIMUM	DETECTION	NYSDEC CLASS STA	NUMBER ABOVE STD.	NUMBER OF DETECTS	NUMBER OF ANALYSES	N	N	N	N	N
<b>VOLATILE ORGANICS</b>												
1,1,1-Trichloroethane	UG/L	0	0%	5	0	0	54	1 U	1 U	18 U	1 U	3 U
1,1,2,2-Tetrachloroethane	UG/L	0	0%	5	0	0	54	1 U	1 U	18 U	1 U	3 U
1,1,2-Trichloroethane	UG/L	0	0%	5	0	0	54	1 U	1 U	18 U	1 U	3 U
1,1-Dichloroethane	UG/L	0	0%	5	0	0	54	1 U	1 U	18 U	1 U	3 U
1,1-Dichloroethene	UG/L	0	0%	5	0	0	54	1 U	1 U	18 U	1 U	3 U
1,2,4-Trichlorobenzene	UG/L	0	0%	5	0	0	54	1 U	1 U	18 U	1 U	3 U
1,2-Dibromo-3-chloropropane	UG/L	0	0%	5	0	0	54	1 U	1 U	18 U	1 U	3 U
1,2-Dibromoethane	UG/L	0	0%	5	0	0	54	1 U	1 U	18 U	1 U	3 U
1,2-Dichlorobenzene	UG/L	0	0%	4.7	0	0	54	1 U	1 U	18 U	1 U	3 U
1,2-Dichloroethane	UG/L	3	2%	5	0	1	54	1 U	1 U	18 U	1 U	3 U
1,2-Dichloropropane	UG/L	0	0%	5	0	0	54	1 U	1 U	18 U	1 U	3 U
1,3-Dichlorobenzene	UG/L	0	0%	5	0	0	54	1 U	1 U	18 U	1 U	3 U
1,4-Dichlorobenzene	UG/L	0	0%	4.7	0	0	54	1 U	1 U	18 U	1 U	3 U
Acetone	UG/L	1	4%	5	0	2	54	5 U	5 U	88 R	5 U	17 U
Benzene	UG/L	0	0%	0.7	0	0	54	1 U	1 U	18 U	1 U	3 U
Bromochloromethane	UG/L	0	0%	5	0	0	54	1 U	1 U	18 U	1 U	3 U
Bromodichloromethane	UG/L	0	0%	5	0	0	54	1 U	1 U	18 U	1 U	3 U
Bromoform	UG/L	0	0%	5	0	0	54	1 U	1 U	18 U	1 U	3 U
Carbon disulfide	UG/L	0	0%	5	0	0	54	1 U	1 U	18 U	1 U	3 U
Carbon tetrachloride	UG/L	0	0%	5	0	0	54	1 U	1 U	18 U	1 U	3 U
Chlorobenzene	UG/L	0	0%	5	0	0	54	1 U	1 U	18 U	1 U	3 U
Chlorodibromomethane	UG/L	0	0%	5	0	0	54	1 U	1 U	18 U	1 U	3 U
Chloroethane	UG/L	0	0%	5	0	0	54	1 U	1 U	18 U	1 U	3 U
Chloroform	UG/L	0	0%	7	0	0	54	1 U	1 U	18 U	1 U	3 U
Cis-1,2-Dichloroethene	UG/L	980	28%	5	14	15	54	1 U	1 U	270	1 U	42
Cis-1,3-Dichloropropene	UG/L	0	0%	5	0	0	54	1 U	1 U	18 U	1 U	3 U
Ethyl benzene	UG/L	0	0%	5	0	0	54	1 U	1 U	18 U	1 U	3 U
Methyl bromide	UG/L	0	0%	5	0	0	54	1 U	1 U	18 U	1 U	3 U
Methyl butyl ketone	UG/L	0	0%	5	0	0	54	5 U	5 U	88 U	5 U	17 U
Methyl chloride	UG/L	0	0%	5	0	0	54	1 U	1 U	18 U	1 U	3 U
Methyl ethyl ketone	UG/L	0	0%	50	0	0	54	5 U	5 U	88 U	5 U	17 U
Methyl isobutyl ketone	UG/L	0	0%	5	0	0	54	5 U	5 U	88 U	5 U	17 U
Methylene chloride	UG/L	0	0%	5	0	0	54	2 U	2 U	35 U	2 U	7 U
Styrene	UG/L	0	0%	5	0	0	54	1 U	1 U	18 U	1 U	3 U
Tetrachloroethene	UG/L	0	0%	5	0	0	54	1 U	1 U	18 U	1 U	3 U
Toluene	UG/L	2	6%	5	0	3	54	1 U	1 U	18 U	1 U	3 U

TABLE 2  
GROUND WATER CHEMICAL RESULTS  
ROUND 2 GROUNDWATER MONITORING  
ASH REMEDIAL DESIGN  
SENECA ARMY DEPOT ACTIVITY ROMULUS, NY

								ASH LANDFILL	ASH LANDFILL	ASH LANDFILL	ASH LANDFILL	ASH LANDFILL
								MW-42D	MW-43	MW-44A	MW-45	MW-46
								GROUND WATER	GROUND WATER	GROUND WATER	GROUND WATER	GROUND WATER
								ARD2109	ARD2103	ARD2155	ARD2112	ARD2113
DEPTH TO TOP OF SAMPLE								38	6.5	12	7.5	9.5
DEPTH TO BOTTOM OF SAMPLE								38	6.5	12	7.5	9.5
SAMPLE DATE								01/07/2000	01/06/2000	01/22/2000	01/08/2000	01/08/2000
QC CODE								SA	SA	SA	SA	SA
STUDY ID								ASH REMEDIAL DESI	ASH REMEDIAL DESI	ASH REMEDIAL DESI	ASH REMEDIAL DESI	ASH REMEDIAL DESI
SAMPLE ROUND								2	2	2	2	2
PARAMETER	UNIT	MAXIMUM	FREQUENCY OF DETECTION	NYSDEC CLASS GA STD.	NUMBER ABOVE STD.	NUMBER OF DETECTS	NUMBER OF ANALYSES	N	N	N	N	N
Total Xylenes	UG/L	0	0%	5	0	0	54	1 U	1 U	18 U	1 U	3 U
Trans-1,2-Dichloroethene	UG/L	2	4%	5	0	2	54	1 U	1 U	18 U	1 U	3 U
Trans-1,3-Dichloropropene	UG/L	0	0%	5	0	0	54	1 U	1 U	18 U	1 U	3 U
Trichloroethene	UG/L	760	28%	5	8	15	54	1 U	1 U	13 J	1 U	23
Vinyl chloride	UG/L	25	2%	2	1	1	54	1 UJ	1 U	25	1 U	3 U
<b>METALS</b>												
Aluminum	UG/L	7700	49%		0	25	51	15.5 UJ	15.5 UJ	34.4 UJ	15.5 UJ	15.5 UJ
Antimony	UG/L	4.5	12%		0	6	51	2.2 U	2.2 U	2.5 J	2.2 U	2.2 U
Arsenic	UG/L	5	22%	25	0	11	51	2.5 U	2.5 U	2.8 J	2.5 U	2.5 U
Barium	UG/L	173	100%	1000	0	51	51	93.2 J	39.6 J	66.9 J	41 J	56 J
Beryllium	UG/L	0.26	14%		0	7	51	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Cadmium	UG/L	0.35	2%	10	0	1	51	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
Calcium	UG/L	391000	100%		0	51	51	53700	114000	391000	93800	126000
Chromium	UG/L	4.1	14%	50	0	7	51	1 U	1 U	1 U	1.5 J	1 U
Cobalt	UG/L	2	6%		0	3	51	1.3 U	1.3 U	1.3 U	1.3 U	1.3 U
Copper	UG/L	14.6	33%	200	0	17	51	1.6 U	3.1 J	1.9 U	3.1 J	2.2 J
Cyanide	UG/L	0	0%	100	0	0	51	10 U	10 U	10 U	10 U	10 U
Iron	UG/L	6350	63%	300	14	32	51	137 J	20.3 UJ	48.9 J	20.3 UJ	179 J
Lead	UG/L	3.8	10%	25	0	5	51	1.3 U	1 U	1 U	1.3 U	1.3 U
Magnesium	UG/L	85900	100%		0	51	51	28300	10800	85900	10900	15000
Manganese	UG/L	344	100%	300	2	51	51	71	0.95 J	300	1.6 J	38.1
Mercury	UG/L	0.14	2%	2	0	1	51	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Nickel	UG/L	6.2	10%		0	5	51	1.7 U	1.7 U	1.7 U	1.7 U	1.7 U
Potassium	UG/L	25600	100%		0	51	51	1960 J	420 J	25600	706 J	730 J
Selenium	UG/L	3	2%	10	0	1	51	2.5 U	2.5 U	2.2 U	2.5 U	2.5 U
Silver	UG/L	2.8	2%	50	0	1	51	1 UJ	1 UJ	1.3 UJ	1 UJ	1 UJ
Sodium	UG/L	175000	90%	20000	23	46	51	15900	9960	91500 J	7060	10500
Thallium	UG/L	7.4	6%		0	3	51	3.2 U	3.2 U	3.2 U	3.2 U	3.2 U
Vanadium	UG/L	10.8	8%		0	4	51	1.8 U	1.8 U	1.8 U	1.8 U	1.8 U
Zinc	UG/L	1620	100%	300	1	51	51	3.2 J	4.1 J	2.4 J	4.5 J	3.8 J



TABLE 2  
GROUND WATER CHEMICAL RESULTS  
ROUND 2 GROUNDWATER MONITORING  
ASH REMEDIAL DESIGN  
SENECA ARMY DEPOT ACTIVITY ROMULUS, NY

FACILITY				ASH LANDFILL				ASH LANDFILL				ASH LANDFILL				ASH LANDFILL			
LOCATION ID				MW-48				MW-49D				MW-50D				MW-51D			
MATRIX				GROUND WATER				GROUND WATER				GROUND WATER				GROUND WATER			
SAMPLE ID				ARD2111				ARD2134				ARD2135				ARD2142			
DEPTH TO TOP OF SAMPLE				9.5				26				50				28			
DEPTH TO BOTTOM OF SAMPLE				9.5				26				50				28			
SAMPLE DATE				01/08/2000				01/18/2000				01/18/2000				01/19/2000			
QC CODE				SA				SA				SA				SA			
STUDY ID				FREQUENCY				NYSDEC				NUMBER				NUMBER			
SAMPLE ROUND				OF				CLASS GA				ABOVE				OF			
PARAMETER				DETECTION				STD.				STD.				DETECTS			
UNIT				MAXIMUM				OF				OF				OF			
N				2				2				2				2			
<b>VOLATILE ORGANICS</b>																			
1,1,1-Trichloroethane	UG/L	0	0%	5	0	0	54	1	U	1	U	1	U	1	U	1	U		
1,1,2,2-Tetrachloroethane	UG/L	0	0%	5	0	0	54	1	UJ	1	U	1	U	1	U	1	U		
1,1,2-Trichloroethane	UG/L	0	0%	5	0	0	54	1	U	1	U	1	U	1	U	1	U		
1,1-Dichloroethane	UG/L	0	0%	5	0	0	54	1	U	1	U	1	U	1	U	1	U		
1,1-Dichloroethene	UG/L	0	0%	5	0	0	54	1	U	1	U	1	U	1	U	1	U		
1,2,4-Trichlorobenzene	UG/L	0	0%	5	0	0	54	1	U	1	U	1	U	1	U	1	U		
1,2-Dibromo-3-chloropropane	UG/L	0	0%		0	0	54	1	U	1	U	1	U	1	U	1	U		
1,2-Dibromoethane	UG/L	0	0%		0	0	54	1	U	1	U	1	U	1	U	1	U		
1,2-Dichlorobenzene	UG/L	0	0%	4.7	0	0	54	1	U	1	U	1	U	1	U	1	U		
1,2-Dichloroethane	UG/L	3	2%	5	0	1	54	1	U	1	U	1	U	1	U	1	U		
1,2-Dichloropropane	UG/L	0	0%	5	0	0	54	1	U	1	U	1	U	1	U	1	U		
1,3-Dichlorobenzene	UG/L	0	0%	5	0	0	54	1	U	1	U	1	U	1	U	1	U		
1,4-Dichlorobenzene	UG/L	0	0%	4.7	0	0	54	1	U	1	U	1	U	1	U	1	U		
Acetone	UG/L	1	4%		0	2	54	5	U	5	UJ	5	UJ	5	UJ	5	UJ		
Benzene	UG/L	0	0%	0.7	0	0	54	1	U	1	U	1	U	1	U	1	U		
Bromochloromethane	UG/L	0	0%		0	0	54	1	U	1	U	1	U	1	U	1	U		
Bromodichloromethane	UG/L	0	0%		0	0	54	1	U	1	U	1	U	1	U	1	U		
Bromoform	UG/L	0	0%		0	0	54	1	U	1	U	1	U	1	U	1	U		
Carbon disulfide	UG/L	0	0%		0	0	54	1	U	1	U	1	U	1	U	1	U		
Carbon tetrachloride	UG/L	0	0%	5	0	0	54	1	U	1	U	1	U	1	U	1	U		
Chlorobenzene	UG/L	0	0%	5	0	0	54	1	U	1	U	1	U	1	U	1	U		
Chlorodibromomethane	UG/L	0	0%		0	0	54	1	U	1	U	1	U	1	U	1	U		
Chloroethane	UG/L	0	0%	5	0	0	54	1	U	1	U	1	U	1	U	1	U		
Chloroform	UG/L	0	0%	7	0	0	54	1	U	1	U	1	U	1	U	1	U		
Cis-1,2-Dichloroethene	UG/L	980	28%	5	14	15	54	1	U	19	U	1	U	1	U	1	U		
Cis-1,3-Dichloropropene	UG/L	0	0%	5	0	0	54	1	U	1	U	1	U	1	U	1	U		
Ethyl benzene	UG/L	0	0%	5	0	0	54	1	U	1	U	1	U	1	U	1	U		
Methyl bromide	UG/L	0	0%		0	0	54	1	U	1	U	1	U	1	U	1	U		
Methyl butyl ketone	UG/L	0	0%		0	0	54	5	U	5	U	5	U	5	U	5	U		
Methyl chloride	UG/L	0	0%	5	0	0	54	1	U	1	U	1	U	1	U	1	U		
Methyl ethyl ketone	UG/L	0	0%	50	0	0	54	5	U	5	U	5	U	5	U	5	U		
Methyl isobutyl ketone	UG/L	0	0%		0	0	54	5	U	5	U	5	U	5	U	5	U		
Methylene chloride	UG/L	0	0%	5	0	0	54	2	U	2	U	2	U	2	U	2	U		
Styrene	UG/L	0	0%		0	0	54	1	U	1	U	1	U	1	U	1	U		
Tetrachloroethene	UG/L	0	0%	5	0	0	54	1	U	1	U	1	U	1	U	1	U		
Toluene	UG/L	2	6%	5	0	3	54	1	U	1	U	1	U	1	U	1	U		

TABLE 2  
GROUND WATER CHEMICAL RESULTS  
ROUND 2 GROUNDWATER MONITORING  
ASH REMEDIAL DESIGN  
SENECA ARMY DEPOT ACTIVITY ROMULUS, NY

				ASH LANDFILL	ASH LANDFILL	ASH LANDFILL	ASH LANDFILL	ASH LANDFILL				
FACILITY				MW-48	MW-49D	MW-50D	MW-51D	MW-52D				
LOCATION ID				GROUND WATER	GROUND WATER	GROUND WATER	GROUND WATER	GROUND WATER				
MATRIX				ARD2111	ARD2134	ARD2135	ARD2142	ARD2143				
SAMPLE ID												
DEPTH TO TOP OF SAMPLE				9.5	26	50	28	50				
DEPTH TO BOTTOM OF SAMPLE				9.5	26	50	28	50				
SAMPLE DATE				01/08/2000	01/18/2000	01/18/2000	01/19/2000	01/18/2000				
QC CODE				SA	SA	SA	SA	SA				
STUDY ID				ASH REMEDIAL DESI	ASH REMEDIAL DESI	ASH REMEDIAL DESI	ASH REMEDIAL DESI	ASH REMEDIAL DESI				
SAMPLE ROUND				2	2	2	2	2				
PARAMETER	UNIT	MAXIMUM	FREQUENCY OF DETECTION	NYSDEC CLASS GA STD.	NUMBER ABOVE STD.	NUMBER OF DETECTS	NUMBER OF ANALYSES	N	N	N	N	N
Total Xylenes	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	1 U	1 U
Trans-1,2-Dichloroethene	UG/L	2	4%	5	0	2	54	1 U	1 U	1 U	1 U	1 U
Trans-1,3-Dichloropropene	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	1 U	1 U
Trichloroethene	UG/L	760	28%	5	8	15	54	1 U	4	1 U	1 U	1 U
Vinyl chloride	UG/L	25	2%	2	1	1	54	1 U	1 U	1 U	1 U	1 U
<b>METALS</b>												
Aluminum	UG/L	7700	49%		0	25	51	15.5 UJ	32.6 J	15.8 J	34.4 UJ	3220 J
Antimony	UG/L	4.5	12%		0	6	51	2.2 U	2.2 U	2.2 U	2.2 U	2.2 U
Arsenic	UG/L	5	22%	25	0	11	51	2.5 U	2.5 U	2.5 U	2.9 J	4.5 J
Barium	UG/L	173	100%	1000	0	51	51	36.6 J	133 J	119 J	90.2 J	72.5 J
Beryllium	UG/L	0.26	14%		0	7	51	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Cadmium	UG/L	0.35	2%	10	0	1	51	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
Calcium	UG/L	391000	100%		0	51	51	90100	93100	54100	86700	5900
Chromium	UG/L	4.1	14%	50	0	7	51	1 U	1 U	1 U	1 U	1 U
Cobalt	UG/L	2	6%		0	3	51	1.3 U	1.3 U	1.3 U	1.3 U	1.3 U
Copper	UG/L	14.6	33%	200	0	17	51	1.6 U	1.9 U	1.9 U	1.9 U	1.9 U
Cyanide	UG/L	0	0%	100	0	0	51	10 U	10 U	10 U	10 U	10 U
Iron	UG/L	6350	63%	300	14	32	51	81.1 J	418 J	150 J	43.5 J	1980 J
Lead	UG/L	3.8	10%	25	0	5	51	1 U	1.3 U	1.3 U	1 U	1.3 J
Magnesium	UG/L	85900	100%		0	51	51	11200	24400	25100	13900	2150 J
Manganese	UG/L	344	100%	300	2	51	51	6.6 J	99.4	79.2	17.4	48.1
Mercury	UG/L	0.14	2%	2	0	1	51	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Nickel	UG/L	6.2	10%		0	5	51	1.7 U	1.7 U	1.7 U	1.7 U	1.7 U
Potassium	UG/L	25600	100%		0	51	51	1260 J	1860 J	2360 J	1100 J	1280 J
Selenium	UG/L	3	2%	10	0	1	51	2.5 U	2.2 U	2.2 U	2.2 U	2.2 U
Silver	UG/L	2.8	2%	50	0	1	51	1 UJ	1.3 UJ	1.3 UJ	1.3 UJ	1.3 UJ
Sodium	UG/L	175000	90%	20000	23	46	51	6690	8970	19800	27100	161000 J
Thallium	UG/L	7.4	6%		0	3	51	3.2 U	3.2 U	3.2 U	3.2 UJ	3.2 U
Vanadium	UG/L	10.8	8%		0	4	51	1.8 U	1.8 U	1.8 U	1.8 U	2.6 J
Zinc	UG/L	1620	100%	300	1	51	51	4 J	4.5 J	10 J	3.2 J	7.5 J



TABLE 2  
GROUND WATER CHEMICAL RESULTS  
ROUND 2 GROUNDWATER MONITORING  
ASH REMEDIAL DESIGN  
SENECA ARMY DEPOT ACTIVITY ROMULUS, NY

FACILITY				ASH LANDFILL		ASH LANDFILL		ASH LANDFILL		ASH LANDFILL		ASH LANDFILL	
LOCATION ID				MW-53		MW-53		MW-54D		MW-55D		MW-56	
MATRIX				GROUND WATER		GROUND WATER		GROUND WATER		GROUND WATER		GROUND WATER	
SAMPLE ID				ARD2147		ARD2145		ARD2137		ARD2136		ARD2130	
DEPTH TO TOP OF SAMPLE				9		9		25		50		6	
DEPTH TO BOTTOM OF SAMPLE				9		9		25		50		6	
SAMPLE DATE				01/20/2000		01/20/2000		01/18/2000		01/18/2000		01/11/2000	
QC CODE				DU		SA		SA		SA		SA	
STUDY ID				ASH REMEDIAL DESI		ASH REMEDIAL DESI		ASH REMEDIAL DESI		ASH REMEDIAL DESI		ASH REMEDIAL DESI	
SAMPLE ROUND				2		2		2		2		2	
PARAMETER	UNIT	MAXIMUM	DETECTION	NYSDEC CLASS GA STD.	NUMBER ABOVE STD.	NUMBER OF DETECTS	NUMBER OF ANALYSES	N	N	N	N	N	N
Total Xylenes	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	1 U	1 U	1 U
Trans-1,2-Dichloroethene	UG/L	2	4%	5	0	2	54	1 U	1 U	1 U	1 U	1 U	1 U
Trans-1,3-Dichloropropene	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	1 U	1 U	1 U
Trichloroethene	UG/L	760	28%	5	8	15	54	2	2	1 U	1 U	1 U	1 U
Vinyl chloride	UG/L	25	2%	2	1	1	54	1 U	1 U	1 U	1 U	1 U	1 U
<b>METALS</b>													
Aluminum	UG/L	7700	49%		0	25	51	34.4 UJ	34.4 UJ	35.6 J	1410 J	7700 J	
Antimony	UG/L	4.5	12%		0	6	51	2.2 U	2.2 U	2.2 U	3.4 J	2.2 U	
Arsenic	UG/L	5	22%	25	0	11	51	2.5 U	2.5 U	2.5 U	2.8 J	2.5 U	
Barium	UG/L	173	100%	1000	0	51	51	59.4 J	58.9 J	130 J	73.7 J	90.2 J	
Beryllium	UG/L	0.26	14%		0	7	51	0.1 U	0.1 U	0.1 U	0.1 U	0.18 J	
Cadmium	UG/L	0.35	2%	10	0	1	51	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	
Calcium	UG/L	391000	100%		0	51	51	145000	144000	86200	2960 J	106000	
Chromium	UG/L	4.1	14%	50	0	7	51	1 U	1 U	1 U	1 U	4.1 J	
Cobalt	UG/L	2	6%		0	3	51	1.3 U	1.3 U	1.3 U	1.3 U	2 J	
Copper	UG/L	14.6	33%	200	0	17	51	1.9 U	1.9 U	1.9 U	1.9 U	5.5 J	
Cyanide	UG/L	0	0%	100	0	0	51	10 U	10 U	10 U	10 U	10 U	
Iron	UG/L	6350	63%	300	14	32	51	20.3 U	20.3 U	151 J	1076 J	6350 J	
Lead	UG/L	3.8	10%	25	0	5	51	1 U	1 U	1.3 U	1.3 U	3.8	
Magnesium	UG/L	85900	100%		0	51	51	18800	17800	26000	916 J	13000	
Manganese	UG/L	344	100%	300	2	51	51	2.2 J	2.1 J	161	29.9	103	
Mercury	UG/L	0.14	2%	2	0	1	51	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	
Nickel	UG/L	6.2	10%		0	5	51	1.7 U	1.7 U	1.7 U	1.7 U	6.2 J	
Potassium	UG/L	25600	100%		0	51	51	951 J	971 J	2430 J	1250 J	3530 J	
Selenium	UG/L	3	2%	10	0	1	51	2.2 U	2.2 U	2.2 U	2.2 U	2.2 U	
Silver	UG/L	2.8	2%	50	0	1	51	1.3 UJ	1.3 UJ	1.3 UJ	1.3 UJ	1.3 UJ	
Sodium	UG/L	175000	90%	20000	23	46	51	23200	22900 U	22900	102000	13200	
Thallium	UG/L	7.4	6%		0	3	51	3.2 UJ	3.2 UJ	3.2 U	3.2 U	3.2 U	
Vanadium	UG/L	10.8	8%		0	4	51	1.8 U	1.8 U	1.8 U	1.8 U	10.8 J	
Zinc	UG/L	1620	100%	300	1	51	51	3.6 J	4.5 J	3.9 J	18.2 J	28.4	

TABLE 2  
GROUND WATER CHEMICAL RESULTS  
ROUND 2 GROUNDWATER MONITORING  
ASH REMEDIAL DESIGN  
SENECA ARMY DEPOT ACTIVITY ROMULUS, NY

FACILITY				ASH LANDFILL				ASH LANDFILL				ASH LANDFILL				ASH LANDFILL			
LOCATION ID				MW-57D				MW-58D				MW-59				MW-60			
MATRIX				GROUND WATER				GROUND WATER				GROUND WATER				GROUND WATER			
SAMPLE ID				ARD2131				ARD2128				ARD2105				ARD2104			
DEPTH TO TOP OF SAMPLE				25				48				7				8			
DEPTH TO BOTTOM OF SAMPLE				25				48				7				8			
SAMPLE DATE				01/11/2000				01/11/2000				01/07/2000				01/07/2000			
QC CODE				SA				SA				SA				SA			
STUDY ID				ASH REMEDIAL DESI				ASH REMEDIAL DESI				ASH REMEDIAL DESI				ASH REMEDIAL DESI			
SAMPLE ROUND				2				2				2				2			
PARAMETER	UNIT	MAXIMUM	DETECTION	NYSDEC CLASS GA STD.	NUMBER ABOVE STD.	NUMBER OF DETECTS	NUMBER OF ANALYSES	N	N	N	N	N	N	N	N	N	N		
VOLATILE ORGANICS																			
1,1,1-Trichloroethane	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U		
1,1,2,2-Tetrachloroethane	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U		
1,1,2-Trichloroethane	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U		
1,1-Dichloroethane	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U		
1,1-Dichloroethene	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U		
1,2,4-Trichlorobenzene	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U		
1,2-Dibromo-3-chloropropane	UG/L	0	0%		0	0	54	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U		
1,2-Dibromoethane	UG/L	0	0%		0	0	54	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U		
1,2-Dichlorobenzene	UG/L	0	0%	4.7	0	0	54	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U		
1,2-Dichloroethane	UG/L	3	2%	5	0	1	54	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U		
1,2-Dichloropropane	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U		
1,3-Dichlorobenzene	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U		
1,4-Dichlorobenzene	UG/L	0	0%	4.7	0	0	54	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U		
Acetone	UG/L	1	4%		0	2	54	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U		
Benzene	UG/L	0	0%	0.7	0	0	54	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U		
Bromochloromethane	UG/L	0	0%		0	0	54	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U		
Bromodichloromethane	UG/L	0	0%		0	0	54	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U		
Bromoform	UG/L	0	0%		0	0	54	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U		
Carbon disulfide	UG/L	0	0%		0	0	54	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U		
Carbon tetrachloride	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U		
Chlorobenzene	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U		
Chlorodibromomethane	UG/L	0	0%		0	0	54	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U		
Chloroethane	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U		
Chloroform	UG/L	0	0%	7	0	0	54	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U		
Cis-1,2-Dichloroethene	UG/L	980	28%	5	14	15	54	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U		
Cis-1,3-Dichloropropene	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U		
Ethyl benzene	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U		
Methyl bromide	UG/L	0	0%		0	0	54	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U		
Methyl butyl ketone	UG/L	0	0%		0	0	54	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U		
Methyl chloride	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U		
Methyl ethyl ketone	UG/L	0	0%	50	0	0	54	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U		
Methyl isobutyl ketone	UG/L	0	0%		0	0	54	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U		
Methylene chloride	UG/L	0	0%	5	0	0	54	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U		
Styrene	UG/L	0	0%		0	0	54	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U		
Tetrachloroethene	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U		
Toluene	UG/L	2	6%	5	0	3	54	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U		

TABLE 2  
GROUND WATER CHEMICAL RESULTS  
ROUND 2 GROUNDWATER MONITORING  
ASH REMEDIAL DESIGN  
SENECA ARMY DEPOT ACTIVITY ROMULUS, NY

				ASH LANDFILL	ASH LANDFILL	ASH LANDFILL	ASH LANDFILL	ASH LANDFILL					
FACILITY				MW-57D	MW-58D	MW-59	MW-60	PT-10					
LOCATION ID				GROUND WATER	GROUND WATER	GROUND WATER	GROUND WATER	GROUND WATER					
MATRIX				ARD2131	ARD2128	ARD2105	ARD2104	ARD2101					
SAMPLE ID													
DEPTH TO TOP OF SAMPLE				25	48	7	8	40					
DEPTH TO BOTTOM OF SAMPLE				25	48	7	8	40					
SAMPLE DATE				01/11/2000	01/11/2000	01/07/2000	01/07/2000	01/06/2000					
QC CODE				SA	SA	SA	SA	SA					
STUDY ID				ASH REMEDIAL DESI	ASH REMEDIAL DESI	ASH REMEDIAL DESI	ASH REMEDIAL DESI	ASH REMEDIAL DESI					
SAMPLE ROUND				2	2	2	2	2					
PARAMETER	UNIT	MAXIMUM	FREQUENCY OF DETECTION	NYSDEC CLASS GA STD.	NUMBER ABOVE STD.	NUMBER OF DETECTS	NUMBER OF ANALYSES	N	N	N	N	N	
Total Xylenes	UG/L	0	0%	5	0	0	54	1	U	1	U	1	U
Trans-1,2-Dichloroethene	UG/L	2	4%	5	0	2	54	1	U	1	U	1	U
Trans-1,3-Dichloropropene	UG/L	0	0%	5	0	0	54	1	U	1	U	1	U
Trichloroethene	UG/L	760	28%	5	8	15	54	1	U	1	U	1	U
Vinyl chloride	UG/L	25	2%	2	1	1	54	1	UJ	1	U	1	U
<b>METALS</b>													
Aluminum	UG/L	7700	49%		0	25	51	738	J	3940	J	33.9	J
Antimony	UG/L	4.5	12%		0	6	51	2.2	U	2.2	U	2.2	U
Arsenic	UG/L	5	22%	25	0	11	51	2.7	J	2.5	U	2.5	U
Barium	UG/L	173	100%	1000	0	51	51	71.4	J	86.9	J	94.2	J
Beryllium	UG/L	0.26	14%		0	7	51	0.1	U	0.26	J	0.1	U
Cadmium	UG/L	0.35	2%	10	0	1	51	0.2	U	0.2	U	0.2	U
Calcium	UG/L	391000	100%		0	51	51	3270	J	5450		177000	
Chromium	UG/L	4.1	14%	50	0	7	51	1	U	1	U	1	U
Cobalt	UG/L	2	6%		0	3	51	1.3	U	1.4	J	1.3	U
Copper	UG/L	14.6	33%	200	0	17	51	7.5	J	1.9	U	1.7	J
Cyanide	UG/L	0	0%	100	0	0	51	10	U	10	U	10	U
Iron	UG/L	6350	63%	300	14	32	51	962	J	5010	J	68.2	J
Lead	UG/L	3.8	10%	25	0	5	51	1.3	U	1.9	J	1	U
Magnesium	UG/L	85900	100%		0	51	51	642	J	1770	J	40500	
Manganese	UG/L	344	100%	300	2	51	51	40		96.6		3.1	J
Mercury	UG/L	0.14	2%	2	0	1	51	0.1	U	0.1	U	0.1	U
Nickel	UG/L	6.2	10%		0	5	51	5.2	J	5.2	J	1.7	U
Potassium	UG/L	25600	100%		0	51	51	1100	J	1900	J	1470	J
Selenium	UG/L	3	2%	10	0	1	51	2.2	U	2.2	U	2.5	U
Silver	UG/L	2.8	2%	50	0	1	51	1.3	UJ	1.3	UJ	1	UJ
Sodium	UG/L	175000	90%	20000	23	46	51	164000		175000		29700	
Thallium	UG/L	7.4	6%		0	3	51	3.2	UJ	3.2	UJ	3.2	U
Vanadium	UG/L	10.8	8%		0	4	51	1.8	U	5.5	J	1.8	U
Zinc	UG/L	1620	100%	300	1	51	51	7.7	J	15.1	J	6.1	J

TABLE 2  
GROUND WATER CHEMICAL RESULTS  
ROUND 2 GROUNDWATER MONITORING  
ASH REMEDIAL DESIGN  
SENECA ARMY DEPOT ACTIVITY ROMULUS, NY

FACILITY LOCATION ID				ASH LANDFILL PT-11		ASH LANDFILL PT-15		ASH LANDFILL PT-16		ASH LANDFILL PT-16		ASH LANDFILL PT-17	
MATRIX				GROUND WATER		GROUND WATER		GROUND WATER		GROUND WATER		GROUND WATER	
SAMPLE ID				ARD2107		ARD2133		ARD2121		ARD2125		ARD2149	
DEPTH TO TOP OF SAMPLE				18		0		9		9		10	
DEPTH TO BOTTOM OF SAMPLE				18		0		9		9		10	
SAMPLE DATE				01/07/2000		01/11/2000		01/10/2000		01/10/2000		01/20/2000	
QC CODE				SA		SA		DU		SA		SA	
STUDY ID				ASH REMEDIAL DESI		ASH REMEDIAL DESI		ASH REMEDIAL DESI		ASH REMEDIAL DESI		ASH REMEDIAL DESI	
SAMPLE ROUND				2		2		2		2		2	
PARAMETER	UNIT	MAXIMUM	FREQUENCY OF DETECTION	NYSDEC CLASS GA STD.	NUMBER ABOVE STD.	NUMBER OF DETECTS	NUMBER OF ANALYSES	N	N	N	N	N	N
<b>VOLATILE ORGANICS</b>													
1,1,1-Trichloroethane	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	1 U	1 U	7 U
1,1,2,2-Tetrachloroethane	UG/L	0	0%	5	0	0	54	1 U	1 UJ	1 U	1 UJ	1 U	7 U
1,1,2-Trichloroethane	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	1 U	1 U	7 U
1,1-Dichloroethane	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	1 U	1 U	7 U
1,1-Dichloroethene	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	1 U	1 U	7 U
1,2,4-Trichlorobenzene	UG/L	0	0%	5	0	0	54	1 UJ	1 U	1 U	1 U	1 U	7 U
1,2-Dibromo-3-chloropropane	UG/L	0	0%	5	0	0	54	1 UJ	1 U	1 U	1 U	1 U	7 U
1,2-Dibromoethane	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	1 U	1 U	7 U
1,2-Dichlorobenzene	UG/L	0	0%	4.7	0	0	54	1 UJ	1 U	1 U	1 U	1 U	7 U
1,2-Dichloroethane	UG/L	3	2%	5	0	1	54	1 U	1 U	1 U	1 U	1 U	7 U
1,2-Dichloropropane	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	1 U	1 U	7 U
1,3-Dichlorobenzene	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	1 U	1 U	7 U
1,4-Dichlorobenzene	UG/L	0	0%	4.7	0	0	54	1 UJ	1 U	1 U	1 U	1 U	7 U
Acetone	UG/L	1	4%	0.7	0	2	54	5 UJ	5 UJ	5 U	5 UJ	5 UJ	36 R
Benzene	UG/L	0	0%	0.7	0	0	54	1 U	1 U	1 U	1 U	1 U	7 U
Bromochloromethane	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	1 U	1 U	7 U
Bromodichloromethane	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	1 U	1 U	7 U
Bromoform	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	1 U	1 U	7 U
Carbon disulfide	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	1 U	1 U	7 U
Carbon tetrachloride	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	1 U	1 U	7 U
Chlorobenzene	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	1 U	1 U	7 U
Chlorodibromomethane	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	1 U	1 U	7 U
Chloroethane	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	1 U	1 U	7 U
Chloroform	UG/L	0	0%	7	0	0	54	1 U	1 UJ	1 U	1 UJ	1 U	7 U
Cis-1,2-Dichloroethene	UG/L	980	28%	5	14	15	54	1 U	1 U	1 U	1 U	1 U	27
Cis-1,3-Dichloropropene	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	1 U	1 U	7 U
Ethyl benzene	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	1 U	1 U	7 U
Methyl bromide	UG/L	0	0%	5	0	0	54	1 U	1 UJ	1 U	1 UJ	1 U	7 U
Methyl butyl ketone	UG/L	0	0%	5	0	0	54	5 UJ	5 U	5 U	5 U	5 U	36 UJ
Methyl chloride	UG/L	0	0%	5	0	0	54	1 U	1 UJ	1 U	1 UJ	1 U	7 U
Methyl ethyl ketone	UG/L	0	0%	50	0	0	54	5 UJ	5 UJ	5 U	5 UJ	5 UJ	36 U
Methyl isobutyl ketone	UG/L	0	0%	5	0	0	54	5 U	5 U	5 U	5 U	5 U	36 U
Methylene chloride	UG/L	0	0%	5	0	0	54	2 U	2 U	2 U	2 U	2 U	15 U
Styrene	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	1 U	1 U	7 U
Tetrachloroethene	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	1 U	1 U	7 U
Toluene	UG/L	2	6%	5	0	3	54	1 U	1 U	1 J	1 J	1 J	7 U

TABLE 2  
GROUND WATER CHEMICAL RESULTS  
ROUND 2 GROUNDWATER MONITORING  
ASH REMEDIAL DESIGN  
SENECA ARMY DEPOT ACTIVITY ROMULUS, NY

FACILITY LOCATION ID				ASH LANDFILL PT-11		ASH LANDFILL PT-15		ASH LANDFILL PT-16		ASH LANDFILL PT-16		ASH LANDFILL PT-17	
MATRIX				GROUND WATER		GROUND WATER		GROUND WATER		GROUND WATER		GROUND WATER	
SAMPLE ID				ARD2107		ARD2133		ARD2121		ARD2125		ARD2149	
DEPTH TO TOP OF SAMPLE				18		0		9		9		10	
DEPTH TO BOTTOM OF SAMPLE				18		0		9		9		10	
SAMPLE DATE				01/07/2000		01/11/2000		01/10/2000		01/10/2000		01/20/2000	
QC CODE				SA		SA		DU		SA		SA	
STUDY ID				ASH REMEDIAL DESI		ASH REMEDIAL DESI		ASH REMEDIAL DESI		ASH REMEDIAL DESI		ASH REMEDIAL DESI	
SAMPLE ROUND				2		2		2		2		2	
PARAMETER	UNIT	MAXIMUM	FREQUENCY OF DETECTION	NYSDEC CLASS GA STD.	NUMBER ABOVE STD.	NUMBER OF DETECTS	NUMBER OF ANALYSES	N	N	N	N	N	N
Total Xylenes	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	1 U	1 U	7 U
Trans-1,2-Dichloroethene	UG/L	2	4%	5	0	2	54	1 U	1 U	1 U	1 U	1 U	7 U
Trans-1,3-Dichloropropene	UG/L	0	0%	5	0	0	54	1 U	1 U	1 U	1 U	1 U	7 U
Trichloroethene	UG/L	760	28%	5	8	15	54	1 U	1 U	1 U	1 U	1 U	140
Vinyl chloride	UG/L	25	2%	2	1	1	54	1 U	1 UJ	1 U	1 UJ	1 U	7 U
<b>METALS</b>													
Aluminum	UG/L	7700	49%		0	25	51	1550 J	135 J	65.5 J	31.2 J		34.4 UJ
Antimony	UG/L	4.5	12%		0	6	51	2.2 U	2.2 U	2.2 U	2.5 J		2.2 U
Arsenic	UG/L	5	22%	25	0	11	51	2.5 U	2.5 U	2.5 U	2.5 U		2.7 J
Barium	UG/L	173	100%	1000	0	51	51	95.9 J	79.6 J	39.4 J	39 J		54.6 J
Beryllium	UG/L	0.26	14%		0	7	51	0.13 J	0.1 U	0.1 U	0.1 U		0.1 U
Cadmium	UG/L	0.35	2%	10	0	1	51	0.2 U	0.2 U	0.2 U	0.2 U		0.2 U
Calcium	UG/L	391000	100%		0	51	51	126000	75700	99100	99400		123000
Chromium	UG/L	4.1	14%	50	0	7	51	4 J	1 U	1 U	1 U		1 U
Cobalt	UG/L	2	6%		0	3	51	1.3 U	1.3 U	1.3 U	1.3 U		1.3 U
Copper	UG/L	14.6	33%	200	0	17	51	5.3 J	1.9 U	2.6 J	1.9 U		2.6 J
Cyanide	UG/L	0	0%	100	0	0	51	10 U	10 U	10 U	10 U		10 U
Iron	UG/L	6350	63%	300	14	32	51	2020 J	168 J	82.6 J	20.3 UJ		20.3 U
Lead	UG/L	3.8	10%	25	0	5	51	1.3 U	1.3 U	1.3 U	1.3 U		1 U
Magnesium	UG/L	85900	100%		0	51	51	34300	18000	12400	12400		12100
Manganese	UG/L	344	100%	300	2	51	51	99.8	9.8 J	15.7 J	7.1 J		2.2 J
Mercury	UG/L	0.14	2%	2	0	1	51	0.1 U	0.1 U	0.1 U	0.1 U		0.1 U
Nickel	UG/L	6.2	10%		0	5	51	4.6 J	1.7 U	1.7 U	1.7 U		1.7 U
Potassium	UG/L	25600	100%		0	51	51	2520 J	1940 J	712 J	822 J		690 J
Selenium	UG/L	3	2%	10	0	1	51	2.5 U	2.2 U	2.2 U	2.2 U		2.2 U
Silver	UG/L	2.8	2%	50	0	1	51	1 UJ	1.3 UJ	1.3 UJ	1.3 UJ		1.3 UJ
Sodium	UG/L	175000	90%	20000	23	46	51	32200	19800	5800	6010		24100 U
Thallium	UG/L	7.4	6%		0	3	51	3.6 U	3.2 UJ	3.2 UJ	3.2 UJ		3.2 UJ
Vanadium	UG/L	10.8	8%		0	4	51	2 J	1.8 U	1.8 U	1.8 U		1.8 U
Zinc	UG/L	1620	100%	300	1	51	51	13.8 J	6.1 J	3.1 J	4 J		4.1 J



TABLE 2  
GROUND WATER CHEMICAL RESULTS  
ROUND 2 GROUNDWATER MONITORING  
ASH REMEDIAL DESIGN  
SENECA ARMY DEPOT ACTIVITY ROMULUS, NY

FACILITY				ASH LANDFILL				ASH LANDFILL				ASH LANDFILL				ASH LANDFILL							
LOCATION ID				PT-18				PT-19				PT-20				PT-21A				PT-22			
MATRIX				GROUND WATER				GROUND WATER				GROUND WATER				GROUND WATER				GROUND WATER			
SAMPLE ID				ARD2154				ARD2110				ARD2153				ARD2150				ARD2151			
DEPTH TO TOP OF SAMPLE				10				8.5				9.5				17.5				11.3			
DEPTH TO BOTTOM OF SAMPLE				10				8.5				9.5				17.5				11.3			
SAMPLE DATE				01/21/2000				01/08/2000				01/21/2000				01/21/2000				01/21/2000			
QC CODE				SA				SA				SA				SA				SA			
STUDY ID				ASH REMEDIAL DESI				ASH REMEDIAL DESI				ASH REMEDIAL DESI				ASH REMEDIAL DESI				ASH REMEDIAL DESI			
SAMPLE ROUND				2				2				2				2				2			
PARAMETER	UNIT	MAXIMUM	DETECTION	FREQUENCY OF DETECTION	NYSDEC CLASS GA STD.	NUMBER ABOVE STD.	NUMBER OF DETECTS	NUMBER OF ANALYSES	N	2	N	2	N	2	N	2	N	2					
<b>VOLATILE ORGANICS</b>																							
1,1,1-Trichloroethane	UG/L	0	0%	0%	5	0	0	54	23	U	1	U	2	U	1	U	5	U					
1,1,2,2-Tetrachloroethane	UG/L	0	0%	0%	5	0	0	54	23	U	1	UJ	2	U	1	U	5	U					
1,1,2-Trichloroethane	UG/L	0	0%	0%	5	0	0	54	23	U	1	U	2	U	1	U	5	U					
1,1-Dichloroethane	UG/L	0	0%	0%	5	0	0	54	23	U	1	U	2	U	1	U	5	U					
1,1-Dichloroethene	UG/L	0	0%	0%	5	0	0	54	23	U	1	U	2	U	1	U	5	U					
1,2,4-Trichlorobenzene	UG/L	0	0%	0%	5	0	0	54	23	U	1	U	2	U	1	U	5	U					
1,2-Dibromo-3-chloropropane	UG/L	0	0%	0%	5	0	0	54	23	U	1	U	2	U	1	U	5	U					
1,2-Dibromoethane	UG/L	0	0%	0%	5	0	0	54	23	U	1	U	2	U	1	U	5	U					
1,2-Dichlorobenzene	UG/L	0	0%	0%	4.7	0	0	54	23	U	1	U	2	U	1	U	5	U					
1,2-Dichloroethane	UG/L	3	2%	0%	5	0	1	54	23	U	1	U	2	U	1	U	3	J					
1,2-Dichloropropane	UG/L	0	0%	0%	5	0	0	54	23	U	1	U	2	U	1	U	5	U					
1,3-Dichlorobenzene	UG/L	0	0%	0%	5	0	0	54	23	U	1	U	2	U	1	U	5	U					
1,4-Dichlorobenzene	UG/L	0	0%	0%	4.7	0	0	54	23	U	1	U	2	U	1	U	5	U					
Acetone	UG/L	1	4%	0%	5	0	2	54	120	R	5	U	9	R	5	R	25	R					
Benzene	UG/L	0	0%	0%	0.7	0	0	54	23	U	1	U	2	U	1	U	5	U					
Bromochloromethane	UG/L	0	0%	0%	5	0	0	54	23	U	1	U	2	U	1	U	5	U					
Bromodichloromethane	UG/L	0	0%	0%	5	0	0	54	23	U	1	U	2	U	1	U	5	U					
Bromoform	UG/L	0	0%	0%	5	0	0	54	23	U	1	U	2	U	1	U	5	U					
Carbon disulfide	UG/L	0	0%	0%	5	0	0	54	23	U	1	U	2	U	1	U	5	U					
Carbon tetrachloride	UG/L	0	0%	0%	5	0	0	54	23	U	1	U	2	U	1	U	5	U					
Chlorobenzene	UG/L	0	0%	0%	5	0	0	54	23	U	1	U	2	U	1	U	5	U					
Chlorodibromomethane	UG/L	0	0%	0%	5	0	0	54	23	U	1	U	2	U	1	U	5	U					
Chloroethane	UG/L	0	0%	0%	5	0	0	54	23	U	1	U	2	U	1	U	5	U					
Chloroform	UG/L	0	0%	0%	7	0	0	54	23	U	1	U	2	U	1	U	5	U					
Cis-1,2-Dichloroethene	UG/L	980	28%	0%	5	14	15	54	16	J	1	U	24	U	6	U	76	U					
Cis-1,3-Dichloropropene	UG/L	0	0%	0%	5	0	0	54	23	U	1	U	2	U	1	U	5	U					
Ethyl benzene	UG/L	0	0%	0%	5	0	0	54	23	U	1	U	2	U	1	U	5	U					
Methyl bromide	UG/L	0	0%	0%	5	0	0	54	23	U	1	U	2	U	1	U	5	U					
Methyl butyl ketone	UG/L	0	0%	0%	5	0	0	54	120	UJ	5	U	9	UJ	5	UJ	25	UJ					
Methyl chloride	UG/L	0	0%	0%	5	0	0	54	23	U	1	U	2	U	1	U	5	U					
Methyl ethyl ketone	UG/L	0	0%	0%	50	0	0	54	120	U	5	U	9	U	5	U	25	U					
Methyl isobutyl ketone	UG/L	0	0%	0%	5	0	0	54	120	U	5	U	9	U	5	U	25	U					
Methylene chloride	UG/L	0	0%	0%	5	0	0	54	46	U	2	U	4	U	2	U	10	U					
Styrene	UG/L	0	0%	0%	5	0	0	54	23	U	1	U	2	U	1	U	5	U					
Tetrachloroethene	UG/L	0	0%	0%	5	0	0	54	23	U	1	U	2	U	1	U	5	U					
Toluene	UG/L	2	6%	0%	5	0	3	54	23	U	1	U	2	U	1	U	5	U					

TABLE 2  
GROUND WATER CHEMICAL RESULTS  
ROUND 2 GROUNDWATER MONITORING  
ASH REMEDIAL DESIGN  
SENECA ARMY DEPOT ACTIVITY ROMULUS, NY

				ASH LANDFILL		ASH LANDFILL		ASH LANDFILL		ASH LANDFILL		ASH LANDFILL			
FACILITY				PT-18		PT-19		PT-20		PT-21A		PT-22			
LOCATION ID				GROUND WATER		GROUND WATER		GROUND WATER		GROUND WATER		GROUND WATER			
MATRIX				ARD2154		ARD2110		ARD2153		ARD2150		ARD2151			
SAMPLE ID				10		8.5		9.5		17.5		11.3			
DEPTH TO TOP OF SAMPLE				10		8.5		9.5		17.5		11.3			
DEPTH TO BOTTOM OF SAMPLE				01/21/2000		01/08/2000		01/21/2000		01/21/2000		01/21/2000			
SAMPLE DATE				SA		SA		SA		SA		SA			
QC CODE				ASH REMEDIAL DESI		ASH REMEDIAL DESI		ASH REMEDIAL DESI		ASH REMEDIAL DESI		ASH REMEDIAL DESI			
STUDY ID				2		2		2		2		2			
FREQUENCY OF				NYSDEC CLASS GA		NYSDEC CLASS GA		NYSDEC CLASS GA		NYSDEC CLASS GA		NYSDEC CLASS GA			
NUMBER OF ABOVE				NUMBER OF DETECTS		NUMBER OF ANALYSES		N		N		N			
STANDARD				STANDARD		STANDARD		STANDARD		STANDARD		STANDARD			
PARAMETER				UNIT		UNIT		UNIT		UNIT		UNIT			
MAXIMUM				DETECTION		DETECTION		DETECTION		DETECTION		DETECTION			
Total Xylenes	UG/L	0	0%	5	0	0	54	23	U	1	U	2	U	5	U
Trans-1,2-Dichloroethene	UG/L	2	4%	5	0	2	54	23	U	1	U	0.8	J	1	U
Trans-1,3-Dichloropropene	UG/L	0	0%	5	0	0	54	23	U	1	U	2	U	1	U
Trichloroethene	UG/L	760	28%	5	8	15	54	370	U	1	U	27	U	2	U
Vinyl chloride	UG/L	25	2%	2	1	1	54	23	U	1	U	2	U	1	U
<b>METALS</b>															
Aluminum	UG/L	7700	49%		0	25	51	34.4	UJ	15.5	UJ	34.4	UJ	34.4	UJ
Antimony	UG/L	4.5	12%		0	6	51	5.4	U	2.2	U	5.4	U	5.4	U
Arsenic	UG/L	5	22%	25	0	11	51	2.4	U	2.5	U	2.4	U	2.4	U
Barium	UG/L	173	100%	1000	0	51	51	47.8	J	44.8	J	89.2	J	69.2	J
Beryllium	UG/L	0.26	14%		0	7	51	0.6	U	0.11	J	0.6	U	0.6	U
Cadmium	UG/L	0.35	2%	10	0	1	51	0.35	J	0.2	U	0.2	U	0.2	U
Calcium	UG/L	391000	100%		0	51	51	289000	J	110000	J	154000	J	164000	J
Chromium	UG/L	4.1	14%	50	0	7	51	1	U	1	U	1	U	1	U
Cobalt	UG/L	2	6%		0	3	51	3.5	U	1.3	U	3.5	U	3.5	U
Copper	UG/L	14.6	33%	200	0	17	51	14.6	J	1.6	U	5	J	3	J
Cyanide	UG/L	0	0%	100	0	0	51	10	U	10	U	10	U	10	U
Iron	UG/L	6350	63%	300	14	32	51	14.8	UJ	812	J	14.8	UJ	369	U
Lead	UG/L	3.8	10%	25	0	5	51	1	U	1.3	U	1	U	1	U
Magnesium	UG/L	85900	100%		0	51	51	44500	J	15300	J	19500	J	37800	J
Manganese	UG/L	344	100%	300	2	51	51	9.7	J	316	J	9.2	J	344	J
Mercury	UG/L	0.14	2%	2	0	1	51	0.14	J	0.1	U	0.1	U	0.1	U
Nickel	UG/L	6.2	10%		0	5	51	4.2	U	1.7	U	4.2	U	4.2	U
Potassium	UG/L	25600	100%		0	51	51	4740	J	1900	J	1420	J	10300	J
Selenium	UG/L	3	2%	10	0	1	51	2.2	U	2.5	U	2.2	U	2.2	U
Silver	UG/L	2.8	2%	50	0	1	51	1	UJ	1	UJ	2.8	J	1	UJ
Sodium	UG/L	175000	90%	20000	23	46	51	39800	J	20700	J	26200	J	36300	J
Thallium	UG/L	7.4	6%		0	3	51	7.4	J	3.2	U	5.1	J	3.2	UJ
Vanadium	UG/L	10.8	8%		0	4	51	2.8	U	1.8	U	2.8	U	2.8	U
Zinc	UG/L	1620	100%	300	1	51	51	1620	J	8	J	3.7	J	3	J

TABLE 2  
GROUND WATER CHEMICAL RESULTS  
ROUND 2 GROUNDWATER MONITORING  
ASH REMEDIAL DESIGN  
SENECA ARMY DEPOT ACTIVITY ROMULUS, NY

FACILITY				ASH LANDFILL				ASH LANDFILL				ASH LANDFILL				ASH LANDFILL			
LOCATION ID				PT-23				PT-24				PT-25				PT-26			
MATRIX				GROUND WATER				GROUND WATER				GROUND WATER				GROUND WATER			
SAMPLE ID				ARD2123				ARD2144				ARD2116				ARD2138			
DEPTH TO TOP OF SAMPLE				10.8				10.4				10				13.5			
DEPTH TO BOTTOM OF SAMPLE				10.8				10.4				10				13.5			
SAMPLE DATE				01/10/2000				01/20/2000				01/09/2000				01/29/2000			
QC CODE				SA				SA				SA				SA			
STUDY ID				ASH REMEDIAL DESI				ASH REMEDIAL DESIG				ASH REMEDIAL DESIGN				ASH REMEDIAL DESIGN			
SAMPLE ROUND				2				2				2				2			
PARAMETER	UNIT	MAXIMUM	FREQUENCY OF DETECTION	NYSDEC CLASS GA STD.	NUMBER ABOVE STD.	NUMBER OF DETECTS	NUMBER OF ANALYSES	N	N	N	N	N	N	N	N	N	N		
<b>VOLATILE ORGANICS</b>																			
1,1,1-Trichloroethane	UG/L	0	0%	5	0	0	54	1 U		4 U		1 U		1 U		1 U			
1,1,2,2-Tetrachloroethane	UG/L	0	0%	5	0	0	54	1 U		4 U		1 UJ		1 U		1 U			
1,1,2-Trichloroethane	UG/L	0	0%		0	0	54	1 U		4 U		1 U		1 U		1 U			
1,1-Dichloroethane	UG/L	0	0%	5	0	0	54	1 U		4 U		1 U		1 U		1 U			
1,1-Dichloroethene	UG/L	0	0%	5	0	0	54	1 U		4 U		1 U		1 U		1 U			
1,2,4-Trichlorobenzene	UG/L	0	0%	5	0	0	54	1 U		4 U		1 U		1 U		1 U			
1,2-Dibromo-3-chloropropane	UG/L	0	0%		0	0	54	1 U		4 U		1 U		1 U		1 U			
1,2-Dibromoethane	UG/L	0	0%		0	0	54	1 U		4 U		1 U		1 U		1 U			
1,2-Dichlorobenzene	UG/L	0	0%	4.7	0	0	54	1 U		4 U		1 U		1 U		1 U			
1,2-Dichloroethane	UG/L	3	2%	5	0	1	54	1 U		4 U		1 U		1 U		1 U			
1,2-Dichloropropane	UG/L	0	0%	5	0	0	54	1 U		4 U		1 U		1 U		1 U			
1,3-Dichlorobenzene	UG/L	0	0%	5	0	0	54	1 U		4 U		1 U		1 U		1 U			
1,4-Dichlorobenzene	UG/L	0	0%	4.7	0	0	54	1 U		4 U		1 U		1 U		1 U			
Acetone	UG/L	1	4%		0	2	54	5 U		19 R		5 UJ		5 UJ		5 UJ			
Benzene	UG/L	0	0%	0.7	0	0	54	1 U		4 U		1 U		1 U		1 U			
Bromochloromethane	UG/L	0	0%		0	0	54	1 U		4 U		1 U		1 U		1 U			
Bromodichloromethane	UG/L	0	0%		0	0	54	1 U		4 U		1 U		1 U		1 U			
Bromoform	UG/L	0	0%		0	0	54	1 U		4 U		1 U		1 U		1 U			
Carbon disulfide	UG/L	0	0%		0	0	54	1 U		4 U		1 U		1 U		1 U			
Carbon tetrachloride	UG/L	0	0%	5	0	0	54	1 U		4 U		1 U		1 U		1 U			
Chlorobenzene	UG/L	0	0%	5	0	0	54	1 U		4 U		1 U		1 U		1 U			
Chlorodibromomethane	UG/L	0	0%		0	0	54	1 U		4 U		1 U		1 U		1 U			
Chloroethane	UG/L	0	0%	5	0	0	54	1 U		4 U		1 U		1 U		1 U			
Chloroform	UG/L	0	0%	7	0	0	54	1 U		4 U		1 UJ		1 U		1 U			
Cis-1,2-Dichloroethene	UG/L	980	28%	5	14	15	54	1 U		72		1 U		1 U		1 U			
Cis-1,3-Dichloropropene	UG/L	0	0%	5	0	0	54	1 U		4 U		1 U		1 U		1 U			
Ethyl benzene	UG/L	0	0%	5	0	0	54	1 U		4 U		1 U		1 U		1 U			
Methyl bromide	UG/L	0	0%		0	0	54	1 U		4 U		1 UJ		1 U		1 U			
Methyl butyl ketone	UG/L	0	0%		0	0	54	5 U		19 UJ		5 U		5 U		5 U			
Methyl chloride	UG/L	0	0%	5	0	0	54	1 U		4 U		1 UJ		1 UJ		1 U			
Methyl ethyl ketone	UG/L	0	0%	50	0	0	54	5 U		19 U		5 UJ		5 UJ		5 U			
Methyl isobutyl ketone	UG/L	0	0%		0	0	54	5 U		19 U		5 U		5 U		5 U			
Methylene chloride	UG/L	0	0%	5	0	0	54	2 U		8 U		2 U		2 U		2 U			
Styrene	UG/L	0	0%		0	0	54	1 U		4 U		1 U		1 U		1 U			
Tetrachloroethene	UG/L	0	0%	5	0	0	54	1 U		4 U		1 U		1 U		1 U			
Toluene	UG/L	2	6%	5	0	3	54	1 U		4 U		1 U		1 U		1 U			

TABLE 2  
GROUND WATER CHEMICAL RESULTS  
ROUND 2 GROUNDWATER MONITORING  
ASH REMEDIAL DESIGN  
SENECA ARMY DEPOT ACTIVITY ROMULUS, NY

FACILITY										ASH LANDFILL	ASH LANDFILL	ASH LANDFILL	ASH LANDFILL
LOCATION ID										PT-23	PT-24	PT-25	PT-26
MATRIX										GROUND WATER	GROUND WATER	GROUND WATER	GROUND WATER
SAMPLE ID										ARD2123	ARD2144	ARD2116	ARD2138
DEPTH TO TOP OF SAMPLE										10.8	10.4	10	13.5
DEPTH TO BOTTOM OF SAMPLE										10.8	10.4	10	13.5
SAMPLE DATE										01/10/2000	01/20/2000	01/09/2000	01/29/2000
QC CODE										SA	SA	SA	SA
STUDY ID										ASH REMEDIAL DESI	ASH REMEDIAL DESIG	ASH REMEDIAL DESIGN	ASH REMEDIAL DESIGN
SAMPLE ROUND										2	2	2	2
PARAMETER	UNIT	MAXIMUM	FREQUENCY OF DETECTION	NYSDEC CLASS GA STD.	NUMBER ABOVE STD.	NUMBER OF DETECTS	NUMBER OF ANALYSES	N	N	N	N		
Total Xylenes	UG/L	0	0%	5	0	0	54	1 U	4 U	1 U	1 U		
Trans-1,2-Dichloroethene	UG/L	2	4%	5	0	2	54	1 U	4 U	1 U	1 U		
Trans-1,3-Dichloropropene	UG/L	0	0%	5	0	0	54	1 U	4 U	1 U	1 U		
Trichloroethene	UG/L	760	28%	5	8	15	54	1 U	4	1 U	1 U		
Vinyl chloride	UG/L	25	2%	2	1	1	54	1 U	4 U	1 UJ	1 U		
<b>METALS</b>													
Aluminum	UG/L	7700	49%		0	25	51	243 J	34.4 UJ	15.5 UJ	303 J		
Antimony	UG/L	4.5	12%		0	6	51	2.6 J	2.2 U	2.2 U	4.5 J		
Arsenic	UG/L	5	22%	25	0	11	51	2.5 U	3.1 J	2.5 U	5 J		
Barium	UG/L	173	100%	1000	0	51	51	37.8 J	31.1 J	24.7 J	78.9 J		
Beryllium	UG/L	0.26	14%		0	7	51	0.1 U	0.1 U	0.1 U	0.1 U		
Cadmium	UG/L	0.35	2%	10	0	1	51	0.2 U	0.2 U	0.2 U	0.2 U		
Calcium	UG/L	391000	100%		0	51	51	102000	91400	68100	91400		
Chromium	UG/L	4.1	14%	50	0	7	51	1 U	1 U	1 U	1 U		
Cobalt	UG/L	2	6%		0	3	51	1.3 U	1.3 U	1.3 U	1.3 U		
Copper	UG/L	14.6	33%	200	0	17	51	1.9 U	1.9 U	1.6 U	1.9 U		
Cyanide	UG/L	0	0%	100	0	0	51	10 U	10 U	10 U	10 U		
Iron	UG/L	6350	63%	300	14	32	51	386 J	20.3 U	20.3 UJ	251 J		
Lead	UG/L	3.8	10%	25	0	5	51	1.3 U	1 U	1.3 U	1.3 U		
Magnesium	UG/L	85900	100%		0	51	51	10800	9800	7480	33100		
Manganese	UG/L	344	100%	300	2	51	51	5.6 J	198	2.4 J	23.7		
Mercury	UG/L	0.14	2%	2	0	1	51	0.1 U	0.1 U	0.1 U	0.1 U		
Nickel	UG/L	6.2	10%		0	5	51	1.7 U	1.7 U	1.7 U	1.7 U		
Potassium	UG/L	25600	100%		0	51	51	574 J	753 J	626 J	1850 J		
Selenium	UG/L	3	2%	10	0	1	51	2.2 U	2.2 U	2.5 U	2.2 U		
Silver	UG/L	2.8	2%	50	0	1	51	1.3 UJ	1.3 UJ	1 UJ	1.3 UJ		
Sodium	UG/L	175000	90%	20000	23	46	51	5850	12000 U	10100	38400		
Thallium	UG/L	7.4	6%		0	3	51	3.2 UJ	3.2 UJ	3.2 U	3.2 U		
Vanadium	UG/L	10.8	8%		0	4	51	1.8 U	1.8 U	1.8 U	1.8 U		
Zinc	UG/L	1620	100%	300	1	51	51	5 J	4.7 J	4 J	5.1 J		



**Table 5**  
**Ash Landfill**  
**1998 Third Quarter Groundwater Monitoring**  
**Indicator Parameters**

Well ID	pH (units)	Spec. Cond. (umhos/cm)	Redox Pot.* (mV)	DO (mg/l)	Fe+2 (mg/l)	Methane (mg/l)	Ethane (mg/l)	Ethene (mg/l)	DOC (mg/l)	Nitrate/Nitrite (mg/l)	Tot. Alkalinity (mg/l CaCO3)	Sulfate (mg/l)	Chloride (mg/l)
PT-11	6.95	975	308	3.55	0.15	0.0021	<0.0021	<0.0025	6.9	0.71	356	121	32.2
PT-12A	6.57	1530	270	0.91	0.46	0.0089	<0.0021	<0.0025	7.3	0.03	356	358	106
PT-18	6.59	1267	50	1.89	0.51	0.13	<0.0021	<0.0025	4.7	0.19	250	195	123.0
PT-19	6.88	774	102	1.00	3.36	0.15	<0.0021	<0.0025	3.7	0.16	334	43.7	25
PT-21A	7.02	1202	199	0.93	0.33	0.0043	<0.0021	<0.0025	4.7	0.19	250	195	123
PT-24	6.70	800	250	0.99	0.00	<0.0012	<0.0021	<0.0025	6.2	0.04	310	84.2	16.8
MW-27	6.44	703	301	2.00	na	0.057	<0.0021	<0.0025	6.2	0.32	306	46.1	19.2
MW-29	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
MW-30	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
MW-36	6.93	716	322	1.00	0.00	<0.0012	<0.0021	<0.0025	1.4	0.88	292	53.8	20.2
MW-40	6.96	591	281	1.89	0.04	<0.0012	<0.0021	<0.0025	4.4	0.08	254	55.7	7.9
MW-44A	6.95	3050	137	1.02	0.99	0.053	<0.0021	0.013	8.5	0.01	212	816	421
MW-45	6.92	606	222	1.18	0.18	<0.0012	<0.0021	<0.0025	5.9	0.01	312	28.1	9.7
MW-46	6.75	778	176	0.83	0.38	0.003	<0.0021	<0.0025	2.7	0.01	350	58	13.4
MW-47	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
MW-48	6.87	637	200	0.82	0.15	<0.0012	<0.0021	<0.0025	6	0.01	308	30.1	9.8
MW-56	6.77	801	310	1.00	0.01	0.014	<0.0021	<0.0025	2.1	0.31	284	118	24.9
MW-59	6.63	1394	85	1.18	0.03	0.01	<0.0021	<0.0025	5.9	0.01	656	125	27.8
MW-60	6.72	910	163	0.87	0.06	0.015	<0.0021	<0.0025	4.1	0.01	422	67.5	17.9
FH-S	na	na	na	na	na	na	na	na	na	na	na	na	na
FH-D	na	na	na	na	na	na	na	na	na	na	na	na	na
BN-S	na	na	na	na	na	na	na	na	na	na	na	na	na

na - not analyzed

ns - not sampled due to lack of water

\* = Redox values were adjusted to the standard hydrogen electrode.

## Appendix F

### Trichloroethylene, Cis-1,2-Dichloroethylene, and Vinyl Chloride Degradation Modeling

- Table F-1 Summary of Degradation Model
- Trichloroethylene, Cis-1,2-Dichloroethylene, and Vinyl Chloride Concentration vs. Time for Selected Monitoring Wells at the Ash Landfill

Table F-1  
 Summary of Degradation Model  
 Ash Landfill Feasibility Memorandum  
 Seneca Army Depot Activity, Romulus, NY

Location	Date	Residence Time, $t_{res}$ (hours)
PT-12A	Sep-98	55
PT-12A	Jun-97	55
MW-44A	Oct-99	43
MW-44A	Sep-98	49
PT-18	Oct-99	59
MWT-7	Jun-99	33
MWT-9	Jan-00	21

Notes:

- 1) Degradation plot raw data provided by ETI on April 13, 2000. Degradation model prepared using Scientist for Windows Ver 2.0. Model assumed half life of 3 hours for TCE and half lives of 6 hours for cDCE and VC.
- 2) Residence time means time needed for TCE and cDCE to degrade to concentrations of 5ug/L or below, and for VC to degrade below concentrations of 2ug/L.
- 3) Residence time calculated using the following equation:

$$t_{res} = \frac{\ln \frac{C}{C_0}}{-\lambda} \quad \text{where } C=5\text{mg/L, (NYSDEC Class GA Standard)}$$

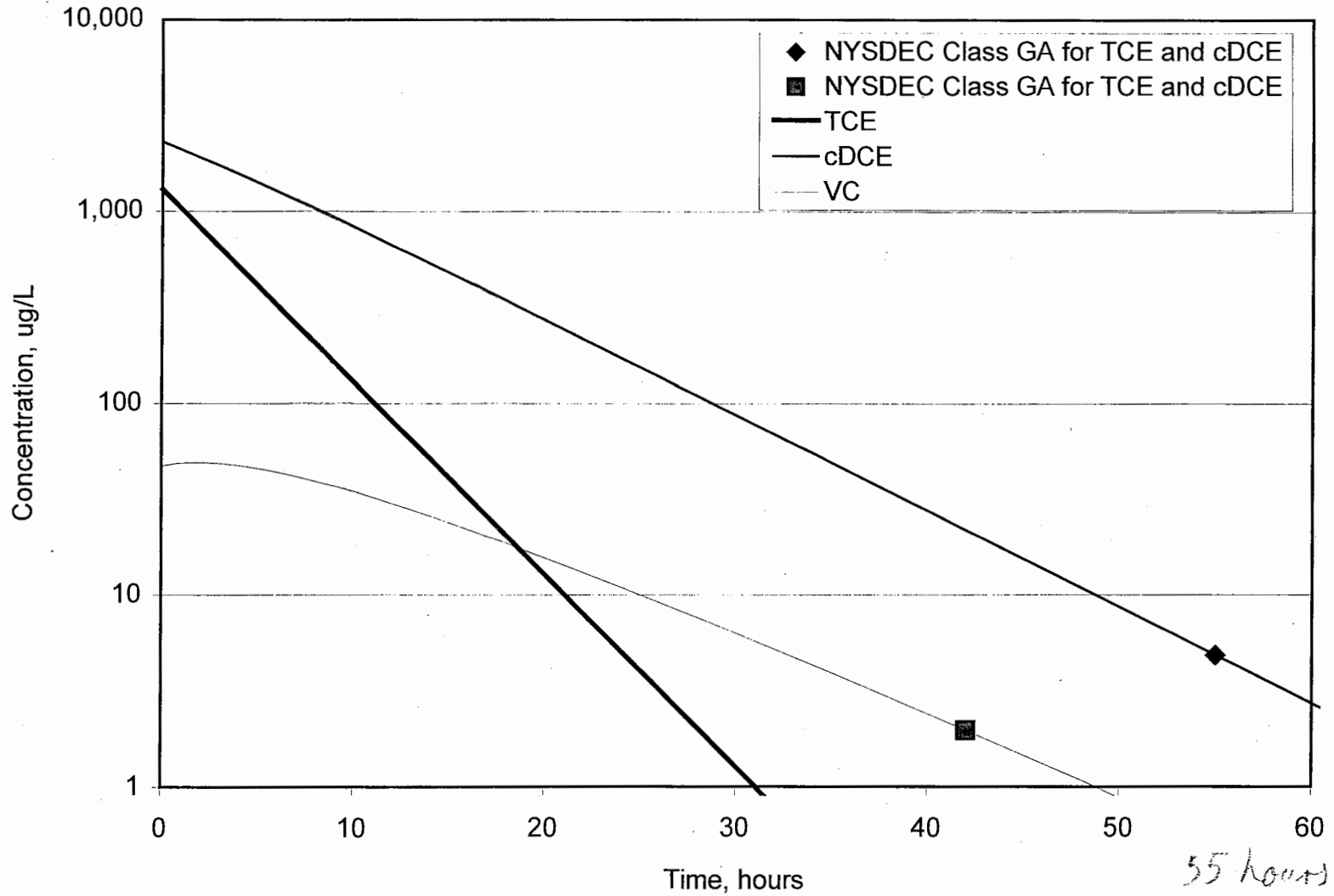
$$C_0=55\text{mg/L, (Maximum Effluent Cis-1,2-Dichloroethene)}$$

$$\lambda = - \frac{\ln(0.5)}{\text{halflife}}$$

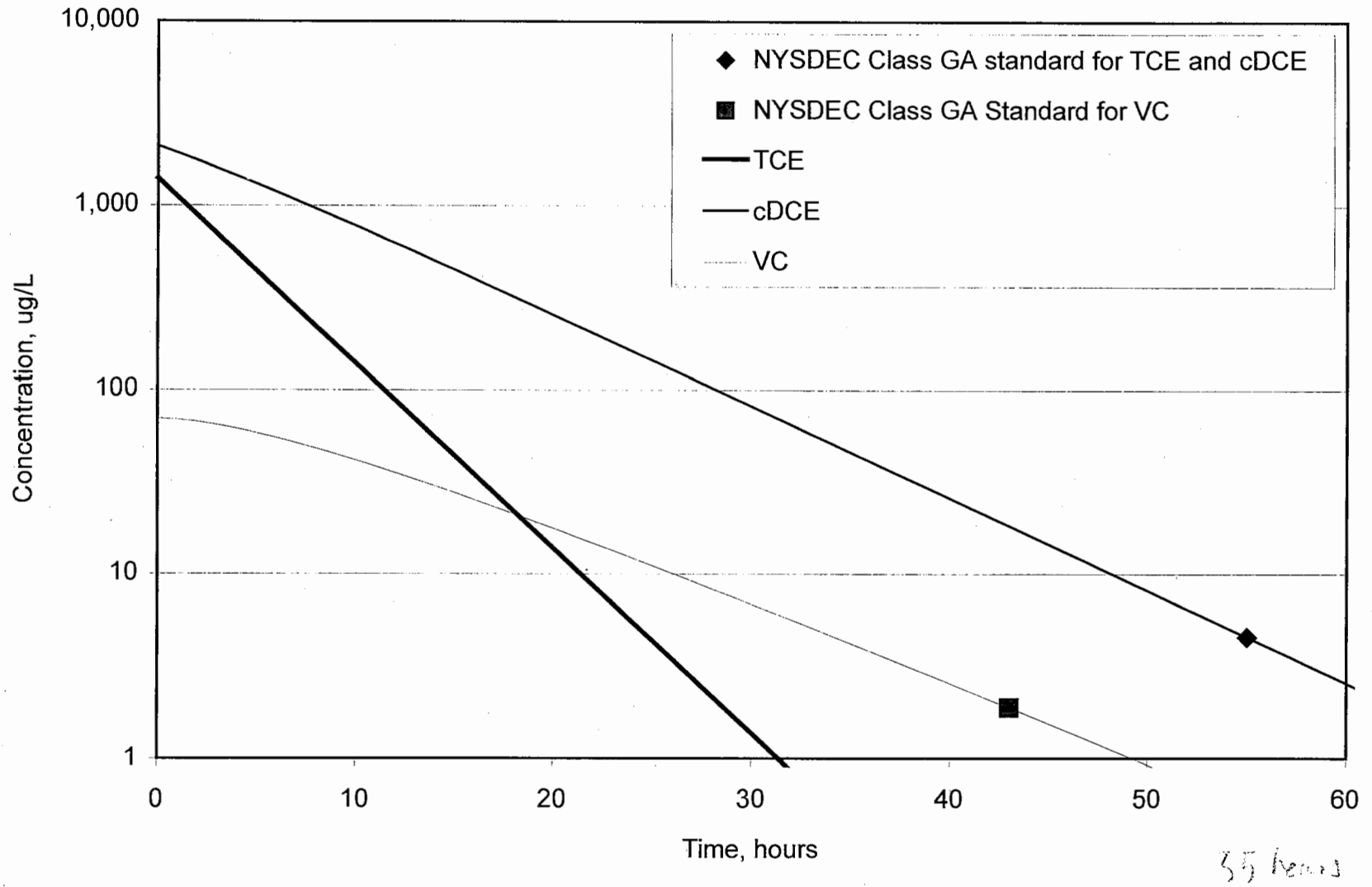




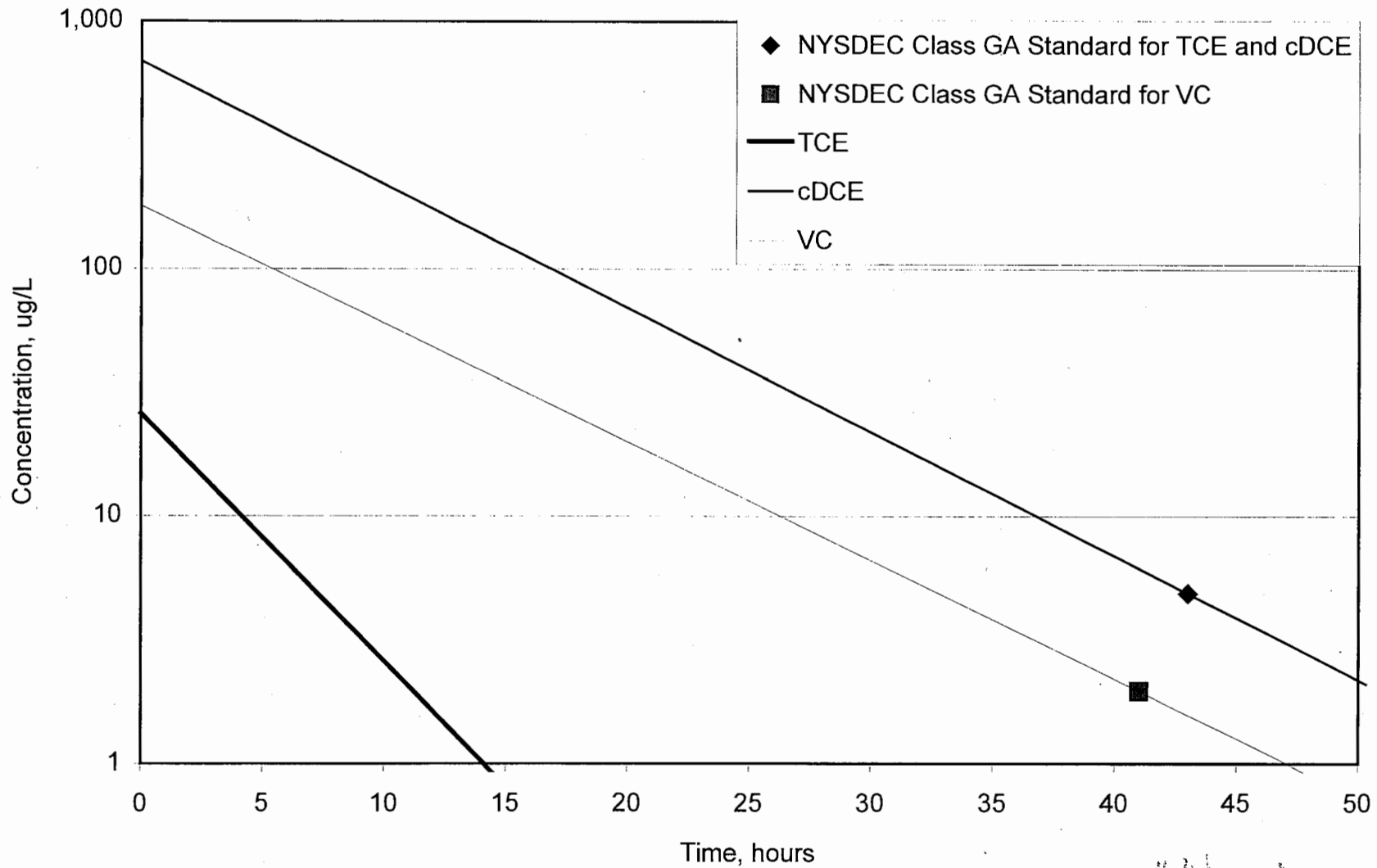
### TCE, cDCE, and VC Degradation vs. Time for PT-12, September 1998



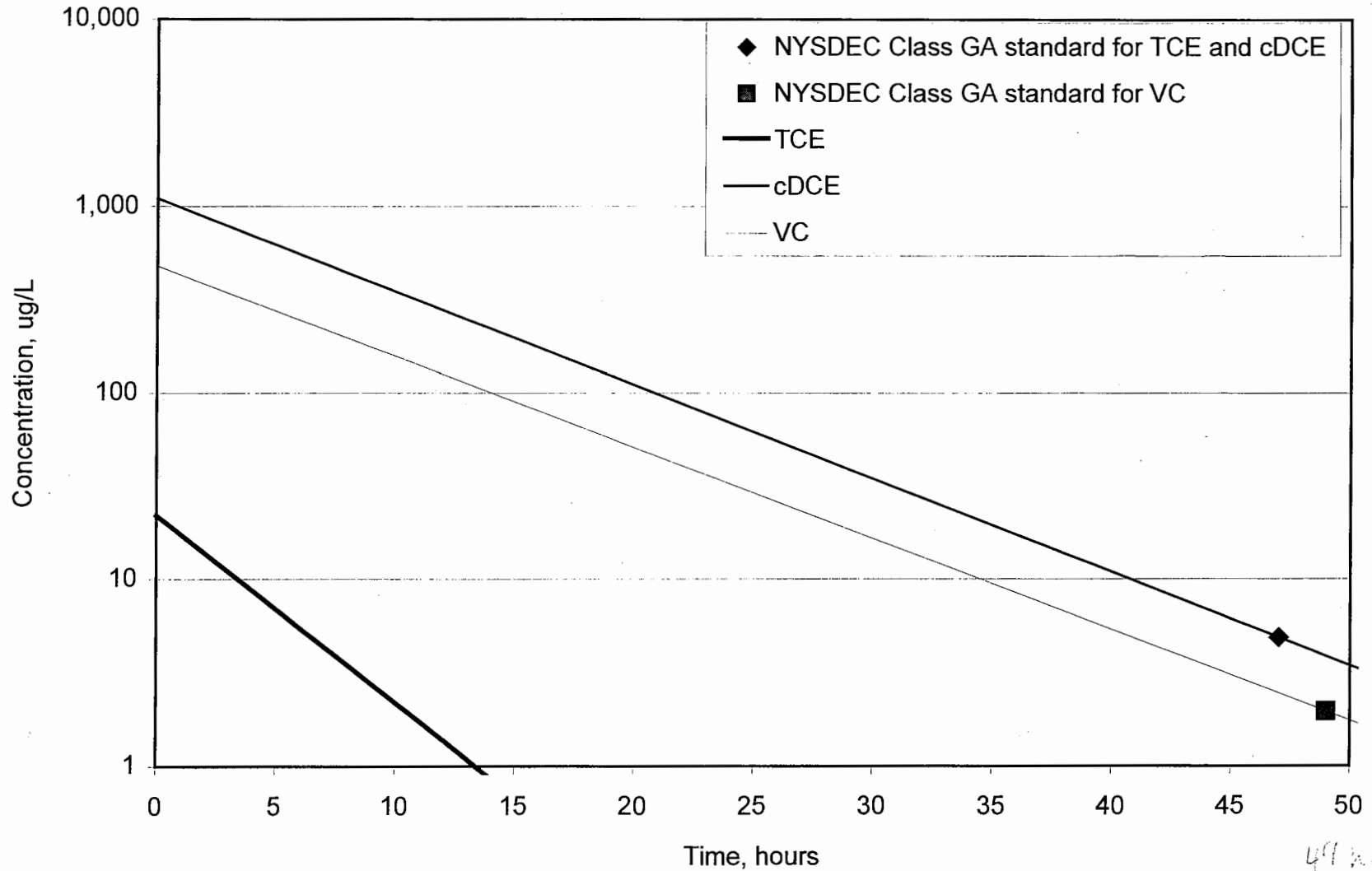
### TCE, cDCE, and VC Degradation vs. Time for PT-12, June 1997



### TCE, cDCE, and VC Degradation vs. Time for MW-44A, October 1999

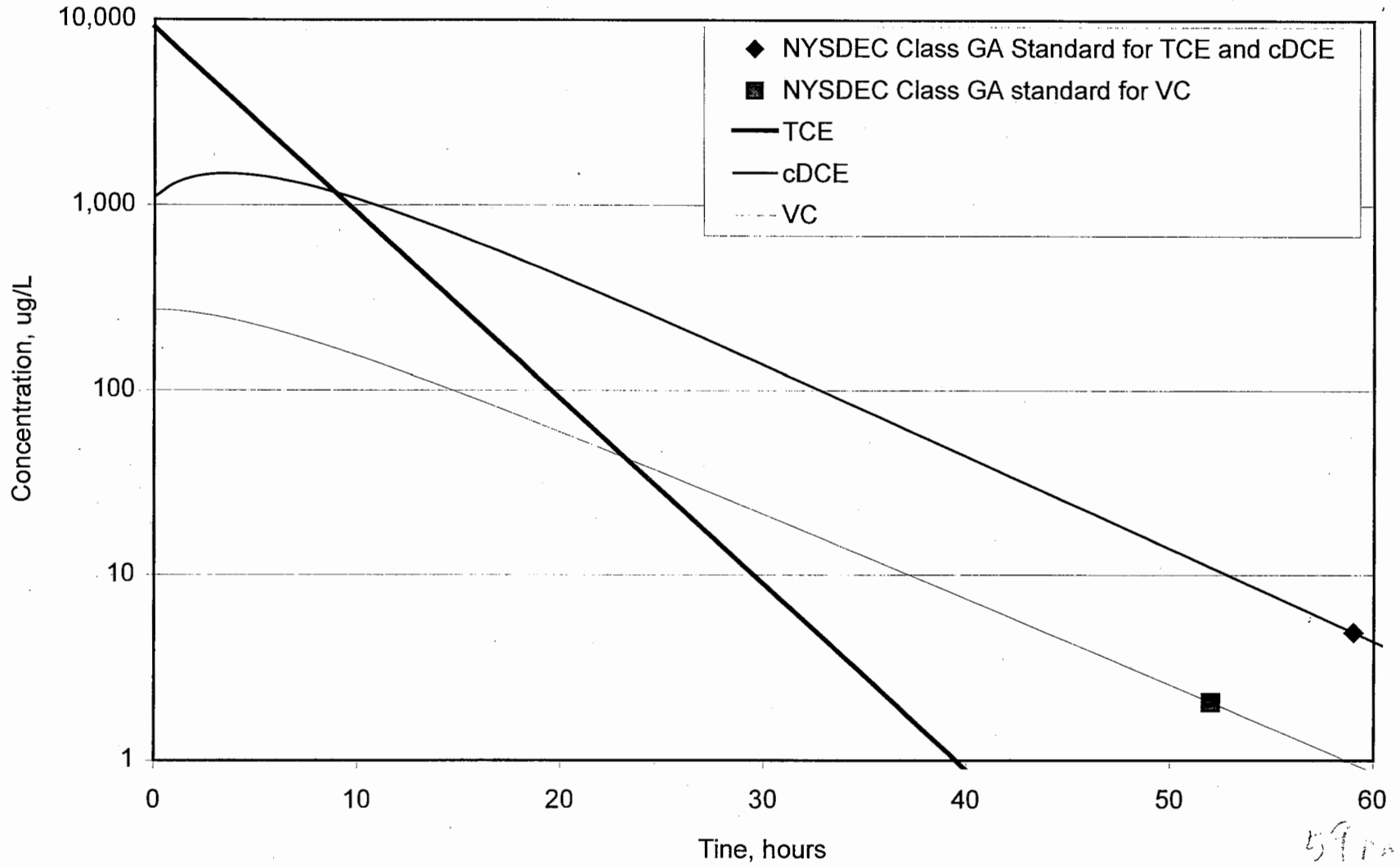


### TCE, cDCE, and VC Degradation vs. Time for MW-44A, September 1998

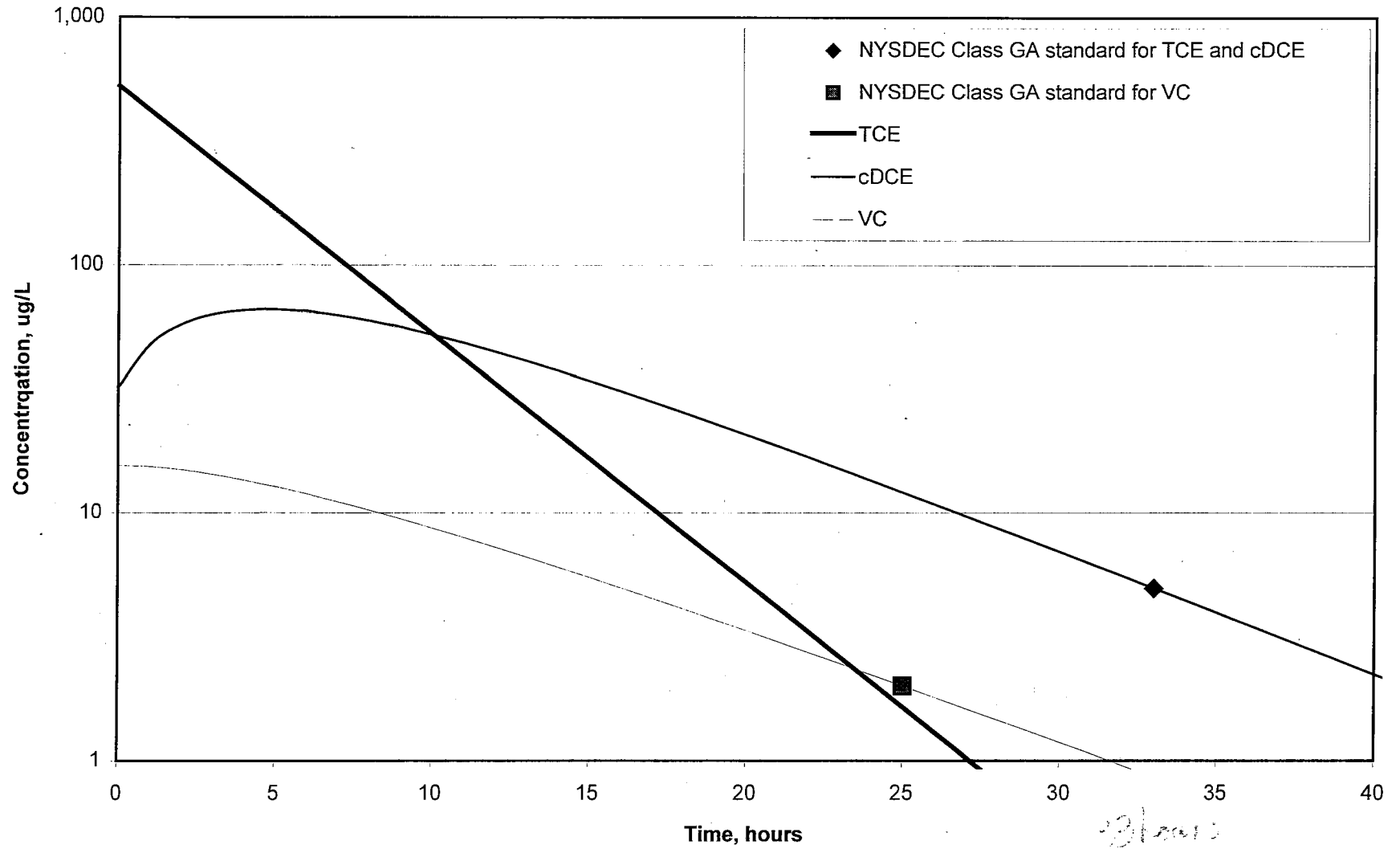


49 (W-13)

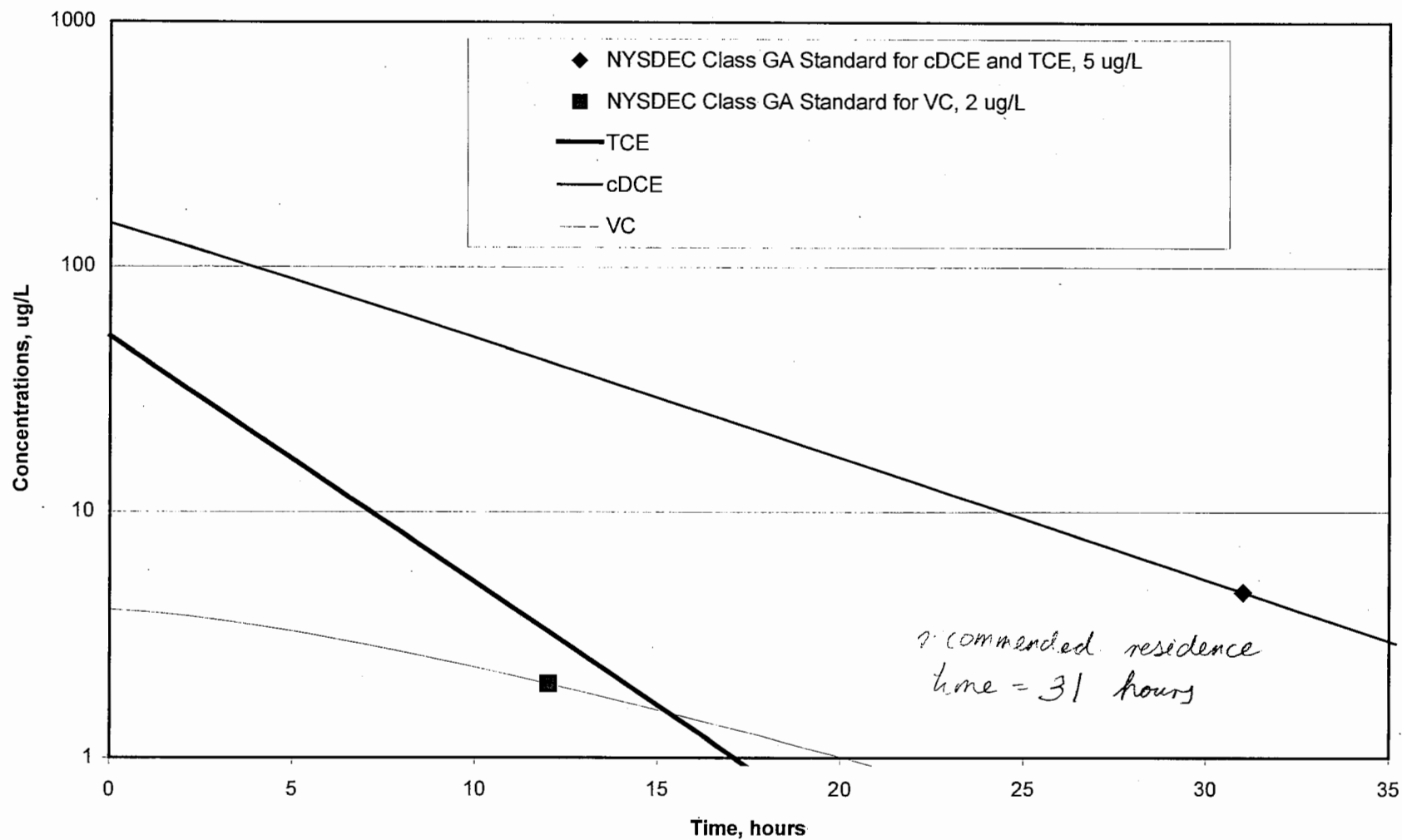
### TCE, cDCE, and VC Degradation vs. Time for PT-18, October 1999



### TCE, cDCE, and VC Degradation vs. Time for MWT-7, June 1999



### TCE, cDCE, and VC Concentrations vs. Time for MWT-9, June 1999





Appendix G  
Cost Estimation for Focused Groundwater Remediation Alternatives

- Cost Calculations
  - Table G-1 Calculation of Recommended Thicknesses for Proposed Reactive Walls
  - Table G-2 Dimensions of Groundwater Treatment Systems
  - Table G-3 Iron Quantity and Price Calculations
  - Table G-4 Monitoring Well Installation Costs
  - Table G-5 Groundwater Monitoring Costs
  - Table G-6 Cost calculations of TCLP testing, soil stockpiling, and soil disposal costs during installation of reactive walls
  - Table G-7 Calculation of Costs for Application of Vegetable Oil as Part of Alternative 2
  - Table G-8 Costs of Groundwater Treatment Alternatives at the Ash Landfill
  
- Price Quotes
  - Peerless Metal Powders & Abrasive, November, 9 1998
  - Diverse Solutions, April 14, 2000

Table G-1  
 Calculation of Recommended Thicknesses for Proposed Reactive Walls  
 Ash Landfill Feasibility Memorandum  
 Seneca Army Depot Activity, Romulus, NY

Design	Well(s) Considered for Estimation of Influent Concentrations	Recommended Residence Time, $t_{rec}$ hours	Maximum Expected Velocity, $v_{max}$ ft/day	Recommended Thickness for Proposed Wall, h ft	Recommended Thickness for Proposed Wall, h, SF=2 ft
Source Wall	PT-12A, MW-44A, PT-18A	59	0.4 <sup>2</sup>	1.1	2.1
Middle Wall	MWT-7	33	0.4 <sup>2</sup>	0.6	1.2
Compliance Wall	MWT-8, MWT-9	21	1.2 <sup>3</sup>	1.1	2.1

1 Residence time calculated in **Appendix F**. See Summary of Degradation Model table in **Appendix F**.

2  $v_{max}=0.43$  ft/day. Maximum velocity used for conservative assumptions;  $v_{max}$  estimated from  $v_{ave}$  using following equation:

$$v_{max} = v_{ave} \times \frac{K_{max}}{K_{ave}} = 0.2 \text{ ft/day} \times \frac{2.21 \text{ ft/day}}{1.03 \text{ ft/day}}$$

$K_{max}=2.21$  ft/day is maximum hydraulic conductivity, at Ash Landfill not including reactive wall area.

See Appendix D

$v_{ave}=0.2$  ft/day velocity used for design of existing reactive wall.

$K_{ave}=1.03$  ft/day is hydraulic conductivity used for design of existing wall. See **Appendix D**

3  $v_{max}$ =Maximum velocity calculated in **Table 6-2**

4  $h=(v_{max})(t_{rec})$

5  $t_{rec}$  determined using ETT's Scientist® for Windows Version 2.0

6 For the design of the Compliance wall, residence time of 21 hours was used, which is the degradation time for concentrations measured in MWT-8 in June 1999 since over time, residual TCE and cDCE will flush out and Compliance wall will only have to treat effluent of Boundary wall. With a safety factor of 2, the Boundary wall has a residence time of 42 hours which should still be able to reduce these residual concentrations. The highest concentration was observed in MWT-9 in June 1999 requiring a minimum residence time of 31 hours.

Table G-2  
Dimensions of Groundwater Treatment Systems  
Ash Landfill Feasibility Memorandum  
Seneca Army Depot Activity, Romulus, NY

Configuration type	Wall Thickness, h	Wall length, l	Wall Depth, d	Volume of Iron, V	Volume of Iron, V	Total weight of iron, w	Surface Area of Wall,	
units	ft	ft	ft	ft <sup>3</sup>	yd <sup>3</sup>	tons	ft <sup>2</sup>	
Boundary (Existing) wall	1.2	645					0	
Compliance wall	2.1	645	8	10,836	401	704	5,160	
Source wall	2.1	820	11	19,025	705	1,237	9,020	
Middle wall	1.2	700	9	7,432	275	483	6,300	
<b>Total for Alternative 1</b>					401	<sup>5)</sup> 704	<sup>6)</sup> 5,160	<sup>7)</sup>
<b>Total for Alternative 2</b>					1,381	<sup>5)</sup> 2,424	<sup>6)</sup> 20,480	<sup>7)</sup>

Notes:

- 1) Wall depths are taken from Figures 3-9 through 3-12 from the Remedial Investigation report (Parsons, 1994). These are approximate depths to competent shale at proposed location of continuous wall. Actual depths will be determined through excavation of test pits during construction.
- 2)  $A=(h)(l)$
- 3)  $V=(h)(l)(d)$
- 4)  $w = 130 \frac{lb}{ft^3} \times \frac{V}{2000 \frac{lb}{ton}}$
- 5) Total installation volume for Alternative 1 includes volume of compliance wall only, for Alternative 2 total installation volume includes volume of compliance wall, source wall, and middle wall.
- 6) Total installation weight for Alternative 1 includes weight of compliance wall only, for Alternative 2 total installation weight includes weight of compliance wall, source wall, and middle wall.
- 7) Total surface area of walls is calculated so that maintenance costs of iron walls can be estimated. Total surface area for Alternative 1 includes surface area of boundary wall and compliance wall. For Alternative 2 total surface area includes surface area of boundary wall, compliance wall, source wall, and middle wall.

Table G-3  
 Iron quantity and price calculations  
 Ash Landfill Feasibility Memorandum  
 Seneca Army Depot Activity, Romulus, NY

		Alternative 1	Alternative 2
<b>Iron Quantity, tons</b>	Iron for upgradient aquifer		1,720
	iron for effluent of existing wall	704	704
	Total installation weight	704	2424
<b>Iron Cost</b>	iron + packaging	\$235,440	\$794,610
	delivery	\$25,760	\$86,940
	<b>total iron cost</b>	<b>\$261,200</b>	<b>\$881,550</b>
<b>Total surface area of iron, ft<sup>2</sup></b>		2107	4662
<b>Cost of maintenance of wall(s)</b>		<b>\$1,475</b>	<b>\$3,264</b>

Notes:

- 1) Prices include unit cost of iron (\$313), unit cost of packaging (\$14), and cost of delivery, (\$805 for each 22.5ton). Prices provided by Peerless Metal Powders and Abrasives. See **Appendix G**
- 2) Maintenance cost is cost of agitation of iron in the upgradient aquifer/iron interface with a hollow stem auger. Cost includes mobilization, demobilization to site, drilling rig, and 1 feet augering that overlap. Overall it is \$7/square feet every 10 years. Method recommended by ETI in Memo of April 20, 2000 See **Appendix D**.

Table G-4  
Monitoring Well Installation Costs  
Ash Landfill Feasibility Memorandum  
Seneca Army Depot Activity, Romulus, NY

Item	Installation of Monitoring Wells at Ash Landfill- Description of Services	Unit Cost	Alternative 1		Alternative 2	
			Estimated Quantity	Total Cost	Estimated Quantity	Total Cost
1. Mobilization/ Demobilization	Mob./Demob. a truck mounted drilling rig to the site in Romulus, NY. Include security requirements to enter the base.	\$300 per event	2	\$600	4	\$1,200
3. Construct a Decon. Pad	Construct and remove a temporary decon. pad, on-site, to perform all decon. of drilling equipment. Pad will collect all decon. water.	\$150 per pad	1	\$150	1	\$150
4. Decon. Time	Provide an hourly rate to steam decon. drilling equipment; include decon. equipment rental.	\$125 per hour	5	\$625	15	\$1,875
5. Provide Empty Drums	Provide a cost to supply a DOT approved steel drum, with covers, to contain all drilling wastes, including decon. water.	\$40 per drum	5	\$200	15	\$600
6. Move Drums	Provide a cost to move a drum, 3/4 full, a distance of 100 ft to a central storage location	\$25 per drum	7	\$175	13	\$325
7. Hollow Stem Augering	Provide cost to perform Hollow Stem Augering using a 6.25" auger with a plug. @ 15 feet depth	\$18 per foot	90	\$1,620	150	\$2,700
8. Standby Time	Provide a cost for the drilling crew to standby during completion of an activity.	\$125 per hour	7	\$875	14	\$1,750
9. Installation of Monitoring Wells	Provide a cost, including materials, to install a 15' overburden monitoring well.	\$225 per well	6	\$1,350	10	\$2,250
10. Installation of Well Points *	Provide a cost, including materials, to install a 6' to 12' overburden well point.	\$250 per well point	1	\$250	3	\$750
11. Ballards	Provide a cost, including materials, to install three (3) ballards around each monit. well/point	\$60 per well	7	\$420	15	\$900
12. Concrete Collar	Provide a cost, including materials, to install a concrete collar around each monitoring well	\$50 per well	7	\$350	15	\$750
13. Steel Casing	Provide a cost, including materials, to install a 4" steel casing, with a cap & a weep hole.	\$70 per well	6	\$420	12	\$840
14. Brass Locks	Provide a cost to supply a brass, weather resistant, lock for each well.	\$25 per well	7	\$175	15	\$375
15. Level C Surcharge	Provide a cost for the drill crew to upgrade to Level C, including support equipment.	\$35 per hour	2	\$70	4	\$140
<b>Total subcontractor costs:</b>				<b>\$7,280</b>	<b>\$14,605</b>	

Parsons labor costs	\$4,254.50	\$8,509
Parsons materials	\$2,257	\$2,257
Parsons travel	\$2,353	\$2,353
Parsons equipment rental, others	\$1,560	\$1,560
<b>Total other costs:</b>	<b>\$10,425</b>	<b>\$14,679</b>

**TOTAL COST: \$17,705 \$29,284**

\* Well points will be installed once iron walls are in the ground. For Alternative 2, mobilization/demobilization is necessary again when well points are installed.

Table G-5  
Groundwater Monitoring Costs  
Ash Landfill Feasibility Memorandum  
Seneca Army Depot Activity, Romulus, NY

	Alternative 1	Alternative 2
<b>First Year</b>		
gw sampling	\$28,029.75	\$37,373
chemical analysis	\$10,852.50	\$14,470
prepare report	\$11,243	\$14,991
interim letter report	\$2,017	\$2,017
project management	\$9,020	\$12,026
	<b>\$61,162</b>	<b>\$80,877</b>
<b>Every 5 Years</b>		
gw sampling	\$100,926	\$108,790
chemical analysis	\$29,269	\$31,550
prepare report	\$26,560	\$26,560
interim letter report	\$2,017	\$2,017
project management	\$7,702	\$7,702
	<b>\$166,474</b>	<b>\$176,619</b>
<b>Annual</b>		
gw sampling	\$10,261	\$11,180
chemical analysis	\$3,430	\$3,737
prepare report	\$4,095	\$4,095
interim letter report	\$2,017	\$2,017
project management	\$7,702	\$7,702
	<b>\$27,505</b>	<b>\$28,731</b>
<b>AVERAGE ANNUAL</b>	<b>\$55,299</b>	<b>\$58,309</b>

\* Average annual cost = (4 \* Annual Cost + Cost of sampling every 5 years) / 5

Table G-6  
 Cost calculations of TCLP testing, soil stockpiling, and soil disposal costs during installation of reactive walls  
 Ash Landfill Feasibility Memorandum  
 Seneca Army Depot Activity, Romulus, NY

	in-situ volume 1) cy	ex-situ volume 2) cy	# of piles (samples tested for TCLP) 3)	area of piles 4) .sf	cost of TCLP test 5)	# of samples expected to fail test 6)	amount taken to hazwaste landfill 6) ton	amount staying on site 6) ton	disposal cost 7)	cost of polyethylene lining on bottom 8)	cost of polyethylene lining on top 8)	TOTAL
Alternative 1	401	522	4	34,782	\$700	0	0	602	\$0	\$2,783	\$4,174	\$7,656
Alternative 2	1,381	1,796	12	119,709	\$2,100	1	207	1,865	\$24,241	\$9,577	\$14,365	\$50,283

Notes

- 1) Volume calculated in Table G-2.
- 2) Assumed that ex-situ volume is 30% greater than in-situ volume.
- 3) Excavated soil stored in 150 cy piles. One sample from each pile will be tested for TCLP-VOC's.
- 4) It is assumed that each pile will be 100 ft x 100 ft large.
- 5) Cost TCLP test is \$175/sample.
- 6) For Alternative 1 it is assumed that none of the samples will fail the TCLP test, since no samples collected from the excavation of the boundary wall have failed it. Compliance wall, downgradient from it should have even lower VOC concentrations. For Alternative 2, it is assumed that about 1/5 of the excavated soil will fail the TCLP test. Estimate is based on VOC concentrations of groundwater in October 1999, and January 2000. Non-hazardous soil will remain on-site in the same pile where the excavation material from the border wall trench has been stored.
- 7) Disposal off-site costs \$117/ton which includes stabilization and hazardous waste tax of 6%.
- 8) Polyethylene lining costs \$0.08/ft<sup>2</sup>. Area of top lining is 1.5 x area of bottom lining.

Table G-7  
 Calculation of Costs for Application of Vegetable Oil As Part of Alternative 2  
 Ash Landfill Feasibility Memorandum  
 Seneca Army Depot Activity, Romulus, NY

<u>Oil Volume Addition Calculations Using Assumptions of DDHU project (Parsons, 2000)</u>		<u>Soil Volume Calculations</u>	
Barrier Depth:	10 feet	depth of trench	10 feet
Radius of Influence	5 below ground surface	length of trench	20 feet
Porosity	0.15 feet	width of trench	3 feet
Number of trenches	10		
Emulsion Oil in Water	50% percent	volume of one trench	600 cf
Single Point Void (Oil) Volume:	59 cu.ft.		
	441 gal	Total Volume soil:	6,000 cf
Total Volume Oil:	4,406 gal		222 cy
	80 -55gal oil barrels	Weight of soil	333 ton
Oil Specific Gravity:	0.919		
Total Mass Oil:	33770 lb		
	16.89 ton		

**COST ESTIMATE FOR VEGOIL ADDITION**

Item	Units	Quantity	Unit Cost	Total Cost
VegOil	lb	33,770	\$0.38	\$12,833
Oil Transport	load	2	\$500.00	\$1,000 10 tons/load
excavator rental (excav & backfill)	day	10	\$800.00	\$8,000
TCLP test for excavated soil	test	3	\$175.00	\$525
Crew	day	20	\$366.80	\$7,336 20-10hr days, for 2 people
Constr. Mgmt.	day	5	\$322.10	\$1,611 5-10hr days for 1 person
Engineering	hours	40	\$25.53	\$1,021
project management	hours	8	\$48.77	\$390
			<b>TOTAL</b>	<b>\$32,716</b>



Table G-8  
Costs of Groundwater Treatment Alternatives at the Ash Landfill  
Ash Landfill Feasibility Memorandum  
Seneca Army Depot Activity, Romulus, NY

Item	ALTERNATIVE 1	ALTERNATIVE 2
<b>CAPITAL COSTS</b>		
Site visit records review	\$5,923 <sup>9</sup>	\$5,923 <sup>9</sup>
Prepare workplan for implementation of design	\$37,610 <sup>9</sup>	\$50,146 <sup>9</sup>
Preconstruction sampling (VOC analyses, and slug tests)	\$17,140 <sup>9</sup>	\$17,140 <sup>9</sup>
Monitoring well installation and development	\$17,705 <sup>5</sup>	\$29,284 <sup>5</sup>
Installation of iron wall(s)		
<i>Mobilization/Demobilization</i>	\$38,000 <sup>1</sup>	\$38,000 <sup>1</sup>
<i>Trench Excavation</i>	\$82,500 <sup>1</sup>	\$240,000 <sup>1</sup>
<i>Backfilling of excavated material, grading and revegetation</i>	\$9,000 <sup>1</sup>	\$9,000 <sup>1</sup>
<i>iron</i>	\$235,440 <sup>2</sup>	\$794,610 <sup>2</sup>
<i>iron shipment</i>	\$25,760 <sup>2</sup>	\$86,940 <sup>2</sup>
<i>Construction supervision</i>	\$11,423 <sup>9</sup>	\$22,846 <sup>9</sup>
<i>TCLP testing, soil stockpiling, disposal to hazwaste landfill (Alt 2)</i>	\$7,656 <sup>6</sup>	\$50,283 <sup>6</sup>
Surveying of newly installed wall(s) and monitoring wells	\$2,087 <sup>4</sup>	\$6,260 <sup>4</sup>
Vegetable oil addition		\$32,716 <sup>7</sup>
First year GW monitoring (sampling + analysis + prepare report + interim letter + project management)	\$61,162 <sup>3</sup>	\$80,877 <sup>3</sup>
<b>sub total</b>	<b>\$551,405</b>	<b>\$1,464,024</b>
contingency 20%	\$110,281	\$292,805
engineering/oversight 20%	\$110,281	\$292,805
<b>total capital (subtotal + contingency + engineering/oversight)</b>	<b>\$771,967</b>	<b>\$2,049,634</b>

<b>OPERATIONS AND MAINTENANCE COSTS</b>		
groundwater monitoring	\$55,299 <sup>3</sup>	\$58,309 <sup>3</sup>
maintenance of iron wall(s)	\$1,475 <sup>8</sup>	\$3,264 <sup>8</sup>
<b>sub total</b>	<b>\$56,774</b>	<b>\$61,572</b>
contingency 20%	\$11,355	\$12,314
engineering/oversight 20%	\$11,355	\$12,314
<b>total O &amp; M (subtotal + contingency + engineering/oversight)</b>	<b>\$79,483</b>	<b>\$86,201</b>
interest	10%	10%
years of operation	60	15
<b>present worth O &amp; M</b>	<b>\$792,224</b>	<b>\$655,655</b>

<b>TOTAL PRESENT WORTH COST (total capital + present worth O/M)</b>	<b>\$1,564,191</b>	<b>\$2,705,289</b>
---	--------------------	--------------------

**Notes**

- 1 Mobilization/demobilization, trench excavation, installation of iron into trench, backfilling, grading and revegetation costs provided by Diverse Solutions April 14, 2000.
- 2 Unit costs provided by Peerless Metal Powders and Abrasive. See iron quantity calculations in **Table G-3**.
- 3 See **Table G-5** for costs of groundwater monitoring.
- 4 Estimated based on actual cost of surveying of Boundary wall (existing wall) and wells around Boundary wall.
- 5 See **Table G-4** costs of installation of monitoring wells.
- 6 See **Table G-6** for costs of TCLP testing, soil stockpiling, disposal to hazwaste landfill (Alt 2)
- 7 See **Table G-7** for installation of vegetable oil
- 8 Maintenance cost is cost of agitation of iron in the upgradient aquifer/iron interface with a hollow stem auger. Cost includes mobilization, demobilization to site, drilling rig, and 1 feet augering that overlap. Overall it is \$7/square feet every 10 years. See **Table G-3**
- 9 Estimate based on expected labor hours for task





November 9, 1998

Jackie Travers  
Parsons Engineering Science  
30 Dan Road  
Canton, MA 02021

FAX: 781-401-2043

Dear Jackie:

Per your conversation with Noreen today, I understand that you would like to increase the tonnage to 225 tons (10 full truckloads) of Iron Aggregate so I have refigured the dollars as follows:

Iron Aggregate Size ETI 8/50-----	\$313/per net ton
225 net ton @ \$313/NT-----	\$70,425.00
Packaging in 3000# bags, palletized, covered with secured plastic covers @ \$14/per ton X 225 tons-----	\$ 3,150.00
Prices are FOB Detroit, MI. Freight is \$700 per truckload on flatbed truck or \$31.12/per net ton based on 22.5 tons.	
For delivered pricing take above freight X 115% = \$805 per truckload on flatbed trucks X 10 trucks -----	\$ 8,050.00
Grand total for delivered price of 225 tons is-----	<u>\$81,625.00</u>

Terms are Net 30 Days. If we receive your order within the next couple of days we would be able to meet your required delivery schedule of 12/7 thru 12/9/98.

I have contacted the freight company and the drivers will be not be able to unload the trucks for you; however, the freight company could call the site several hours in advance and you could arrange for someone to be available at that time.

We look forward to supplying you with our iron.

Very truly yours,

Paul W. Tousley  
President & CEO

Noreen P. Warrens  
Sales Associate

PWT/npw

Peerless Metal Powders & Abrasive

124 South Military • Detroit, Michigan 48209  
(313) 841-5400 Fax (313) 841-0240

# DIVERSE SOLUTIONS

Tel: 775-853-9447

Fax: 775-853-9448

## FACSIMILE COVER PAGE

To: Jacqueline Travers

From: Dan Oakley

Fax #: 1-781-4012575

Fax #: 775-853-9448

Company: Parsons Engineering Inc.

Tel #: 775-853-9447

Subject: Iron Filing Wall Installation Estimate

Sent: 4/14/00 at 12:59:36 PM

Pages: 6 (including cover)

### MESSAGE:

Attached is the budgetary estimate you requested. If you need anything else, please call. Thanks for requesting this information. Have a great weekend!

Dan

**DEWIND DEWATERING INC.  
PRELIMINARY TECHNICAL PROPOSAL  
FOR  
CONSTRUCTION OF PERMEABLE TREATMENT WALLS  
PARSONS ENGINEERING  
SENECA ARMY DEPOT  
ROMULUS, NEW YORK  
April 14, 2000**

**Introduction**

DeWind Dewatering Incorporated is a specialty construction company based in Holland, Michigan with an additional construction office located in Edgewater, Florida. With our custom-made one-pass trenching machines DeWind provides services such as construction of collection trenches, slurry walls, and permeable treatment walls for groundwater containment and/or treatment.

With our customized one-pass trenching equipment, DeWind offers a rapid and cost-effective method of installing Iron Filing Permeable Treatment Walls. Advantages of our installation method over other excavation and placement techniques include:

- The ability to excavate and backfill nominal fixed-width trenches to depths of 25 ft below the working platform. This ensures that minimal cuttings are generated and, consequently, minimal waste of iron filing.
- No large and open holes minimizes health and safety concerns.
- Rapid installation rates of 100-400 ft/day depending on site lithology.
- During excavation and placement de-watering is not typically required.

Parsons Engineering has requested preliminary technical and budgetary cost proposals for installing two Permeable Treatment Walls at the Seneca Army Depot in Romulus, New York. DeWind offers the following preliminary proposal in response to this request.

**Job Requirements**

The site geology consists glacial till overlying a fractured shale bedrock overlying a competent shall bedrock. The depth to bedrock is expected to vary from 7 to 12-ft bls.

Two permeable treatment walls will be installed. The first wall is located near the source and will be approximately 700 ft long and 2-ft wide. The second wall is located between the source and the existing iron filing wall. This wall will be approximately 700 ft long and 1-ft wide.

**DEWIND DEWATERING INC.  
PRELIMINARY TECHNICAL PROPOSAL  
FOR  
CONSTRUCTION OF PERMEABLE TREATMENT WALLS  
PARSONS ENGINEERING  
SENECA ARMY DEPOT  
ROMULUS, NEW YORK  
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The site geology consists glacial till overlying a fractured shale bedrock overlying a competent shall bedrock. The depth to bedrock is expected to vary from 7 to 12-ft bls.

Two permeable treatment walls will be installed. The first wall is located near the source and will be approximately 700 ft long and 2-ft wide. The second wall is located between the source and the existing iron filing wall. This wall will be approximately 700 ft long and 1-ft wide.

The iron filings will be installed from 1-ft below land surface to the top of the competent shale bedrock. Our one-pass trenching machine will be set up to install 12-inch wide iron filing walls. For the 2-ft thick permeable treatment wall we propose installing two 12-inch wide iron filing walls that will be parallel to each other and approximately 10-ft apart.

### Installation Procedure

Our trenchers are custom-built in Michigan using both standard and proprietary components. The trencher is a track mounted vehicle that has a cutting boom that resembles a large chain saw. To our knowledge these are the most powerful unconsolidated soil trenchers available in the North America with the trenchers being powered by 600-800 hp motors generating up to 200,000 ft/lbs of torque. The trenching and delivery operation cuts a nominal 14-inch or 20-inch wide trench and in one-pass continuously backfills the trench with the iron filings to create a Permeable Treatment Wall. There are no large and open trenches and de-watering is not typically required for installation.

The trenching machine will be readied for installation by attaching the cutting boom and iron filing delivery system. The cutting boom will excavate a trench by rotating the cutting chain until the boom and delivery system has cut into a vertical position relative to ground surface. At this point the delivery system will be loaded with the iron filings and a back slide plate on the delivery system will be removed. The back slide plate minimizes the waste of iron filings during the initial cut-in phase. The trencher will begin a forward motion while simultaneously cutting the trench, placing the cuttings adjacent to the trench via a conveyor system, and backfilling the trench with the iron filings from near ground surface to the total depth. Installation proceeds until the design length of the Permeable Treatment Wall has been installed. The installation procedure will be repeated for the additional walls.

A laser-guided control system will be used to control the depth of installation. This system enables DeWind to install the permeable treatment walls with a depth accuracy of plus or minus 0.1 ft.

### Schedule

We can typically mobilize to a site within 30 days of contract award. Our preliminary schedule is as follows:

Mobilization - 2 Days  
Equipment Assembly - 1 Day  
Installation - 8 Days  
Equipment Disassembly - 1 Day  
Demobilization - 2 Days

### Clarifications and Exclusions

The budgetary cost proposal is based on the following assumptions:

- The client will provide health and safety monitoring during construction.
- There are no underground utilities in the path of the treatment walls.
- The trenching machine will require approximately 20-ft overhead clearance along the installation path.
- DeWind is not responsible for the ultimate disposal of any water and soils generated as part of the installation or equipment decontamination processes.
- The client will supply the iron filings in 3000-lb bags.
- The client will perform any pavement removal or repair required for installation.
- Soils generated during installation will be placed within 100-ft of the permeable treatment walls.



DEWIND DEWATERING INC.  
 BUDGETARY COST PROPOSAL  
 PARSONS ENGINEERING  
 PERMEABLE TREATMENT WALL  
 2100 FT LONG AND 12-INCHES WIDE  
 SENECA ARMY DEPOT  
 April 14, 2000

ITEM	QUANTITY	UNITS	COST/UNIT	COST
Mobilization	1	L.S.	\$20,000	\$20,000
Excavate 12-inch wide trench up to 12 ft deep and backfill with iron filings	2100	LF	\$75	\$157,500
Site Restoration with reseeding	1	LS	\$9,000	\$9,000
Demobilization	1	LS	\$18,000	\$18,000
			<b>TOTAL</b>	<b>\$204,500</b>

File: seneca depot 2 bid