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Work Plan for a Treatability Study in Support of Remediation by Natural Attenuation at Sites OU-4 (FT-1) and the Building 1613 Site (ST-30)



**Shaw Air Force Base
South Carolina**

Prepared For

**Air Force Center for Environmental Excellence
Technology Transfer Division
Brooks Air Force Base
San Antonio, Texas**

and

**20 CES/CEVR
Shaw Air Force Base
South Carolina**

April 1997



**PARSONS
PARSONS ENGINEERING SCIENCE, INC.**

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**WORK PLAN FOR A TREATABILITY STUDY IN SUPPORT OF
REMEDiation BY NATURAL ATTENUATION AT SITE OU-4 (FT-1)
AND THE BUILDING 1613 SITE (ST-30)**

at

**SHAW AIR FORCE BASE
SOUTH CAROLINA**

April 1997

Prepared for:

**AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE
BROOKS AIR FORCE BASE
SAN ANTONIO, TEXAS**

AND

**20 CES/CEVR
SHAW AIR FORCE BASE
SOUTH CAROLINA**

Prepared by:

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SECTION 1

INTRODUCTION

This work plan, prepared by Parsons Engineering Science, Inc. (Parsons ES), presents the scope of work required for the collection of data necessary to conduct a treatability study (TS) for groundwater contaminated with chlorinated aliphatic hydrocarbons (CAHs) and benzene, toluene, ethylbenzene, and xylenes (BTEX) at two sites located at Shaw Air Force Base (AFB), South Carolina. The two sites to be investigated are Former Fire Training Area No. 1 Operable Unit 4 (OU-4) and the former fuel transfer line and underground storage tank (UST) leak at the Installation Restoration Program (IRP) Building 1613 Site. Hydrogeologic and groundwater chemical data collected under this program can also be used to evaluate various engineered remedial options; however, this work plan is oriented toward the collection of hydrogeologic data to be used in support of remediation by natural attenuation (RNA) with long-term monitoring (LTM) for restoration of groundwater contaminated with CAHs and/or BTEX.

As used in this report, RNA refers to a management strategy that relies on natural attenuation mechanisms to remediate contaminants dissolved in groundwater and to control receptor exposure risks associated with contaminants in the subsurface. The United States Environmental Protection Agency (USEPA) Offices of Research and Development (ORD) and Solid Waste and Emergency Response (OSWER) have proposed the following definition of natural attenuation (Wilson, 1996):

The biodegradation, dispersion, sorption, volatilization, and/or chemical and biochemical stabilization of contaminants to effectively

reduce contaminant toxicity, mobility, or volume to levels that are protective of human health and the ecosystem.

As suggested by this definition, mechanisms for natural attenuation of CAHs and BTEX include advection, dispersion, dilution from recharge, sorption, volatilization, abiotic degradation, and biodegradation. Of these processes, biodegradation commonly is the primary mechanism working to transform contaminants into innocuous byproducts. Contaminant destruction occurs through natural attenuation when indigenous microorganisms work to bring about a reduction in the total mass of contamination in the subsurface without the addition of nutrients. Patterns and rates of natural attenuation can vary markedly from site to site depending on governing physical and chemical processes.

RNA is advantageous for the following reasons:

- Contaminants can ultimately be transformed to innocuous byproducts (e.g., carbon dioxide, ethane, or water), not just transferred to another phase or location within the environment;
- Current pump-and-treat technologies are energy intensive and generally not effective at reducing residual contamination;
- The process is non-intrusive and allows continuing use of infrastructure during remediation;
- Current engineered remedial technologies may pose a greater risk to potential receptors than RNA (e.g., contaminants may be transferred into another medium during remediation activities); and
- RNA is less costly than conventional, engineered remedial technologies.

The disadvantages of RNA include the following:

- Contaminants considered to be more mobile and toxic can be produced as byproducts of biodegradation [e.g., vinyl chloride (VC)];
- The effectiveness of RNA is generally limited by site geochemistry and the availability of substrates;
- RNA may require a larger groundwater remediation zone than other remedial alternatives; and
- RNA frequently takes longer to reach specified concentration limits than other remedial alternatives.

This work plan was developed on the basis of discussions among representatives from Shaw AFB, the Air Force Center for Environmental Excellence (AFCEE), the USEPA National Risk Management Research Laboratory (NRMRL), Rust Environment and Infrastructure (Rust E&I), International Technology Corporation (IT), and Parsons ES. These discussions included a roundtable meeting attended by representatives from Shaw AFB, AFCEE, and Parsons ES at Shaw AFB on December 12, 1996, to discuss candidate sites and a specific approach for this RNA evaluation. In addition, available site characterization data were reviewed during the preparation of this work plan. All field work will follow the health and safety procedures presented in the *Program Health and Safety Plan for the Demonstration of Remediation by Natural Attenuation* (Parsons ES, 1996a) and the site-specific addendum to the program Health and Safety Plan (Parsons ES, 1997). This work plan was prepared for AFCEE and Shaw AFB.

1.1 SCOPE OF CURRENT WORK PLAN

This project is part of a large, broad-based initiative being conducted by AFCEE in conjunction with the NRMRL and Parsons ES. The intent of the RNA demonstration program is to develop a systematic process for scientifically investigating and documenting natural, subsurface chemical attenuation processes that can be factored into overall site remediation plans (e.g., see Wiedemeier *et al.*, 1995 and 1996a). For this reason, the work described in this work plan is directed toward the collection of

data in support of demonstrating the effectiveness of RNA of CAHs and BTEX in groundwater. Data required to develop alternative remedial strategies, should RNA prove not to be a viable groundwater remedial option at one or both of these sites, also will be collected under this program. A secondary goal of this multi-site initiative is to provide a database from multiple sites that demonstrates that natural processes of contaminant degradation often can reduce contaminant concentrations in groundwater to below acceptable cleanup standards before potential receptor exposure pathways are complete.

The specific objective for the demonstrations at OU-4 and the Building 1613 Site is to investigate the degree to which both CAH and/or BTEX compounds dissolved in groundwater are being remediated through natural attenuation so that this information can be used by Shaw AFB to develop an effective groundwater remediation strategy. These demonstrations are not necessarily intended to fulfill specific federal or state requirements regarding site assessments, remedial action plans, or other such mandated investigations and reports.

This work plan describes the site characterization activities to be performed by personnel from Parsons ES and the Subsurface Protection and Remediation Division of the NRMRL (formerly the USEPA Robert S. Kerr Environmental Research Laboratory) in support of the TS. Field activities will be performed to collect data for evaluating the effectiveness of RNA for restoration of groundwater contaminated with dissolved CAHs and/or BTEX at OU-4 and the Building 1613 Site. The data collected during the TS will be used along with data from previous investigations to characterize contaminant and geochemical patterns at the sites, and as input for analytical groundwater flow and solute transport models to make predictions of the future concentrations and extent of contamination.

Site characterization activities in support of the demonstration will include:

- Determination of preferential contaminant migration and potential receptor exposure pathways;

- Soil sample collection;
- Temporary groundwater monitoring point installation;
- Groundwater sample collection from newly installed monitoring wells or points, and existing monitoring wells;
- Light, non-aqueous phase liquid (LNAPL) sampling (if present in wells);
- Surface water and sediment sample collection;
- Soil, groundwater, sediment, and surface water sample analysis; and
- Aquifer testing.

The materials and methodologies to accomplish these activities are described in Section 3.

The contaminant fate and transport modeling effort has three primary objectives: 1) predict the future extent and concentration of dissolved contaminant plumes by modeling the effects of advection, dispersion, sorption, and biodegradation; 2) assess the possible exposure of potential downgradient receptors to contaminant concentrations that exceed levels intended to be protective of human health and the environment; and 3) provide technical support for selection of RNA as a component of site remediation at regulatory negotiations, as appropriate.

Previously reported site-specific data and data collected during the supplemental site characterization activities described in this work plan will be used as input for the groundwater flow and solute transport models. Where site-specific data are not available, conservative parameter values for the types of aquifer materials present at the site will be obtained from widely accepted, published literature and used for model input. Sensitivity analyses will be conducted for the parameters that are known to have the greatest influence on the model results, and where possible, the models will be calibrated using historical site data. If it is shown that RNA by itself is not the most

appropriate remedial option, Parsons ES will recommend an appropriate groundwater remedial technology on the basis of available data.

This work plan consists of six sections, including this introduction. Section 2 presents a review of available, previously reported, site-specific data and preliminary conceptual models for OU-4 and the Building 1613 Site. Section 3 describes the proposed sampling strategy and procedures to be used for the collection of additional site characterization data. Section 4 describes the quality assurance/quality control (QA/QC) measures to be used during this project. Section 5 describes the remedial option evaluation procedure and report format. Section 6 contains the references used in preparing this document. There are four appendices to this work plan. Appendix A contains a listing of containers, preservatives, packaging, and shipping requirements for soil and groundwater analytical samples. Appendices B and C contain supplemental site data for OU-4 and the Building 1613 Site, respectively. Appendix D contains a sampling memo guiding preliminary monitoring point installation and stratigraphic analysis at OU-4 and the Building 1613 Site performed by the US Army Corps of Engineers (USACE).

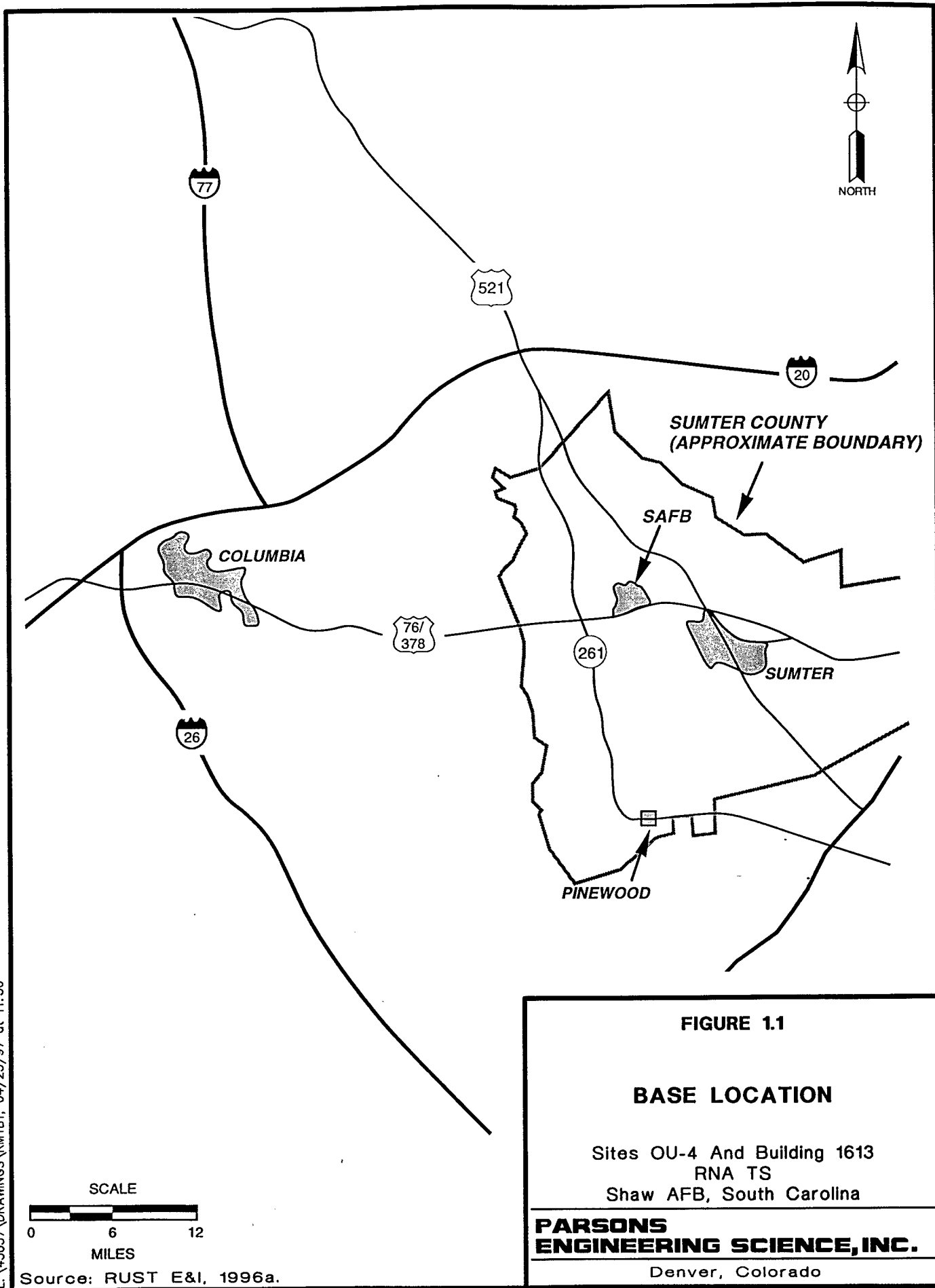
1.2 BACKGROUND

Shaw AFB is located near the center of South Carolina in northwest Sumter County, approximately 37 miles east of Columbia and seven miles west of the City of Sumter along US Highway 76 (Figure 1.1). The Base encompasses 3,326 acres of land set in a mostly rural and agricultural area; however, residential and commercial developments are present on the western and southeastern sites of the Base (Rust E&I, 1995b).

1.2.1 OU-4 Background

Operable Unit 4 encompasses the area impacted by activities at Former Fire Training Area 1. The site is defined as approximately 14 acres located between Patrol

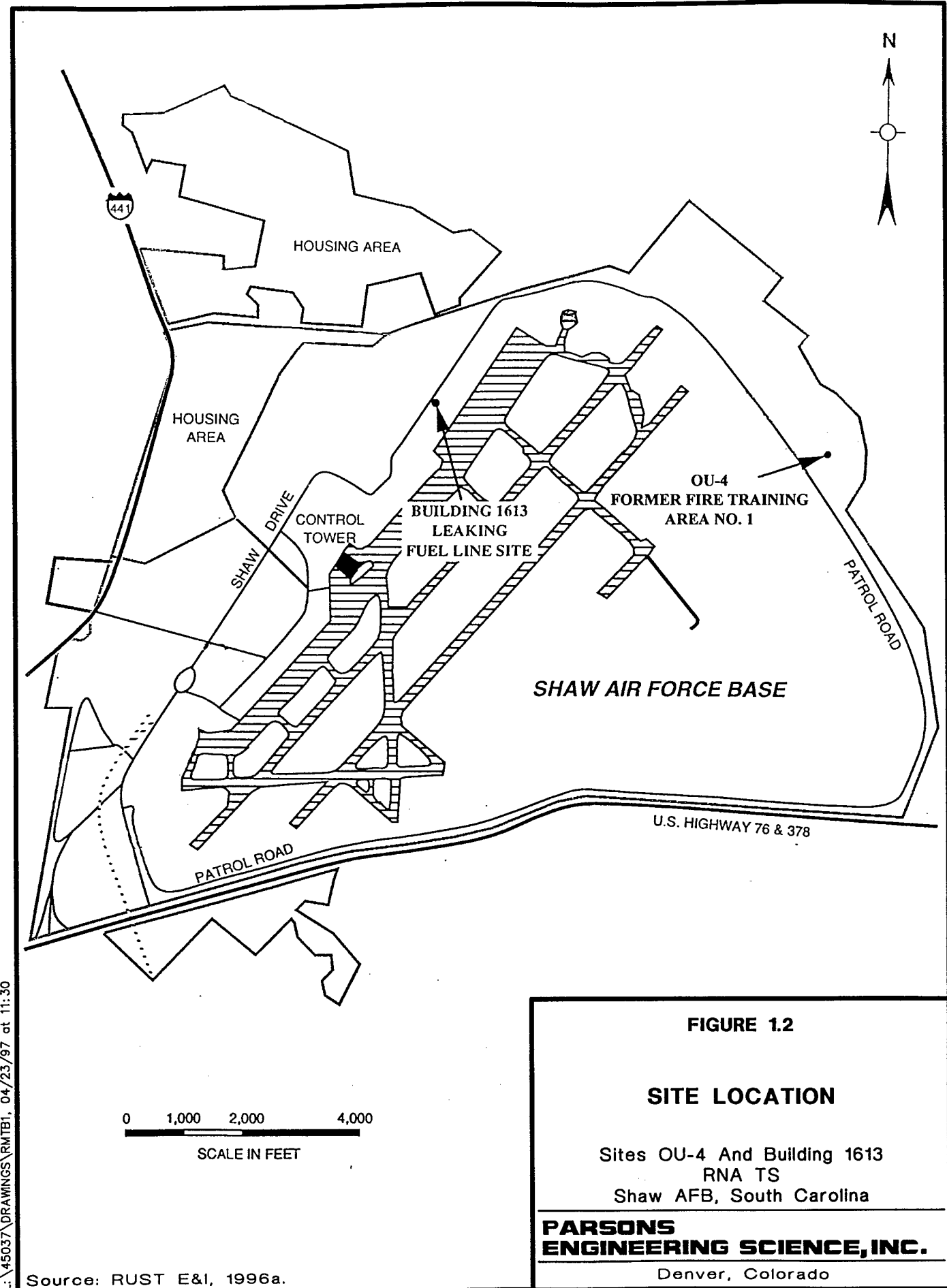
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Road on the west and Long Branch a surface water drainage along the east-northeast Base property boundary) on the east (Figures 1.2 and 1.3). The remnants of a berm provide evidence for the location of a former burn pit; however, interpretation of historic aerial photographs suggests that the location of the fire ring was moved periodically during the operation of the facility. The site features sparse vegetation except in the heavily wooded perimeter and on the slopes near Long Branch.

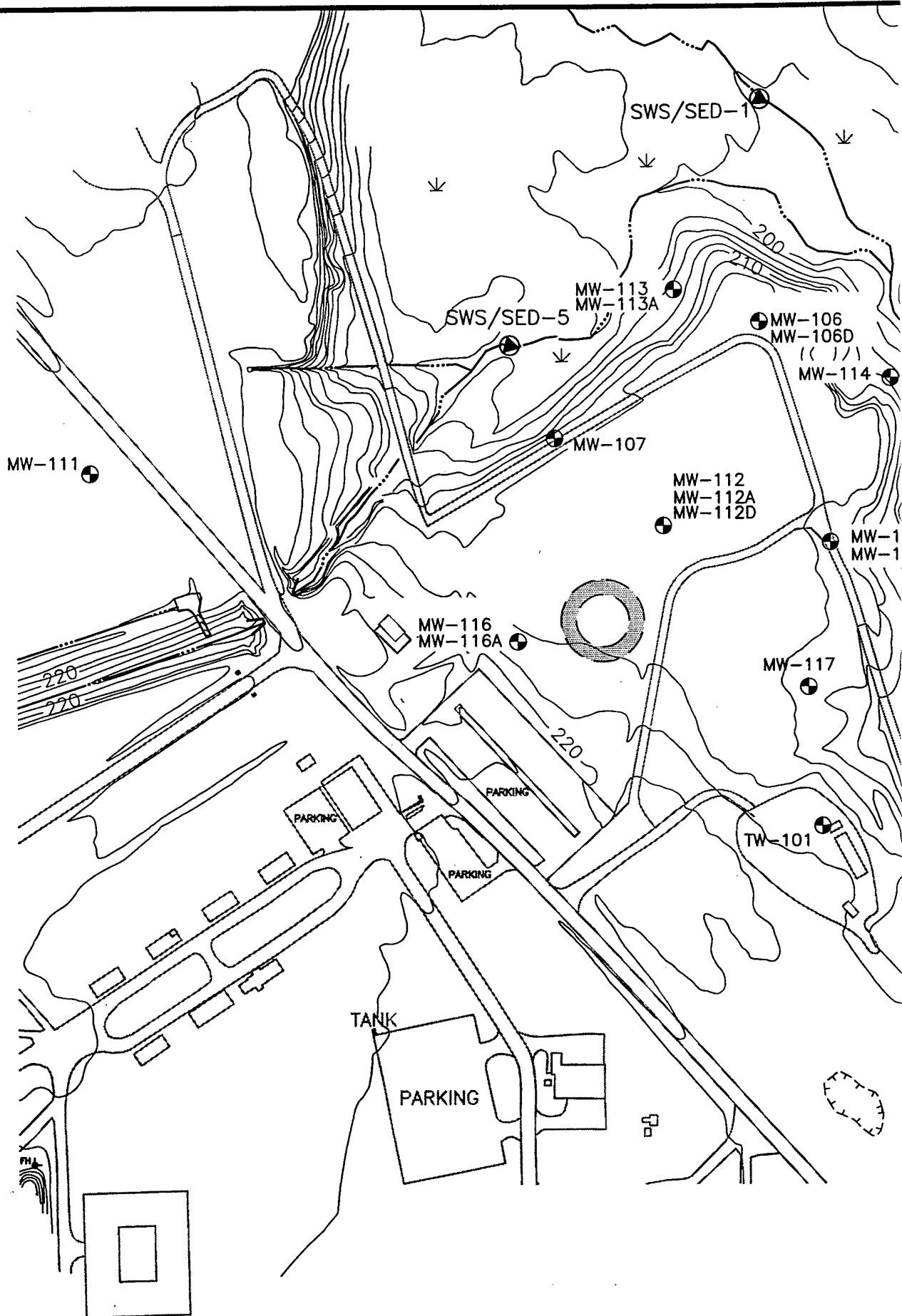
Reportedly, the former fire training area was used for weekly fire training exercises from 1941 to 1969. A variety of combustible wastes were burned during the fire training exercises, including jet fuel, waste oils, hydraulic fluids, spent solvents, contaminated fuels, and napalm. Waste materials were hauled to the site in drums and poured into the unlined burn pits for ignition. Extinguishing agents reportedly used during training exercises included water, carbon dioxide, protein foam, and aqueous-film-forming foam. Some of the drums used to store and transport the combustibles may have been buried at the site (Parsons ES, 1994; Rust E&I, 1995b).

The following abbreviated site history has been distilled from the Final Remedial Investigation Report (Rust E&I, 1995b). The fire training area was first identified as having a "high potential for environmental contamination" in a 1983 Phase I assessment by Engineering-Science (Engineering-Science, 1983). Following Phase II, Stage I and Stage II investigations performed respectively by Research Triangle Institute (RTI) in January 1986 (RTI, 1986) and Law Environmental (Law) between July 1986 and February 1987 (Law, 1989), Law prepared a remedial action plan to identify, evaluate, and recommend remedial action alternatives which would address the contamination at the site (Law, 1989). At that time, a groundwater monitoring program was selected as the alternative which would provide the appropriate level of protection to the environment and public health at the most reasonable cost. After collection of two years of quarterly groundwater monitoring data (1988 - 1990), it was decided that long-term monitoring did not adequately address site remediation and that additional investigations were warranted. Since reopening the investigation, Law

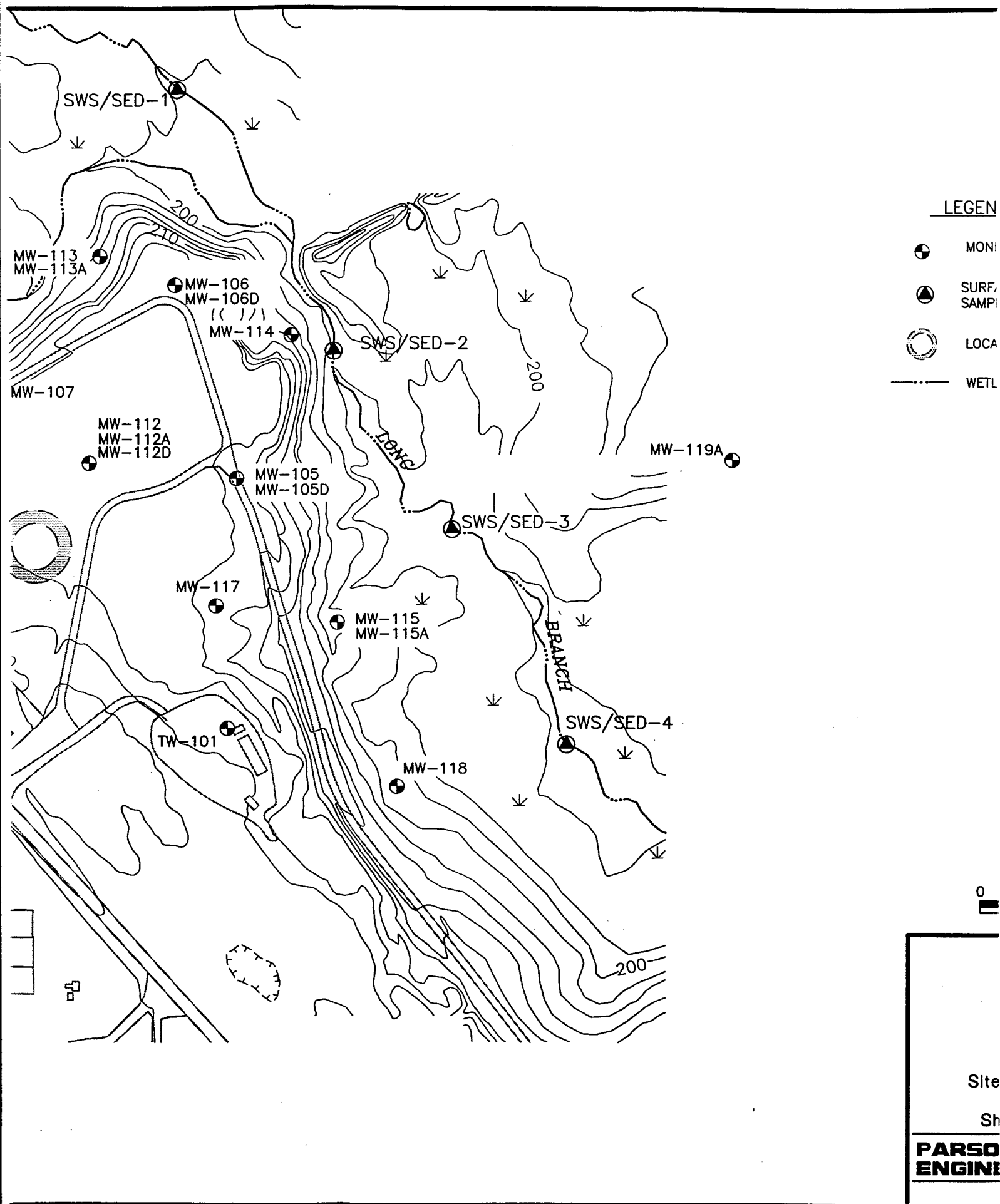


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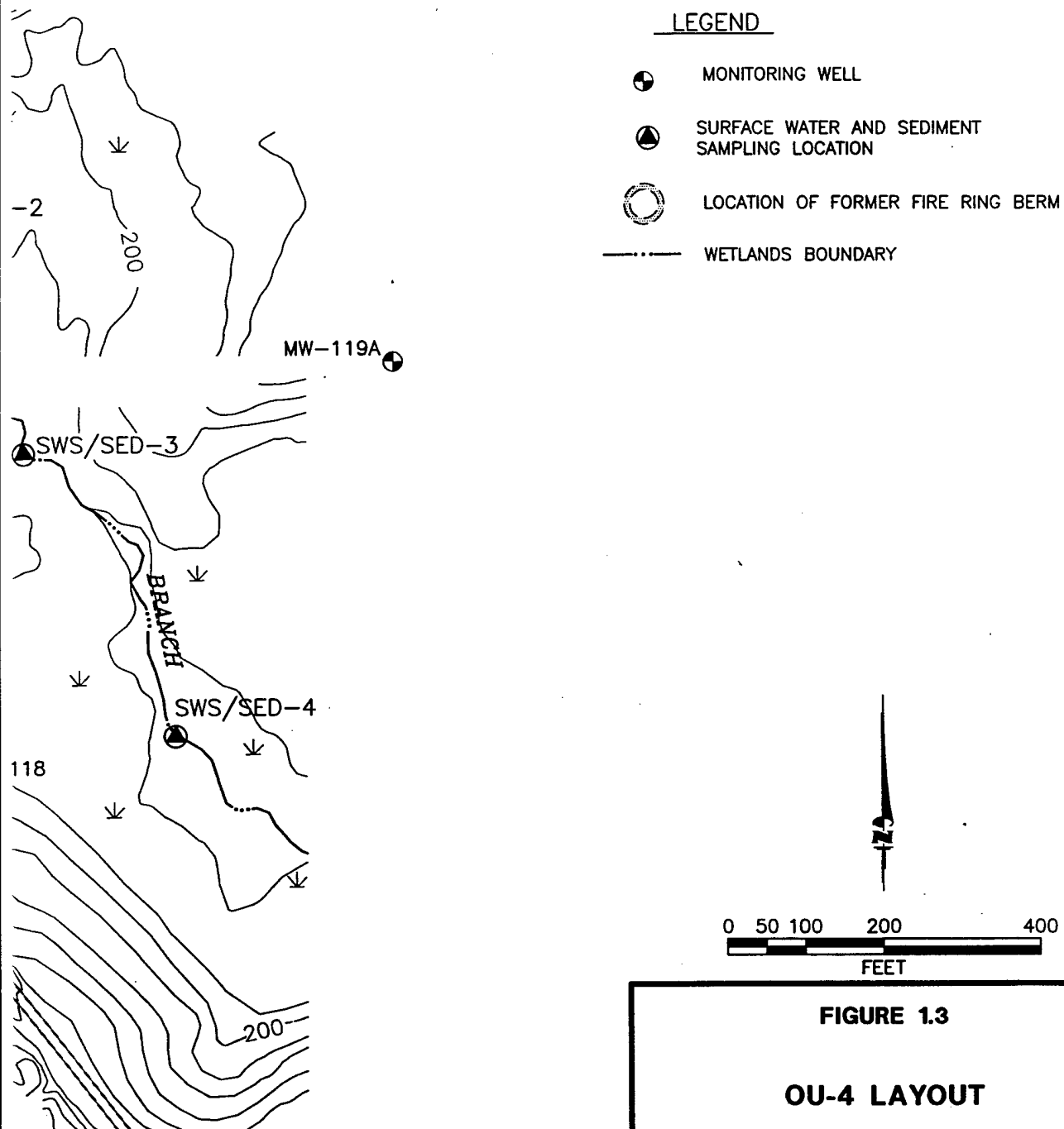


FIGURE 1.3

OU-4 LAYOUT

Sites OU-4 And Building 1613
RNA TS
Shaw AFB, South Carolina

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Denver, Colorado

prepared a draft remedial investigation/feasibility study (RI/FS) report in 1991 (Law, 1991), and Rust E&I conducted supplemental RI activities and issued the Final RI in 1995 (Rust, 1995b). The following activities have been performed at the site as a part of the last decade's investigations:

- Drilling for subsurface evaluation and installation of monitoring wells;
- Collection of soil, sediment, groundwater, and surface water samples;
- Completion of soil gas, geophysical, and topographic surveys; and
- Performance of aquifer tests in the shallow aquifer.

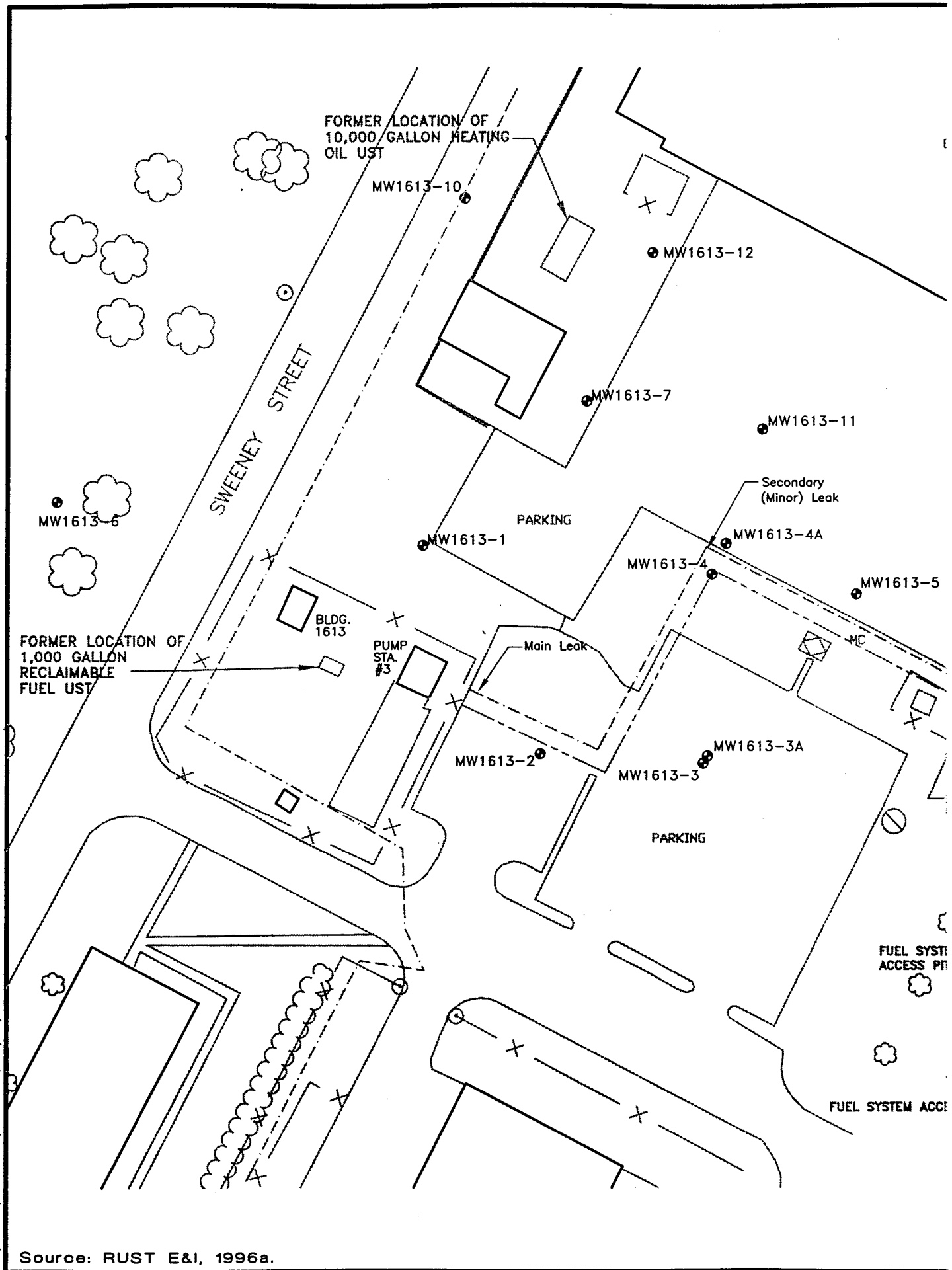
Beginning with the supplemental remedial investigation activities at the fire training area, the applicability of several remedial alternatives has been evaluated through pilot tests and bench-scale studies. The majority of these activities have focused on soils in the vicinity of the former (bermed) burn pit. Rust E&I conducted short-duration soil vapor extraction (SVE) pilot tests in the former bermed burn pit in 1993 to collect operating data for full-scale design, to monitor oxygen-enhanced respiration rates of indigenous microorganisms, and to compare the operating effectiveness of horizontal SVE wells versus vertical SVE wells. Success was limited due to vent well construction designs which contributed to air short-circuiting and soil water recovery (Rust E&I, 1993). A laboratory bench-scale study, also performed in 1993, concluded that a significant population of indigenous microorganisms are present in contaminated site soils, and rapid growth was exhibited when supplied with oxygen (Rust E&I, 1993). In 1994, Parsons ES performed a bioventing pilot test in a portion of the former bermed burn pit unaffected by the SVE system (Parsons ES, 1994 and 1995). After 1 year, soil BTEX concentrations decreased 1 to 3 orders of magnitude within approximately 30 feet of the vent wells (Parsons ES, 1996b). The bioventing pilot system has remained in operation in order to continue remediation of the heavier hydrocarbons within the former bermed burn pit.

The most recent pilot test, conducted in November 1996, addressed chlorinated solvent contamination dissolved in groundwater in the vicinity of monitoring well MW-117, where the highest historical concentrations of dissolved chlorinated solvents have been detected at OU-4 (IT, 1997). The pilot test attempted to stimulate chemical oxidation through the one-time injection of hydrogen peroxide, sulfuric acid, and ferrous sulfate. On the basis of results collected during the first week following the injection, total VOC concentrations decreased approximately 30 percent at MW-P1. The study concluded that approximately 80 percent of mass removal was attributed to stripping, with the remaining 20 percent attributed to chemical oxidation. This rate of chemical oxidation was approximately 35 percent of the anticipated chemical oxidation rate. Once again, these statistics were based on results collected one week after injection. Long-term chemical oxidation has not been evaluated, nor have long-term concentration changes. Data to evaluate these items will be collected in April 1997. The cost to remediate site groundwater using hydrogen peroxide injection was estimated at approximately 2.5 million dollars (IT, 1997).

1.2.2 Building 1613 Site Background

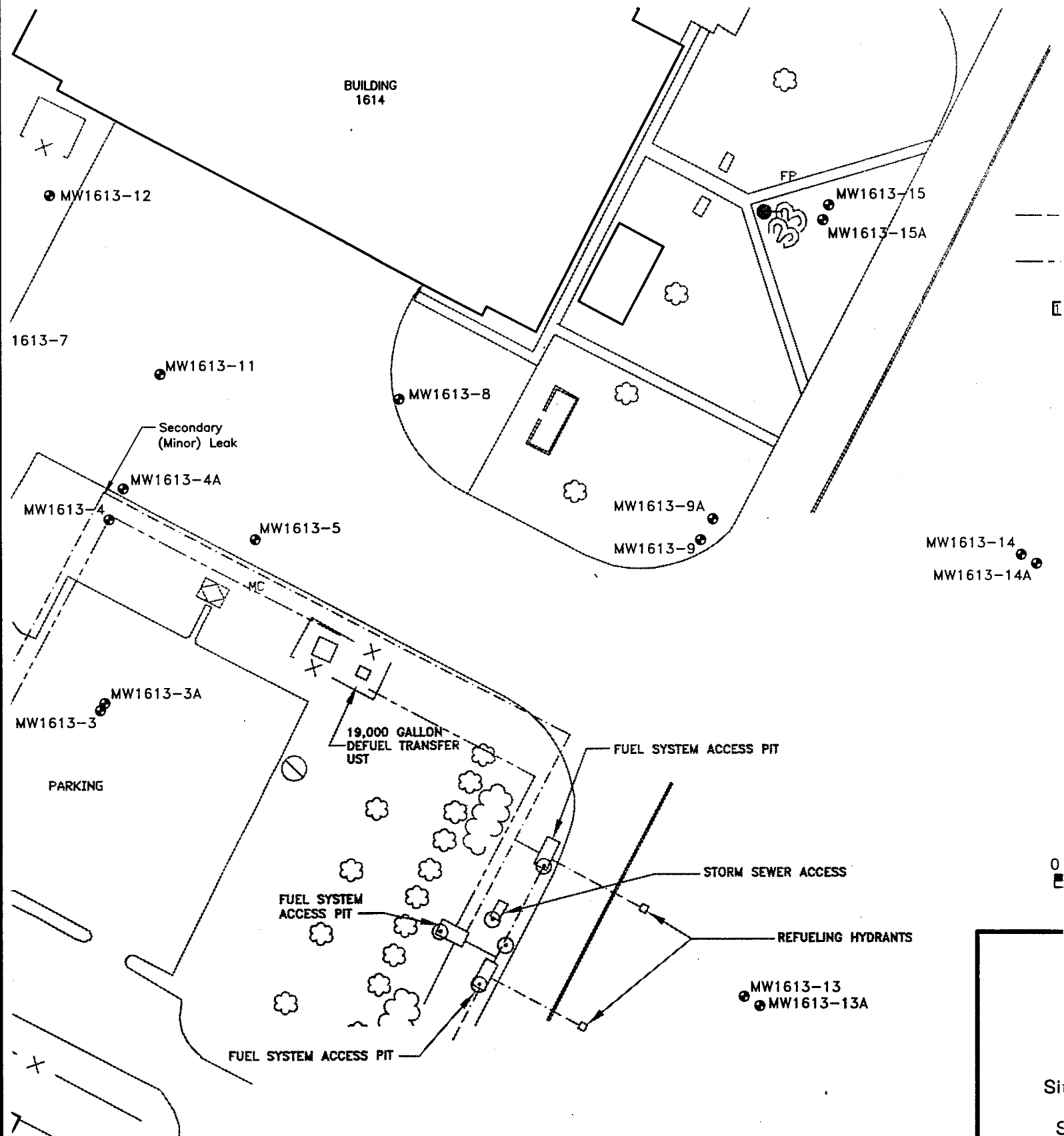
The Building 1613 Site is located in the northeast section of the base between Sweeney Street and the flight line (Figure 1.2). Several structures are present at the site including Building 1613, Building 1614, Pump Station #3, and asphalt and concrete parking areas with landscaped medians (Figure 1.4). The Building 1613 site includes soil and groundwater contamination originating from fuel transfer lines and USTs in the area. Known sources of soil and groundwater contamination at the site include:

- Underground fuel transfer lines stretching between Pump Station #3 and flight line refueling hydrants (approximately 360 feet east/southeast of Pump Station #3);
- A former 1,000-gallon reclaimable fuel UST (associated with a fuel/water separator system) located approximately 30 feet west of Pump Station #3; and



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Source: RUST E&I, 1996a.



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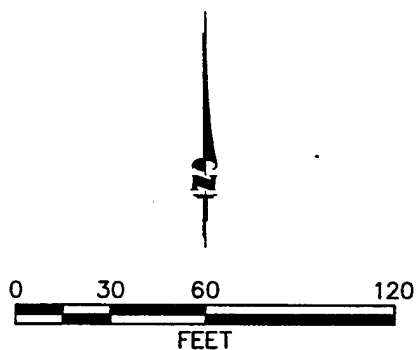
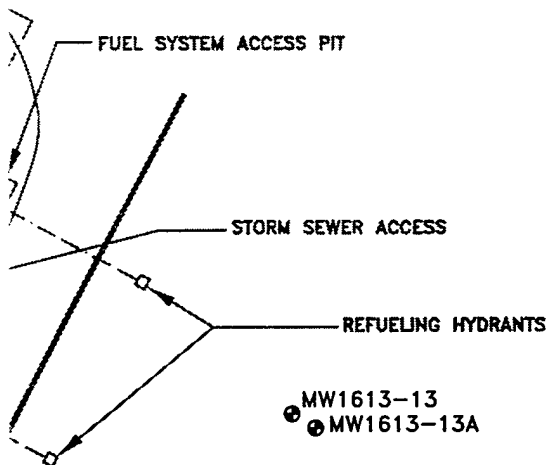
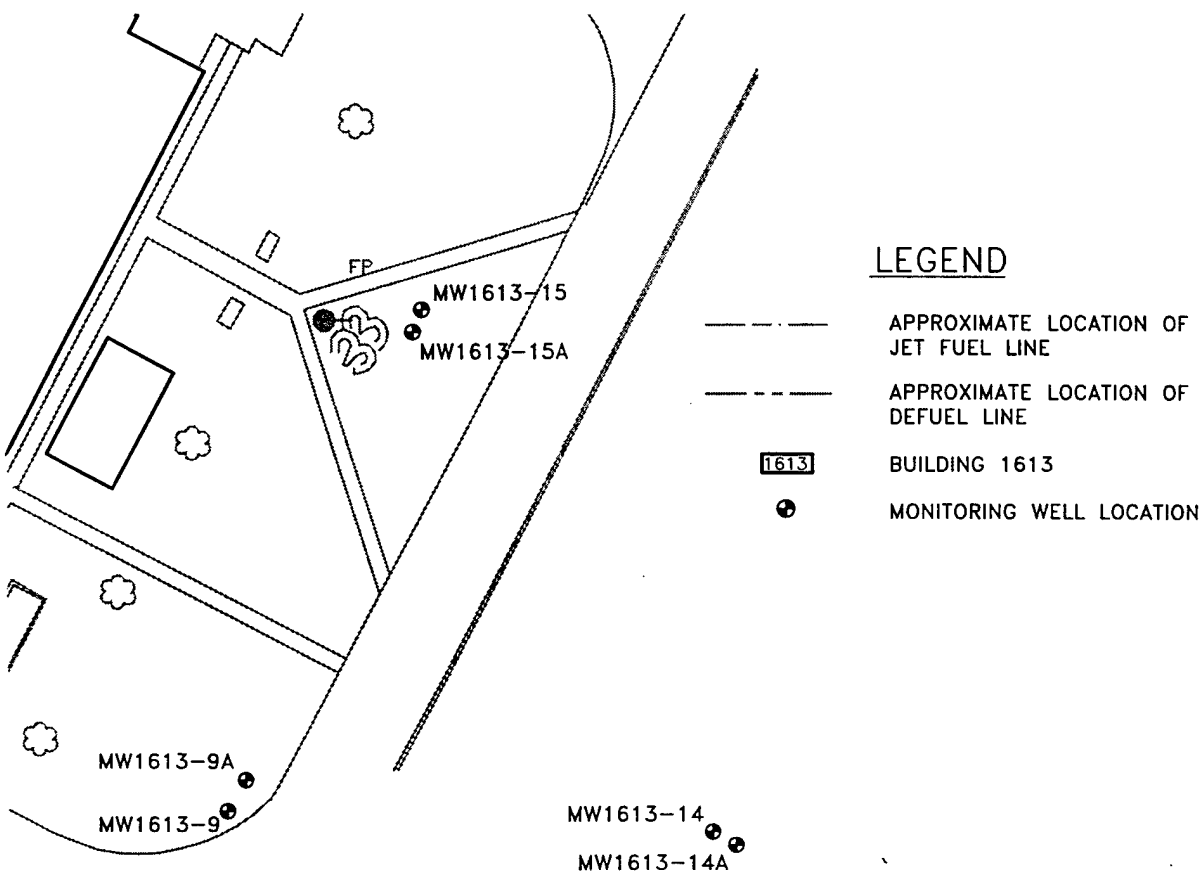


FIGURE 1.4

**BUILDING 1613
SITE LAYOUT**

Sites OU-4 and Building 1613
RNA TS
Shaw AFB, South Carolina

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Denver, Colorado

- A former 10,000-gallon heating oil UST located 50 feet southwest of Building 1614 (about 180 feet northeast of Pump Station #3).

Two underground components of the fuel system that reportedly have not leaked include a 19,000 gallon UST located along the defuel line between Pump Station #3 and the flight line, and the underground defuel line that parallels the supply line between Pump Station #3 and the flight line (Rust E&I, .

On June 25, 1991, a six-inch jet-fuel supply line was suspected to be leaking at a location 20 feet east of Pump Station #3. The soils above the fuel line were excavated and it was visually confirmed that the dresser coupling at the union of two pipe lengths had failed, resulting in a fuel release. As a precautionary measure, the dresser coupling on the adjacent defuel line was also excavated and examined for leaks. Although no leaks were detected in the defuel line, Shaw AFB personnel replaced the dresser couplings on both the transfer and defuel lines. Subsequent pressure tests indicated additional leakage in the fuel transfer line. Further excavation uncovered a second small leak at a failed dresser coupling approximately 200 feet northeast from Pump Station #3. Dresser couplings on both the transfer and defuel lines were removed and replaced with welded pipe sections. The quantity of jet fuel released into the subsurface is unknown, although soils from one side of the first excavation were saturated with fuel. Approximately 80 tons of jet-fuel-impacted soil was excavated during repair efforts and shipped off-site for remediation and disposal by G&K Tank Services of Sumter, South Carolina. Soil analyses obtained from the excavation and excavated soil piles indicated maximum BTEX and TPH concentrations of 84 µg/kg and 592 mg/kg, respectively.

In June 1993, a site inspection (SI) was conducted at the Building 1613 site to evaluate the possibility of site closure or the need for additional site investigation. The

SI concluded that additional soil and groundwater investigations were required to determine the extent of contamination at the Building 1613 site (Rust E&I, 1994).

In March 1994, the 10,000-gallon heating oil UST located 50 feet southwest of the southwest corner of Building 1614 was removed by a U.S. Navy contractor. No soil analytical data is available for the tank removal activities. All soil excavated during the tank removal process was returned to the excavation, along with clean fill to replace the void created by the tank.

From May through September 1994, an Expanded Assessment (EA) was performed at the site. The included the installation of 11 monitoring wells (MW1613-1, -2, -3, -3A, -4, -4A, -5, -6, -7, -8, and -9) and soil and groundwater chemical analyses. Sampling results indicated the presence of soil and groundwater contamination, although the extents were not determined. On the basis of the EA Report and a meeting between representatives of the South Carolina Department of Health and Environmental Control (DHEC) and Shaw AFB on February 9, 1995, additional site investigation activities were recommended to further define the extent of contamination and to identify the possible source areas.

On October 6, 1994, the 1,000-gallon UST located 20 feet east of Pump Station #3 was removed. ARM Environmental Services, Inc. (ARM) performed a closure assessment for the UST removal (ARM, 1994a) and reported strong petroleum odors emanating from the excavation. As part of the assessment two soil samples (1613-1 and 1613-2) were collected from a depth of 8 feet below ground surface (bgs) in the UST excavation. Elevated BTEX concentrations were detected in soils from both locations. According to ARM (1994a), all soil excavated during the tank removal was returned to the excavation and clean fill was used to replace the void created by the tank, in accordance with DHEC guidance.

From June through August 1995, a Supplemental EA was conducted at the Building 1613 Site to further define the source areas and the extent of soil and groundwater contamination (Rust, 1995c). The investigation included installation of monitoring wells (MW1613-9A, -10, -11, -12, -13, -13A, -14, -14A, -15, and 15A), a soil gas survey, and soil and groundwater sampling for chemical analysis. The results of the EA and the Supplemental EA reports were combined into a single report (Rust, 1995c).

In May 1995, IT began removing the LNAPL that had collected in wells MW1613-4 and MW1613-7. As of April 17, 1996 IT had removed 95 gallons of product from the wells (Rust E&I, 1996b).

On May 23 and 24, 1995, pressure tests were conducted on the jet supply and defuel pipelines located in the vicinity of Pump Station #3. Pressure tests were performed on the six-inch jet fuel supply line that connects Pump Station #3 to the hydrant filter pits along the northwest edge of the flightline. In addition, pressure tests were performed on the four-inch defuel pipeline that connects the hydrant pits to the 19,000-gallon defuel UST (Figure 1.4). The pressure tests indicated that the pipes were not leaking.

In October 1995 and January 1996, quarterly groundwater monitoring was conducted at the Building 1613 Site by Rust E&I. The results of these monitoring events are summarized in Quarterly Monitoring Reports (Rust E&I, 1996a).

On April 2-4, 1997 the USACE attempted to collect preliminary site stratigraphic data with a cone penetrometer and laser induced fluorescence (CPT/LIF) apparatus. Very hard soils at approximately 17 and 27 feet bgs prevented the successful collection of soil stratigraphy data with the CPT/LIF, and this work terminated after two pushes.

SECTION 2

DATA REVIEW AND CONCEPTUAL MODEL DEVELOPMENT

Site-specific data were reviewed and used to develop conceptual models for groundwater flow and contaminant transport regimes at OU-4 and the Building 1613 Site. The conceptual models guided the selection of sampling locations and the analytical data requirements needed to support the modeling efforts and to evaluate potential remediation technologies, including natural attenuation. Section 2.1 presents a synopsis of available site characterization data. Section 2.2 presents the preliminary conceptual groundwater flow and solute transport models that were developed on the basis of these data.

2.1 DATA REVIEW

The following sections are based upon review of data from the following sources:

OU-4

- Final RI Report, Operable Unit #4, Former Fire Training Area No. 1, IRP Site No. FT-1, Shaw AFB, SC (Rust E&I, 1995b);
- Draft Chemical Oxidation Pilot Test Report, Operable Unit 4, IRP Site No. FT-01, Shaw AFB, SC (IT, 1997);
- Draft Interim Bioventing Pilot Test Results Report, IRP Site FT-01 (Former Fire Training Area 1) and IRP Site SS-15 (POL Fuel Depot) Shaw AFB, SC (Parsons ES, 1995);

Building 1613 Site

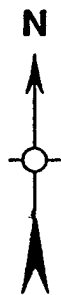
- Draft Final Site Inspection Report, Multi-Sites Group II, Shaw AFB, SC (Rust E&I, 1994);
- Draft EA Report, Multi-Sites Group II, Shaw AFB, SC (Rust E&I, 1995a);
- Draft Supplemental EA Report, Multi-Sites Group II: Building 1613 Site and Building 706/200 Site, Shaw AFB, SC (Rust E&I, 1995c);
- Final Corrective Action Plan/Groundwater Mixing Zone Application for the Building 1613 Site (Rust E&I, 1996b); and
- Quarterly Monitoring Report for Multi-Sites Group II, April 11, 1996 (Rust E&I, 1996a).

2.1.1 Topography, Surface Hydrology, and Climate

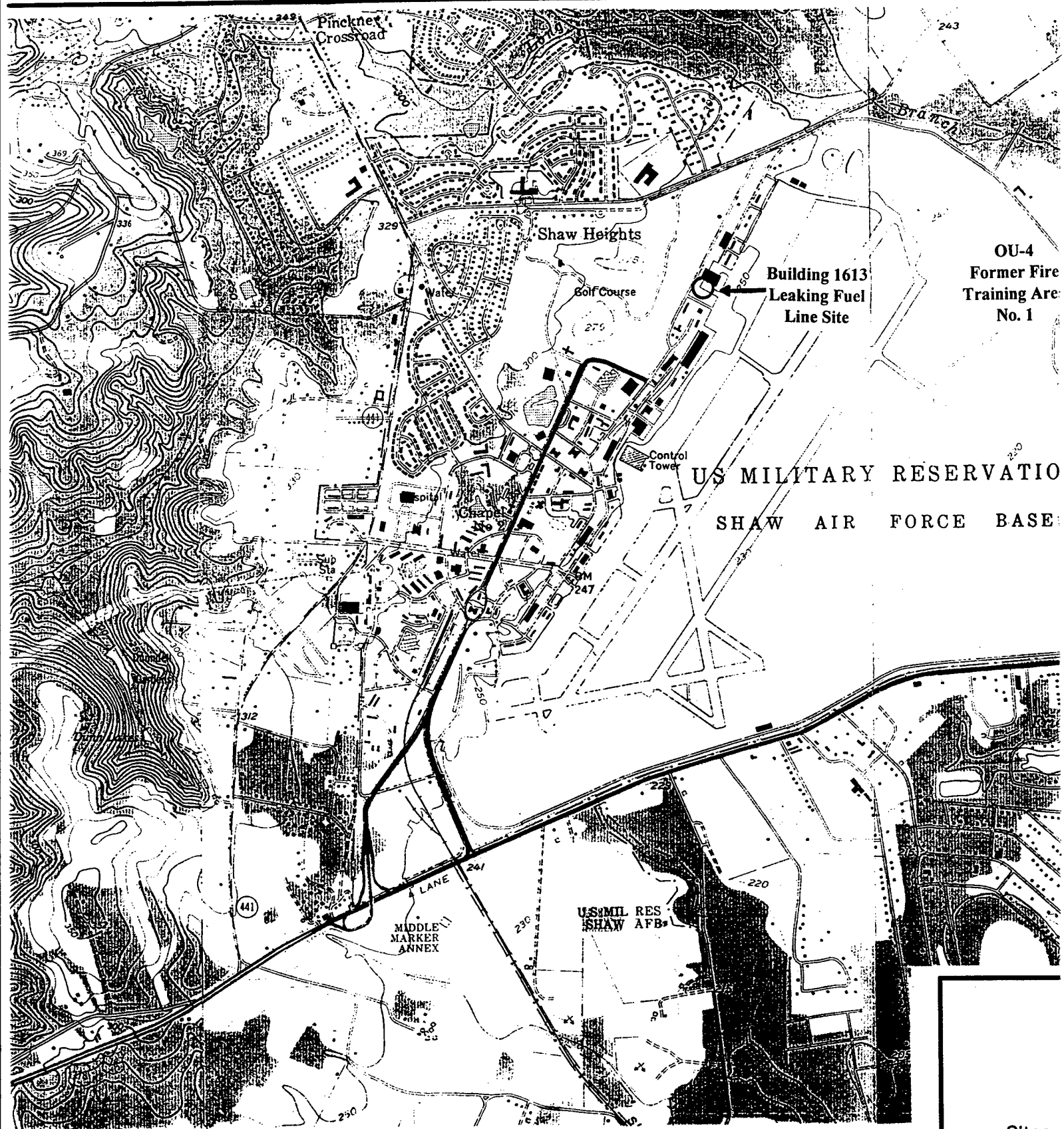
Shaw AFB lies along the border of the Upper and Middle Coastal Plain subprovinces of the Atlantic Coastal Plain Physiographic Province. This transitional boundary is marked by the Orangeburg and expressed at the surface by a change in elevation (Rust E&I, 1995b). A topographic map with the locations of OU-4 and the Building 1613 Site identified is presented as Figure 2.1.

Surface water and drainage features in the vicinity of the Base are shown on Figure 2.2. Long Branch and a drainage ditch border the Base to the east and south, respectively. The east-flowing drainage ditch joins the south-flowing Long Branch to the southeast of the Base, approximately 1 mile downgradient from Booths Pond. Several other ponds, including Sawmill Pond, Frierson Pond, and Loring Mill Pond, also are located southeast of the Base.

Topography surrounding OU-4 can be characterized as relatively flat in the vicinity of the former bermed fire pit to steeply sloping near Long Branch (Figure 1.3). Long



Reference: U.S.G.S. 7.5 Minute Topographic Quadrangle;
Wedgfield, 1953, Photo Revised 1982;
Sumter West, 1957, Photo Revised 1982.



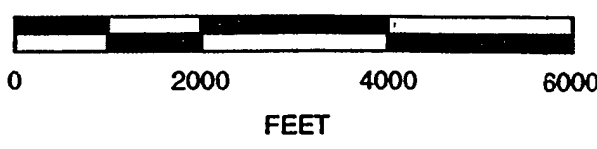
OU-4
Former Fire
Training Area
No. 1

US MILITARY RESERVATION
SHAW AIR FORCE BASE

US MIL RES
SHAW AFB

MIDDLE
MARKER
ANNEX

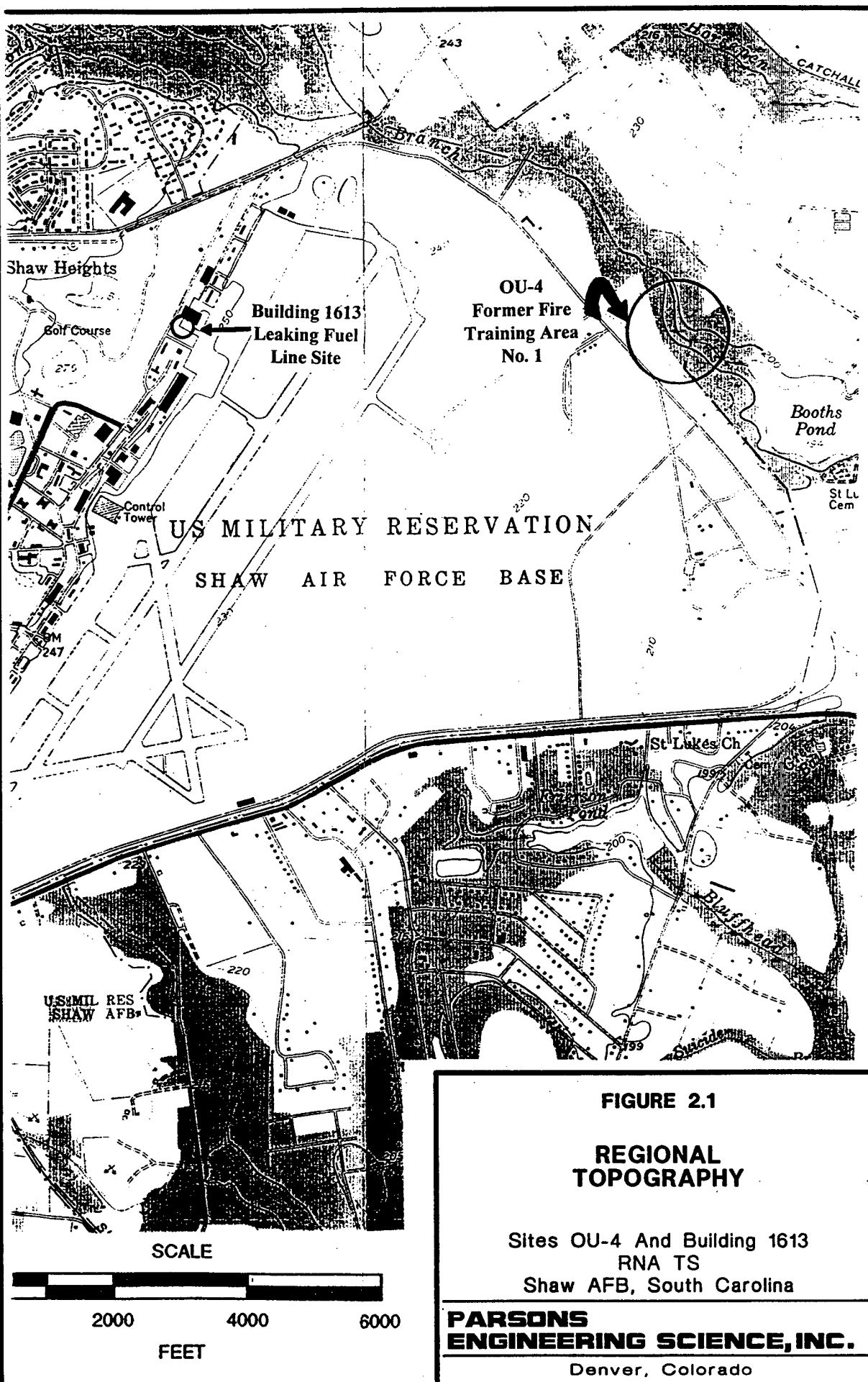
SCALE

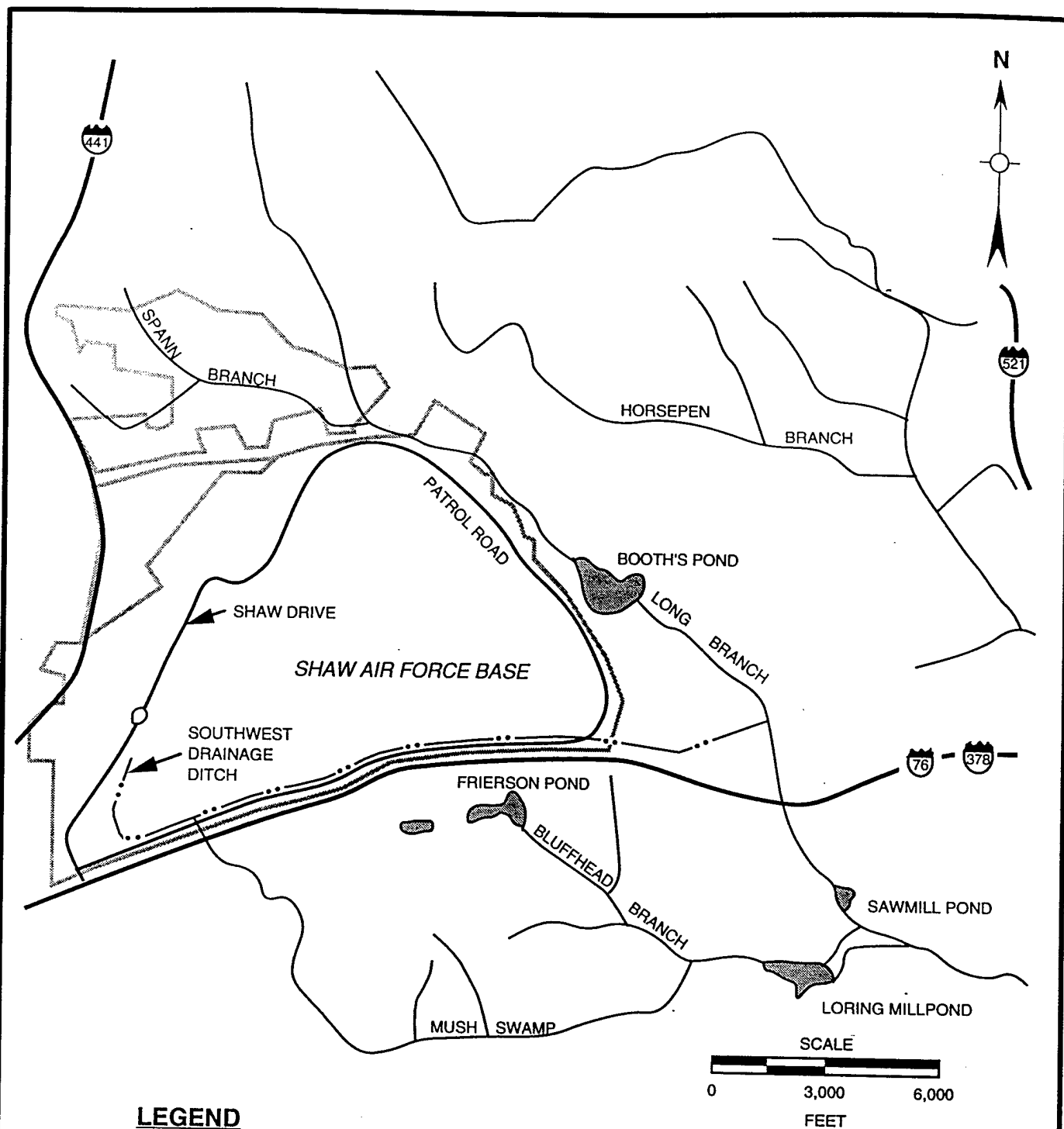


Sites

Shaw

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LEGEND

— BASE BOUNDARY

FIGURE 2.2

SURFACE WATER DRAINAGE

Sites OU-4 And Building 1613
RNA TS
Shaw AFB, South Carolina

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Denver, Colorado

Source: RUST E&I, 1993b.

Branch and an ephemeral stream that enters Long Branch from the west occupy the Long Branch flood plain and mark the eastern and northern site boundaries, respectively. Elevations range from approximately 198 feet above mean sea level (msl) at Long Branch to approximately 216 feet msl at the bermed former burn pit. Surface runoff drains to the north and east into the bordering streams (Rust E&I, 1995c).

In the vicinity of OU-4, Long Branch is 8 to 10 feet wide, 2 to 4 feet deep, and carries an estimated flow of 1,000 gallons per minute. Long Branch discharges to Booths Pond approximately 2,000 feet downstream from the site. When flowing, the ephemeral stream along the northern boundary of OU-4 can have a width of approximately 4 feet and a depth of 9 inches.

The topography in the area of the Building 1613 Site grades sharply from relatively flat concrete and asphalt-covered areas along the runways in the east to rolling grass-covered hill on the golf course in the west. This configuration promotes groundwater recharge on the western edge of the study area. The elevation of the Building 1613 Site ranges from 250 feet msl to 265 feet msl. Local surface drainage is controlled by manmade features such as parking lot curbing, ditches, catchment basins, and storm sewers.

The mean annual temperature at Shaw AFB is 64 degrees Fahrenheit (°F), with an average of 46 °F in January and 81 °F in July. Precipitation averages approximately 46 inches per year distributed relatively evenly throughout the year, with the highest monthly maximum in July and the lowest in October. Average relative humidity is relatively constant (and high) throughout the year, ranging from 72 to 86 percent (Rust E&I, 1995b).

2.1.2 Overview of Geology and Hydrogeology

The following sections provide an overview of regional and site geology and hydrogeology.

2.1.2.1 Regional Geology

The following summary of regional geology is derived from a more thorough version provided in several reports from Rust E&I (1995a, 1995b, and 1995c).

Shaw AFB is underlain by Cretaceous to Quaternary sediments and sedimentary rocks that in turn overlie a basement of Paleozoic crystalline and Triassic sedimentary rocks. These sediments and sedimentary rocks are present as a sedimentary wedge that thickens and dips to the south and southeast. The sedimentary rock sequence at Shaw AFB is approximately 600 to 700 feet thick. Cretaceous formations in this area make up the greatest thickness of sediments and are overlain by 100 to 200 feet of Tertiary and Quaternary sediments. The sedimentary geologic units at the Base, described in ascending order (decreasing age) are the Middendorf Formation, the Black Creek Formation, the Black Mingo Formation, and the Duplin Formation (Figure 2.3).

The Cretaceous Black Creek Formation is the deepest formation encountered during environmental investigations of OU-4 and the Building 1613 Site (Figure 2.3). The lithology of the Black Creek Formation is predominantly fine- to medium-grained, interbedded, white and gray sands with thin sandstone beds and gray, black, and dark-blue clays. The sediments contain fossils, including shells, sharks teeth, and microfauna. Intervals may contain pyrite, pyrite-coated wood fragments, and marcasite, and may be phosphatic, glauconitic, and micaceous, with interbedded, finely laminated organic clays.

The Paleocene-age Black Mingo Formation (Figure 2.3) outcrops west of the runway at Shaw AFB, and is composed of glauconitic quartz sands, thin layers of gray to light-green silty clay, pyritic dark-gray organic clays, and fuller's earth (opaline claystone). The Black Mingo Formation locally includes two member: the Sawdust Landing Member and the Lang Syne Member. The Sawdust Landing Member consists of sands, silts, and clays representing upper delta plain deposits, similar to the modern Mississippi River Delta. In the Sawdust Landing Member significant clay and silt content represents

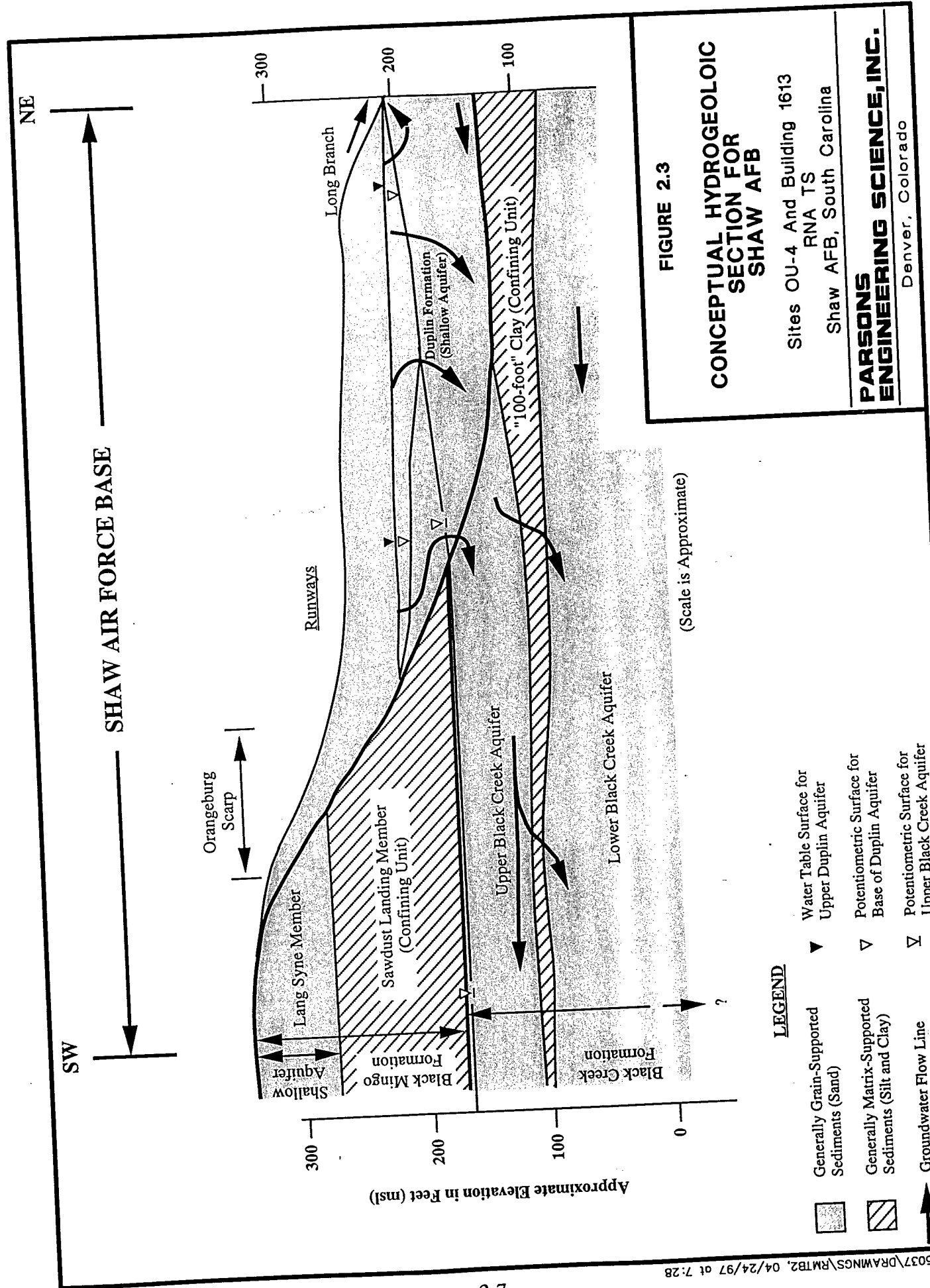


FIGURE 2.3

CONCEPTUAL HYDROGEOLOGIC SECTION FOR SHAW AFB

Sites OU-4 And Building 1613
RNA TS
Shaw AFB, South Carolina

PARSONS ENGINEERING SCIENCE, INC.

Denver, Colorado

flood-stage deposits, while fine to coarse sands represent channel deposits. As the Paleocene sea transgressed the land, it laid down the cleaner Lang Syne sands and clays. The Lang Syne represents the beach barrier island and back-barrier depositional environments at the seaward margin of the Sawdust Landing delta.

At Shaw AFB, the Duplin Formation unconformably overlies the Black Mingo and Black Creek Formations, and outcrops throughout the eastern two-thirds of the Base. The Orangeburg Scarp is expressed at the ground surface where the Pliocene-age Duplin Formation contacts the eroded surface of the underlying deposits. Locally, this scarp is expressed as the hill traversing the western edge of the Base along Highway 441 (Figure 2.1). The Duplin Formation consists largely of sands, silts, and clays that were derived from the underlying formations and reworked during a sea-level decrease.

2.1.2.2 Regional Hydrogeology

The following summary of regional hydrogeology is derived from a more thorough version provided in several reports from Rust E&I (e.g., Rust, 1995 and 1996a).

Shaw AFB is underlain by three aquifer systems: the Middendorf Aquifer System, the Black Creek Aquifer System, and the Shallow Aquifer System. Aquifer system boundaries do not necessarily correspond to boundaries between geologic formations. In addition, lithologies may change significantly from one area to another within these aquifer systems. The Black Creek and Shallow Aquifer Systems are described below because they are used for the Base water supply and their quality has been adversely impacted by Base activities. A schematic representation of the local aquifers is presented in Figure 2.3, which demonstrates the conceptual relationships among the various geologic formations, aquifer systems, and the Orangeburg Scarp.

The Black Creek Aquifer System underlies most of Sumter County and is used for water supply over most of the central Coastal Plain, including most of the Base's supply. In the vicinity of Shaw AFB, the Black Creek Aquifer is present between approximately

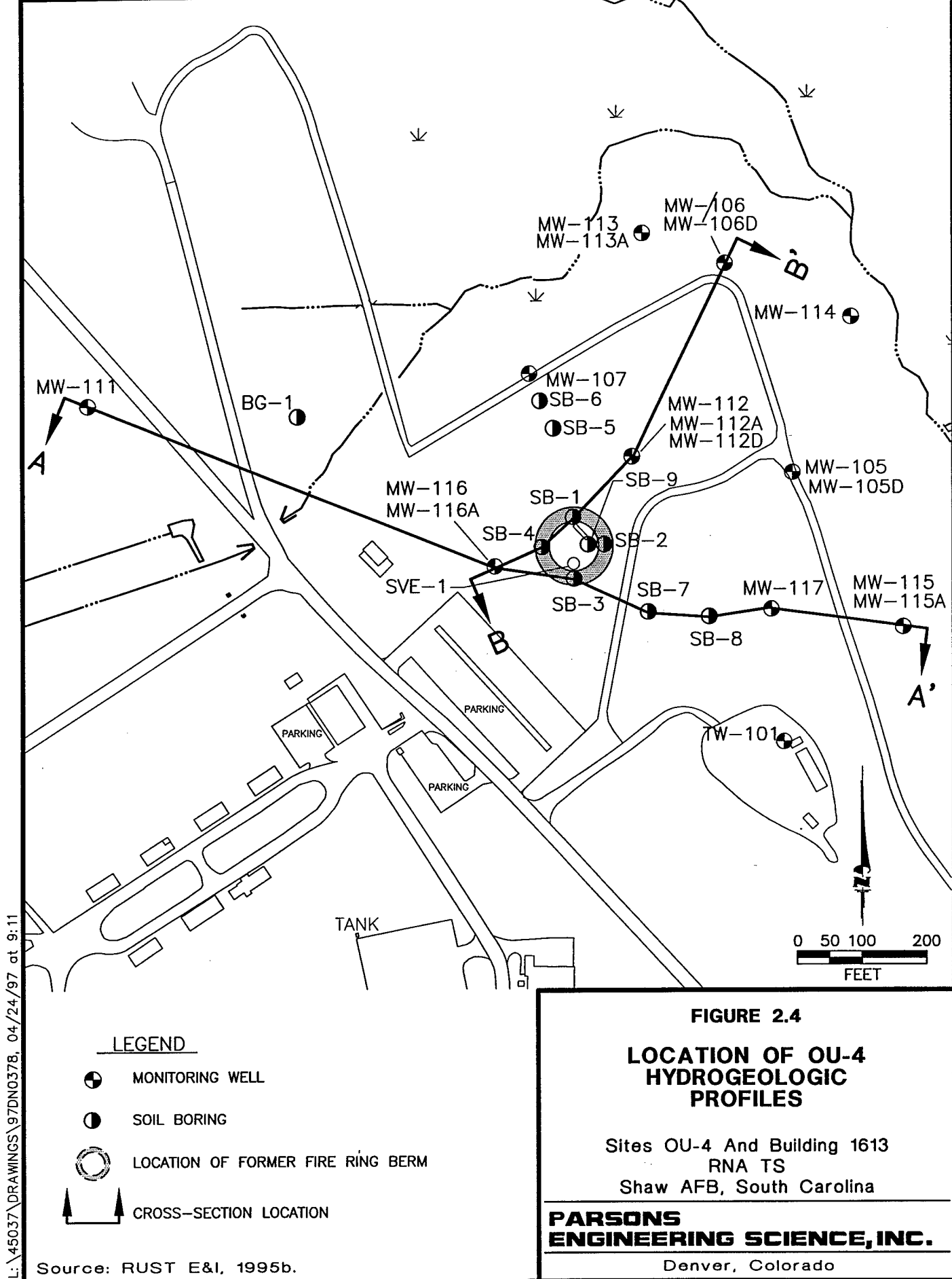
175 feet above msl and 25 feet below msl, and is separated into a lower and upper aquifer by a clay aquitard referred to as the 100-foot clay.

In the western portion of the Base, the Shallow Aquifer System is present in sediments associated with the Black Mingo Formation; however, in the vicinity of both OU-4 and the Building 1613 Site, the aquifer is present in the Duplin Formation. The shallow aquifer extends from the water table (commonly 10 to 40 feet bgs) to approximately 150 to 175 feet above msl.

2.1.2.3 OU-4 Geology and Hydrogeology

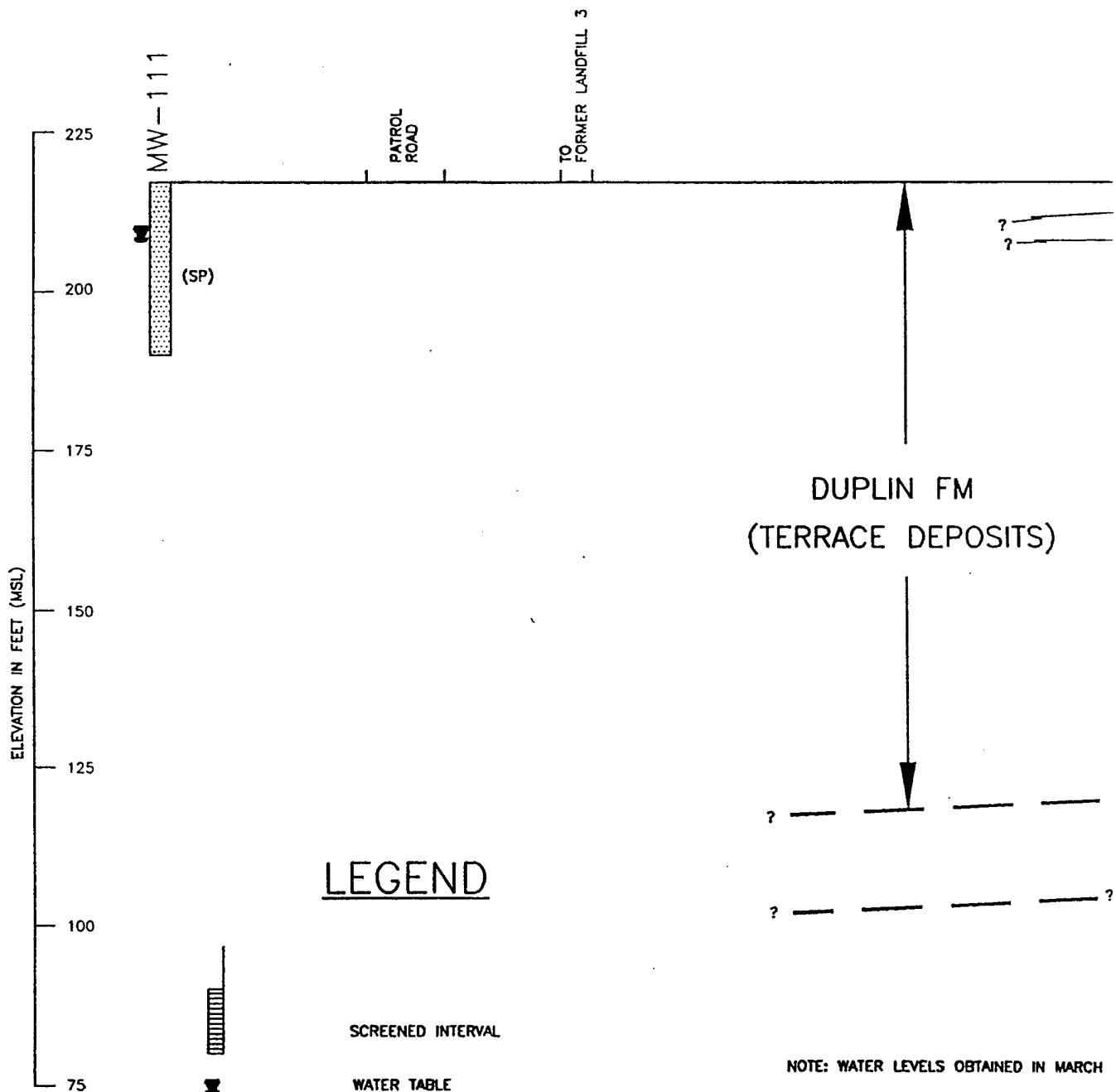
The following description of OU-4 geology and hydrogeology is summarized from the Final RI (Rust, 1995b), which combines information gathered as a part of the supplemental RI field work with previously reported information. The locations of two cross-sections modified from the Final RI, Sections A-A' and B-B', are indicated on Figure 2.4, and the Sections are presented as Figures 2.5 and 2.6 respectively. The cross-sections are roughly parallel to groundwater flow and contaminant migration paths to both the north-northeast and east.

OU-4 lies approximately 1 mile east of the surface expression of the Orangeburg Scarp; therefore, site geology consists of Duplin Formation terrace deposits directly underlain by the Black Creek Formation. The Duplin Formation extends from the surface to a depth of about 80 to 90 feet bgs. Overall, the Duplin Formation at OU-4 consists of unconsolidated, well graded to poorly graded sands, with approximately 15 percent interstitial clays and silts. Soils in the upper part of this unit are mostly coarse- to fine-grained sands; however, a thin, discontinuous clayey unit was observed in the shallow subsurface in a number of borings. The lower part of the Duplin Formation consists of mostly medium to fine sands with increasing clay content with depth. Clay is present both interstitially and in seams. The transition between the lower and upper portions of this unit is gradational.



NORTHWEST

A

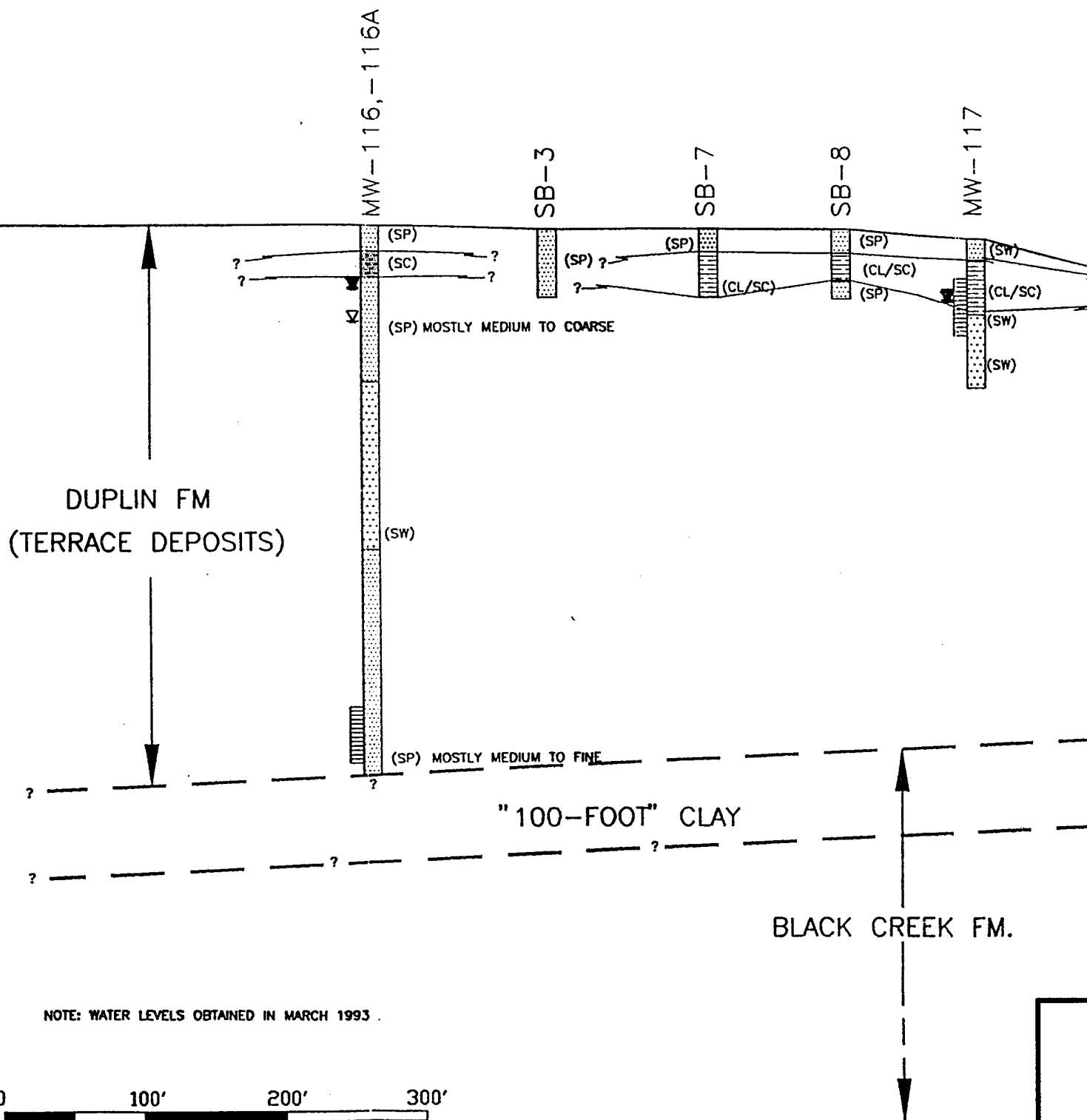


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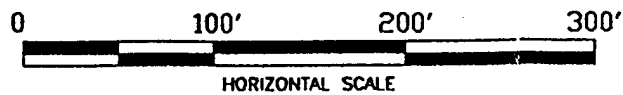
-  SCREENED INTERVAL
-  WATER TABLE
-  BASE OF SHALLOW AQUIFER
-  BLACK CREEK AQUIFER
-  (SP) POORLY GRADED SAND
-  (SW) WELL GRADED SAND
-  (SC) SANDY CLAY
-  (CL/SC) CLAY AND/OR SANDY CLAY
-  (CH) CLAY



VERTICAL EXAGGERATION 4X



NOTE: WATER LEVELS OBTAINED IN MARCH 1993 .



VERTICAL EXAGGERATION 4X

PA
EN

SOUTHEAST

A'

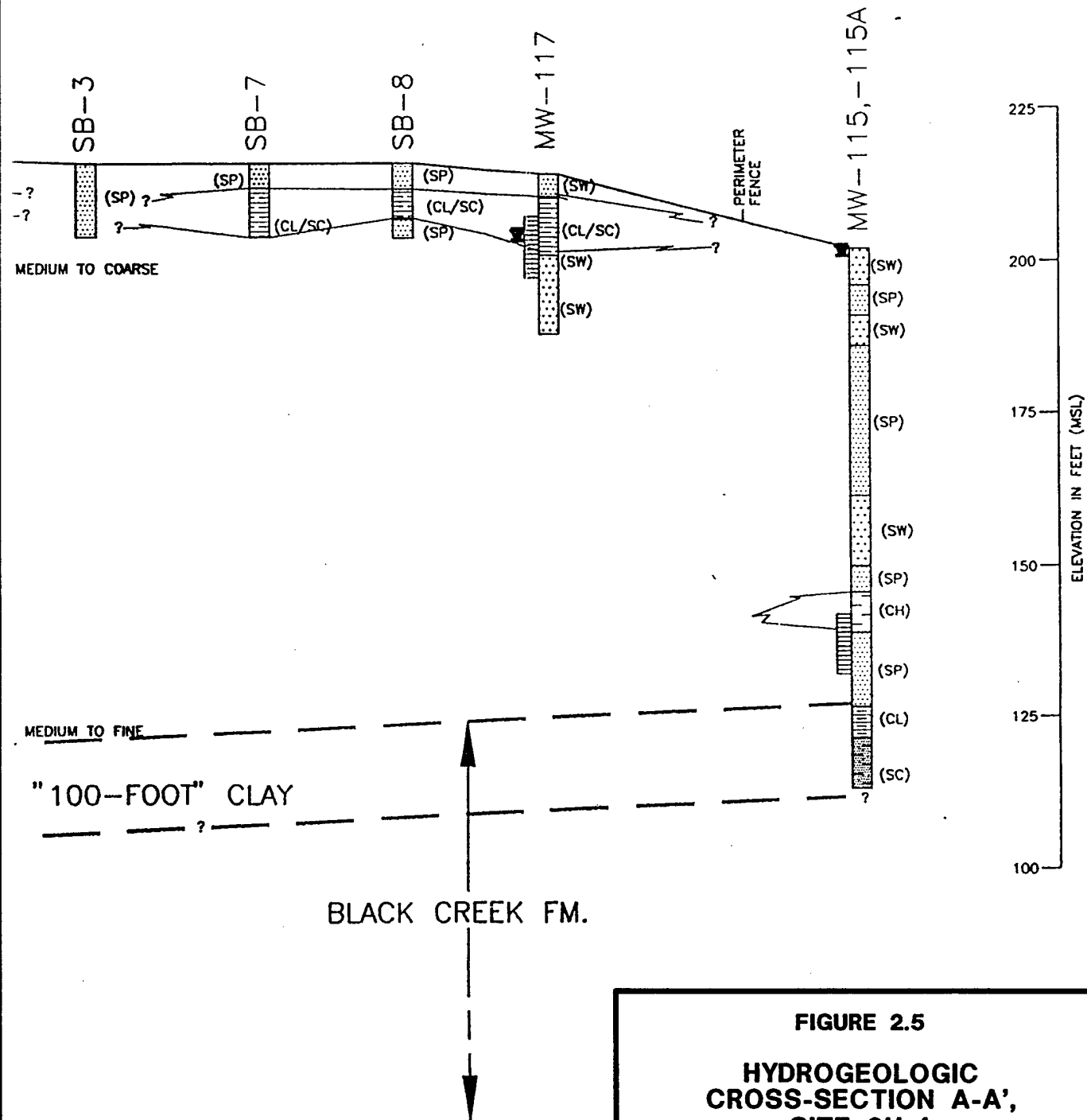


FIGURE 2.5

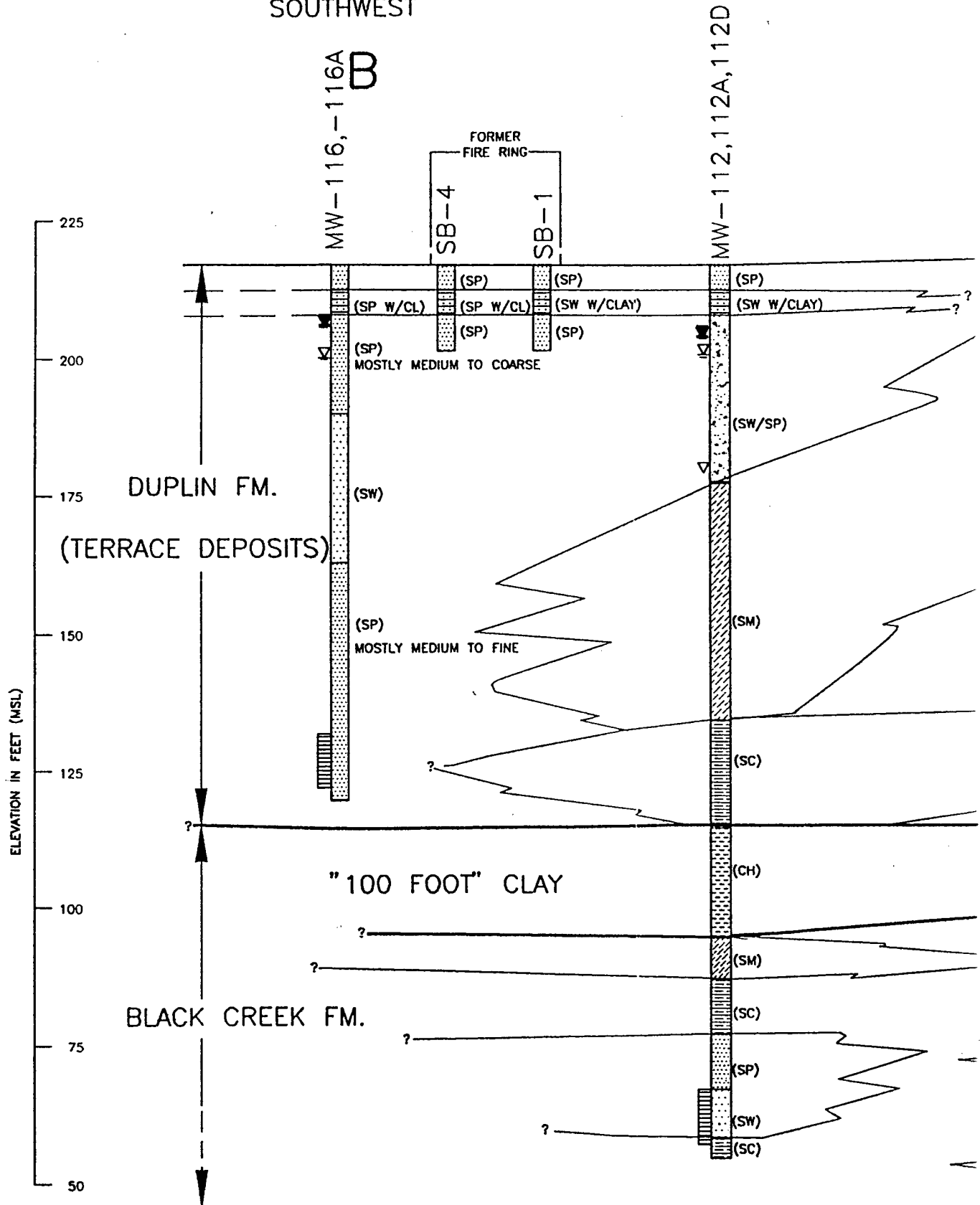
**HYDROGEOLOGIC
CROSS-SECTION A-A',
SITE OU-4**

Sites OU-4 And Building 1613
RNA TS
Shaw AFB, South Carolina

**PARSONS
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Denver, Colorado

SOUTHWEST



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Source: RUST E&I 1995b.

NORTHEAST

MW-106, -106D
B'

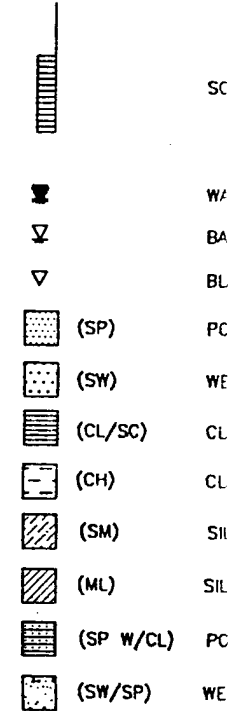
PERIMETER FENCE

MW-112, 112A, 112D

LONG BRANCH

ELEVATION IN FEET (MSL)

LEGE



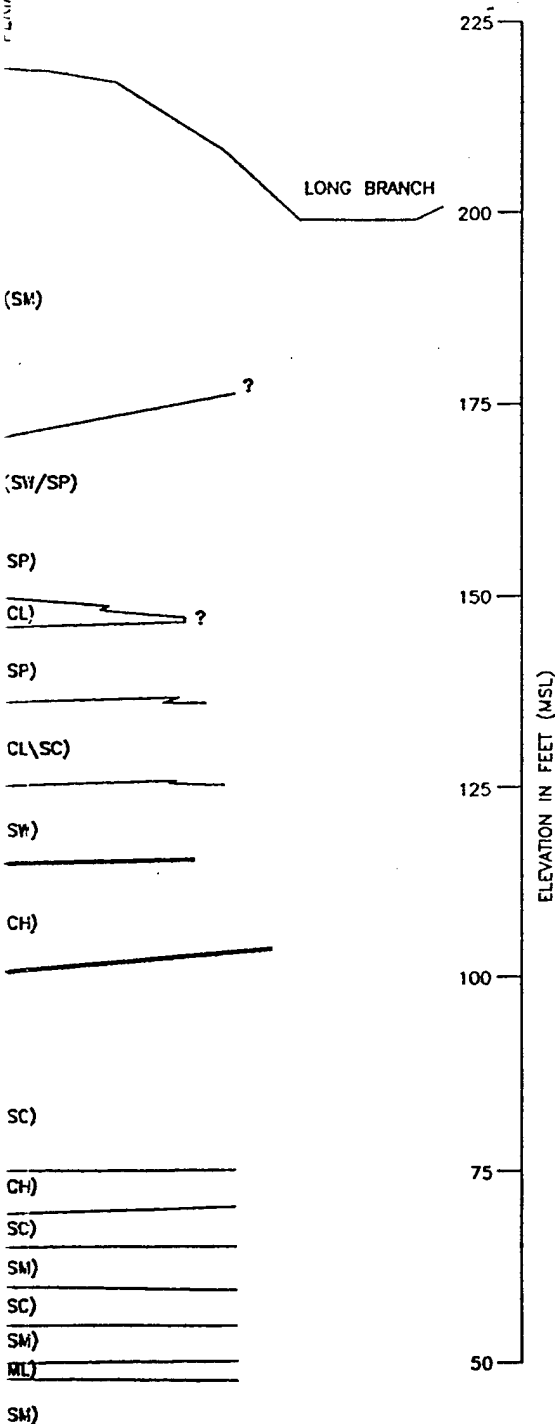
NOTE: WATER LEVELS OF



PARS
ENGIN

EAST

UNIMETER FENCE



LEGEND

	SCREENED INTERVAL
	WATER TABLE
	BASE OF SHALLOW AQUIFER
	BLACK CREEK AQUIFER
	(SP) POORLY GRADED SAND
	(SW) WELL GRADED SAND
	(CL/SC) CLAY AND/OR SANDY CLAY
	(CH) CLAY
	(SM) SILTY SAND
	(ML) SILT
	(SP W/CL) POORLY GRADED SAND WITH CLAY
	(SW/SP) WELL GRADED SAND/POORLY GRADED SAND

NOTE: WATER LEVELS OBTAINED IN MARCH 1993

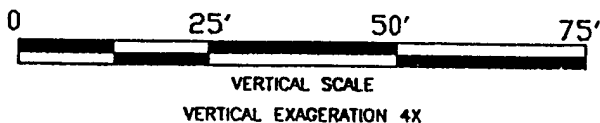


FIGURE 2.6 HYDROGEOLOGIC CROSS-SECTION B-B', SITE OU-4

Sites OU-4 And Building 1613
RNA TS
Shaw AFB, South Carolina

**PARSONS
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Denver, Colorado

At OU-4, upper portions of the Black Creek Formation were eroded prior to the deposition of the Duplin Formation terrace deposits, so that the first encountered unit is a clay referred to as the "100-foot clay". This clay unit was encountered at about 90 feet bgs in three OU-4 boreholes, and is about 20 to 35 feet thick. The unit consists of very stiff, light gray and very pale brown plastic clay with seams of poorly graded sands, sandy clays, and silts. The continuity of the silt seams is uncertain. Previous OU-4 investigations indicate that site contamination has not penetrated this clay unit; therefore, the reader is referred to the Final RI report (Rust, 1995b) for descriptions of the deeper site geology.

The water-bearing zone of primary interest at the site is referred to as the Shallow Aquifer. At OU-4, this aquifer coincides with the Duplin Formation terrace deposits. The Shallow Aquifer is stratigraphically divided into two zones. The upper zone extends to approximately 35 feet bgs and is characterized by mostly medium to very coarse sands with gravelly layers, all containing interstitial fine sands and clays. The lower zone extends from approximately 35 feet bgs to the aquitard at approximately 90 feet bgs, and the sediments gradually become finer with increasing depth. At a depth of approximately 90 feet bgs, the "100-foot clay" of the Black Creek Formation acts as an aquitard between the Shallow aquifer and the underlying Lower Black Creek Aquifer. This is indicated by large head differences between the Shallow Aquifer and Lower Black Creek Aquifer.

In the Shallow Aquifer, depth to groundwater ranges from approximately 15 feet bgs beneath the upland terrace to a few inches bgs in the flood plain. Groundwater elevations and monitoring well completion data are listed in Tables 2.1 and 2.2. Reinterpretation of previous static groundwater elevation measurements suggests that flow direction in the upper zone of the shallow aquifer is markedly influenced by surface topography. This is reflected by relatively shallow gradients within the upland terrace portion of the site with relatively steep gradients parallel to and underlying the

TABLE 2.1
GROUNDWATER ELEVATIONS AT OU-4
SITES OU-4 AND BUILDING 1613
RNA TS
SHAW AFB, SOUTH CAROLINA

Well No.	Date	Top of Casing (TOC) (ft above MSL)	Static Water Level (ft below TOC)	Static Water Level Elevations (ft above MSL)
MW-105	03/08/93	214.87	11.84	203.03
MW-105D	03/09/93	215.11	35.38	179.73
MW-106	03/10/93	219.21	16.82	202.39
MW-106D	03/10/93	218.99	39.34	179.65
MW-107	03/10/93	214.79	10.04	204.75
MW-111	03/11/93	227.08	18.38	208.70
MW-112	03/09/93	218.01	13.36	204.65
MW-112A	03/09/93	217.92	16.49	201.43
MW-112D	03/09/93	217.73	38.17	179.56
MW-113	03/10/93	208.95	6.36	202.59
MW-113A	03/10/93	209.22	6.54	202.68
MW-114	03/08/93	207.10	7.60	199.50
MW-115	03/11/93	204.19	3.17	201.02
MW-115A	03/11/93	204.16	3.65	200.51
MW-116	03/11/93	219.46	12.98	206.48
MW-116A	03/09/93	219.48	17.79	201.69
MW-117	03/10/93	216.42	12.43	203.99
MW-118	03/11/93	203.51	2.35	201.16
TW-101	02/16/93	220.47	13.20	207.27

Note: MSL - Mean Sea Level

Source: RUST E & I, 1995b

TABLE 2.2
OU-4 MONITORING WELL COMPLETION DETAILS
SITES OU-4 AND BUILDING 1613
RNA TS
SHAW AFB, SOUTH CAROLINA

Well No.	Aquifer	Ground Elevation (ft msl)	Total Depth (ft)	Screen Length (ft)	Casing Diameter (in)	Location	
						Latitude	Longitude
MW-105	S	212.92	19.7	5	2	781707.969	2166693.132
MW-105D	BC	212.92	176.5	10	2	781665.342	2166718.029
MW-106	S	217.63	24.3	5	2	781686.963	2166705.655
MW-106D	BC	217.47	179.5	10	2	781622.498	2166741.982
MW-107	S	213.21	19.9	5	2	782128.419	2166707.029
MW-111	S	225.35	27.6	5	2	782134.801	2166707.444
MW-112	S	215.78	25	15	2	782452.344	2166601.959
MW-112A	BS	215.78	89.7	10.33	2	782448.677	2166595.258
MW-112D	BC	215.78	155.2	10	2	782281.684	2166296.107
MW-113	S	206.79	25	15	2	782234.008	2165610.262
MW-113A	BS	207.07	35	15	2	782153.317	2166456.628
MW-114	S	204.83	25	15	2	782153.806	2166465.881
MW-115	S	201.92	25	15	2	782159.916	2166459.506
MW-115A	BS	202.19	69.08	10.31	2	782498.827	2166473.268
MW-116	S	217.20	25.6	15.3	2	782490.479	2166472.454
MW-116A	BS	217.14	94.74	10.33	2	782369.261	2166797.623
MW-117	S	213.89	21.41	15.24	2	781886.414	2166877.511
MW-118	S	201.12	10.36	10.31	2	781888.874	2166869.608
MW-119A	BS	203.59	75.30	10.33	2	782159.953	2167543.911
TW-101	S	218.08	60	30	4	781981.943	2166241.078
PZ-101	S	218.53	30	10	2	781982.286	2166251.067
PZ-102	S	218.53	28	10	2	781914.192	2166673.356
PZ-103	S	218.63	35	10	2	781610.669	2166979.110

Source: RUST E & I, 1995b

S – Shallow Aquifer.

BS – Base of Shallow Aquifer.

BC – Black Creek Aquifer.

MSL – Mean Sea Level.

embankments along the flood plain of Long Branch and the unnamed ephemeral stream. As shown on Figure 2.7, in the upper zone of the Shallow Aquifer, groundwater flows generally toward the northeast beneath the terrace portion of the site; however, in the vicinity of the steep slopes bounding the site to the east and north, groundwater flow directions vary from northwest to east-northeast. Horizontal groundwater gradients computed from this interpretation of groundwater elevations range from 0.006 foot per foot (ft/ft) beneath the terrace to approximately 0.033 ft/ft beneath the slope to the east of well TW-101. On the basis of elevations from 4 wells, the lower zone of the Shallow Aquifer has a horizontal groundwater gradient of 0.0029 ft/ft to the southwest.

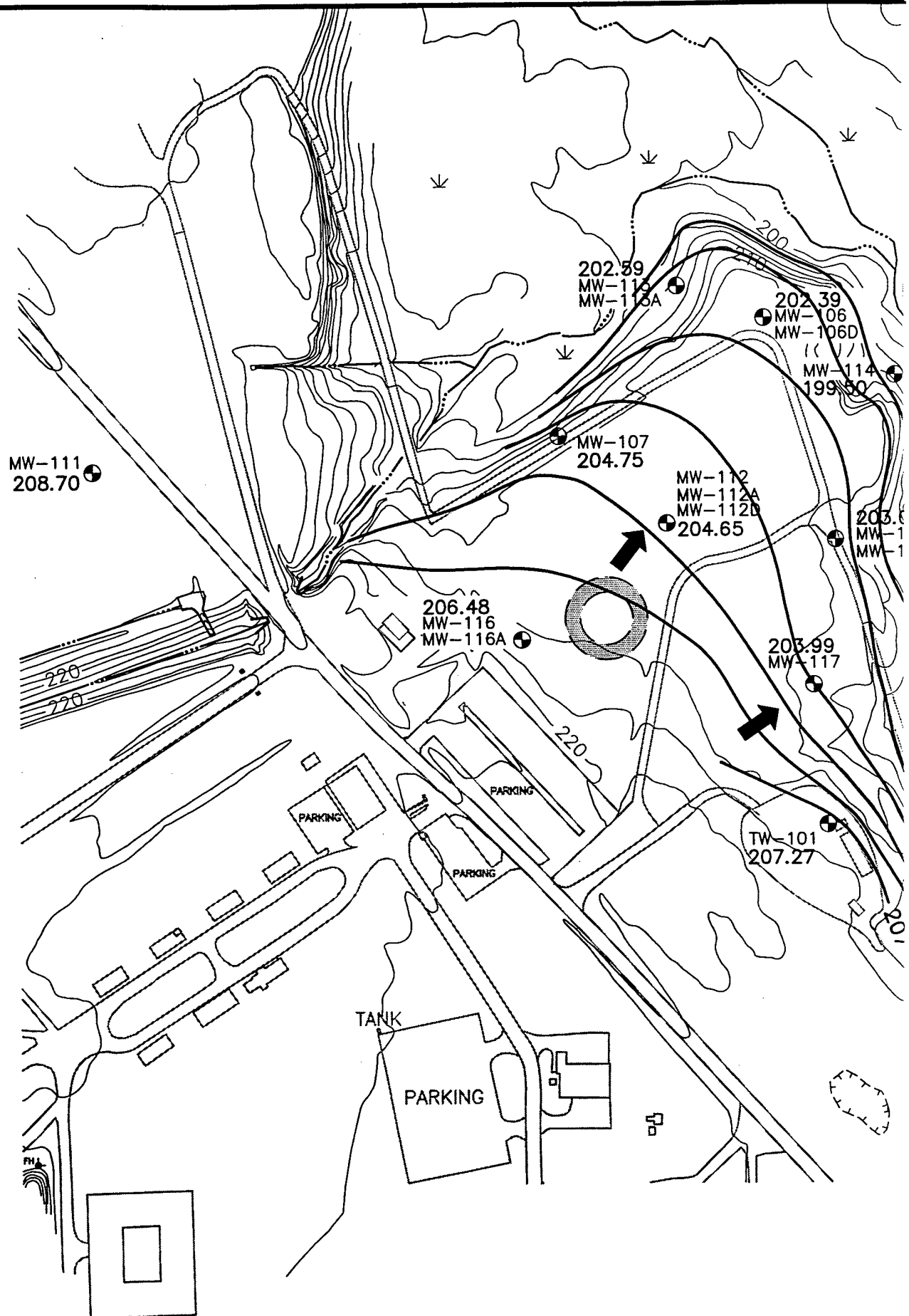
In addition to differences in flow direction, static water level measurements indicate that there are head differences between the upper and lower zones of the Shallow Aquifer. The vertical hydraulic gradient between the upper and lower zones ranges from 0.067 ft/ft (down) at the MW-116 well cluster to 0.0019 ft/ft (up) at the MW-115 well cluster. This is evidence of a local groundwater recharge zone at MW-116, and a local discharge zone at MW-115, which is near Long Branch.

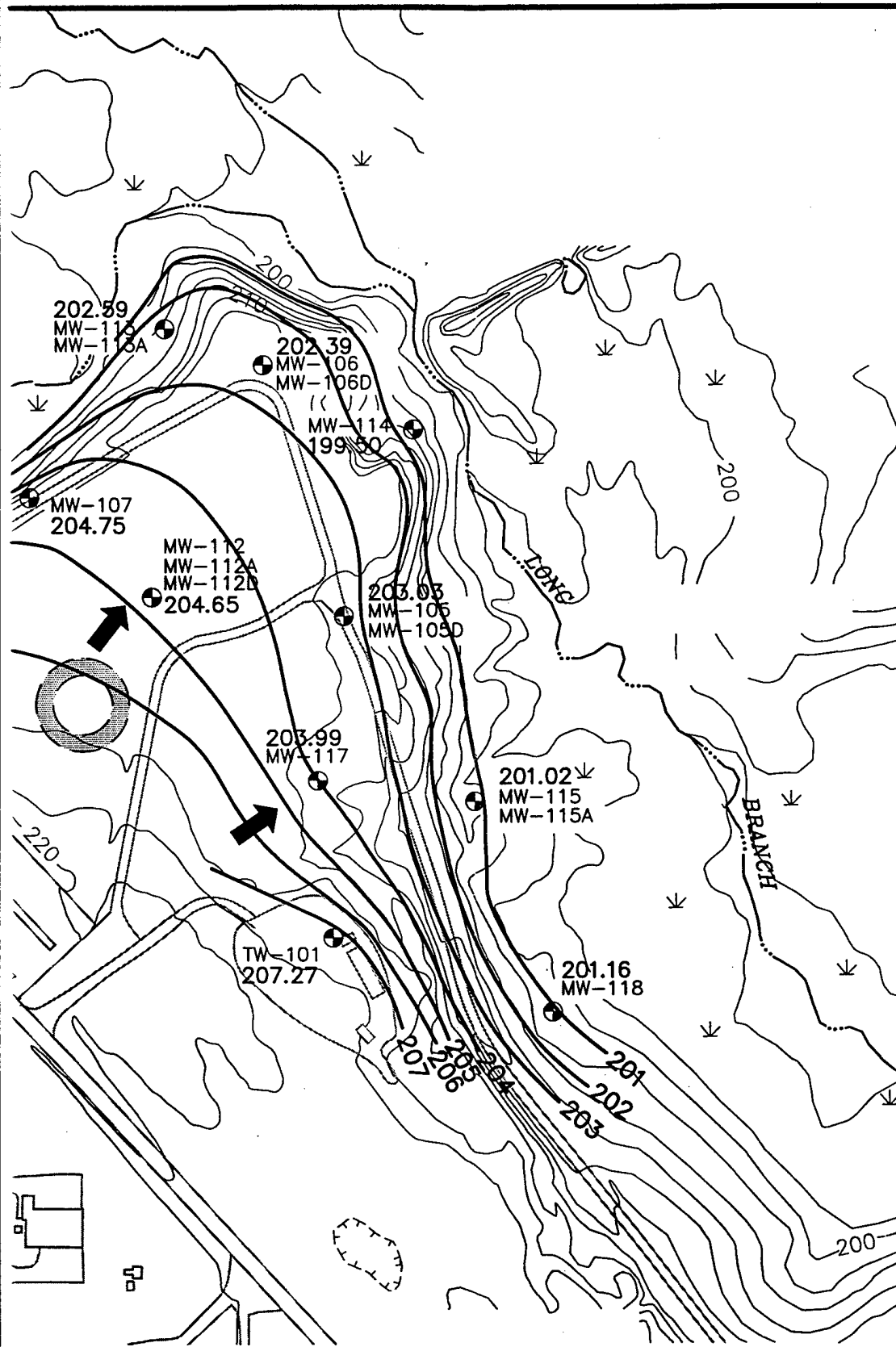
As a part of supplemental RI field activities, Rust E&I performed a 72-hour pumping test at well TW-101. The average transmissivity and storage coefficient were estimated to be 3382 square feet per day and 0.0013 (unitless), respectively (Rust E&I, 1995c). Assuming an aquifer thickness of 81 feet, this transmissivity translates to a hydraulic conductivity of 42 feet per day (ft/day). Summary results for the pumping well as well as 5 other wells monitored during the test are provided in Table 2.3.

A thin, localized unit consisting of low permeability clayey sand is present in the area of the former fire ring at depths ranging from 3 to 9 feet bgs. This low permeability unit results in both a local groundwater perching effect after heavy rain and a local confining effect on the underlying groundwater. With the exception of that clayey unit, the Shallow Aquifer is unconfined. Because the clayey unit was not observed in all

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REFERENCE: TOPOGRAPHIC BASE MAP PREPARED BY
AIR SURVEY CORPORATION, MARCH 1993.





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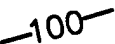
203.99

-100

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LEGEND

- 203.99  MONITORING WELL WITH GROUNDWATER ELEVATION (feet msl)
-  LOCATION OF FORMER FIRE RING BERM
-  SURFACE WATER DRAINAGE
-  DIRECTION OF GROUNDWATER FLOW
-  LINE OF EQUAL GROUNDWATER ELEVATION (feet msl)

MW-119A

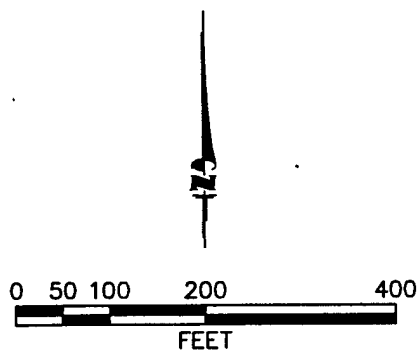


FIGURE 2.7
GROUNDWATER ELEVATIONS FOR
THE UPPER ZONE OF THE
SHALLOW AQUIFER AT OU-4
MARCH 1993

Sites OU-4 And Building 1613
 RNA TS
 Shaw AFB, South Carolina

PARSONS
ENGINEERING SCIENCE, INC.

Denver, Colorado

TABLE 2.3
SUMMARY OF OU-4 SUPPLEMENTAL EXPANDED SITE
ASSESSMENT AQUIFER TEST RESULTS
SITES OU-4 AND BUILDING 1613
RNA TS
SHAW AFB, SOUTH CAROLINA

Well	r (ft)	Average T (ft ² /day)	Average S
TW-101	Pumping Well	*2922	---
PZ-102	25	2912	*6.6 x 10 ⁻⁶
PZ-101	50	3241	2.5 x 10 ⁻⁴
PZ-103	100	4119	1.8 x 10 ⁻³
MW-117	204	3718	2.1 x 10 ⁻³
MW-115	254	**7403	2.4 x 10 ⁻³
AVERAGE		3382	1.3 x 10 ⁻³

NOTE:

r = distance to pumping well
T = transmissivity
S = Storage Coefficient
* = T calculated from recovery data
** = Not used to calculate average

borings its continuity and areal extent have not been fully characterized. Its occurrence at various depths suggests that the layer may not be a continuous unit.

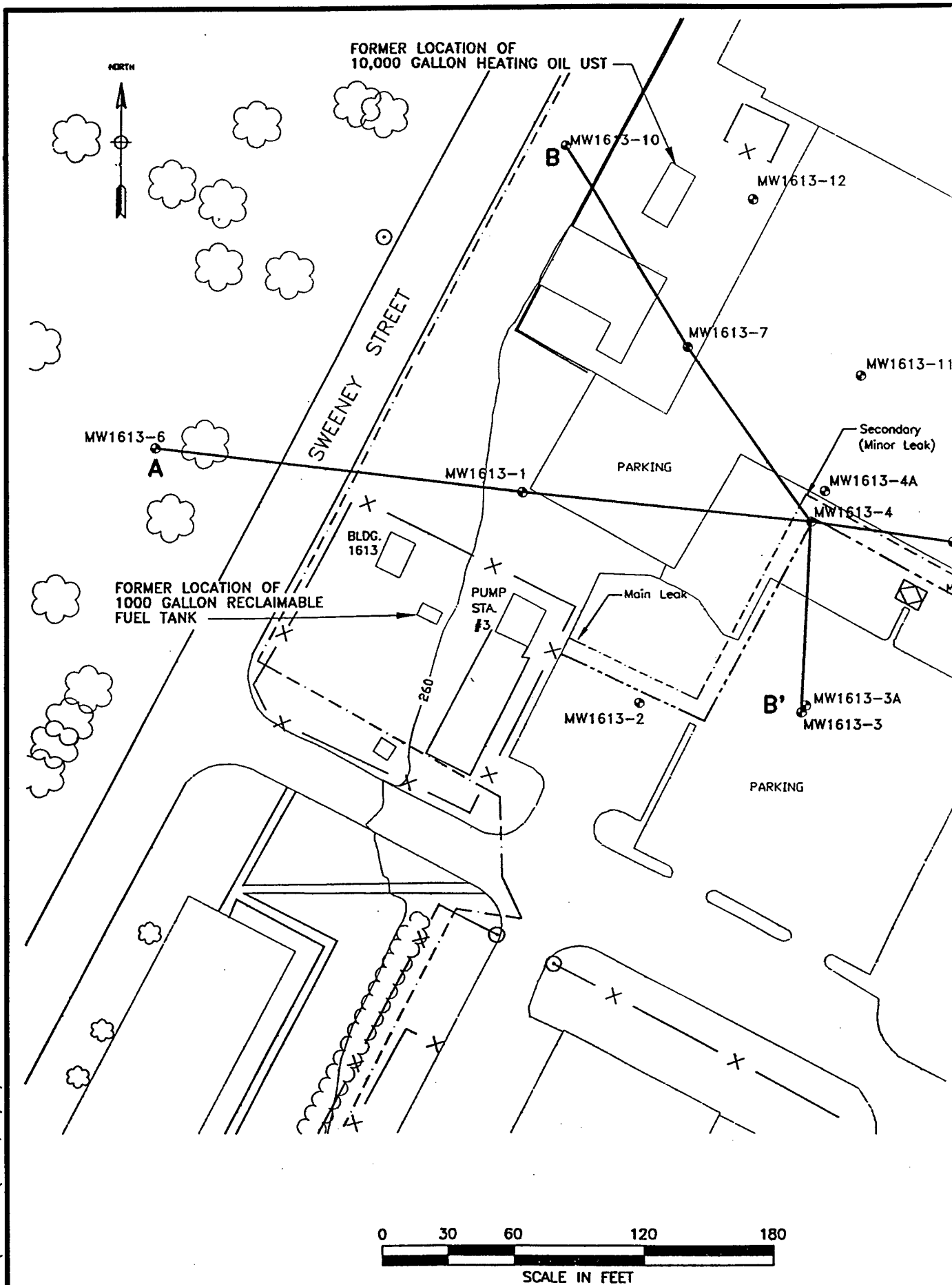
2.1.2.4 Building 1613 Site Geology and Hydrogeology

The locations of cross-sections illustrating the stratigraphy of the Building 1613 Site are presented on Figure 2.8 and are presented on cross-sections A-A', B-B', and C-C' as Figures 2.9 through 2.11. The top 40 feet of soils consist of heterogeneous, poorly graded to well-graded clayey coarse- to fine-grained sands. Clay layers present at the site are discontinuous. At approximately 40 feet bgs, the soils become more uniform and consist mostly of poorly to well-graded sands and silty sands. The water table at the site is approximately 35 to 40 feet bgs, with groundwater present in predominantly sandy soils. The Shallow Aquifer is separated from the underlying Upper Black Creek Aquifer by the Sawdust Landing Member of the Black Mingo Formation at approximately 70 feet bgs. The Sawdust Landing Member at the site consists of gray to yellowish-brown, hard clay soils that act as an aquitard.

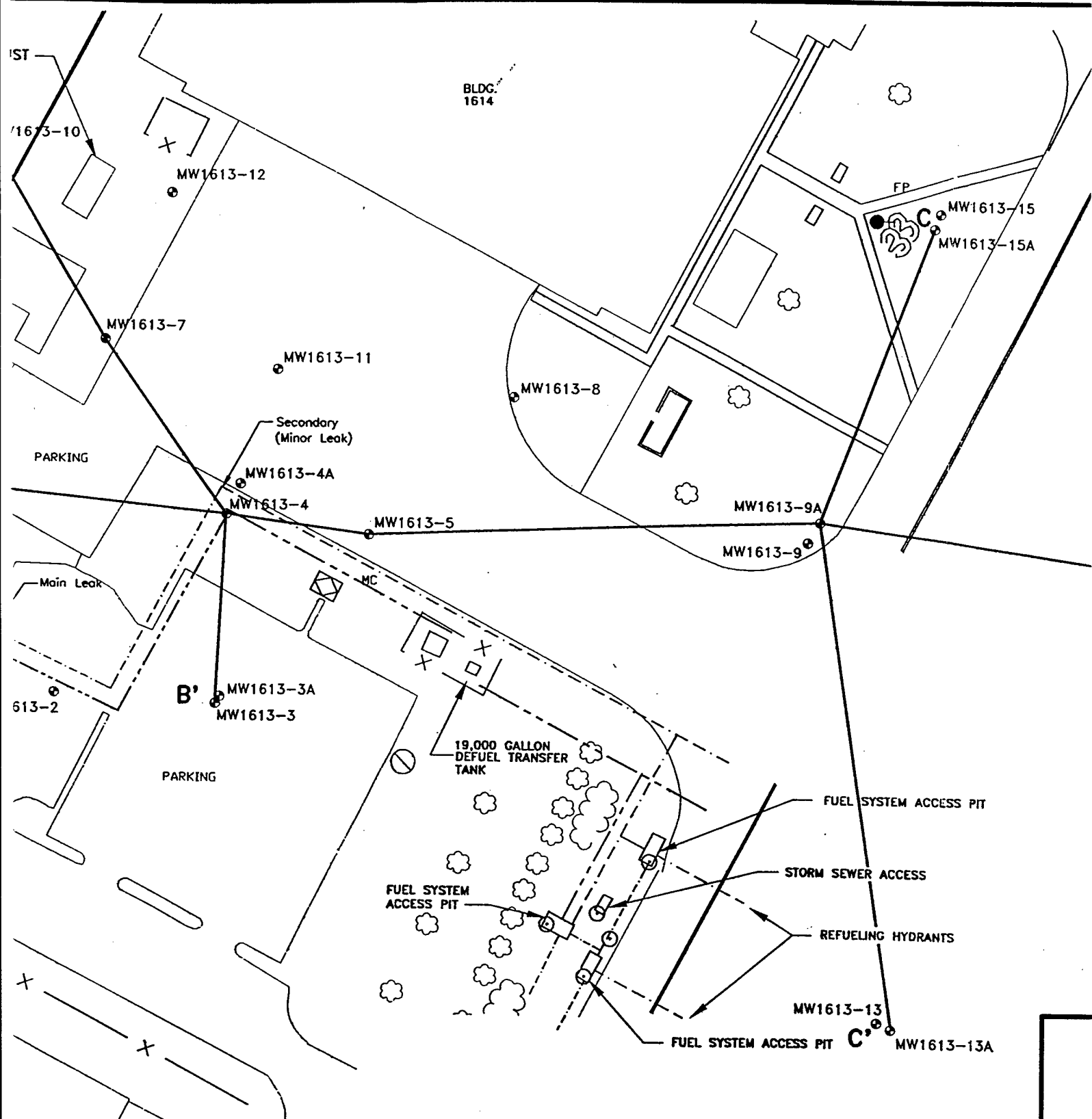
During direct push activities (conducted April 2 through 4, 1997 with a cone penetrometer apparatus near the secondary leak location) encountered a very hard soil layer at approximately 17 feet bgs and an impenetrable layer at 27 feet bgs. In addition, piezocone soil sampling at locations SB1613-2 and SB1613-8 during June 1993 investigations encountered an impenetrable layer at 27 feet. Available soil boring logs from monitoring well locations near the push locations (MW1613-2, -4, and -11) do not indicate hard-packed layers or cobbles at depths of 17 and 27 feet bgs; however, the presence of iron-cemented sandstone was detected from 39.5 to 40.5 feet bgs at monitoring well MW1613-4. The presence of similar iron-cemented soil layers was not detected at the site, but they may exist as thin intervals that are impenetrable to the cone penetrometer.

Twenty-one monitoring wells have been installed at the Building 1613 Site; 15 shallow monitoring wells are screened across the water table (with screen bottoms at

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Source: RUST E&I 1996a.



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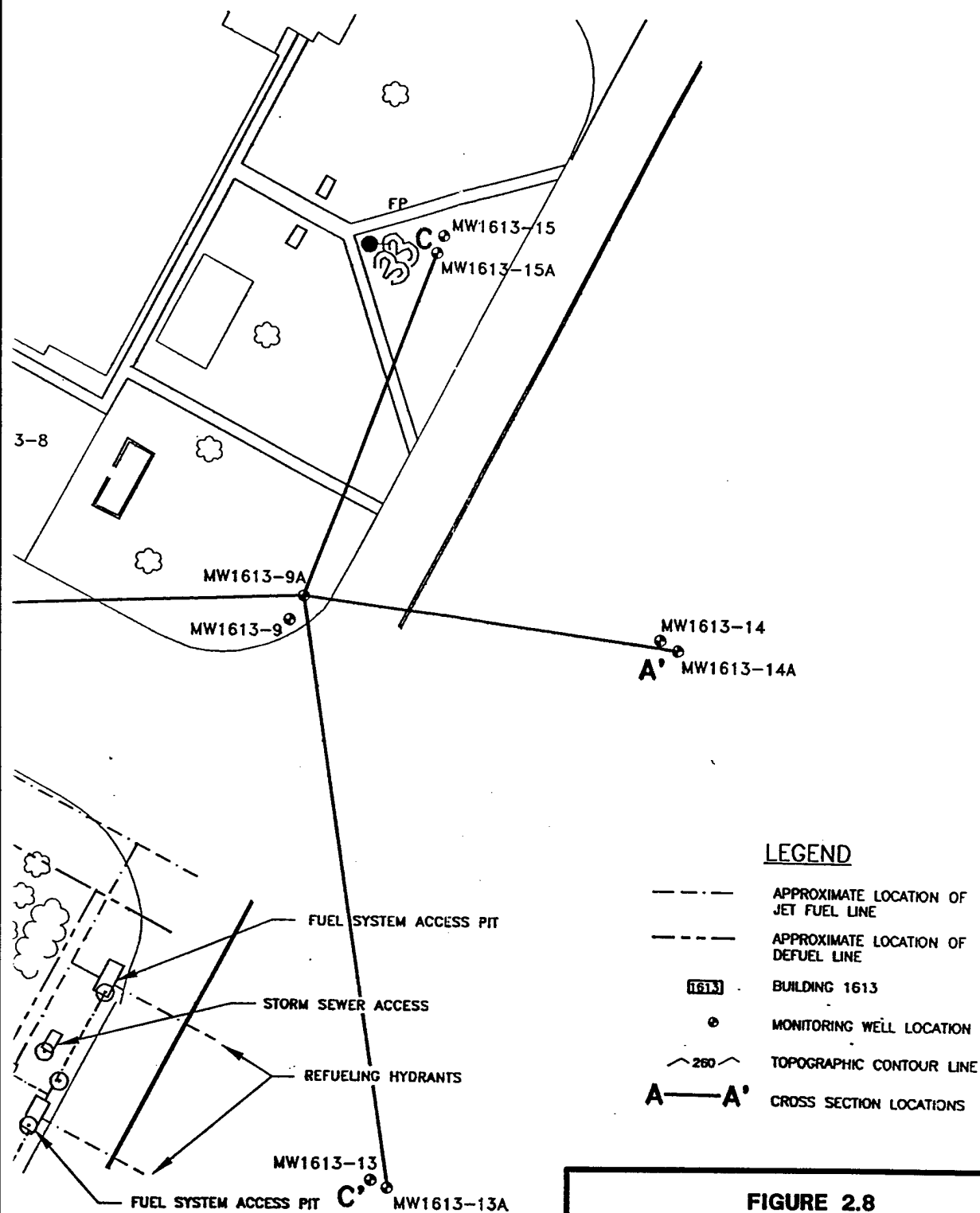


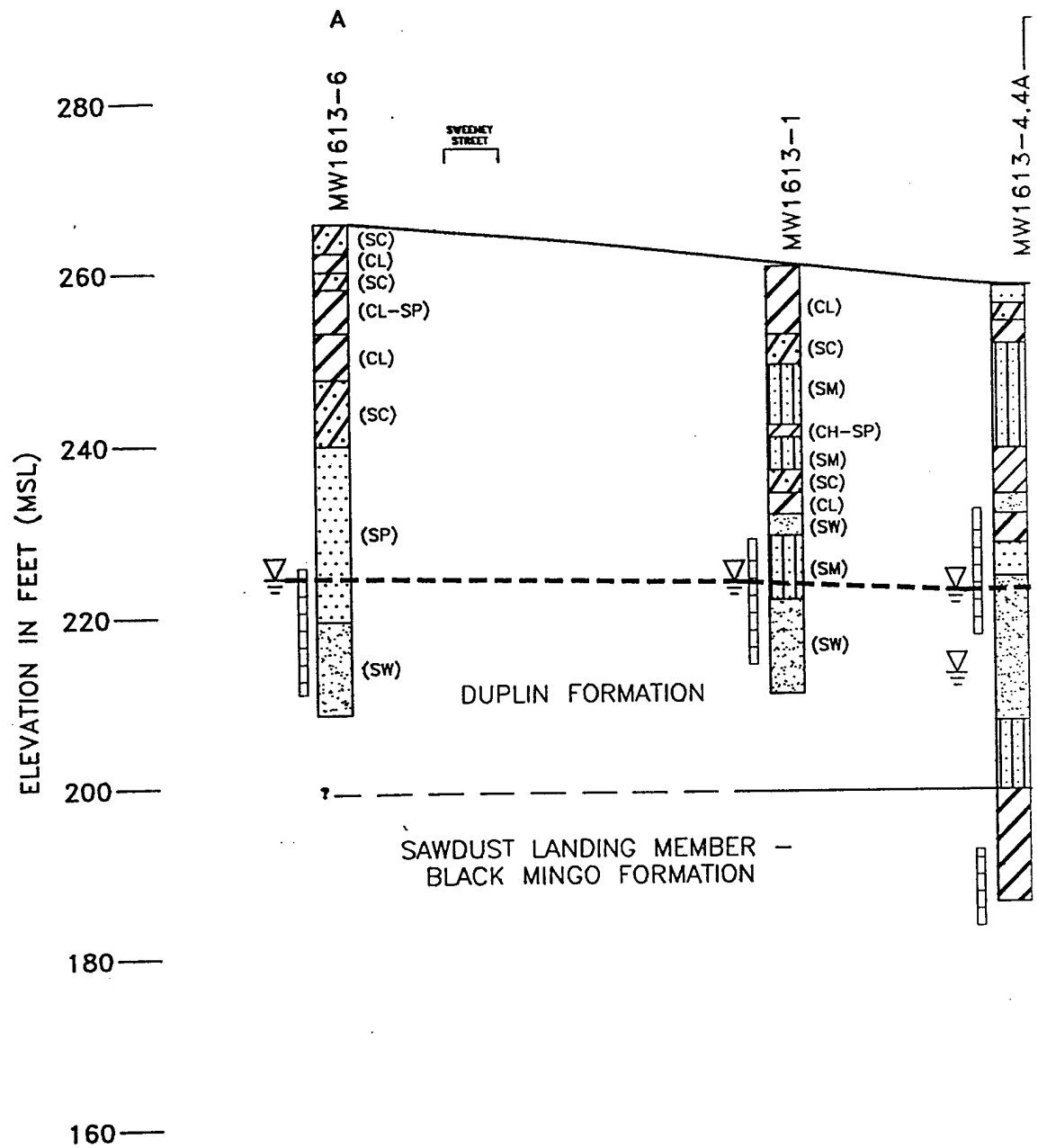
FIGURE 2.8

LOCATION OF
BUILDING 1613
HYDROGEOLOGIC PROFILES

Sites OU-4 And Building 1613
 RNA TS
 Shaw AFB, South Carolina

PARSONS
ENGINEERING SCIENCE, INC.

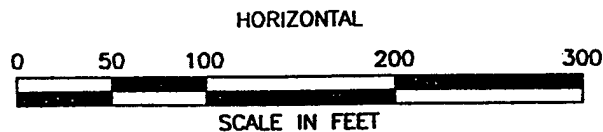
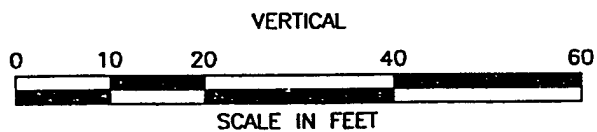
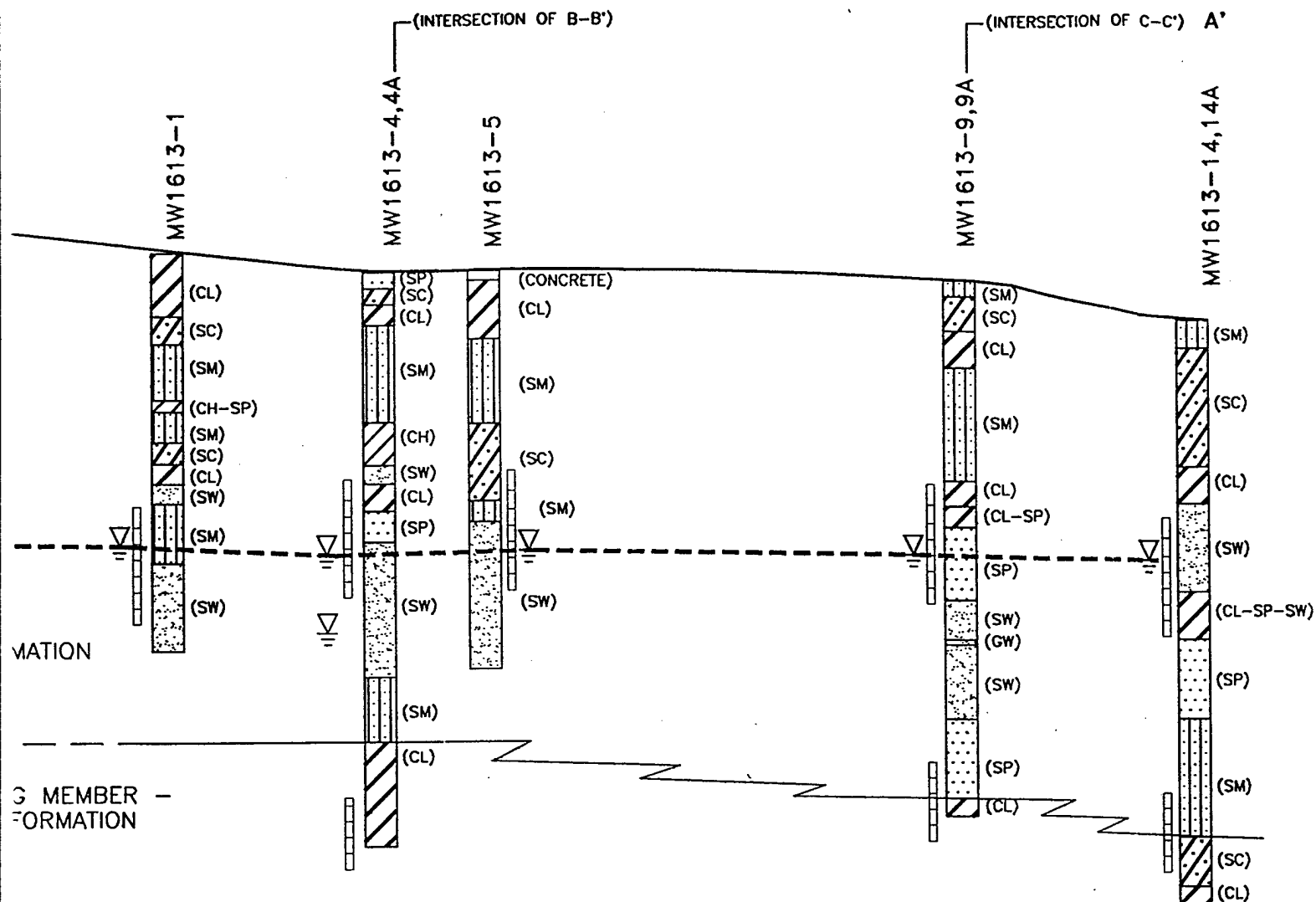
Denver, Colorado



LEGEND

-  (SW) = WELL GRADED SAND
-  (SP) = POORLY GRADED SAND
-  (SC) = CLAYEY SAND
-  (GW) = WELL GRADED GRAVEL

-  (SM) = SILTY SAND
-  (CL) = CLAY
-  (CL-SP) = CLAY WITH POORLY GRADED SAN
-  (CH) = CLAY
-  (CH-SP) = CLAY WITH POORLY GRADED SAN
-  SCREENED INTERVAL



(SM) = SILTY SAND

(CL) = CLAY

(CL-SP) = CLAY WITH POORLY GRADED SAND

(CH) = CLAY

(CH-SP) = CLAY WITH POORLY GRADED SAND

SCREENED INTERVAL

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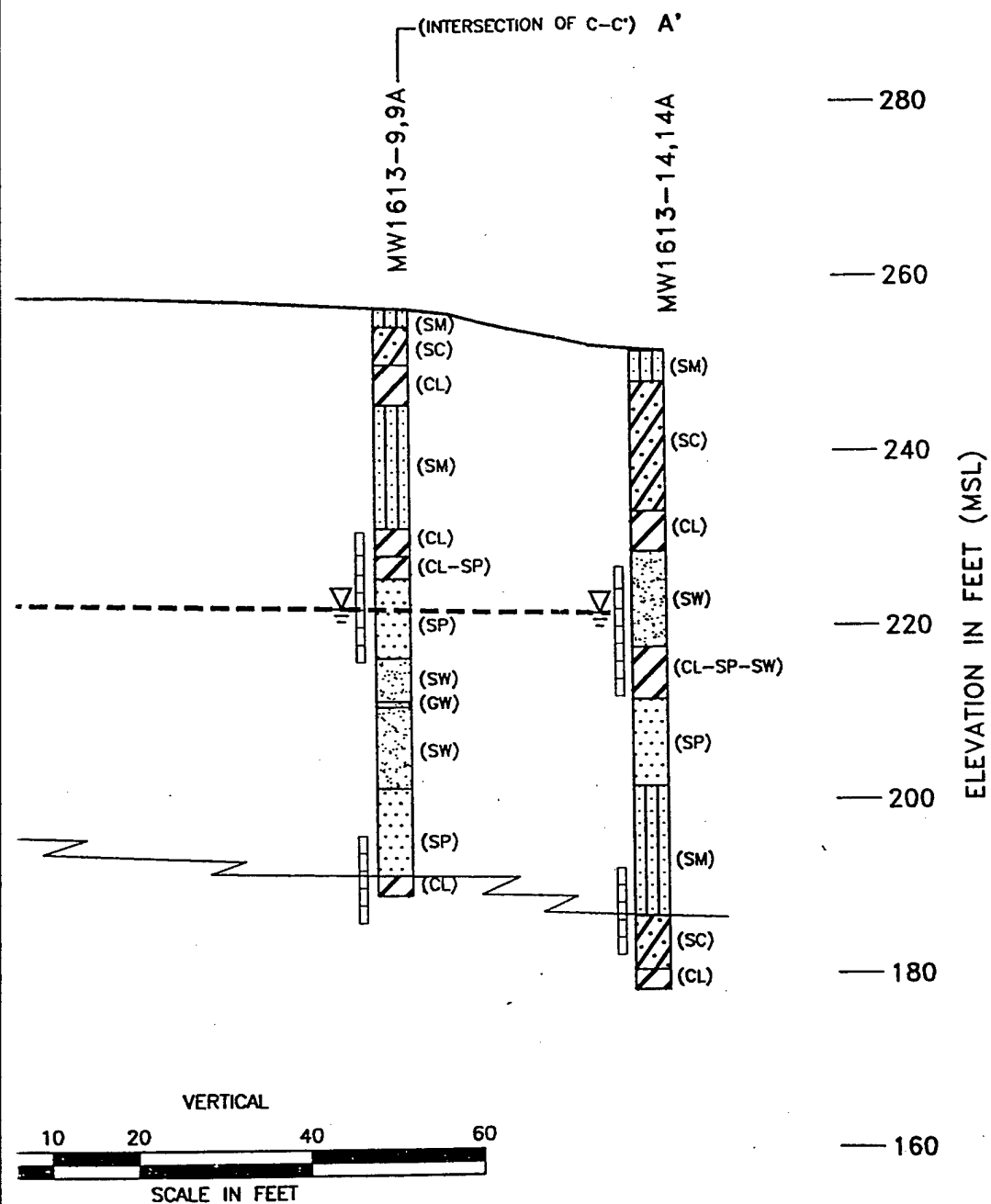
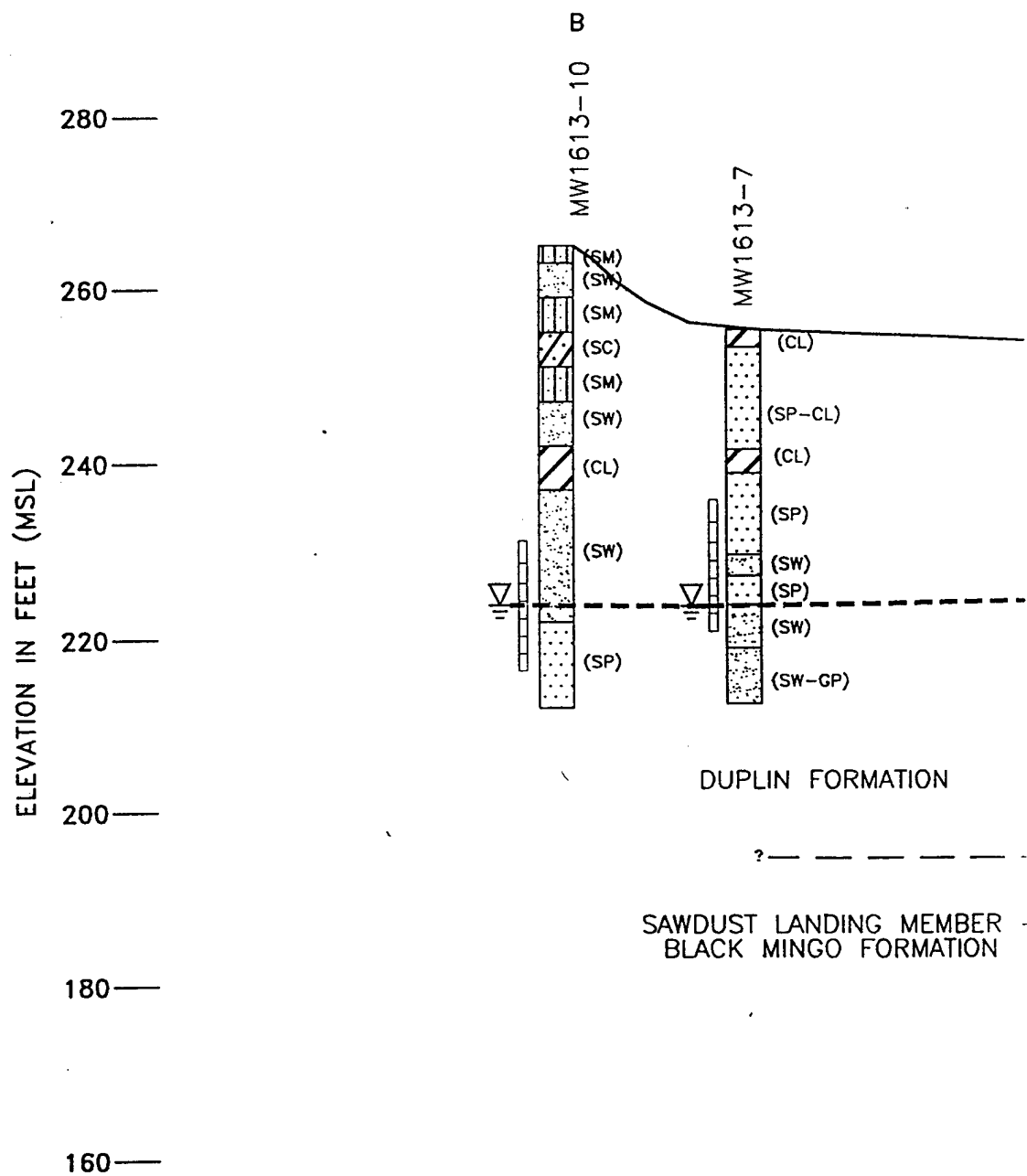


FIGURE 2.9
HYDROGEOLOGIC
CROSS-SECTION
A-A',
THE BUILDING 1613 SITE
 Sites OU-4 And Building 1613
 RNA TS
 Shaw AFB, South Carolina

PARSONS
ENGINEERING SCIENCE, INC.

Denver, Colorado



LEGEND



(SW) = WELL GRADED SAND

(SW-GP) = WELL GRADED SAND WITH GRAVEL



(SP) = POORLY GRADED SAND

(SP-CL) = POORLY GRADED SAND WITH CLAY



(SC) = CLAYEY SAND



(SM) = SILTY SAND



(CL) = CLAY



(CH) = CLAY



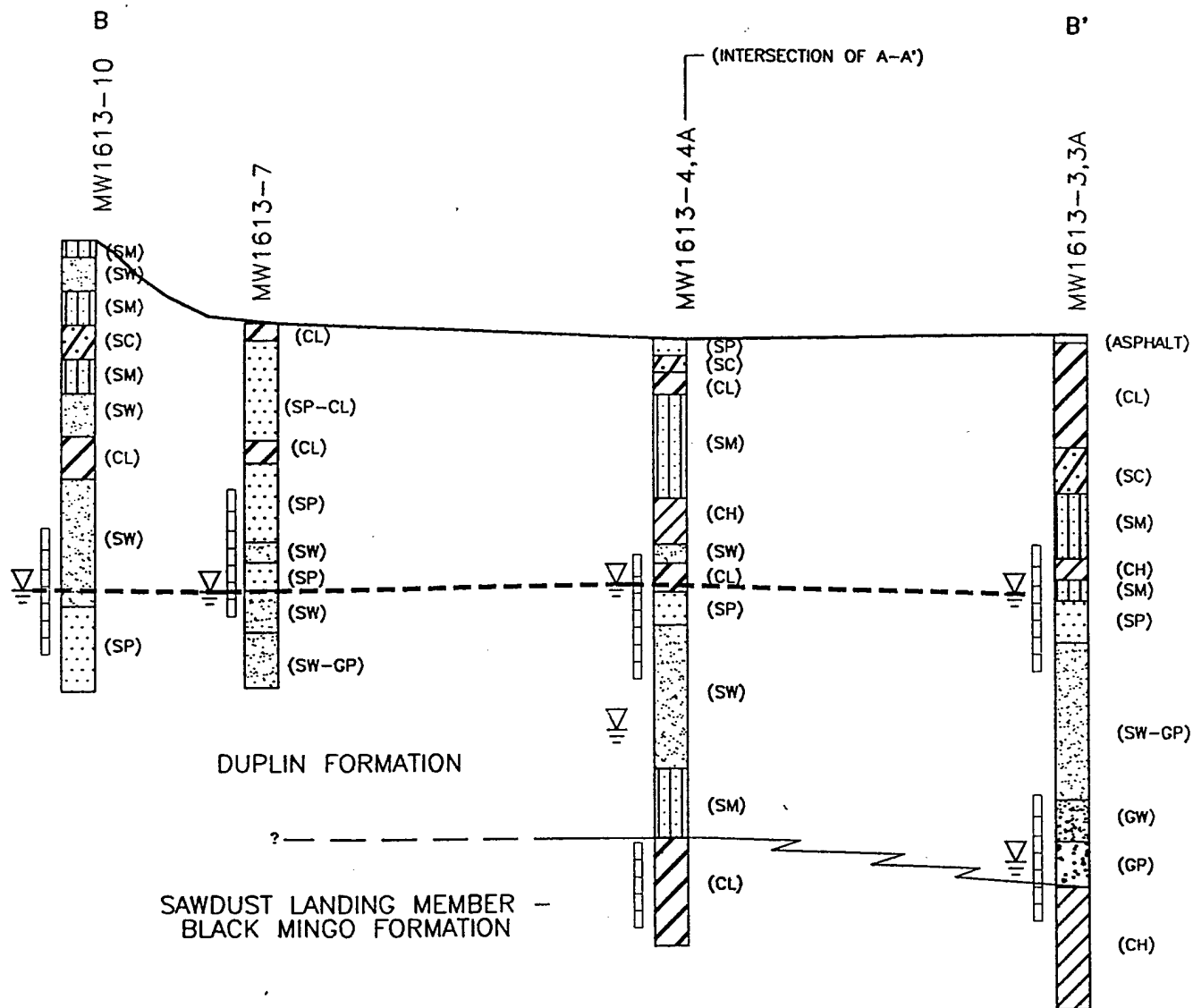
(GW) = WELL GRADED GRAVEL



(GP) = POORLY GRADED GRAVEL

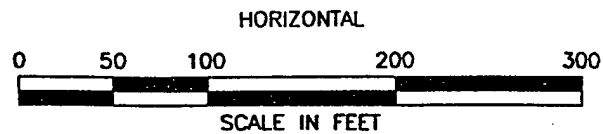
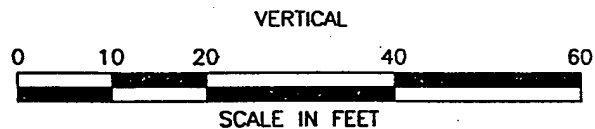


SCREENED INTERVAL



LEGEND

-  (CL) = CLAY
-  (CH) = CLAY
-  (GW) = WELL GRADED GRAVEL
-  (GP) = POORLY GRADED GRAVEL
-  SCREENED INTERVAL



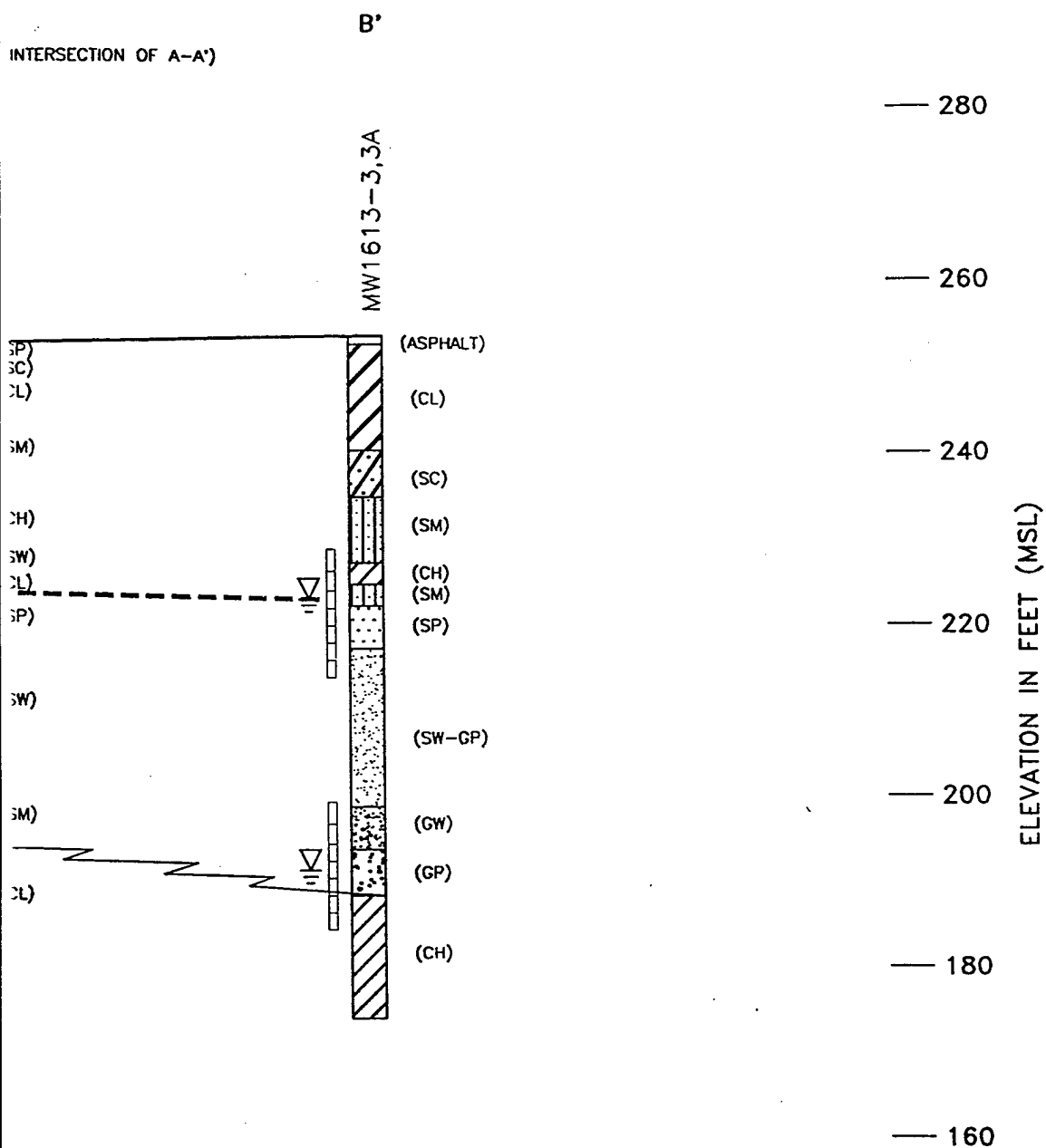


FIGURE 2.10
HYDROGEOLOGIC
CROSS-SECTION
B-B',
THE BUILDING 1613 SITE
 Sites OU-4 And Building 1613
 RNA TS
 Shaw AFB, South Carolina

PARSONS
ENGINEERING SCIENCE, INC.

Denver, Colorado

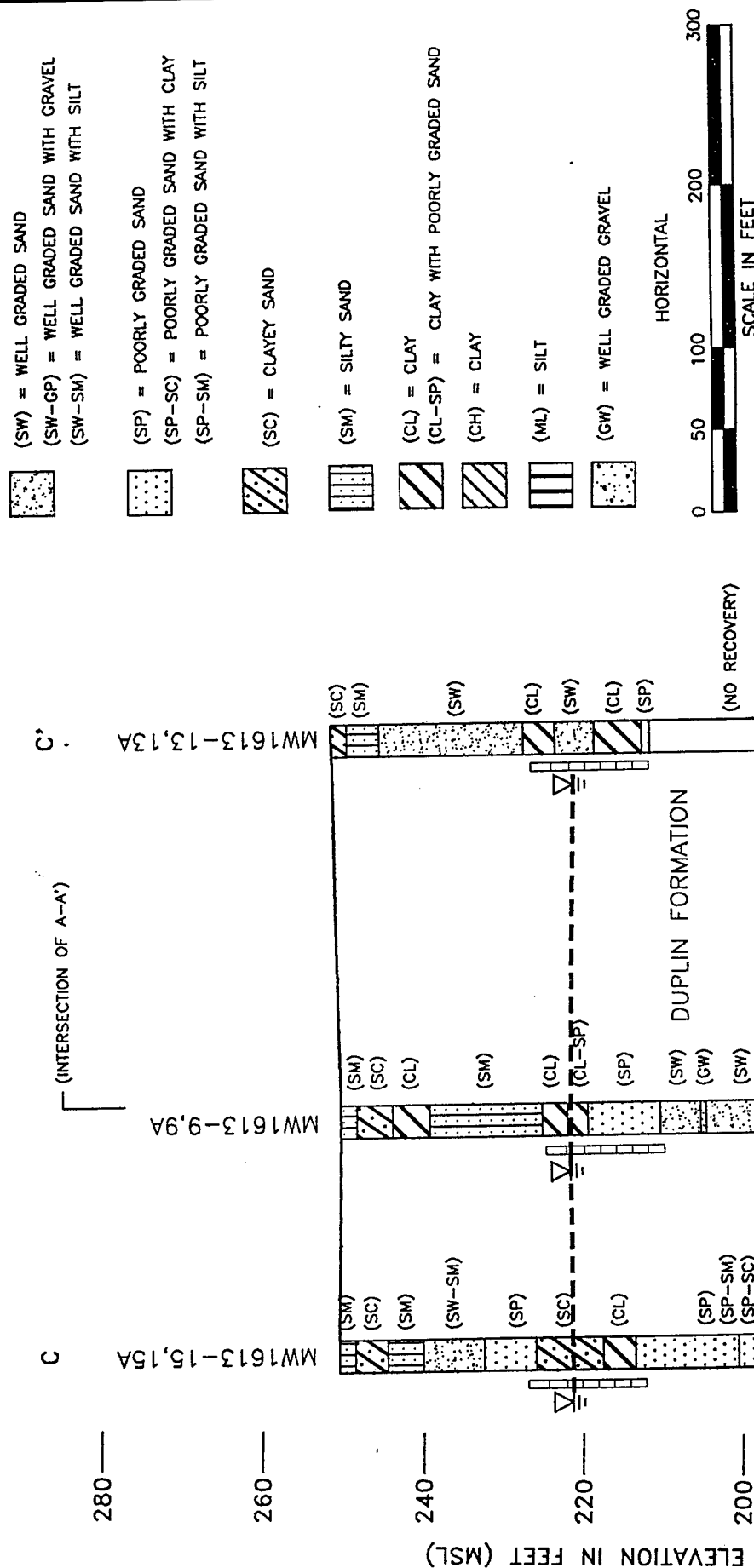


FIGURE 2.11

HYDROGEOLOGIC CROSS-SECTION C-C', THE BUILDING 1613 SITE

Sites OU-4 And Building 1613
RNA TS
Shaw AFB, South Carolina

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

approximately 39 to 48 feet bgs) and 6 deep monitoring wells are screened at the base of the surficial aquifer (bottom of screens at approximately 65 to 75 feet bgs). Four of the deep monitoring wells (MW1613-3A, -4A, -9A, and 14A) extend several feet into the confining clay layer of the Sawdust Landing Member, and one (MW1613-4A) completely screened within it. Monitoring well construction details are listed in Table 2.4.

Groundwater flow in the upper zone of the Shallow Aquifer is uniformly to the east, as determined from groundwater elevations measured at shallow monitoring well locations. Similarly, groundwater elevations measured from deep monitoring well locations in the Shallow Aquifer indicate that flow is also toward the east. Water table elevations for shallow and deep monitoring well depths are provided in Table 2.5 and shown on Figures 2.12 and 2.13. Differences between shallow and deep groundwater elevations typically varied by less than 2 inches with the exception of deep monitoring wells MW1613-3A and -4A, which have anomalous potentiometric water levels. The water level at deep well MW1613-3A is approximately 30 feet lower than the water levels in shallow well MW1613-3. The water level in deep well MW1613-4A is approximately 15 feet lower than the water level in shallow well MW1613-4. Geologic cross sections do not indicate the presence of soil layers that may cause hydraulic isolation between the well clusters; therefore, the difference in groundwater elevations may result from both wells being screened partially or fully within the Sawdust Landing aquitard rather than the lower portion of the Duplin Formation.

Groundwater elevations fluctuated by as much as five feet between June 20, 1994 and April 1, 1996. Changes in groundwater elevations, however, did not affect the easterly flow of groundwater, nor cause a significant variation in the groundwater gradient. The average groundwater gradient in the upper portion of the Shallow Aquifer is approximately 0.0032 ft/ft. The groundwater gradient was estimated at 0.0069 ft/ft for the deeper portion of the Shallow Aquifer; however, groundwater elevations used to

TABLE 2.4
SUMMARY OF WELL INSTALLATION DETAILS
BUILDING 1613 SITE
SITES OU-4 AND BUILDING 1613
RNA TS
SHAW AFB, SOUTH CAROLINA

Well Identification	Northing (feet)	Easting (feet)	Casing Diameter (inches)	TOC Elevation (ft msl) ^{a/}	Ground Elevation (ft msl)	Total Well Depth (ft bgs) ^{b/}	Screen Length (feet)
MW1613-1	781803.178	2159645.730	2.00	256.66	256.63	48.10	14.91
MW1613-2	781706.587	2159700.319	2.00	256.20	256.37	43.34	14.31
MW1613-3	781702.290	2159775.428	2.00	255.43	255.68	43.51	14.31
MW1613-3A	781705.669	2159777.440	2.00	255.52	255.67	75.04	14.66
MW1613-4	781790.037	2159779.430	2.00	252.29	252.39	41.03	14.70
MW1613-4A	781804.147	2159785.943	2.00	252.19	252.65	70.00	9.44
MW1613-5	781780.890	2159846.280	2.00	252.42	252.72	40.52	14.99
MW1613-6	781823.329	2159477.525	2.00	265.05	265.72	54.94	14.26
MW1613-7	781869.579	2159721.743	2.00	252.63	253.07	41.48	14.65
MW1613-8	781845.114	2159912.971	2.00	253.42	253.82	41.55	14.59
MW1613-9	781780.125	2160050.766	2.00	250.90	251.40	41.30	14.60
MW1613-9A	781789.666	2160056.414	2.00	251.00	251.00	64.92	9.72
MW1613-10	781962.129	2159665.136	2.00	264.79	264.79	49.04	14.84
MW1613-11	781855.883	2159802.851	2.00	253.47	253.47	39.55	14.75
MW1613-12	781937.371	2159752.051	2.00	254.23	254.23	37.55	14.66
MW1613-13	781557.308	2160086.147	2.00	251.88	2551.88	38.74	14.70
MW1613-13A	781554.302	2160092.796	2.00	251.94	251.94	74.53	9.68
MW1613-14	781773.546	2160199.506	2.00	251.63	251.63	39.62	14.73
MW1613-14A	781769.463	2160206.629	2.00	251.68	251.68	70.12	9.67
MW1613-15	781932.609	2160110.172	2.00	251.51	251.51	39.03	14.69
MW1613-15A	781925.965	2160107.474	2.00	251.50	251.50	64.44	9.69

^{a/} ft msl = feet above mean sea level.

^{b/} ft bgs = feet below ground surface.

TABLE 2.5
GROUNDWATER ELEVATIONS
BUILDING 1613 SITE
SITES OU-4 AND BUILDING 1613
RNA TS
SHAW AFB, SOUTH CAROLINA

Well Location	Date Monitored	TOC Elevation (ft msl) ^{a/}	Depth to Top of Product (ft btoc) ^{b/}	Product Thickness (ft)	Depth to Groundwater (ft btoc)	Groundwater Elevation (ft msl)
MW1613-1	6/20/94	256.66	NA ^{d/}	NA	34.80	221.86
	9/30/94	256.66	NA	NA	35.14	221.52
	12/14/94	256.66	NA	NA	34.80	221.86
	3/20/95	256.66	NA	NA	32.45	224.21
	7/27/95	256.66	NA	NA	32.64	224.02
	8/28/95	256.66	NA	NA	33.00	223.66
	10/11/95	256.66	NA	NA	33.52	223.14
	1/11/96	256.66	NA	NA	34.13	222.53
	4/4/96	256.66	NA	NA	34.81	221.85
MW1613-2	6/20/94	256.20	NA	NA	34.57	221.63
	9/30/94	256.20	NA	NA	34.84	211.36
	12/15/94	256.20	NA	NA	34.53	221.67
	3/20/95	256.20	NA	NA	32.16	224.04
	7/27/95	256.20	NA	NA	32.42	223.78
	8/28/95	256.20	NA	NA	32.78	223.42
	10/11/95	256.20	NA	NA	31.28	224.92
	1/11/96	256.20	NA	NA	33.89	222.31
	4/4/96	256.20	NA	NA	34.53	221.67
MW1613-3	6/20/94	255.43	NA	NA	34.60	220.83
	9/30/94	255.43	NA	NA	34.34	221.09
	12/15/94	255.43	NA	NA	34.30	221.13
	3/20/95	255.43	NA	NA	31.70	223.73
	7/27/95	255.43	NA	NA	31.94	223.49
	8/28/95	255.43	NA	NA	32.30	223.13
	10/11/95	255.43	NA	NA	32.81	222.62
	1/11/96	255.43	NA	NA	33.41	222.02
	4/4/96	255.43	NA	NA	34.04	221.39
MW1613-3A	6/21/94	255.52	NA	NA	63.54	191.98
	9/30/94	255.52	NA	NA	66.44	189.08
	12/15/94	255.52	NA	NA	63.37	192.15
	3/20/95	255.52	NA	NA	61.82	193.70
	7/27/95	255.52	NA	NA	62.50	193.02
	8/28/95	255.52	NA	NA	63.04	192.48
	10/11/95	255.52	NA	NA	62.62	192.90
	1/11/96	255.52	NA	NA	62.15	193.37
	4/4/96	255.52	NA	NA	62.72	192.80
MW1613-4	6/21/94	252.29	30.59	1.46	32.05	220.24 ^{u/}
	9/30/94	252.29	30.84	1.49	32.33	219.96 ^{u/}
	12/15/94	252.29	30.54	1.39	31.93	220.36 ^{u/}
	3/20/95	252.29	27.69	1.56	29.25	224.29 ^{u/}
	7/27/95	251.82	27.22	0.74	27.96	223.27 ^{u/}
	8/28/95	251.82	28.58	0.13	28.71	222.49 ^{u/}
	10/11/95	252.29	28.82	1.28	30.10	223.21 ^{u/}
	1/11/96	251.82	29.40	1.09	30.49	220.91 ^{u/}
	4/4/96	251.82	30.06	1.28	31.34	221.5 ^{u/}
MW1613-4A	9/30/94	252.19	NA	NA	45.73	206.46
	12/15/94	252.19	NA	NA	47.84	204.35
	3/20/95	252.19	NA	NA	44.98	207.21
	7/27/95	252.19	NA	NA	47.21	204.98
	8/28/95	252.19	NA	NA	47.47	204.72
	10/11/95	252.19	NA	NA	46.92	205.27
	1/11/96	252.19	NA	NA	48.10	204.09
	4/4/96	252.19	NA	NA	49.56	202.63

TABLE 2.5 (continued)
GROUNDWATER ELEVATIONS
BUILDING 1613 SITE
SITES OU-4 AND BUILDING 1613
RNA TS
SHAW AFB, SOUTH CAROLINA

Well Location	Date Monitored	TOC Elevation (ft msl)	Depth to Top of Product (ft btoc)	Product Thickness (ft)	Depth to Groundwater (ft btoc)	Groundwater Elevation (ft msl)
MW1613-5	6/21/94	252.42	NA	NA	31.17	221.25
	9/30/94	252.42	NA	NA	31.46	220.96
	12/15/94	252.42	NA	NA	31.20	221.22
	3/20/95	252.42	NA	NA	28.86	223.56
	7/27/95	252.42	NA	NA	29.08	223.34
	8/28/95	252.42	NA	NA	29.42	223.00
	10/11/95	252.42	NA	NA	29.94	222.48
	1/11/96	252.42	NA	NA	30.50	221.92
	4/4/96	252.42	NA	NA	31.18	221.24
MW1613-6	9/30/94	265.19	NA	NA	42.95	222.24
	12/15/94	265.19	NA	NA	42.49	222.70
	3/20/95	265.19	NA	NA	40.15	225.04
	7/27/95	265.19	NA	NA	40.39	224.80
	8/28/95	265.19	NA	NA	40.78	224.41
	10/11/95	265.05	NA	NA	41.31	223.74
	1/11/96	265.05	NA	NA	41.96	223.09
	4/4/96	265.05	NA	NA	42.62	222.43
MW1613-7	9/30/94	252.63	NA	NA	31.45	221.18
	12/15/94	252.63	30.91	0.58	31.49	221.14 ^d
	3/20/95	252.63	NA	NA	28.72	223.91
	7/27/95	252.63	28.91	0.07	28.98	223.59 ^d
	8/28/95	252.63	29.26	0.04	29.30	223.33 ^d
	10/11/95	252.63	29.75	0.20	29.95	222.84 ^d
	1/11/96	252.63	30.26	0.44	30.70	222.28 ^d
	4/4/96	252.63	30.89	0.77	31.66	221.59 ^d
MW1613-8	9/30/94	253.42	NA	NA	32.58	220.84
	12/15/94	253.42	NA	NA	32.30	221.12
	3/20/95	253.42	NA	NA	29.97	223.45
	7/27/95	253.42	NA	NA	30.19	223.23
	8/28/95	253.42	NA	NA	30.56	222.86
	10/11/95	253.42	NA	NA	31.04	222.38
	1/11/96	253.42	NA	NA	31.59	221.83
	4/4/96	253.42	NA	NA	32.26	221.16
MW1613-9	9/30/94	250.90	NA	NA	30.59	220.31
	12/15/94	250.90	NA	NA	30.33	220.57
	3/20/95	250.90	NA	NA	28.09	222.81
	7/27/95	250.90	NA	NA	28.30	222.60
	8/28/95	250.90	NA	NA	28.62	222.28
	10/11/95	250.90	NA	NA	29.10	221.80
	1/11/96	250.90	NA	NA	29.63	221.27
	4/4/96	250.90	NA	NA	30.28	220.62
MW1613-9A	7/27/95	250.88	NA	NA	28.08	222.80
	8/28/95	250.88	NA	NA	28.48	222.40
	10/11/95	250.88	NA	NA	28.88	222.00
	1/11/96	250.88	NA	NA	29.38	221.50
	4/4/96	250.88	NA	NA	29.98	220.90
MW1613-10	7/27/95	264.44	NA	NA	40.42	224.02
	8/28/95	264.44	NA	NA	40.79	223.65
	10/11/95	264.44	NA	NA	41.32	223.12
	1/11/96	264.44	NA	NA	41.92	222.52
	4/4/96	264.44	NA	NA	42.66	221.78

TABLE 2.5 (concluded)
GROUNDWATER ELEVATIONS
BUILDING 1613 SITE
SITES OU-4 AND BUILDING 1613
RNA TS
SHAW AFB, SOUTH CAROLINA

Well Location	Date Monitored	TOC Elevation (ft msl)	Depth to Top of Product (ft btoc)	Product Thickness (ft)	Depth to Groundwater (ft btoc)	Groundwater Elevation (ft msl)
MW1613-11	7/27/95	252.84	NA	NA	29.31	223.53
	8/28/95	252.84	NA	NA	29.73	223.11
	10/11/95	252.84	NA	NA	30.24	222.60
	1/11/96	252.84	NA	NA	30.80	222.04
	4/4/96	252.84	NA	NA	31.51	221.33
MW1613-12	7/27/95	254.04	NA	NA	30.38	223.66
	8/28/95	254.04	NA	NA	30.69	223.35
	10/11/95	254.04	NA	NA	31.26	222.78
	1/11/96	254.04	NA	NA	31.83	222.21
	4/4/96	254.04	NA	NA	32.55	221.49
MW1613-13	7/27/95	251.20	NA	NA	29.08	222.12
	8/28/95	251.20	NA	NA	29.44	221.76
	10/11/95	251.20	NA	NA	29.98	221.22
	1/11/96	251.20	NA	NA	30.38	220.82
	4/4/96	251.20	NA	NA	30.97	220.23
MW1613-13A	7/27/95	251.11	NA	NA	29.05	222.06
	8/28/95	251.11	NA	NA	29.38	221.73
	10/11/95	251.11	NA	NA	29.90	221.21
	1/11/96	251.11	NA	NA	30.42	220.69
	4/4/96	251.11	NA	NA	31.04	220.07
MW1613-14	7/27/95	250.88	NA	NA	29.90	220.98
	8/28/95	250.88	NA	NA	29.28	221.60
	10/11/95	250.88	NA	NA	29.79	221.09
	1/11/96	250.88	NA	NA	30.24	220.64
	4/4/96	250.88	NA	NA	30.87	220.01
MW1613-14A	7/27/95	251.01	NA	NA	29.24	221.77
	8/28/95	251.01	NA	NA	29.48	221.53
	10/11/95	251.01	NA	NA	29.97	221.04
	1/11/96	251.01	NA	NA	30.31	220.70
	4/4/96	251.01	NA	NA	30.91	220.10
MW1613-15	7/27/95	251.26	NA	NA	28.74	222.52
	8/28/95	251.26	NA	NA	29.12	222.14
	10/11/95	251.28	NA	NA	29.62	221.66
	1/11/96	251.28	NA	NA	29.99	221.29
	4/4/96	251.28	NA	NA	30.79	220.49
MW1613-15A	7/27/95	251.36	NA	NA	28.71	222.65
	8/28/95	251.36	NA	NA	29.02	222.34
	10/11/95	251.36	NA	NA	29.54	221.82
	1/11/96	251.36	NA	NA	30.13	221.23
	4/4/96	251.36	NA	NA	30.61	220.75

^a ft msl = feet above mean sea level.

^b ft btoc = feet below top of casing.

^c NA = data not available or applicable.

^d Water elevation corrected for free product as follows: $WE_c = WE + 0.8P$

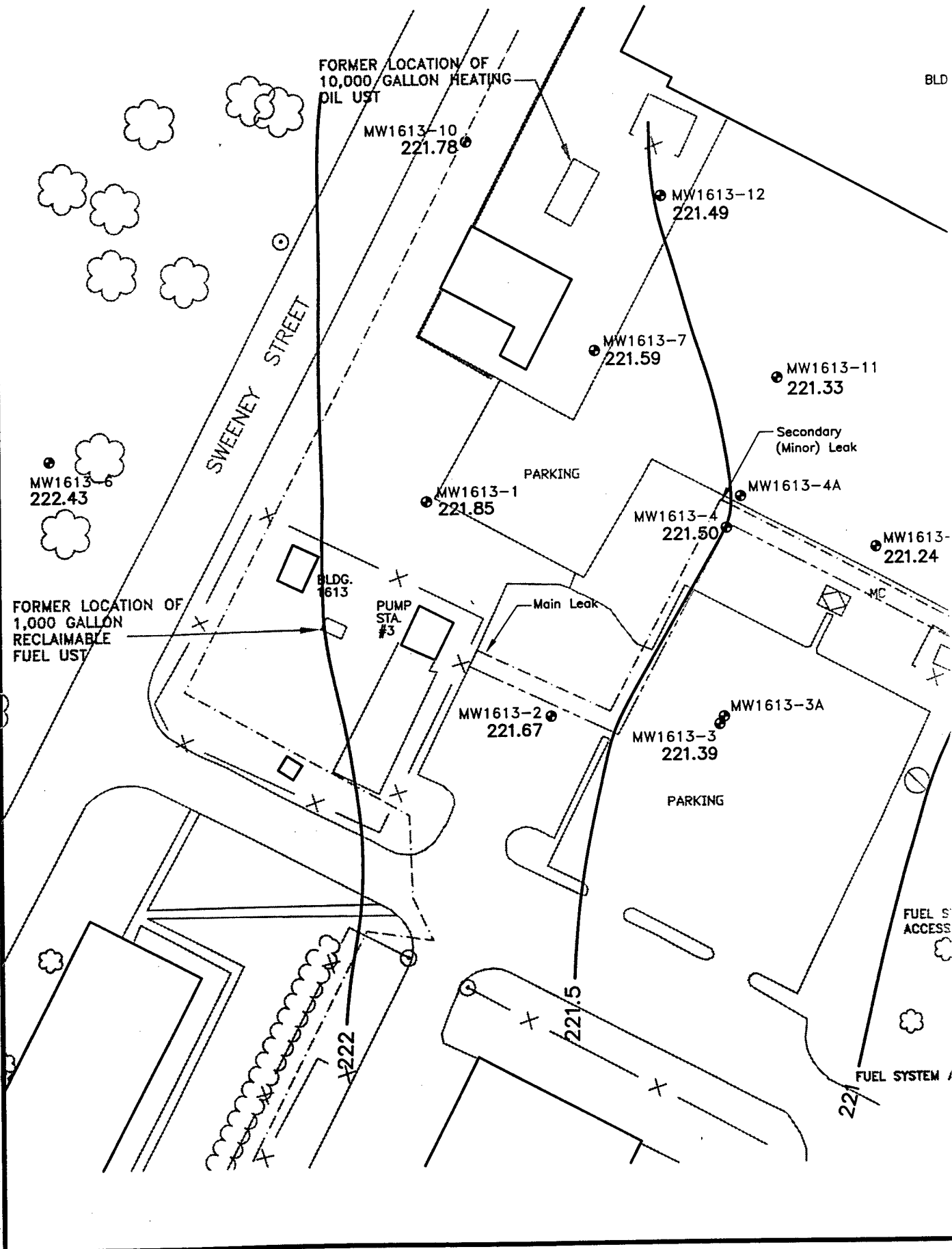
where: WE_c - corrected water elevation

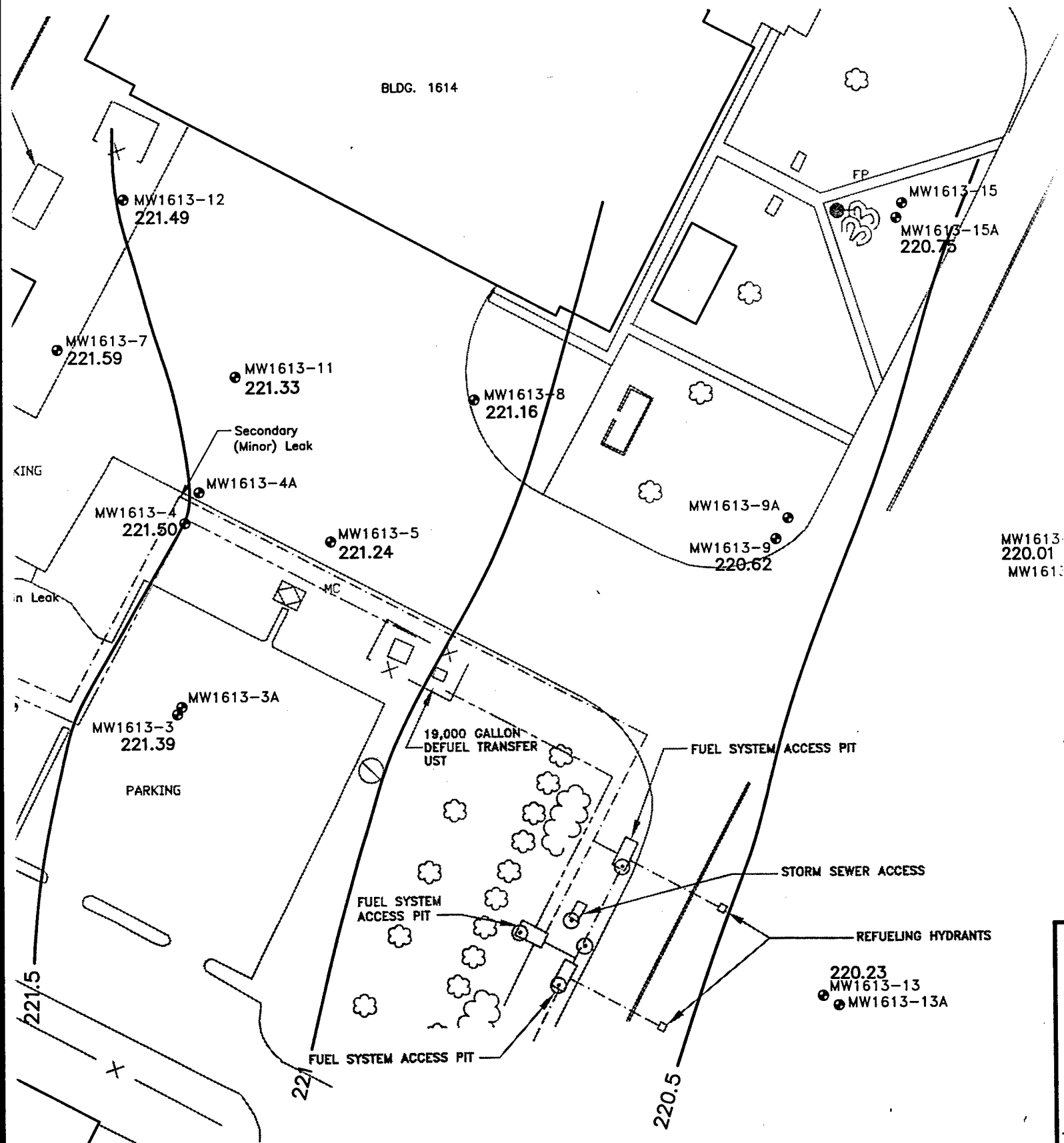
WE - measured water elevation

0.8 - product density relative to water

P - measured product thickness.

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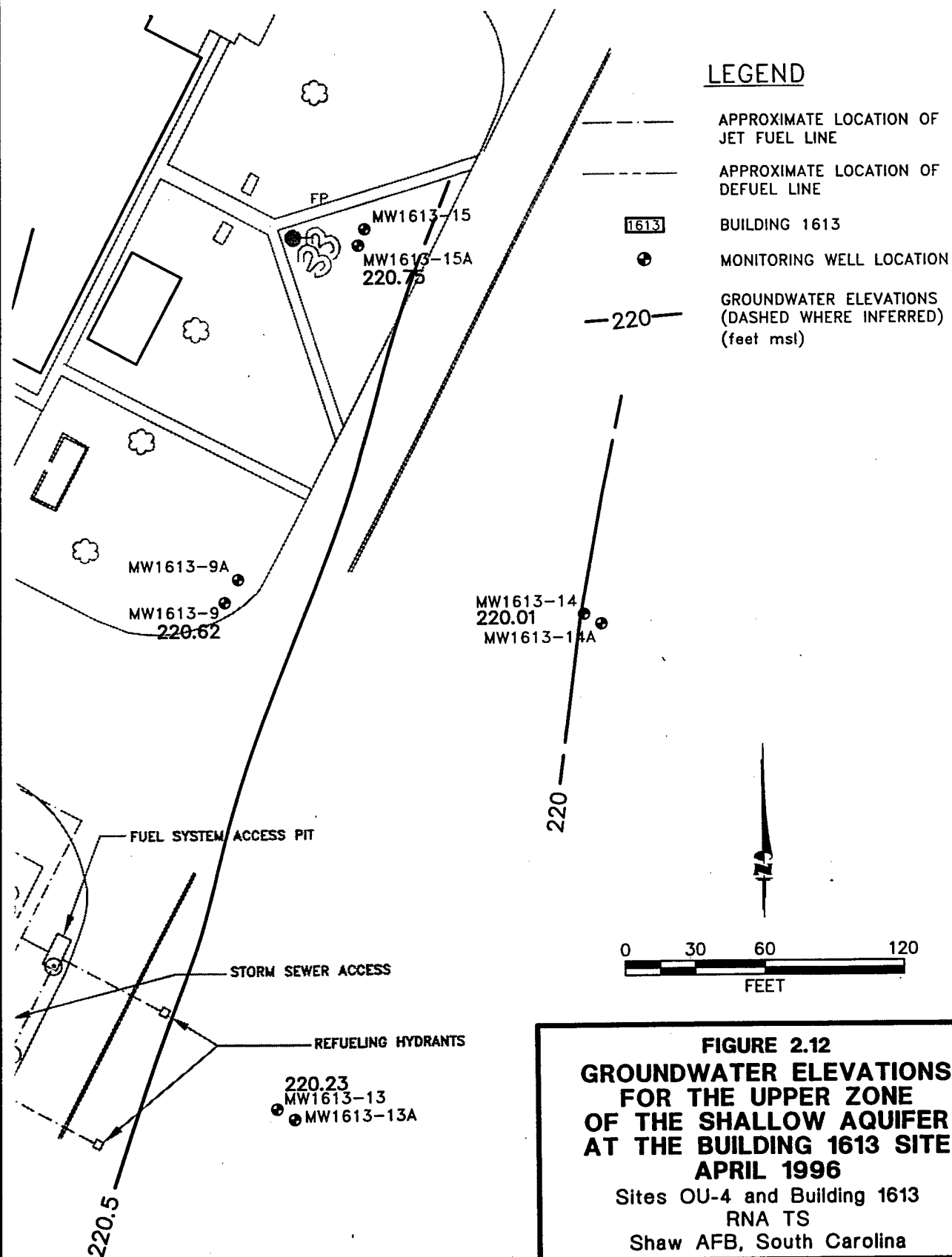


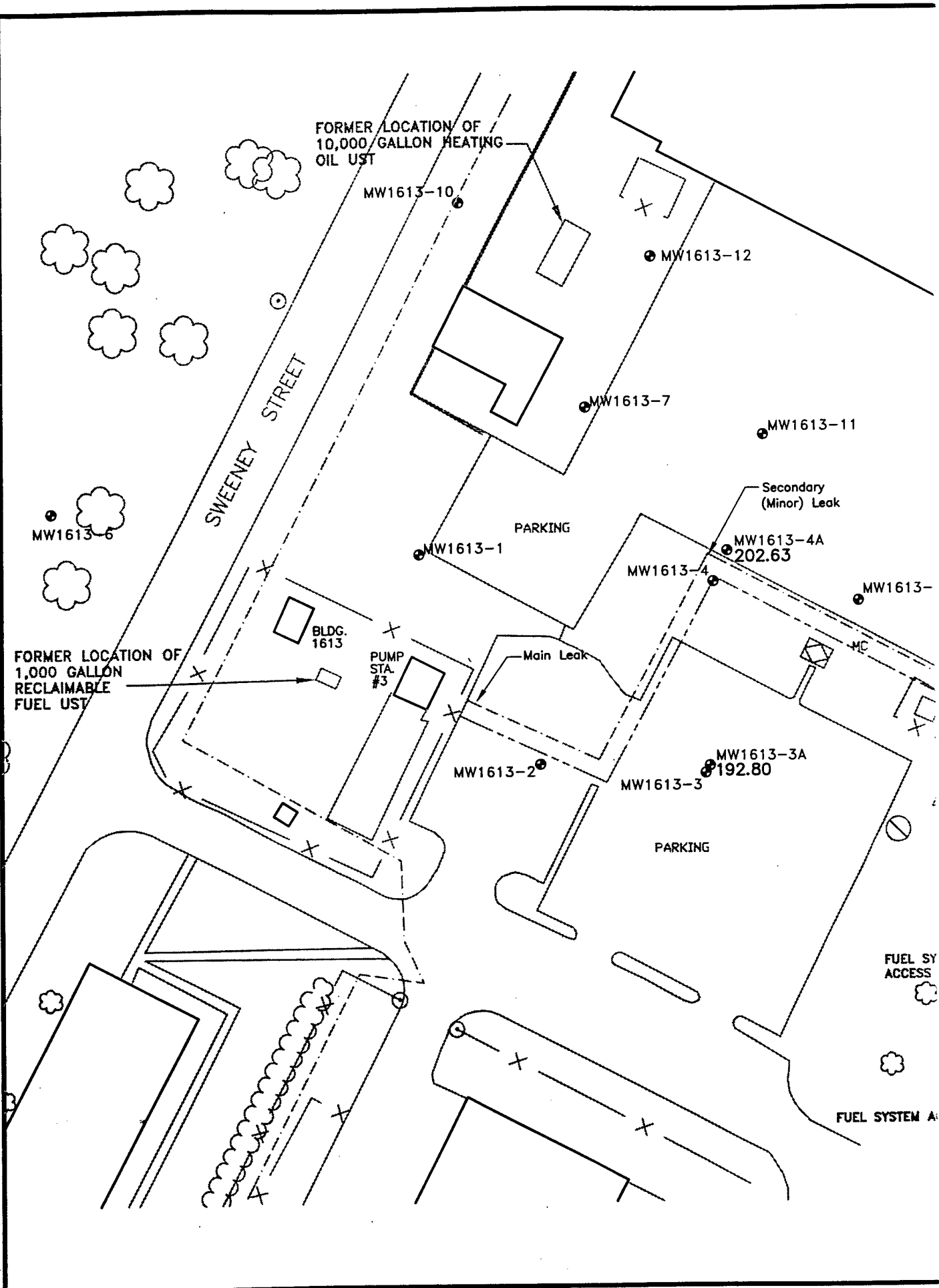
FIGURE 2.12
GROUNDWATER ELEVATIONS
FOR THE UPPER ZONE
OF THE SHALLOW AQUIFER
AT THE BUILDING 1613 SITE
APRIL 1996

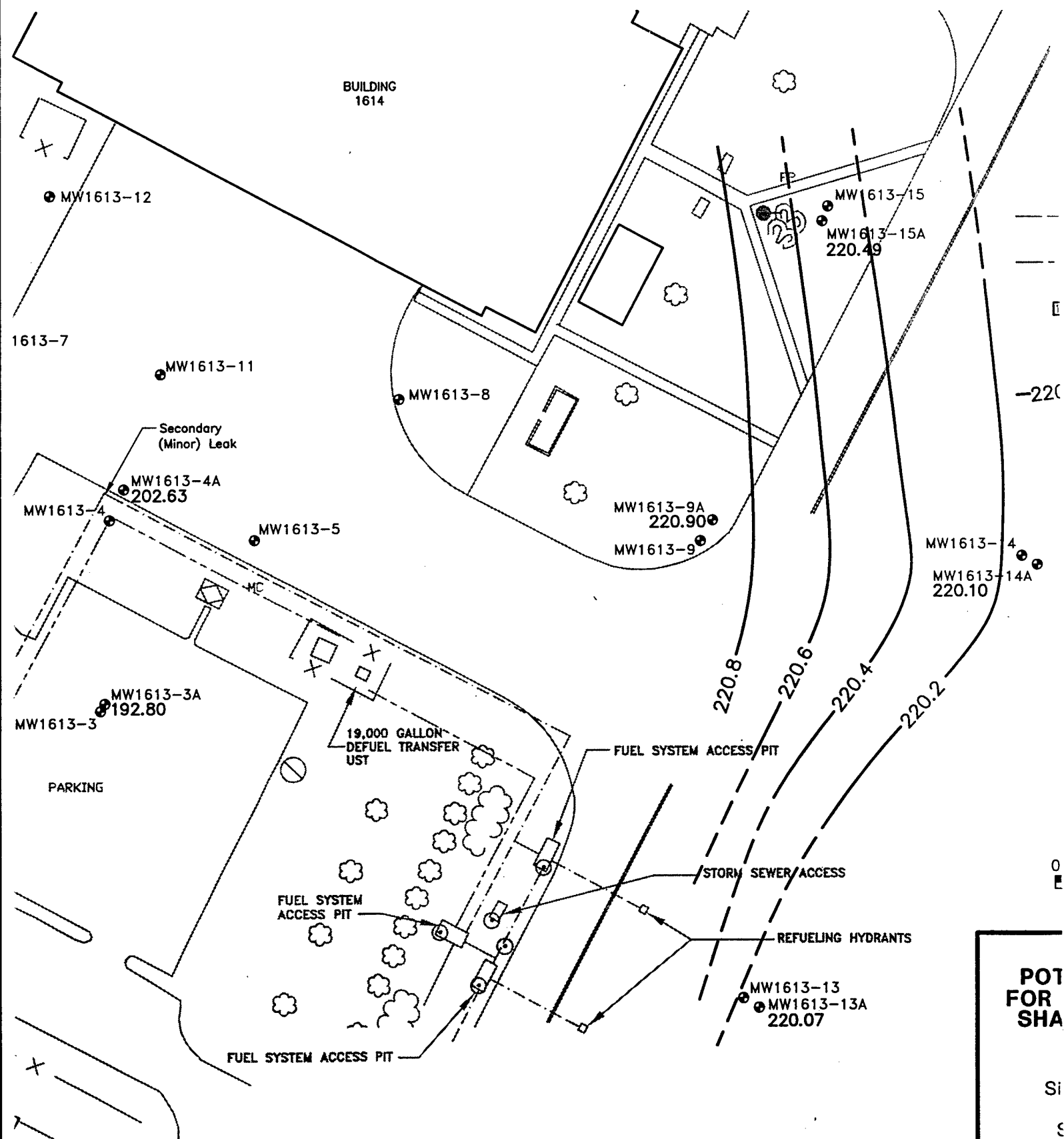
Sites OU-4 and Building 1613
 RNA TS
 Shaw AFB, South Carolina

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Denver, Colorado

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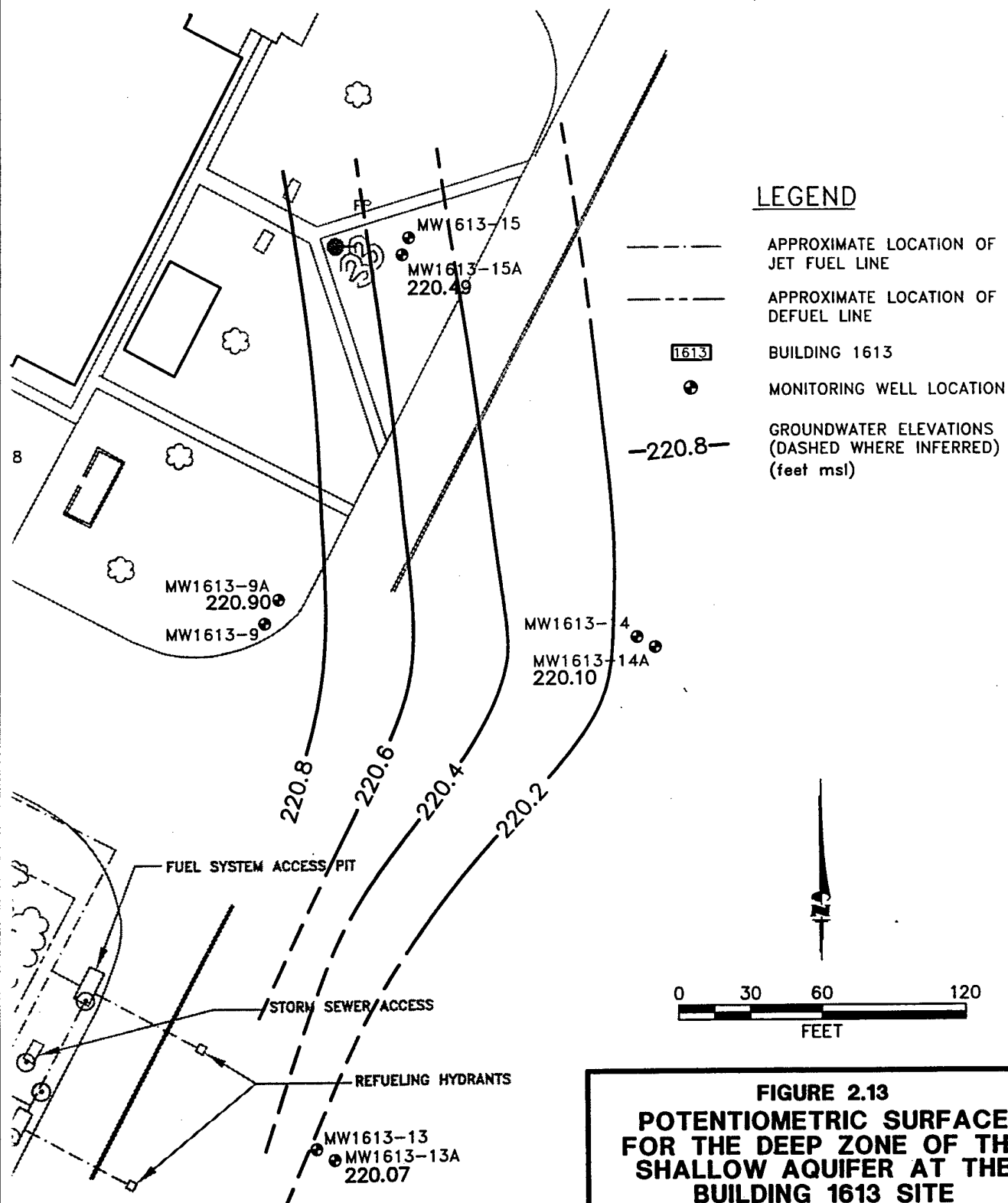


FIGURE 2.13
POTENTIOMETRIC SURFACE
FOR THE DEEP ZONE OF THE
SHALLOW AQUIFER AT THE
BUILDING 1613 SITE
APRIL 1996

Sites OU-4 and Building 1613
 RNA TS
 Shaw AFB, South Carolina

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derive this value were limited to wells on the east side of the site that are screened above the Sawdust Landing Member. With the exception of the anomalous potentiometric surface measurements at well clusters at MW1613-3 and MW1613-4, vertical gradients at the site are minimal and randomly directed both upward and downward.

Aquifer hydraulic conductivities were estimated during the Supplemental EA (June through August, 1995) (Fust, 1995c). Interpretation of slug test results yielded hydraulic conductivity estimates for the upper portion of the Duplin Aquifer that ranged from 62.1 ft/day to 234 ft/day in wells MW1613-1, -5, and -9. Hydraulic conductivities for the lower portion of the Duplin Aquifer were calculated at 0.626 ft/day, 1.14 ft/day, and 0.006 ft/day for wells MW1613-9A, -14A, and -4A, respectively (Rust, 1995c). The slug test results for well MW1613-4A, however, are not considered representative of the silty sands typically encountered in the deeper zone of the Shallow Aquifer. Hydraulic conductivities in the Shallow Aquifer decreased with depth because the percentage of fines increases with depth.

Assuming an average hydraulic conductivity of 135 ft/day, an effective porosity of 0.25, and an average gradient of 0.0032 ft/ft, the average advective groundwater velocity in the upper zone of the Shallow Aquifer beneath the Building 1613 Site is approximately 1.73 ft/day (631 ft/year). Assuming an average hydraulic conductivity of 0.89 ft/day, an effective porosity of 0.20 (for siltier soils), and an average gradient of 0.0069 ft/ft, the average advective groundwater velocity in the deeper zone of the Shallow Aquifer is 0.03 ft/day (11 ft/year).

2.1.3 Summary of Analytical Results for OU-4

Analytical data has been collected at site OU-4 to locate and define the extent of site contamination since the initiation of the Phase II, Stage I investigation in the mid-1980's. Activities have included a soil gas survey, a geophysical survey, and sampling of soil, groundwater, surface water, and sediment for laboratory analysis. The soil gas and geophysical surveys were used to evaluate the areal extent of impacted vadose zone soils,

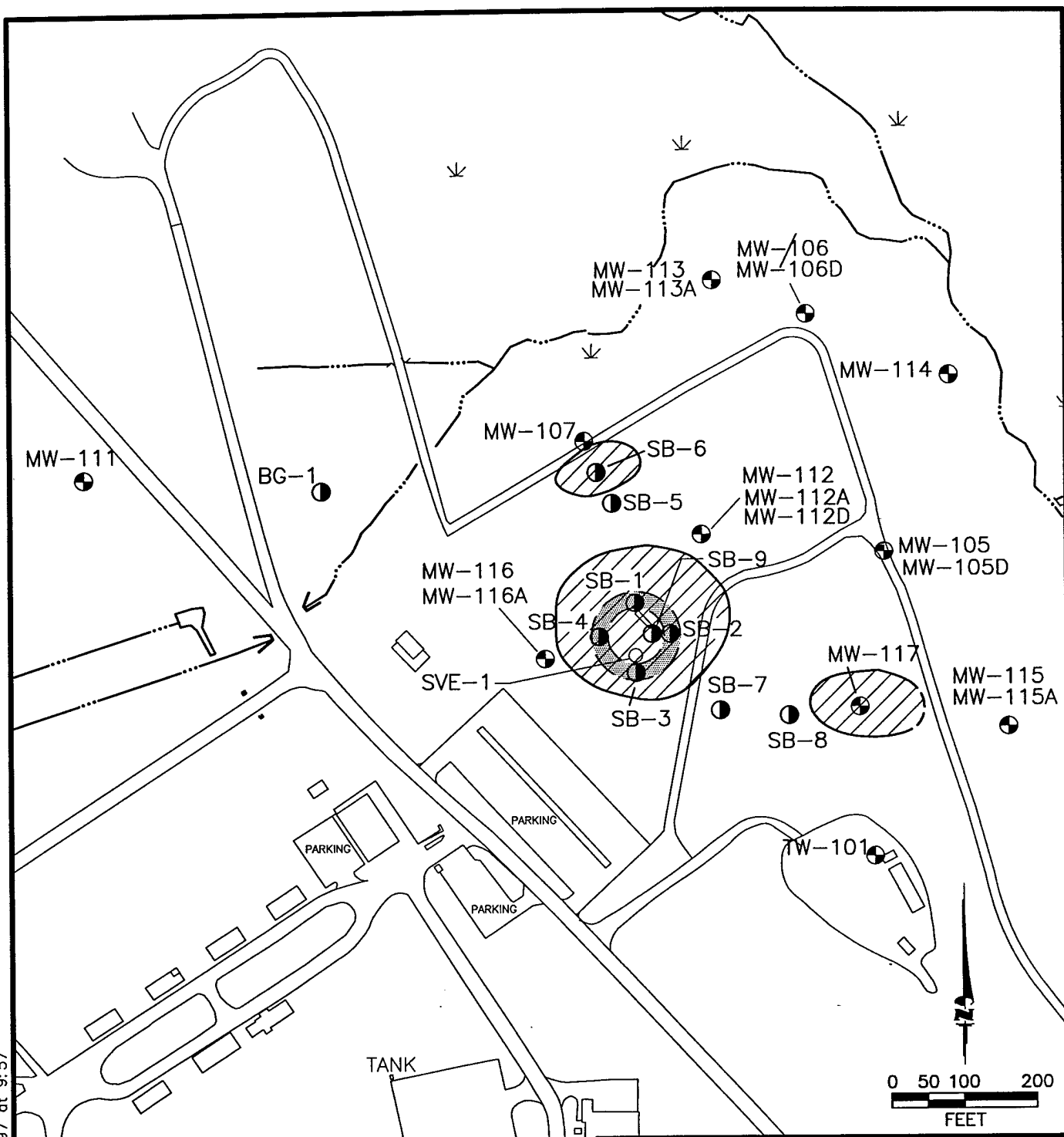
identify potential source areas such as former burn pits or drum burial locations, and guide the soil and groundwater sampling efforts. The environmental samples have been variously analyzed for volatile organic compounds (VOCs), total recoverable petroleum hydrocarbons (TRPH), diesel range organics (DRO), semivolatile organic compounds (SVOCs), pesticides, polychlorinated biphenyls (PCBs), metals, and common anions. Summaries of the analytical results, as they apply to the current RNA investigation, are provided in the following subsections. In particular, this discussion focuses on the concentration and extent of organic constituents associated with fuels and solvents. More complete descriptions of site activities, sample analyses, and results can be found in the Draft RI (Law, 1991) and the Final RI (Rust E&I, 1995b).

2.1.3.1 Soil Quality

The areal extent of total VOC contamination in soils as defined in the RI is presented on Figure 2.14. A summary of VOC results for RI soil samples is provided in Table 2.6. Total VOC concentrations consisted primarily of BTEX and fuel constituents; however, 1,1,1-trichloroethane (TCA), 1,2-dichloroethane (DCE), and tetrachloroethene (PCE) were each measured in one site soil sample at concentrations near or below the detection limit.

The highest total VOC concentrations and the largest areal extent of contamination were both identified in soil samples collected from a depth of 6 to 8 feet bgs. The VOC concentrations detected above 0.1 microgram per kilogram ($\mu\text{mg/kg}$) [0.1 milligrams per kilogram (mg/kg)], center on three areas that roughly coincide with the three "hot" spots identified in the soil gas survey. The highest total VOC concentrations in soil were detected in the vicinity of the former bermed burn pit at concentrations of up to 35,000 $\mu\text{g/kg}$ (35 mg/kg). This area also contained the only VOC concentrations detected above 0.1 mg/kg in soil samples collected from 0 to 3 feet bgs. Nevertheless, the detection of VOC concentrations in two areas beyond the still-recognizable burn pit suggests that

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LEGEND

- MONITORING WELL
- SOIL BORING
- LOCATION OF FORMER FIRE RING BERM
- ▨ APPROXIMATE AREAL EXTENT OF SOIL VOC CONCENTRATION EXCEEDING 0.1 mg/kg

FIGURE 2.14

EXTENT OF VOCs DETECTED IN SOIL SAMPLES AT OU-4

Sites OU-4 And Building 1613
RNA TS
Shaw AFB, South Carolina

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Denver, Colorado

TABLE 2.6
SUMMARY OF DETECTED CHLORINATED ETHANES, CHLORINATED
ETHENES, AND BTEX IN OU-4 SOIL SAMPLES FROM FEBRUARY/MARCH 1993
SITES OU-4 AND BUILDING 1613
RNA TS
SHAW AFB, SOUTH CAROLINA

Sample ID	1,1,1-TCA (µg/kg)	PCE (µg/kg)	Total 1,2-DCE (µg/kg)	Ethylbenzene (µg/kg)	Toluene (µg/kg)	Total Xylenes (µg/kg)	Total BTEX (µg/kg)
MW-112A-2	< 5.6 ^a	3.3 J ^b	< 5.6	< 5.6	< 5.6	< 5.6	3.3 J
MW-112A-8	< 5.8	< 5.8	< 5.8	< 5.8	< 5.8	< 5.8	< 5.8
MW-112A-14	< 5.7	< 5.7	< 5.7	< 5.7	< 5.7	< 5.7	< 5.7
MW-115A-3	< 6.8	< 6.8	11	5 J	6.5 J	14	36.5
MW-116-2	< 5.2	< 5.2	< 5.2	< 5.2	< 5.2	< 5.2	< 5.2
MW-116-7	< 5.2	< 5.2	< 5.2	< 5.2	< 5.2	< 5.2	< 5.2
MW-116-12	< 5.7	< 5.7	< 5.7	< 5.7	< 5.7	< 5.7	< 5.7
MW-116A-2	< 5.2	2.6 J	< 5.2	< 5.2	< 5.2	< 5.2	2.6
MW-116A-8	< 5.5	< 5.5	< 5.5	< 5.5	< 5.5	< 5.5	< 5.5
MW-116A-14	< 5.8	< 5.8	< 5.8	< 5.8	< 5.8	< 5.8	< 5.8
MW-117-2	< 5.4	< 5.4	< 5.4	< 5.4	< 5.4	< 5.4	< 5.4
MW-117-7	< 30	< 30	< 30	100	< 30	640	740
MW-117-12	< 5.9	< 5.9	< 5.9	4.3 J	< 5.9	9.4	13.7
MW-118-2	< 6.3	< 6.3	< 6.3	< 6.3	< 6.3	< 6.3	< 6.3
MW-119A-1	< 5.4	< 5.4	< 5.4	< 5.4	< 5.4	< 5.4	< 5.4
MW-119A-4	< 5.6	< 5.6	< 5.6	< 5.6	< 5.6	< 5.6	< 5.6
SB-1-2	< 28	< 28	< 28	150	28	440	618
SB-1-8	< 570	< 570	< 570	3000	< 570	10000	13000
SB-1-12	< 5500	< 5500	< 5500	17000	23000	75000	115000
SB-2-2	< 5.3	< 5.3	< 5.3	< 5.3	< 5.3	< 5.3	< 5.3
SB-2-8	< 570	490 J	< 570	140 J	< 570	630	1260
SB-3-2	< 5.5	< 5.5	< 5.5	< 5.5	< 5.5	< 5.5	< 5.5
SB-3-8	< 550	< 550	< 550	150J	< 550	750	900
SB-3-12	< 56	< 56	< 56	190	< 56	1500	1690
SB-4-2	< 530	< 530	< 530	490 J	170 J	3700	4360
SB-4-8	< 14000	< 14000	< 14000	< 14000	< 14000	35000	35000
SB-4-12	< 6000	< 6000	< 6000	10000	13000	91000	114000
SB-5-2	< 27	< 27	< 27	< 27	< 27	< 27	< 27
SB-5-8	< 5.9	< 5.9	< 5.9	< 5.9	< 5.9	< 5.9	< 5.9
SB-5-12	< 5.7	< 5.7	< 5.7	< 5.7	< 5.7	< 5.7	< 5.7
SB-6-2	< 5.5	< 5.5	< 5.5	< 5.5	< 5.5	< 5.5	< 5.5
SB-6-8	140 J	< 570	< 570	1900	300 J	12000	14340
SB-6-12	< 5600	< 5600	< 5600	4700 J	1300 J	23000	29000
SB-7-2	< 5.3	< 5.3	< 5.3	< 5.3	< 5.3	< 5.3	< 5.3
SB-7-8	< 5.8	< 5.8	< 5.8	< 5.8	< 5.8	< 5.8	< 5.8
SB-7-12	< 5600	< 5600	< 5600	< 5600	< 5600	< 5600	< 5600
SB-8-2	< 5.3	< 5.3	< 5.3	< 5.3	< 5.3	< 5.3	< 5.3
SB-8-8	< 5.8	< 5.8	< 5.8	< 5.8	< 5.8	< 5.8	< 5.8
SB-9-2	< 530	< 530	< 530	1300	< 530	3100	4400
SB-9-6	< 560	< 560	< 560	640	< 560	980	1620
SB-9-10	< 570	< 570	< 570	790	< 570	710	1500

^a< = Not detected down to 10% of the quantitation limit detected.

^bJ = Estimated value less than the quantitation limit.

secondary contaminant sources are present at the site. These two areas are centered around MW-117 and SB-6.

Although relatively high total VOC concentrations were historically detected in soil samples, site remediation activities that have occurred over the past three years may have significantly altered VOC concentrations in the soil. For example, after 1 year of bioventing in the former bermed burn pit, BTEX concentrations had decreased over 90 percent within approximately 30 feet of the vent wells (Parsons ES, 1996b). The effect of bioventing beyond 30 feet from the vent wells and after an additional 1.5 years of bioventing is not known. Also, hydrogen peroxide injection during November 1996 in the vicinity of MW-117 may have induced changes in soil VOC concentrations in this area. During the test, water levels were temporarily raised to the ground surface, which may have either contributed to an increase in the thickness smear zone or resulted in *in situ* soil washing. Soil gas flux also increased during the test as a result of groundwater sparging. Once again, it is unclear whether this flux affected soil VOC concentrations and whether soil VOC concentrations increased or decreased as a result. Remediation that could have affected soil VOC concentrations has not been attempted in the vicinity of the third area of soil contamination near SB-6.

The areal extent of DRO concentrations roughly coincides with the extent of VOC contamination; however, DRO is more widespread than total VOCs in 0- to 3-foot bgs samples. This is a probable result of site grading reported by Rust E&I (1995). The disturbance from grading would likely volatilize any VOCs in shallow soils while dispersing the DRO over a somewhat larger area. Given that the berm for the former burn pit is still evident, it is likely that this area was not graded; therefore, any VOCs residing in the shallow soils would have remained undisturbed.

2.1.3.2 Groundwater Quality

In 1993, groundwater samples were collected from 20 site monitoring wells as a part of supplemental RI activities. Results for VOCs are summarized in Tables 2.7 and 2.8.

TABLE 2.7
SUMMARY OF BTEX IN OU-4 GROUNDWATER FROM MARCH 1993
SITES OU-4 AND BUILDING 1613
RNA TS
SHAW AFB, SOUTH CAROLINA

Sample ID	Benzene (µg/L)	Ethylbenzene (µg/L)	Toluene (µg/L)	Total Xylenes (µg/L)	Total BTEX (µg/L)
BASE 8	< 5 ^{a/}	< 5	< 5	< 5	< 5
MW-105	< 5	< 5	< 5	< 5	< 5
MW-105D	< 5	< 5	< 5	< 5	< 5
MW-106	25	120	290	530	965
MW-106D	< 5	< 5	< 5	< 5	< 5
MW-107	< 5	< 5	< 5	< 5	< 5
MW-111	< 5	< 5	< 5	< 5	< 5
MW-112	130	280 D ^{b/}	430 D	1100 D	1940
MW-112A	< 5	< 5	< 5	< 5	< 5
MW-112D	< 5	< 5	< 5	< 5	< 5
MW-113	< 5	< 5	1.2 J ^{c/}	< 5	1.2 J
MW-113A	< 5	< 5	< 5	< 5	< 5
MW-114	21	25	38	60	144
MW-115	26 J	< 50	23 J	31 J	80
MW-115A	< 5	< 5	< 5	< 5	< 5
MW-116	< 5	< 5	< 5	< 5	< 5
MW-116A	< 5	< 5	< 5	< 5	< 5
MW-117	280 J	260 J	2200	1300	4040
MW-118	< 5	< 5	< 5	< 5	< 5
MW-119A	< 5	< 5	< 5	< 5	< 5
TW-101	< 5	< 5	7.2 B ^{d/}	< 5	7.2 B

^{a/}< = Not detected down to 10% of the quantitation limit.

^{b/}D = Dilution of sample.

^{c/}J = Estimated value less than the quantitation limit.

^{d/}B = Compound was detected in the associated method blank.

TABLE 2.8
SUMMARY OF DETECTED CHLORINATED ETHANES AND ETHENES
IN OU-4 GROUNDWATER FROM MARCH 1993
SITES OU-4 AND BUILDING 1613
RNA TS
SHAW AFB, SOUTH CAROLINA

Sample ID	1,1,1-TCA (µg/L)	1,1-DCA (µg/L)	Chloroethane (µg/L)	TCE (µg/L)	Total 1,2-DCE (µg/L)	1,1-DCE (µg/L)	Vinyl Chloride (µg/L)
BASE 8	< 5 ^{a/}	< 5	< 10	< 5	< 5	< 5	< 10
MW-105	< 5	< 5	< 10	1.1 J ^{b/}	< 5	< 5	< 10
MW-105D	< 5	< 5	< 10	< 5	< 5	< 5	< 10
MW-106	< 25	200	41 J	< 25	610	6.4 J	< 50
MW-106D	< 5	< 5	< 10	< 5	< 5	< 5	< 10
MW-107	< 5	< 5	< 10	< 5	< 5	< 5	< 10
MW-111	< 5	< 5	< 10	< 5	< 5	< 5	< 10
MW-112	< 5	4.3 J	< 10	< 5	140	1.5 J	< 10
MW-112A	< 5	< 5	< 10	< 5	< 5	< 5	< 10
MW-112D	< 5	< 5	< 10	< 5	< 5	< 5	< 10
MW-113	< 5	6.8	< 10	< 5	14	< 5	< 10
MW-113A	< 5	< 5	< 10	< 5	< 5	< 5	< 10
MW-114	< 5	26	< 10	< 5	31	< 5	< 10
MW-115	310	760	59 J	13 J	310	87	17 J
MW-115A	< 5	< 5	< 10	< 5	< 5	< 5	< 10
MW-116	< 5	< 5	< 10	< 5	< 5	< 5	< 10
MW-116A	< 5	< 5	< 10	< 5	< 5	< 5	< 10
MW-117	14000	13000	200 J	< 500	3500	870	< 1000
MW-118	< 5	< 5	< 10	1.3 J	< 5	< 5	< 10
MW-119A	< 5	< 5	< 10	< 5	< 5	< 5	< 10
TW-101	< 5	< 5	< 10	< 5	< 5	< 5	< 10

^{a/}< = Not detected down to 10% of the quantitation limit.

^{b/}J = Estimated value less than the quantitation limit.

The RI concluded that VOC contamination at the site is confined to the upper zone of the Shallow Aquifer, because no VOCs were detected above quantitation limits from deeper intervals. Therefore, this discussion focuses on VOC contamination identified in the upper zone of the Shallow Aquifer. Figures 2.15 through 2.17 present the areal extents of total BTEX, total chlorinated ethenes, and total chlorinated ethanes, dissolved in groundwater, respectively.

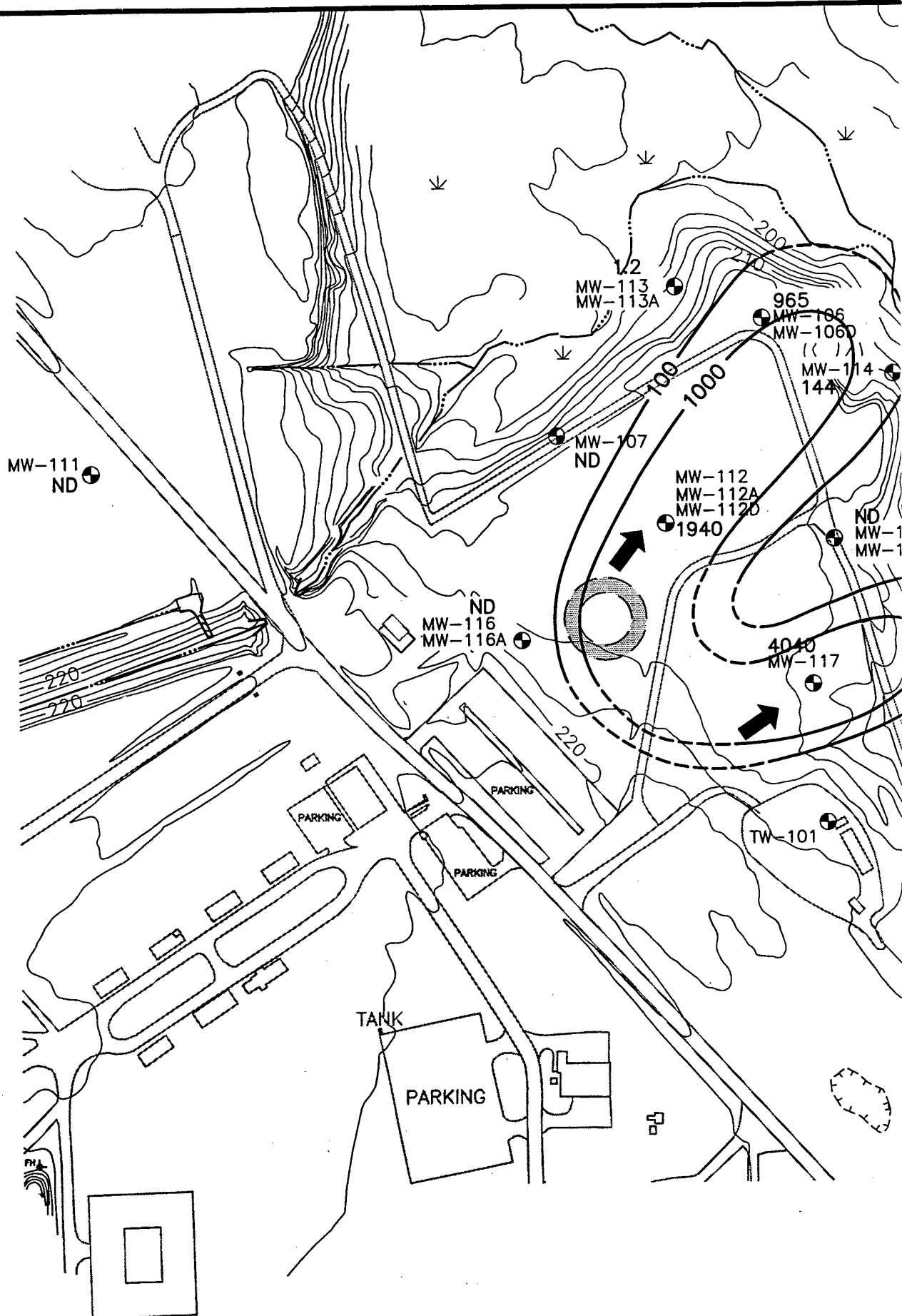
The figures identify two separate contaminant migration pathways. The northern pathway includes monitoring wells MW-112, MW-106, and MW-114. The southern pathway includes monitoring wells MW-117 and MW-115. To date, neither plume's source has been confirmed; however, sampling results for soils and groundwater grab samples suggest that the northern plume originates from the former bermed burn pit (Rust E&I, 1995), whereas the southern plume may originate from an unidentified location to the east of monitoring well MW-117 (IT, 1997). The downgradient migration of each plume is consistent with the local direction of shallow groundwater flow.

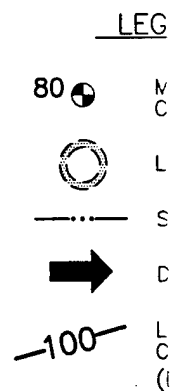
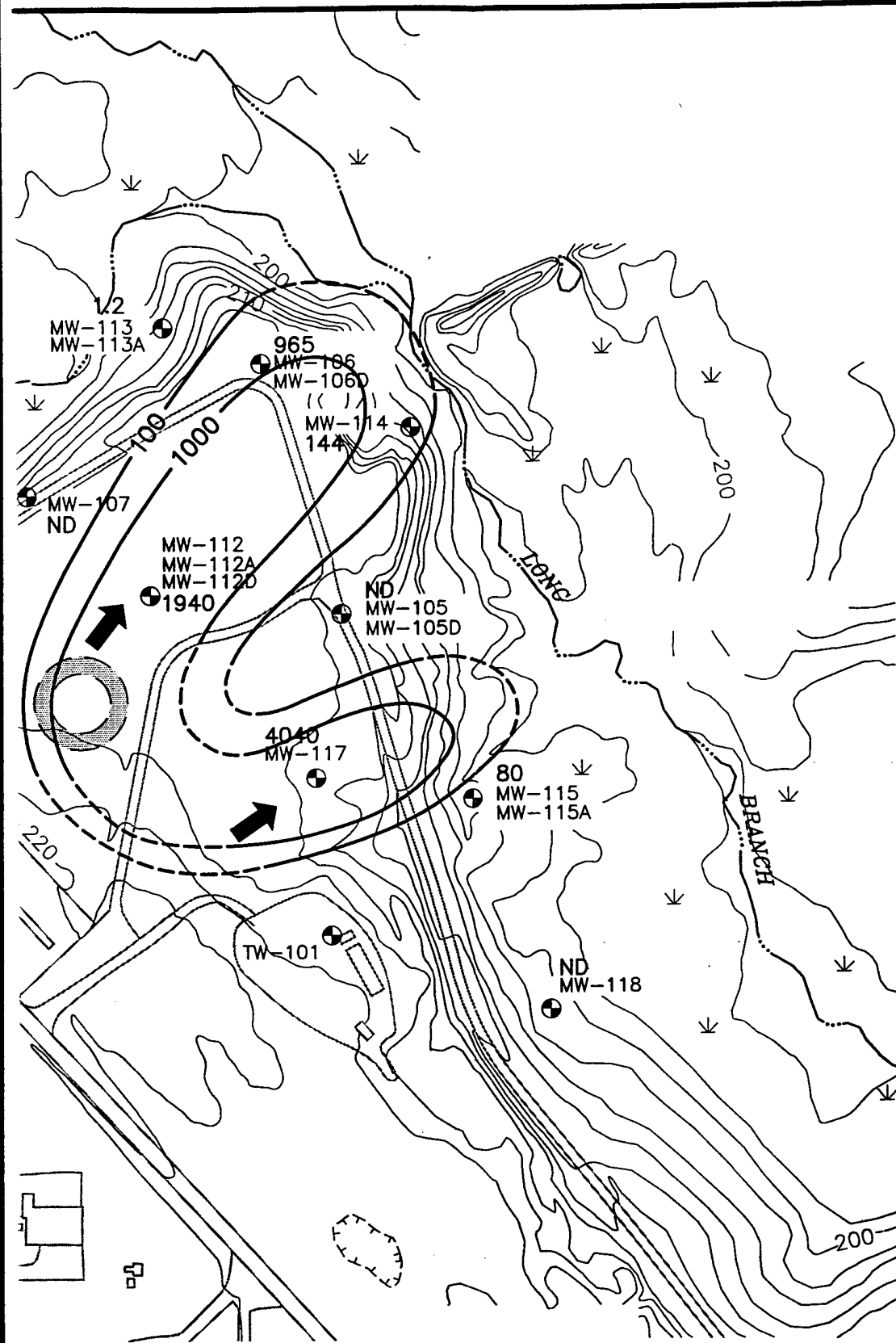
The contaminant mix varies slightly between the plumes, further suggesting that the plumes may have originated from two separate sources. The ratio of BTEX to CAHs is higher in the northern plume than the southern plume. In addition, the northern plume had no detections of the likely source solvents 1,1,1-TCA and trichloroethene (TCE). Instead, only daughter products [(e.g., 1,1-dichloroethene (DCA) *cis*-1,2-DCE, and vinyl chloride (VC) as described in Section 2.2.3)] were detected. Prior to the chemical oxidation pilot test, the southern plume contained comparable concentrations of the source solvents to daughter products, with the percentage of daughter products increasing downgradient.

Prior to the chemical oxidation test the highest dissolved contaminant concentrations for both BTEX and CAH compounds were measured in the southern plume, with the maximum concentrations observed in monitoring well MW-117. Results from the 1993

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REFERENCE: TOPOGRAPHIC BASE MAP PREPARED BY
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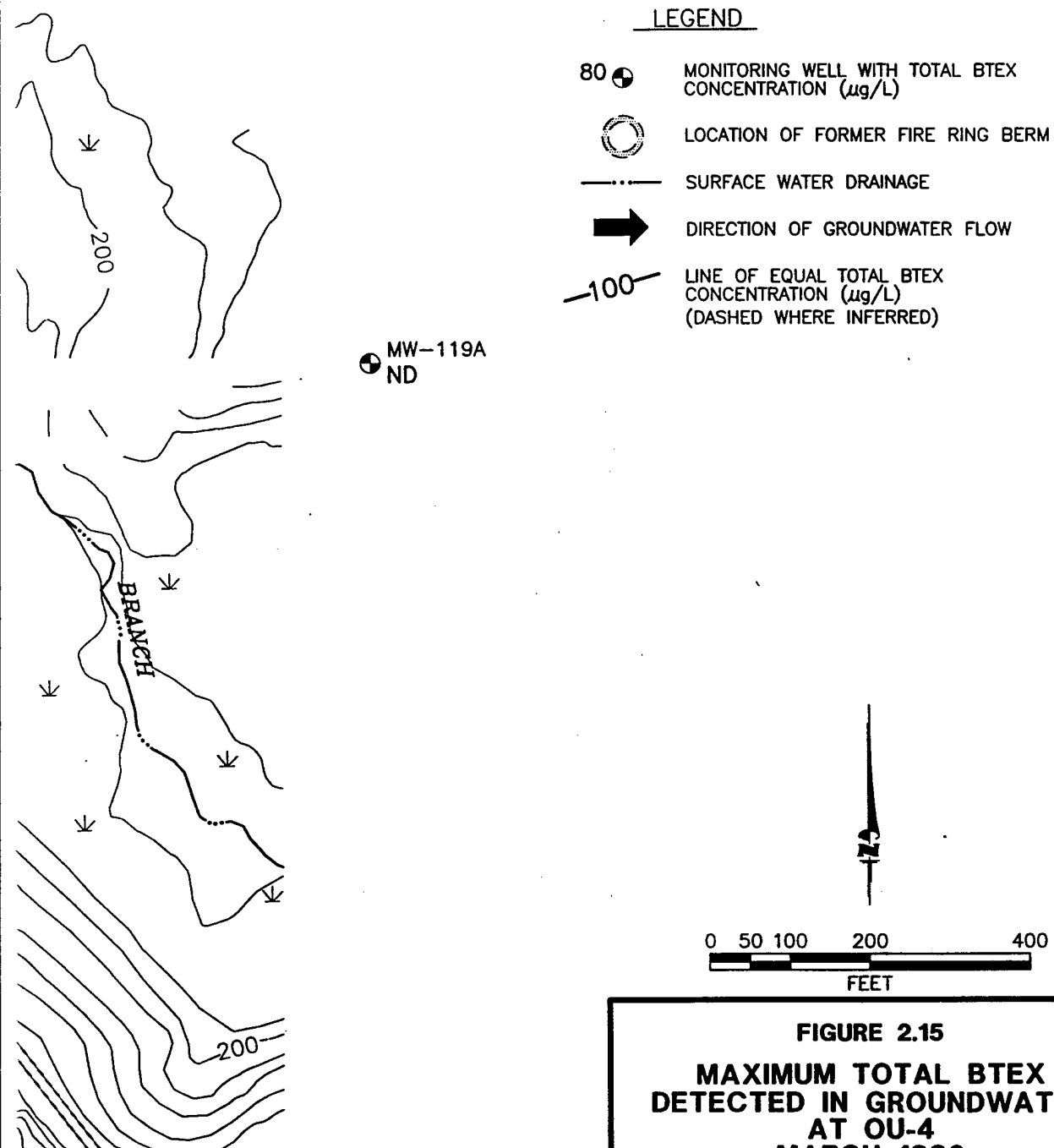


FIGURE 2.15
MAXIMUM TOTAL BTEX
DETECTED IN GROUNDWATER
AT OU-4
MARCH 1993

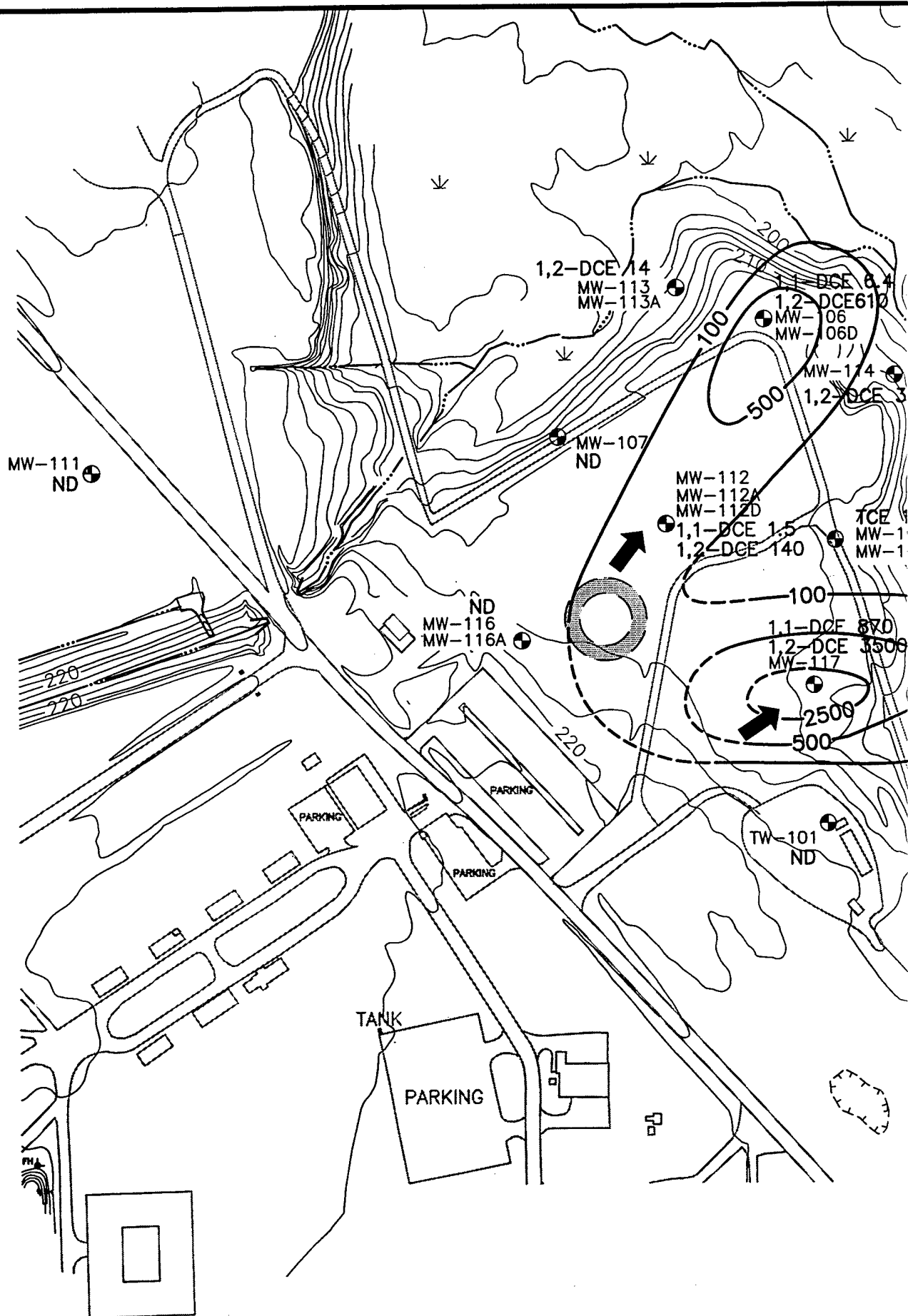
Sites OU-4 And Building 1613
 RNA TS
 Shaw AFB, South Carolina

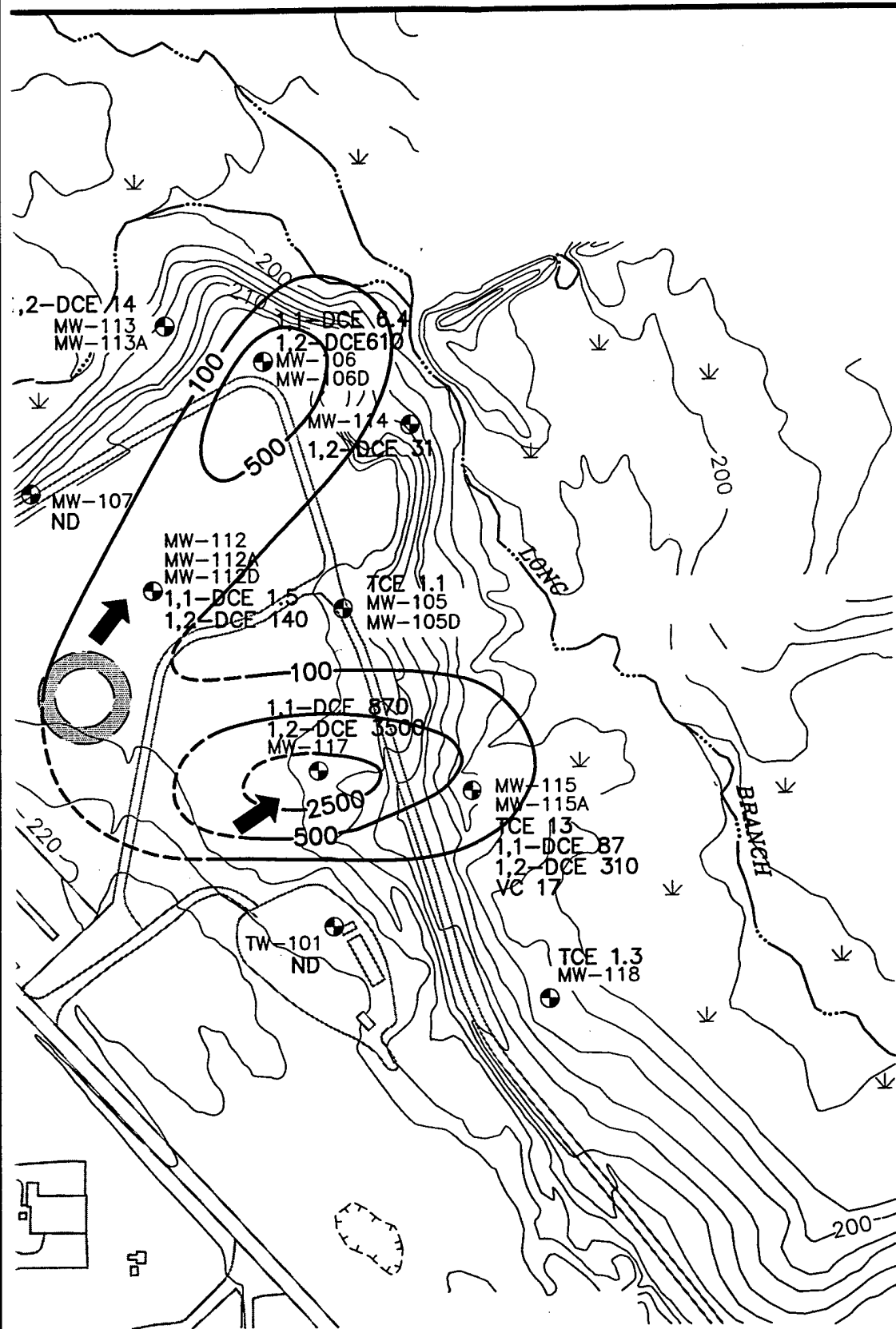
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REFERENCE: TOPOGRAPHIC BASE MAP PREPARED BY
AIR SURVEY CORPORATION, MARCH 1993.

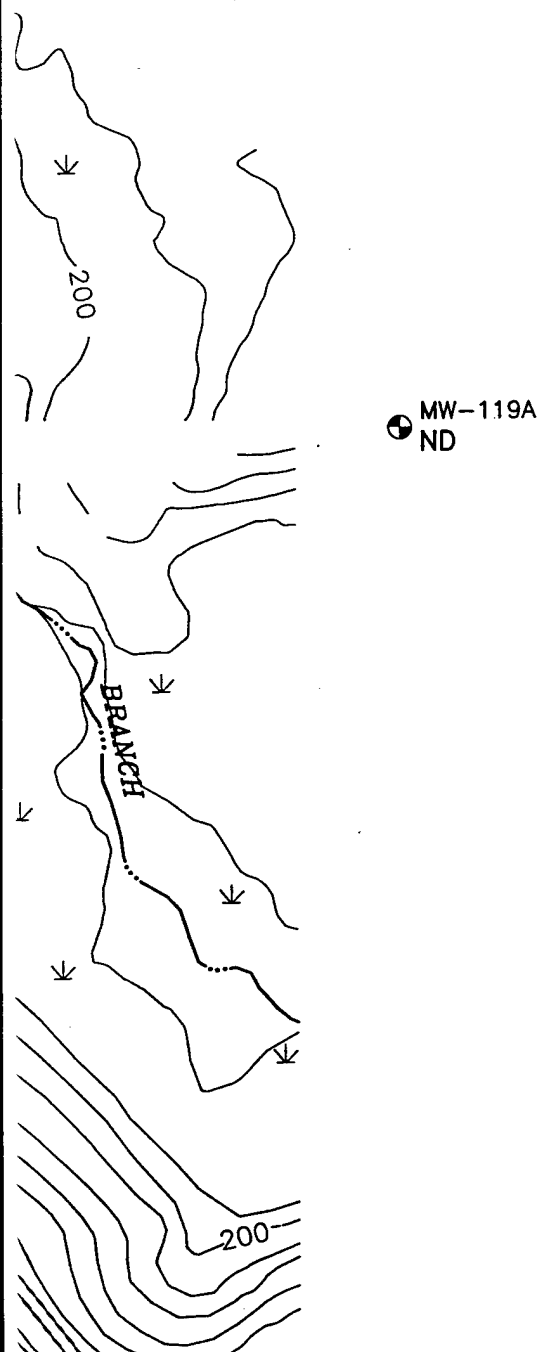




LE

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LEGEND

- 80 ● MONITORING WELL WITH CHLORINATED ETHENE CONCENTRATION ($\mu\text{g/L}$)
- LOCATION OF FORMER FIRE RING BERM
- SURFACE WATER DRAINAGE
- ➔ DIRECTION OF GROUNDWATER FLOW
- 500- LINE OF EQUAL TOTAL CHLORINATED ETHENE CONCENTRATION ($\mu\text{g/L}$) (DASHED WHERE INFERRED)
- TCE = TRICHLOROETHENE
- DCE = DICHLOROETHENE
- VC = VINYL CHLORIDE

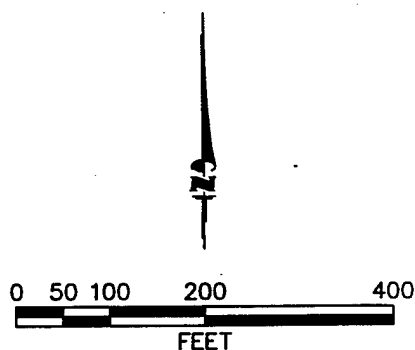
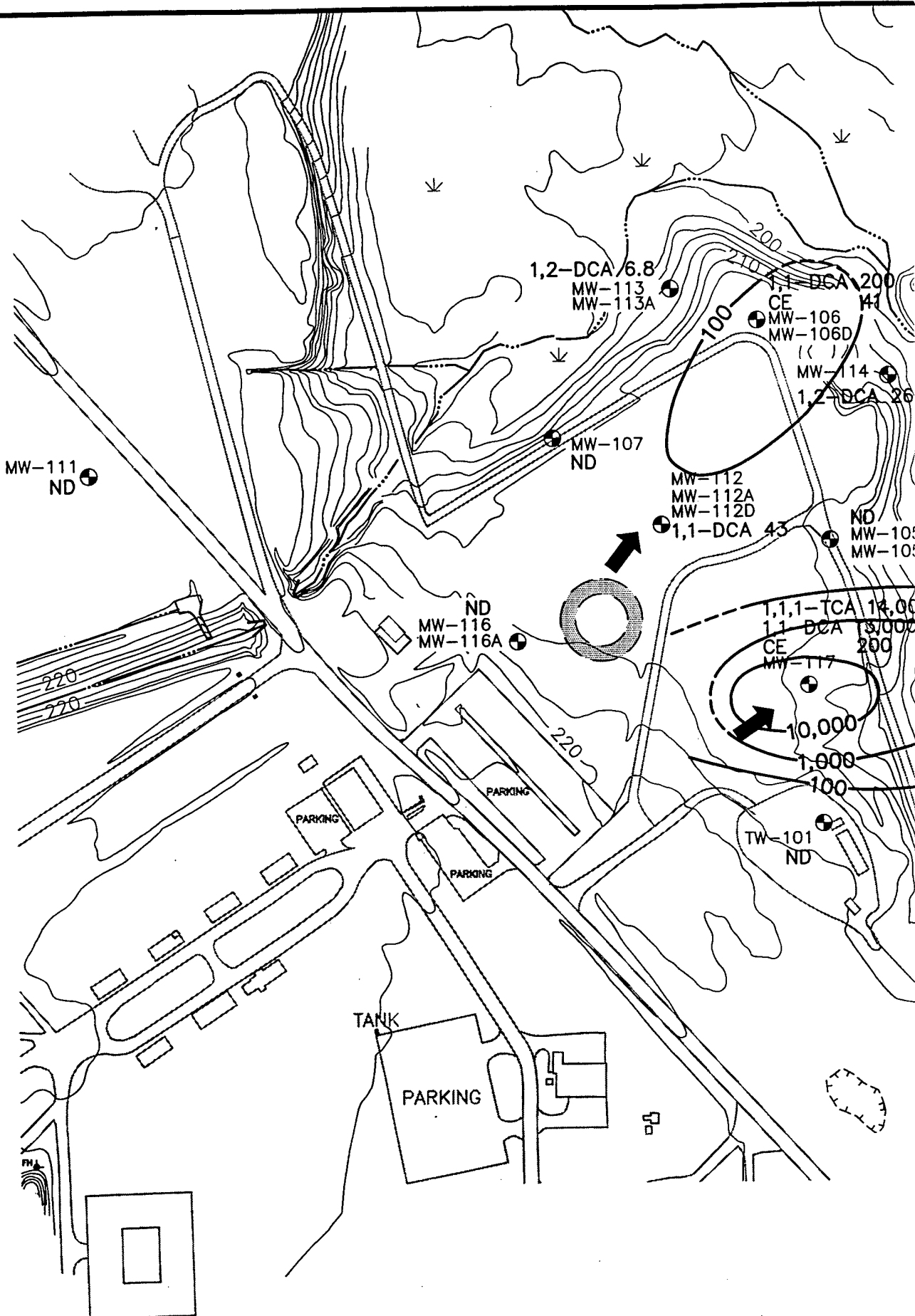


FIGURE 2.16
CHLORINATED ETHENES
DETECTED IN GROUNDWATER
AT OU-4
MARCH 1993

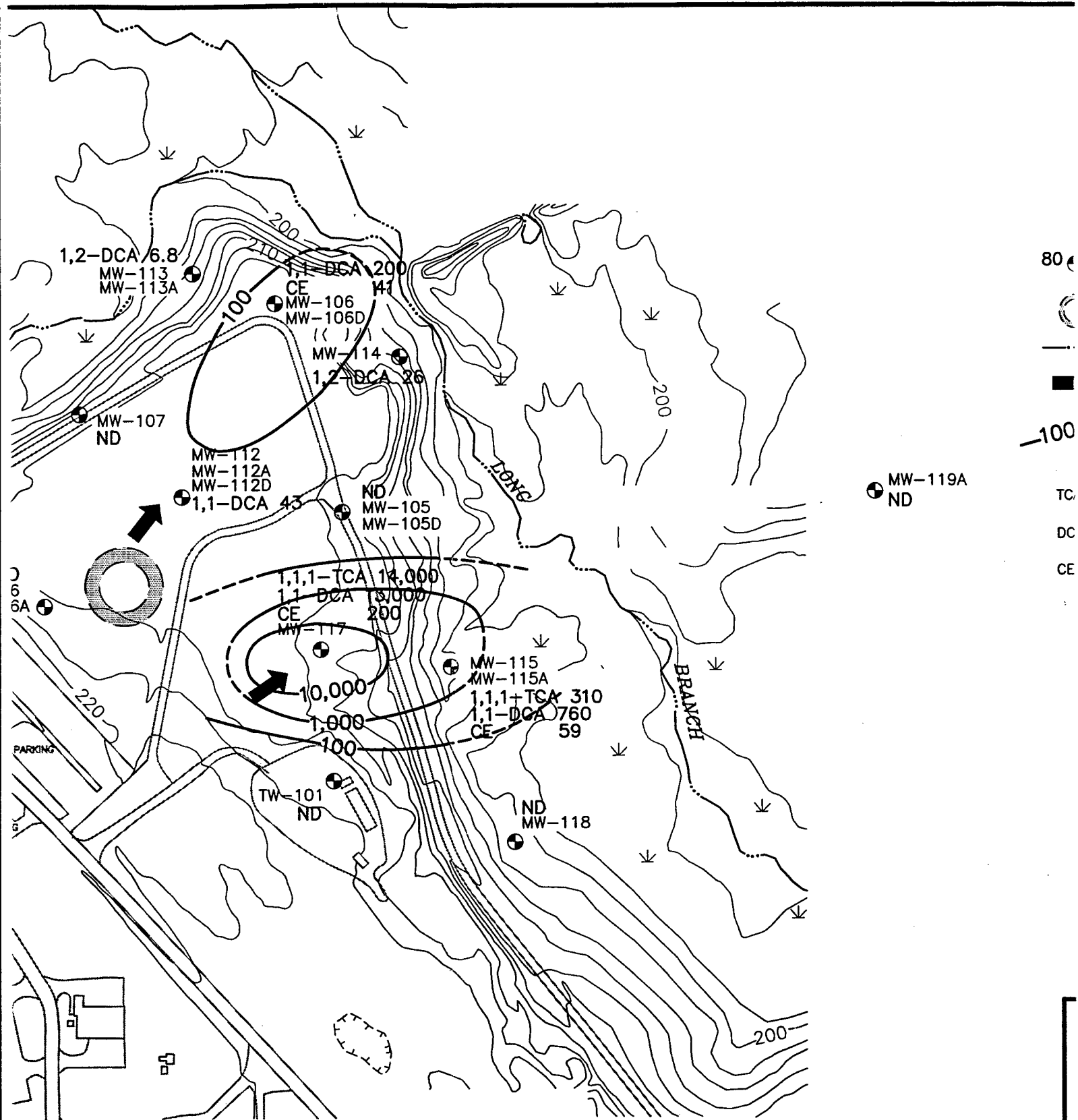
Sites OU-4 And Building 1613
 RNA TS
 Shaw AFB, South Carolina

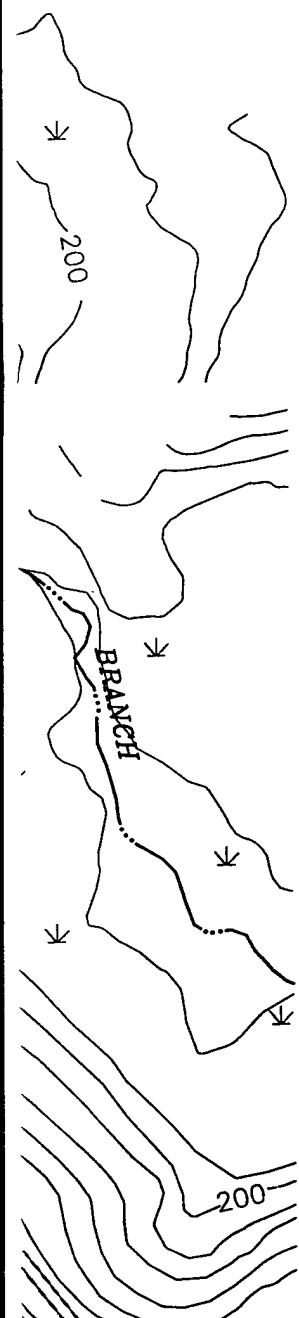
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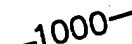
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REFERENCE: TOPOGRAPHIC BASE MAP PREPARED BY
AIR SURVEY CORPORATION, MARCH 1993.





LEGEND

- 80  MONITORING WELL WITH CHLORINATED ETHANE CONCENTRATION ($\mu\text{g/L}$)
-  LOCATION OF FORMER FIRE RING BERM
-  SURFACE WATER DRAINAGE
-  DIRECTION OF GROUNDWATER FLOW
-  LINE OF EQUAL TOTAL CHLORINATED ETHANE CONCENTRATION ($\mu\text{g/L}$) (DASHED WHERE INFERRED)
- TCA = TRICHLOROETHANE
- DCA = DICHLOROETHANE
- CE = CHLOROETHANE

MW-119A
ND

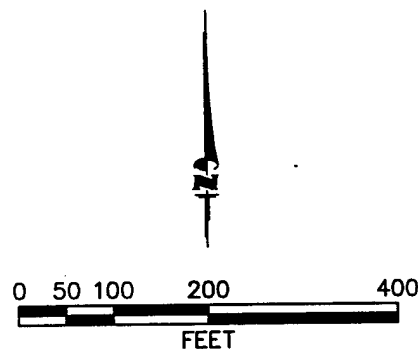


FIGURE 2.17

CHLORINATED ETHANES DETECTED IN GROUNDWATER AT OU-4 MARCH 1993

Sites OU-4 And Building 1613
RNA TS
Shaw AFB, South Carolina

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sampling event indicated a dissolved CAH concentration of over 30,000 micrograms per liter ($\mu\text{g/L}$). The majority of this contamination consisted of 1,1,1-TCA and the chlorinated ethane daughter products. A total BTEX concentration in excess of 4,000 $\mu\text{g/L}$ also was detected at this location. Reductions in dissolved contaminant concentrations were observed following the chemical oxidation pilot test; however, the permanence of these reductions had not been evaluated at the time this work plan was developed. Groundwater sampling for this purpose is scheduled for April 1997.

2.1.3.3 Surface Water and Sediment Quality

Surface water and sediment samples were collected at 17 locations along Long Branch and the unnamed ephemeral tributary as a part of supplemental RI activities. Sampling locations SWS/SED-1 through -5 are located in the immediate proximity of OU-4 and are identified on Figure 1.3. None of these locations contained CAH or BTEX concentrations in the surface water sample; however, one sediment sample (SED-2) collected along Long Branch immediately downgradient from MW-114 and within the potential discharge zone of the northern groundwater plume contained the following VOCs concentrations: 1,1-DCE, 16 $\mu\text{g/kg}$; 1,2-DCE, at 72 $\mu\text{g/kg}$; benzene, at 9.1J $\mu\text{g/kg}$; chloromethane, at 12J $\mu\text{g/kg}$; vinyl chloride, at 11J $\mu\text{g/kg}$; and xylenes, at 8.2J $\mu\text{g/kg}$. Also, a 1,1-DCA concentration of 4.7J $\mu\text{g/kg}$ was measured at SED-4, immediately downgradient of MW-115 and within the potential groundwater discharge zone of the southern plume.

Only two of the remaining Long Branch surface water and sediment samples (SWS/SED-16 and SWS/SED-17) were located further downgradient from OU-4. The only VOC detected in any of these samples was identified in surface water sample SWS-16, collected at the inlet to Booths Pond. The 1,1-DCA, 1,2-DCE, and chloroethane were each detected at this location at estimated concentrations below 2 $\mu\text{g/L}$.

2.1.4 Summary of Analytical Results for Building 1613

Analytical data has been collected at the Building 1613 Site since the identification of a jet fuel supply line leak in June 1991. Investigations have been directed toward source identification and definition of the extent of contamination in both soils and groundwater. Activities have included a soil gas survey, LNAPL sampling, soil sampling, and groundwater sampling. The environmental samples have been variously analyzed for VOCs, gasoline range organics (GRO), DRO, SVOCs, metals, and common anions. Summaries of the analytical results, as they apply to the current RNA investigation, are provided in the following subsections. In particular, the discussions focus on the concentration and extent of organic constituents associated with fuels. More complete descriptions of site activities, sample analyses, and results can be referenced in the 5 reports cited in Section 2.1.

2.1.4.1 Mobile LNAPL Contamination

Mobile LNAPL contamination has been detected at monitoring wells MW1613-4 and MW1613-7 at the Building 1613 Site. The product thickness in well MW1613-4 has ranged from 0.13 feet (August 28, 1995) to 1.49 feet (September 30, 1994). The most recently measured product thickness was 1.28 feet on April 4, 1996. The product thickness in well MW1613-7 has ranged from not detected (September 30, 1994 and March 20, 1995) to 0.77 feet (April 4, 1996). LNAPL recovery has been performed since May 1995. As of April 17, 1996, approximately 95 gallons of product had been removed from the wells by International Technology Corporation (IT) (Rust E&I, 1996a).

On June 21, 1994 a product sample was collected from well MW1613-4 and analyzed for total petroleum hydrocarbons (TPH). Analysis detected a TPH concentration of 340,000 milligrams per liter (mg/L) and a flame ionization detector (FID) signature characteristic of kerosene or jet fuel. Because of this signature and close proximity to

the jet fuel line, the product is believed to have originated from the former jet fuel line leak.

The source of product detected in monitoring well MW1613-7 remains unknown. The limited thickness of LNAPL has deterred the collection of a LNAPL sample from this location for fingerprint analysis. Relatively low BTEX concentrations detected in groundwater at monitoring well MW1613-7 suggest that the product is most likely heating oil. This conclusion is further supported by the proximity of the former 10,000-gallon heating oil UST that was located approximately 60 feet northwest of well MW1613-7.

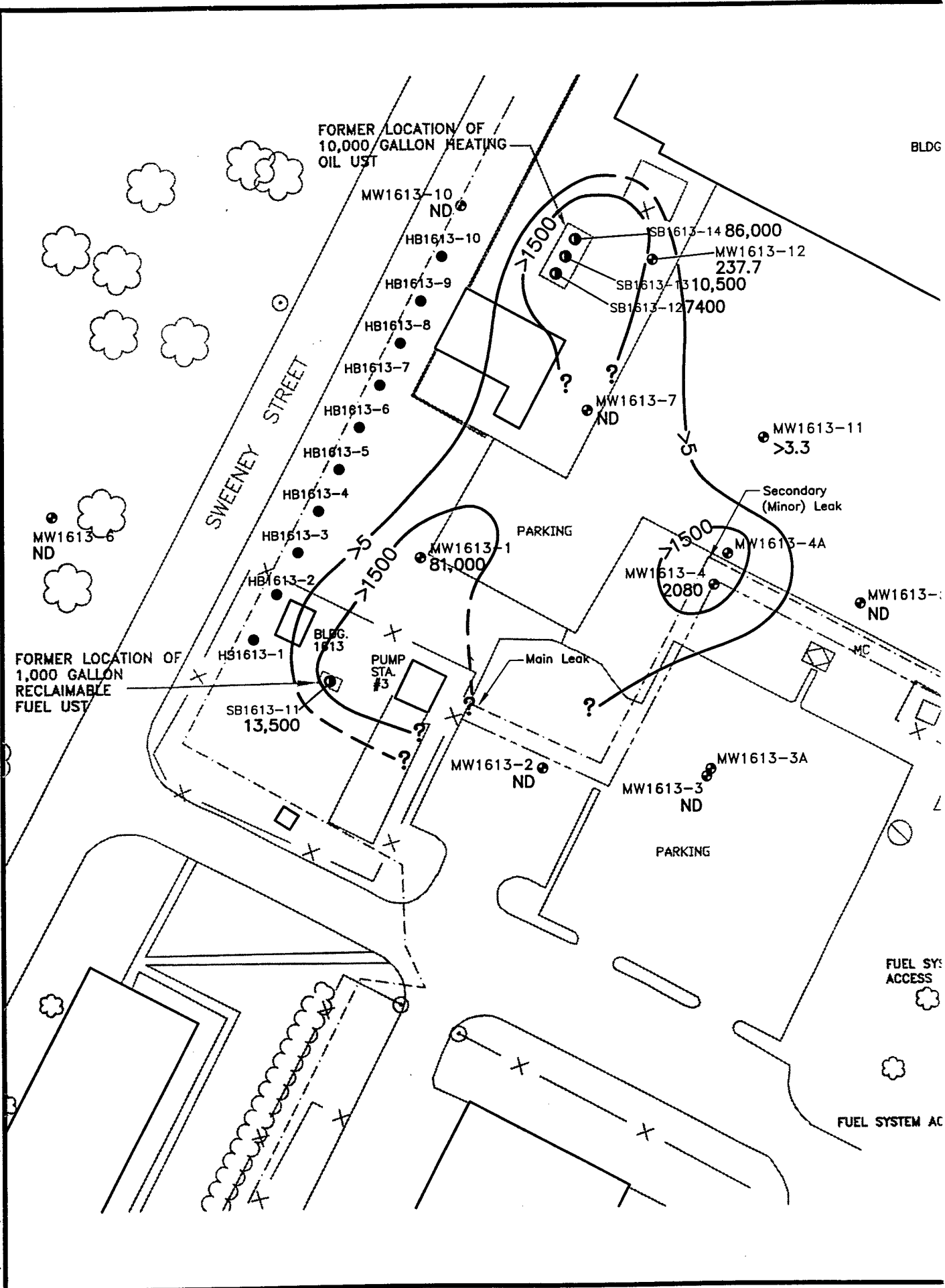
2.1.4.2 Soil Quality

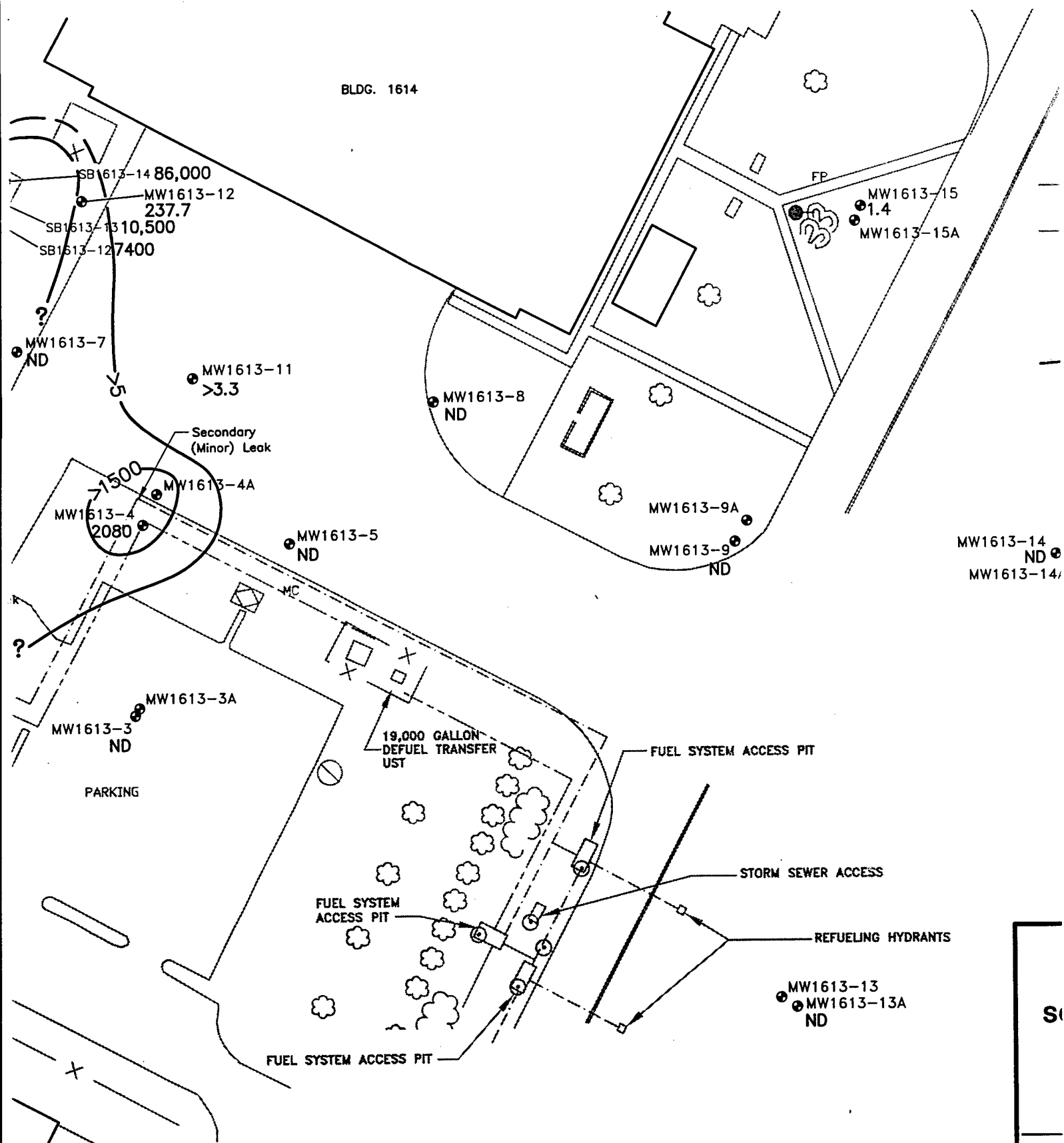
During the SI in June 1993, a total of 6 soil samples were collected from two locations along the underground fuel supply lines: SB1613-2 (30 feet southeast of Pump Station 3) and SB1613-8 (300 feet west/northwest of Pump Station 3). At SB1613-2, GRO concentrations decreased with depth from 22 mg/kg at 5 to 7 feet to 0.61 mg/kg at 20 to 22 feet. Similarly, GRO concentrations decreased with depth at SB1613-8 from 6.1 mg/kg at 5 to 7 feet to 0.39 mg/kg at 14 to 16 feet. The results confirmed that fuel releases had impacted soils at the site, though to an undetermined extent.

Additional soil investigations were conducted to further delineate soil contamination as part of the expanded site assessment between June and September 1994. The investigation included collection of 31 soil samples from nine borehole locations during the installation of monitoring wells MW1613-1 through MW1613-9 (Figure 2.18). The samples were analyzed for DRO and BTEX compounds (Table 2.9).

BTEX compounds were detected at only two expanded site assessment sampling locations (MW1613-1 and MW1613-4), both north and northeast of Pump Station #3. The BTEX concentrations detected at these two locations ranged from 1,600 to 81,000 µg/kg, with the highest BTEX concentration located at MW1613-1-30 (collected from 30

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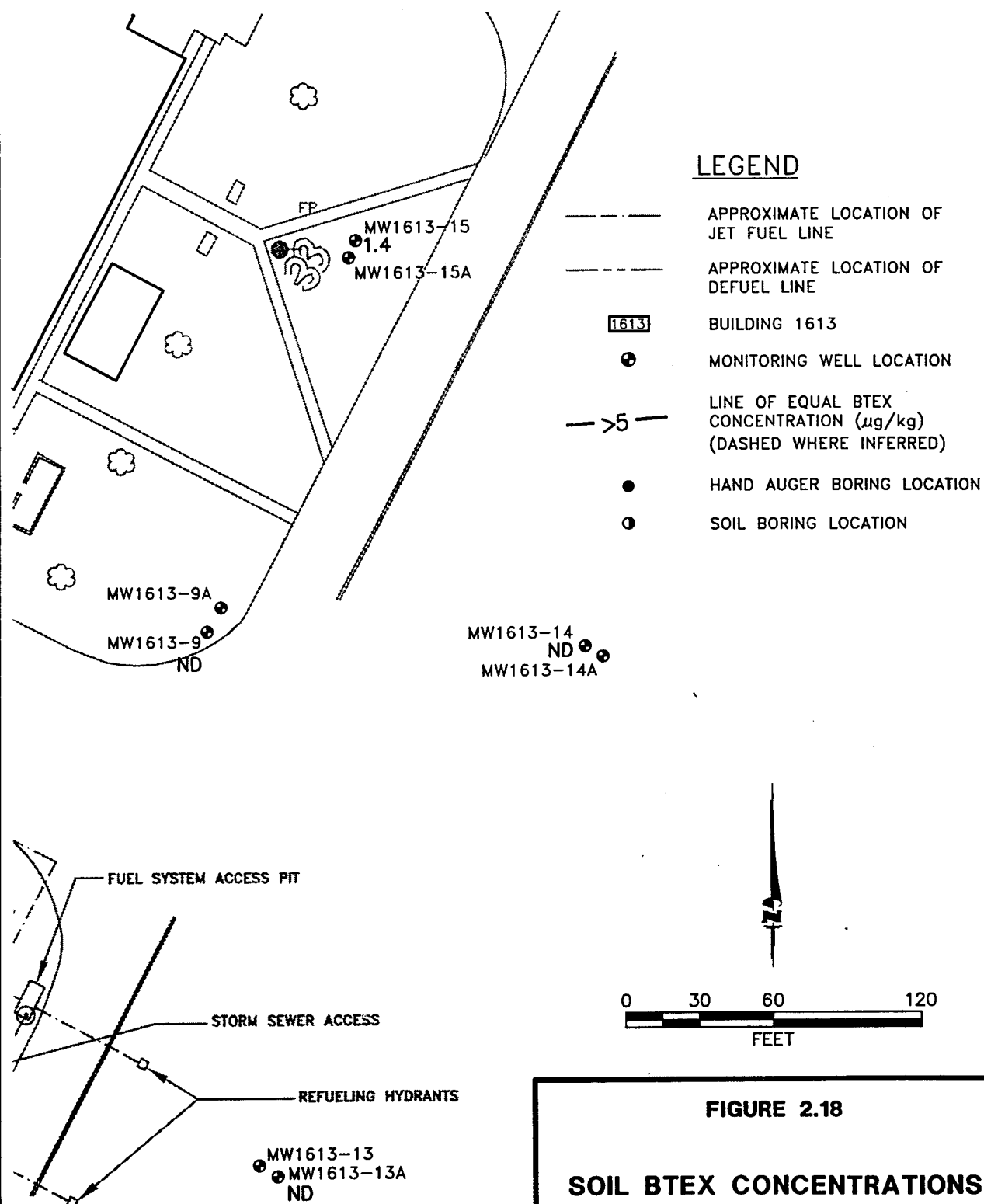


FIGURE 2.18

SOIL BTEX CONCENTRATIONS

Sites OU-4 and Building 1613
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TABLE 2.9
SOIL ANALYTICAL DATA
BUILDING 1613 SITE
SITES OU-4 AND BUILDING 1613
RNA TS
SHAW AFB, SOUTH CAROLINA

Sample ID	Date Collected	Benzene (µg/kg)	Ethylbenzene (µg/kg)	Toluene (µg/kg)	Total Xylenes (µg/kg)	Total BTEX (µg/kg)	Diesel Range Organics (mg/kg)
HB1613-1-5	6/28/95	< 6.1	< 6.1	< 6.1	< 12.2	<12.2	< 3.6
HB1613-6-5	6/13/95	< 5.9	< 5.9	< 5.9	NA ^{a/}	< 5.9	3.8
HB1613-9-5	6/13/95	< 5.8	< 5.8	< 5.8	NA	< 5.8	3.2 J ^{b/}
MW1613-1-10	6/6/94	< 2900	< 2900	< 2900	< 2900	< 2900	770
MW1613-1-20	6/6/94	13	85	87 K ^{c/}	260	445	120
MW1613-1-30	6/6/94	< 560	13000	5000 K	63000	81000	9.5
MW1613-2-10	6/8/94	< 5.7	< 5.7	< 5.7	< 5.7	< 5.7	1.7 J
MW1613-2-20	6/8/94	< 5.4	< 5.4	< 5.4	< 5.4	< 5.4	2.9 J
MW1613-2-30	6/8/94	< 5.2	< 5.2	< 5.2	< 5.2	< 5.2	2.1 J
MW1613-3-10	6/9/94	< 5.6	< 5.6	< 5.6	< 5.6	< 5.6	1.4 J
MW1613-3-20	6/9/94	< 5.3	< 5.3	< 5.3	< 5.3	< 5.3	1.2 J
MW1613-3-30	6/9/94	< 5.3	< 5.3	< 5.3	< 5.3	< 5.3	1.4 J
MW1613-4-10	6/7/94	< 6.7	< 6.7	< 6.7	< 6.7	< 6.7	2.4 J
MW1613-4-20	6/7/94	< 5.6	< 5.6	< 5.6	< 5.6	< 5.6	3.1 J
MW1613-4-30	6/7/94	< 1100	< 1100	< 1100	1600	1600	440
MW1613-5-10	6/14/94	< 5.4	< 5.4	< 5.4	< 5.4	< 5.4	2.2 J
MW1613-5-20	6/14/94	< 5.4	< 5.4	< 5.4	< 5.4	< 5.4	3.1 J
MW1613-5-30	6/14/94	< 5.4	< 5.4	< 5.4	< 5.4	< 5.4	1.8 J
MW1613-6-1	9/22/94	< 5.6	< 5.6	< 5.6	< 5.6	< 5.6	6
MW1613-6-10	9/22/94	< 6.2	< 6.2	< 6.2	< 6.2	< 6.2	< 3.7
MW1613-6-20	9/22/94	< 5.7	< 5.7	< 5.7	< 5.7	< 5.7	< 3.4
MW1613-6-45	9/22/94	< 5.7	< 5.7	< 5.7	< 5.7	< 5.7	< 3.4
MW1613-7-1	9/23/94	< 5.6	< 5.6	< 5.6	< 5.6	< 5.6	150
MW1613-7-10	9/23/94	< 5.6	< 5.6	< 5.6	< 5.6	< 5.6	< 3.4
MW1613-7-20	9/23/94	< 5.4	< 5.4	< 5.4	< 5.4	< 5.4	7.6
MW1613-7-27	9/23/94	< 5.2	< 5.2	< 5.2	< 5.2	< 5.2	4.9
MW1613-8-1	9/27/94	< 5.5	< 5.5	< 5.5	< 5.5	< 5.5	12
MW1613-8-10	9/27/94	< 5.2	< 5.2	< 5.2	< 5.2	< 5.2	< 3.1
MW1613-8-20	9/27/94	< 5.2	< 5.2	< 5.2	< 5.2	< 5.2	3.2
MW1613-8-27	9/27/94	< 5.4	< 5.4	< 5.4	< 5.4	< 5.4	8.3
MW1613-9-1	9/26/94	< 5.4	< 5.4	< 5.4	< 5.4	< 5.4	31
MW1613-9-10	9/26/94	< 5.8	< 5.8	< 5.8	< 5.8	< 5.8	< 3.5
MW1613-9-20	9/26/94	< 5.3	< 5.3	< 5.3	< 5.3	< 5.3	< 3.2
MW1613-9-27	9/26/94	< 5.6	< 5.6	< 5.6	< 5.6	< 5.6	8.3
MW1613-10-1	7/5/95	< 5.5	< 5.5	< 5.5	< 11	< 11	< 3.7
MW1613-10-15	7/5/95	< 5.7	< 5.7	< 5.7	< 11.4	< 11.4	< 3.8
MW1613-10-40	7/5/95	< 5.3	< 5.3	< 5.3	< 10.6	< 10.6	< 3.5
MW1613-11-1	7/12/95	< 5.5	< 5.5	< 5.5	3.3 J	3.3 J	< 3.7
MW1613-11-15	7/12/95	< 5.3	< 5.3	< 5.3	< 10.6	< 10.6	2.8 J
MW1613-11-30	7/12/95	< 5.4	< 5.4	< 5.4	< 10.8	< 10.8	< 3.6

TABLE 2.9 (concluded)
SOIL ANALYTICAL DATA
BUILDING 1613 SITE
SITES OU-4 AND BUILDING 1613
RNA TS
SHAW AFB, SOUTH CAROLINA

Sample ID	Date Collected	Benzene (µg/kg)	Ethylbenzene (µg/kg)	Toluene (µg/kg)	Total Xylenes (µg/kg)	Total BTEX (µg/kg)	Diesel Range Organics (mg/kg)
MW1613-12-1	6/29/95	< 5.7	< 5.7	< 5.7	< 11.4	< 11.4	< 3.4
MW1613-12-15	6/29/95	< 5.3	< 5.3	< 5.3	< 10.6	< 10.6	< 3.2
MW1613-12-28	6/29/95	< 5.4	77	3.7 J/K	157	237.7	71
MW1613-13-1	7/11/95	< 5.7	< 5.7	< 5.7	< 11.4	< 11.4	44 M ^d /D ^e
MW1613-13-15	7/11/95	< 5.3	< 5.3	< 5.3	< 10.6	< 10.6	2.1 J
MW1613-13-30	7/11/95	< 5.9	< 5.9	< 5.9	< 11.8	< 11.8	< 4
MW1613-14-1	7/14/95	< 5.8	< 5.8	< 5.8	< 11.6	< 11.6	14 D
MW1613-14-15	7/14/95	< 5.5	< 5.5	< 5.5	< 11	< 11	3.2 J
MW1613-14-30	7/14/95	< 6	< 6	< 6	< 12	< 12	4.1
MW1613-15-1	6/28/95	< 5.4	< 5.4	< 5.4	< 10.8	< 10.8	5
MW1613-15-15	6/28/95	< 5.4	< 5.4	< 5.4	< 10.8	< 10.8	< 3.2
MW1613-15-28	6/28/95	< 5.5	< 5.5	< 5.5	< 11	< 11	< 3.3
SB1613-11-1	7/7/95	< 5.3	5.1 J	< 5.3	16	21.1	89 M/D
SB1613-11-8	7/7/95	< 590	3200	< 590	3800	7000	1600
SB1613-11-15	7/7/95	< 540	6500	< 540	7000	13500	760
SB1613-12-1	6/22/95	< 5.3	< 5.3	< 5.3	< 10.6	< 10.6	170
SB1613-12-8	6/22/95	< 5.6	< 5.6	< 5.6	< 11.2	< 11.2	95
SB1613-12-20	6/22/95	< 250	1200	< 250	6200	7400	5200
SB1613-13-1	6/22/95	< 5.3	< 5.3	< 5.3	< 10.6	< 10.6	< 3.2
SB1613-13-8	6/22/95	< 5.7	8.3	< 5.7	< 11.4	8.3	1600
SB1613-13-20	6/22/95	< 250	2500	< 250	8000	10500	36000
SB1613-14-1	6/22/95	< 5.4	< 5.4	< 5.4	1.6 J	1.6 J	< 3.2
SB1613-14-8	6/22/95	< 5.6	< 5.6	< 5.6	< 11.2	< 11.2	8.6
SB1613-14-20	6/22/95	< 230	1400	< 230	7200	8600	7400

^aNA = Data not available.

^bJ = Estimated value less than quantitation limit.

^cK = Artifact detected at a concentration less than 10x that detected in the associated field or laboratory blanks,
or some other artifact detected at a concentration greater than 5x that detected in associated field or laboratory blanks.

^dM = Duplicate injection was not met.

^eD = Percent difference of matrix spike duplicate exceeded established criteria.

feet bgs). Fuel contamination at soil sampling location MW1613-1 may have originated from either the former 1,000-gallon reclaimable fuel UST (west of the pumphouse) or from the primary fuel line leak located approximately 20 feet southeast of the pumphouse. The likely source for fuel contamination in the soils at MW1613-4 is the secondary leak in the main fuel transfer line leak (Figure 2.18).

Soil samples at both locations where BTEX was detected also contained concentrations of DRO. The maximum DRO concentration of 770 mg/kg was detected at MW1613-1-10, which is at the same location (but not from the same sampling interval) that had the highest BTEX concentration. At MW1613-4, a DRO concentration of 440 mg/kg was detected from a sample collected at 30 feet bgs (1 foot above the water table), suggesting a possible hydrocarbon smear zone. The only other DRO concentration elevated above 10 mg/kg was detected at MW1613-7 at a depth of 1 foot (150 mg/kg). Soil sampling location MW1613-7 was closest to former location of the 10,000-gallon heating oil UST located near the southwest corner of Building 1614.

On the basis of the soil results obtained through the EA, a Supplemental EA Study was conducted to further define the vertical and horizontal extent of petroleum contamination at the Building 1613 Site. The following soil activities were included as part of the Supplemental EA:

- Ten hand-auger borings (HB1613-1 through -10) were installed adjacent to the jet fuel line that runs along Sweeney Street;
- One soil boring (SB1613-11) was installed at the former location of the 1,000-gallon UST;
- Three soil borings (SB1613-12, -13, and -14) were installed at the former location of the 10,000-gallon UST;

- Collection of soil samples during the installation of monitoring wells MW1613-10 through -15; and
- An active soil gas survey in the vicinity of Pump Station #3;

The 10 hand-auger borings installed beside the jet fuel pipeline were each completed to a depth of 5 feet bgs. Field organic-vapor-analyzer (OVA) readings for the soil samples were all less than 1 part per million on a volume-per-volume basis (ppmv). Three soil samples (HB1613-1-5, HB1613-6-5, and HB1613-9-5) were selected for chemical analysis. No VOCs were detected in these three soil samples.

Analytical results from soil boring SB1613-11 confirm that the former 1,000-gallon UST leaked fuels to the subsurface. BTEX concentrations increased with depth from 21 µg/kg at 1 foot bgs to 7,000 µg/kg at 8 feet bgs and 13,500 µg/kg at 15 feet bgs. In contrast, the maximum DRO concentration of 1,600 mg/kg was observed at a depth of 8 feet bgs. The fuel related SVOCs naphthalene and 2-methylnaphthalene were also detected at 8 and 15 feet bgs). A summary table for SVOC results is provided in Appendix C.

Analytical results from soil borehole locations SB1613-12, -13, and -14 indicate that a significant quantity of fuel leaked from the former 10,000-gallon UST to the surrounding soil. Soil samples were collected from depths of 1, 8, and 20 feet bgs at each of these locations. Total BTEX concentrations were detected in five of the nine samples at concentrations ranging from 1.6 to 10,830 µg/kg. BTEX concentrations were greater than 7,000 µg/kg in all samples collected from 20 feet bgs; conversely, total BTEX concentrations in the 1- and 8-foot soil samples did not exceed 10 µg/kg. DRO concentrations were detected in seven of the nine soil samples at concentrations ranging from 8.6 to 36,000 mg/kg. Like BTEX, DRO concentrations increased with depth. Both the highest BTEX and DRO concentrations were detected in the sample from 20 feet bgs at SB1613-13-20, located near the center of the former 10,000-gallon UST pit.

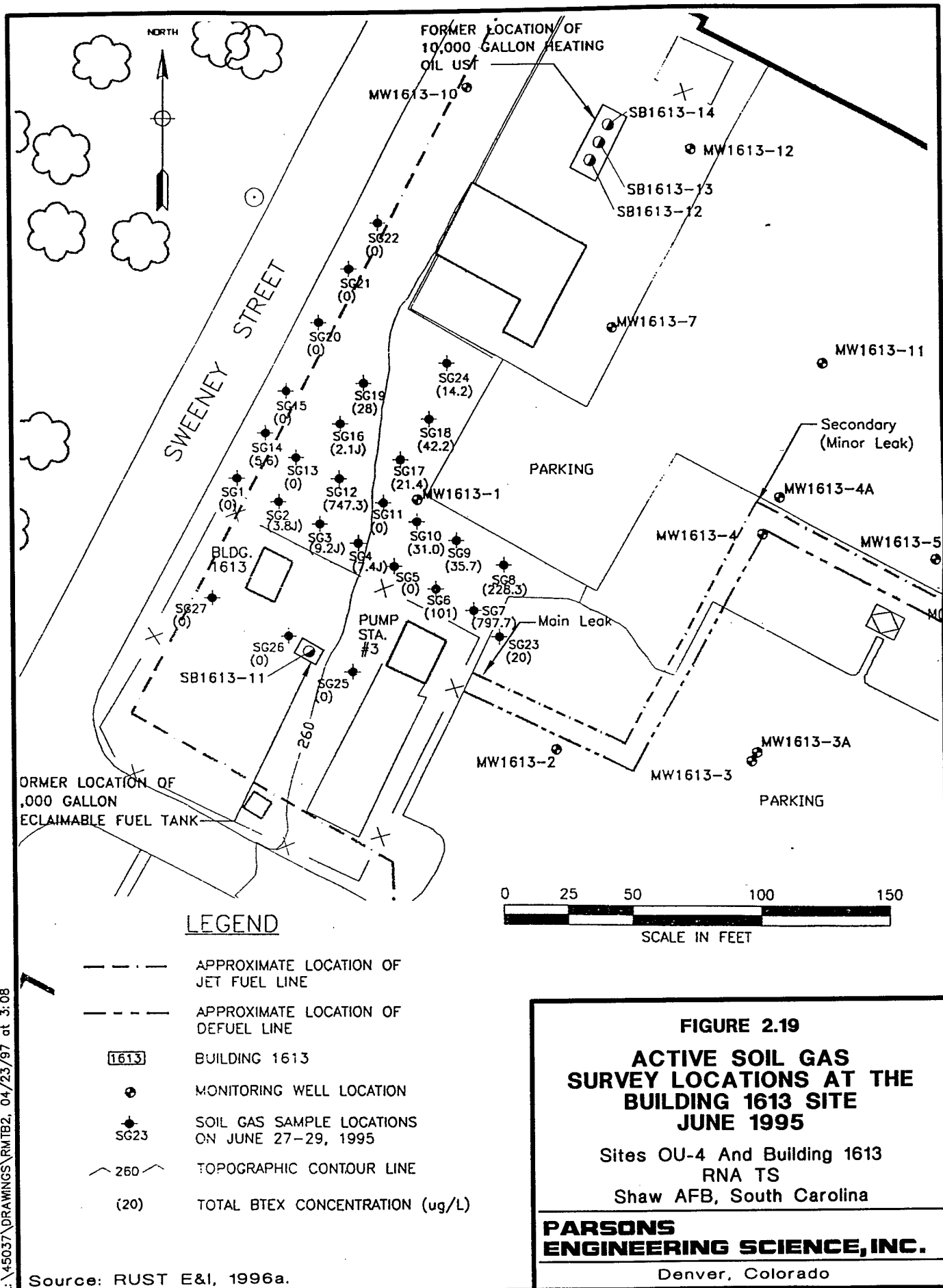
SVOCs detected in these 9 samples included 2-methyl-naphthalene, fluoranthene, naphthalene, phenanthrene, and pyrene. The maximum total concentration of SVOCs also was detected in the 20-foot sample from SB1613-13.

Eighteen soil samples were collected from 6 new monitoring well locations (MW1613-10 through -15). Because these well locations were intended to help define the areal extent of groundwater contamination, none of the locations was placed within a known or suspected source area; consequently, the highest BTEX and DRO concentrations (157 $\mu\text{g/kg}$ and 71 mg/kg , respectively) were detected within a probable smear zone. Other detections were largely from predominantly shallow samples and suggest occasional surface spills related to refueling operations may have resulted in localized residual soil contamination.

Twenty-seven soil gas samples (SG-1 through SG-27) were used to investigate possible sources of the petroleum contamination detected at well MW1613-1 (Figure 2.19). Soil gas concentrations ranged from 0 $\mu\text{g/L}$ to 797.7 $\mu\text{g/L}$; however, the survey data do not conclusively identify the exact source of fuel contamination. The only area of elevated soil gas concentration is not associated with a potential or known source area. Instead, this area may have been impacted by accidental surface spills (Rust E&I, 1996).

2.1.4.3 Groundwater Quality

Groundwater samples were collected on eight different sampling dates between June 20, 1994 and April 1, 1996. Three sets of groundwater samples were collected from monitoring wells that were installed during the EA at the site (June 20 to December 15, 1994). An additional five sets of groundwater samples were collected from all site monitoring wells installed as part of the EA and Supplemental EA Studies (March 21, 1995 to April 1, 1996). Table 2.10 lists BTEX data obtained from these sampling events.



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Source: RUST E&I, 1996a.

TABLE 2.10
DATA SUMMARY FOR BTEX COMPOUNDS
BUILDING 1613 SITE
SITES OU-4 AND BUILDING 1613
RNA TS
SHAW AFB, SOUTH CAROLINA

Sample ID	Date Collected	Benzene (µg/L)	Ethylbenzene (µg/L)	Toluene (µg/L)	Total Xylenes (µg/L)	Total BTEX (µg/L)
HP1613-1	6/21/95	< 5	< 5	< 5	< 15	< 15
HP1613-2	6/22/95	< 50	18 J ^{a/}	< 50	106	124
HP1613-3	6/22/95	1.7 J	3 J	< 5	1.2 J	5.9 J
HP1613-4	6/23/95	< 5	< 5	< 5	1.2 J	1.2 J
HP1613-5	6/26/95	< 5	< 5	< 5	< 10	< 10
HP1613-6	6/20/95	< 5	< 5	< 5	< 15	< 15
HP1613-7	7/11/95	< 5	< 5	< 5	< 10	< 10
MW1613-1	6/20/94	1100	270	< 50	280	1650
	9/30/94	280	53	1.1 J	57	391
	12/15/94	530	130	< 5	88	748
	3/21/95	260	100	< 5 D ^{b/}	77	437
	7/19/95	150	110	< 5	64	324
	10/16/95	180	180	< 5	75	435
	1/11/96	32	31	< 5	20.6	83.6
	4/4/96	560	190	< 25	150	900
MW1613-2	6/20/94	< 5	< 5	< 5	< 5	< 5
	9/30/94	< 5	< 5	< 5	< 5	< 5
	12/15/94	< 5	< 5	< 5	< 5	< 5
	3/21/95	< 5	< 5	< 5 D	1.3 J	1.3 J
	7/19/95	< 5	< 5	< 5	< 5	< 5
	10/16/95	< 5	< 5	< 5	< 5	< 5
	1/11/96	< 5	< 5	< 5	< 5	< 5
	4/1/96	< 5	< 5	< 5	< 5	< 5
MW1613-3	6/20/94	< 5	< 5	< 5	< 5	< 5
	9/30/94	< 5	< 5	< 5	< 5	< 5
	12/15/94	< 5	< 5	< 5	< 5	< 5
	3/21/95	< 5	< 5	< 5 D	< 5	< 5
	7/19/95	< 5	< 5	< 5	< 10	< 10
	10/16/95	< 5	< 5	< 5	1.1 J	1.1 J
	1/11/96	< 5	< 5	< 5	< 7.5	< 7.5
	4/1/96	< 5	< 5	< 5	< 5	< 5
MW1613-3A	6/20/94	< 5	< 5	< 5	< 5	< 5
	9/30/94	< 5	< 5	1.1 J	< 5	1.1 J
	12/15/94	< 5	< 5	< 5	< 5	< 5
	3/21/95	< 5	< 5	< 5 D	< 5	< 5
	7/19/95	< 5	< 5	< 5	< 10	< 10
	10/16/95	< 5	< 5	< 5	< 7.5	< 7.5
	1/11/96	< 5	< 5	< 5	< 7.5	< 7.5
	4/1/96	< 5	< 5	< 5	< 5	< 5
MW1613-4	6/21/94	8300	770	6900 K ^{c/}	4200	20170
	9/30/94	460	210	420	950	2040
	12/15/94	1200	330	1700	1400	4630
	3/22/95	500	170	610 K/D	850	2130
	7/26/95	1300	370	940 K	1360	3970
	10/17/95	810	370 J	880 K	1510	3570

TABLE 2.10 (continued)
DATA SUMMARY FOR BTEX COMPOUNDS
BUILDING 1613 SITE
SITES OU-4 AND BUILDING 1613
RNA TS
SHAW AFB, SOUTH CAROLINA

Sample ID	Date Collected	Benzene (µg/L)	Ethylbenzene (µg/L)	Toluene (µg/L)	Total Xylenes (µg/L)	Total BTEX (µg/L)
MW1613-4	1/11/96	800	320	520 K	1090	2730
	4/5/96	630	230	430 K	790	2080
MW1613-4A	9/30/94	< 5	< 5	< 5	< 5	< 5
	12/15/94	< 5	< 5	< 5	< 5	< 5
	3/22/95	< 5	< 5	< 5 D	< 5	< 5
	7/19/95	< 5	< 5	< 5	< 10	< 10
	10/17/95	< 5	< 5	< 5	< 7.5	< 7.5
	1/11/96	< 5	< 5	< 5	< 7.5	< 7.5
	4/1/96	< 5	< 5	2 J	2 J	4 J
MW1613-5	6/21/94	2000	310	1100 K	870	4280
	9/30/94	1400	250	630	660	2940
	12/15/94	1900	410	800	920	4030
	3/22/95	1500	320	720 KD	800	3340
	7/19/95	470	260	92 K	600	1422
	10/17/95	1100	230	270 K	710	2310
	1/11/96	1800	340	190 K	1100	3430
	4/4/96	760	280	29	730	1799
MW1613-6	9/30/94	< 5	< 5	< 5	< 5	< 5
	12/15/94	< 5	< 5	< 5	< 5	< 5
	3/22/95	< 5	< 5	< 5 D	< 5	< 5
	7/19/95	< 5	< 5	< 5	< 10	< 10
	10/16/95	< 5	< 5	< 5	< 7.5	< 7.5
	1/11/96	< 5	< 5	< 5	< 7.5	< 7.5
	4/1/96	< 5	< 5	< 5	< 5	< 5
MW1613-7	9/30/94	< 20	34	69	160	263
	12/15/94	84 J	230	610	960	1884
	3/22/95	< 5	5.3	13 K/D	33	51.3
	7/26/95	< 50	57	< 50	330	387
	10/17/95	11	70	20 K	360	461
	1/11/96	8.9 J	73	47 K	360	488.9
	4/5/96	23 J	100	170 K	460	753
MW1613-8	9/30/94	95	10	36	31	172
	12/15/94	280	25	45	75	425
	3/22/95	18	3.4 J	4.9 J/KD	11	37.3
	7/19/95	100	6.8	5.3 K	4 J	116.1
	10/17/95	670	45	160 K	81	956
	1/11/96	810	45 J	260 K	180	1295
	4/4/96	730	50	83	68	931
MW1613-9	9/30/94	130 M	59	150 M ^d	81	420
	12/15/94	220	85	360	160	825
	3/22/95	110	140	300 K/D	200	750
	7/20/95	6.4	< 5	1.2 J/K	< 10	7.6
	10/17/95	16	3 J	4.5 J/K	1.2 J	24.7
	1/8/96	25	20	40 K	28	113
	4/3/96	32	31	75	55	193

TABLE 2.10 (concluded)
DATA SUMMARY FOR BTEX COMPOUNDS
BUILDING 1613 SITE
SITES OU-4 AND BUILDING 1613
RNA TS
SHAW AFB, SOUTH CAROLINA

Sample ID	Date Collected	Benzene (µg/L)	Ethylbenzene (µg/L)	Toluene (µg/L)	Total Xylenes (µg/L)	Total BTEX (µg/L)
MW1613-9A	7/20/95	< 5	< 5	< 5 D	< 10	< 10
	10/16/95	< 5	< 5	< 5	< 7.5	< 7.5
	1/8/96	< 5	< 5	< 5	< 7.5	< 7.5
	4/3/96	< 5	< 5	< 5	< 5	< 5
MW1613-10	7/21/95	< 5	< 5	< 5	< 10	< 10
	10/16/95	< 5	< 5	< 5	< 7.5	< 7.5
	1/11/96	< 5	< 5	< 5	< 7.5	< 7.5
	4/1/96	< 5	< 5	< 5	< 5	< 5
MW1613-11	7/21/95	1400	200	890 K	600	3090
	10/17/95	1100	200	570 K	600	2470
	1/11/96	790	130	500 K	460	1880
	4/4/96	980	150	640	560	2330
MW1613-12	7/21/95	13	33	< 5	137	183
	10/17/95	23 J	21 J	< 50	65 J	109 J
	1/11/96	30	34	0.98 J/K	55	120
	4/4/96	13	26	1 J	37	77
MW1613-13	7/20/95	< 5	< 5	< 5	< 10	< 10
	10/17/95	< 5	< 5	< 5	< 7.5	< 7.5
	1/8/96	< 5	< 5	< 5	< 7.5	< 7.5
	4/2/96	< 5	< 5	< 5	< 5	< 5
MW1613-13A	7/27/95	< 5	< 5	< 5	< 10	< 10
	10/17/95	< 5	< 5	< 5	< 7.5	< 7.5
	1/8/96	< 5	< 5	< 5	< 7.5	< 7.5
	4/2/96	< 5	< 5	< 5	< 5	< 5
MW1613-14	7/26/95	< 5	< 5	< 5	< 10	< 10
	10/17/95	< 5	< 5	< 5	< 7.5	< 7.5
	1/8/96	< 5	< 5	< 5	< 7.5	< 7.5
	4/2/96	1 J	< 5	< 5	< 5	1 J
MW1613-14A	7/26/95	< 5	< 5	< 5	< 10	< 10
	10/17/95	< 5	< 5	< 5	< 7.5	< 7.5
	1/8/96	< 5	< 5	< 5	< 7.5	< 7.5
	4/2/96	< 5	< 5	< 5	< 5	< 5
MW1613-15	7/21/95	< 5	< 5	< 5	< 5	< 5
	10/16/95	< 5	< 5	< 5	< 5	< 5
	1/8/96	< 5	< 5	< 5	1.4 J	1.4 J
	4/3/96	< 5	< 5	< 5	1.4 J	1.4 J
MW1613-15A	7/21/95	< 5	< 5	< 5	< 10	< 10
	10/16/95	< 5	< 5	< 5	< 7.5	< 7.5
	1/8/96	< 5	< 5	< 5	< 7.5	< 7.5
	4/3/96	< 5	< 5	< 5	< 5	< 5

^aJ = Estimated value less than quantitation limit.

^bD = Percent difference of matrix spike duplicate exceeded established criteria.

^cK = Artifact detected at a concentration less than 10x that detected in the associated field or laboratory blanks, or some other artifact detected at a concentration greater than 5x that detected in associated field or laboratory blanks.

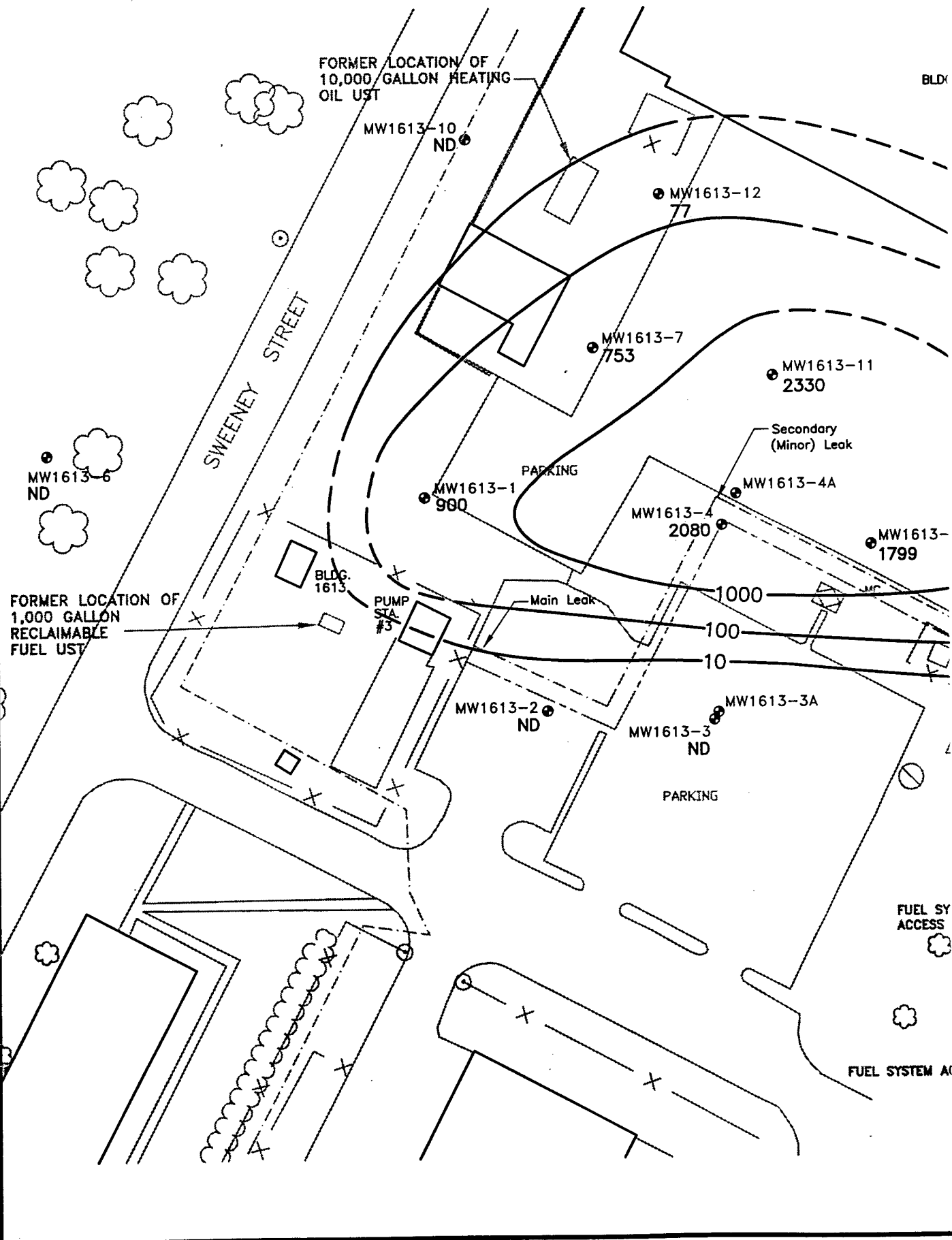
^dM = Duplicate injection precision was not met.

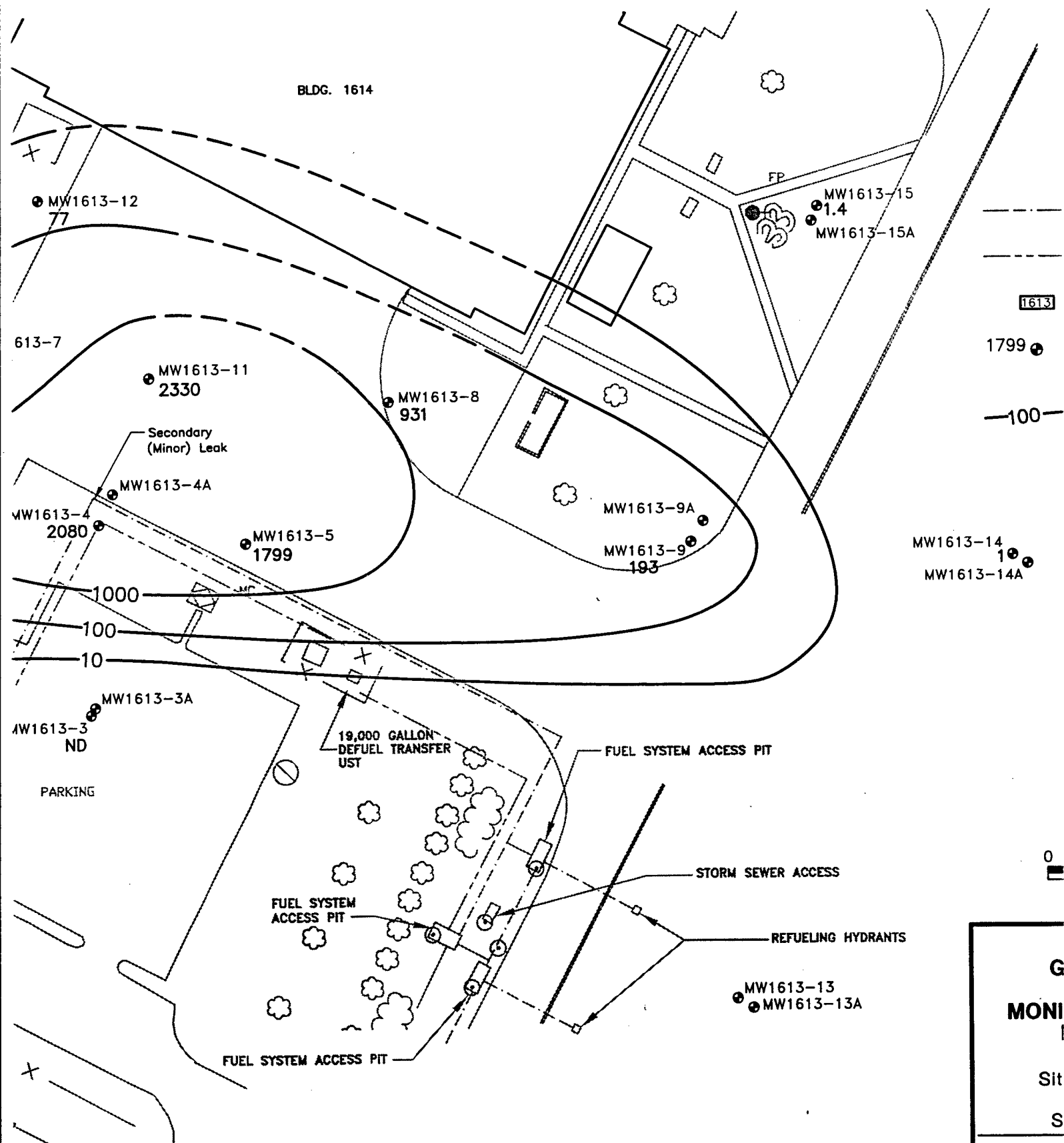
Data collected during the eight sampling events at the site indicate that the size and shape of the BTEX plume has remained relatively constant since June 1994. Figure 2.20 illustrates the groundwater BTEX plume for April 1996. In general, the groundwater BTEX plume at the site has maintained a size of approximately 480 feet long (from east to west) by 270 feet wide (from north to south) and encompasses an area of nearly 3 acres. The largest source area for the groundwater plume centers on monitoring wells MW1613-4 and MW1613-5, adjacent to the previous fuel transfer line leak repaired on June 25, 1991. The groundwater plume is migrating to the east in the direction of groundwater flow.

The site's highest BTEX concentrations have been detected in samples from monitoring well MW1613-4, with concentrations ranging between 2,040 and 20,170 $\mu\text{g/L}$. The maximum BTEX concentration of 20,170 $\mu\text{g/L}$ (measured on June 20, 1994) is approximately one order of magnitude higher than subsequently measured BTEX concentrations at this location. Mobile LNAPL has been observed in well MW1613-4; therefore, this elevated BTEX concentration may be the result of emulsified LNAPL that was collected with the groundwater sample. The second highest concentration measured at this monitoring well was 4,630 $\mu\text{g/L}$, in a sample collected in December 1994. Significantly elevated BTEX concentrations also have been detected in groundwater samples from well MW1613-5 (about 65 feet downgradient of MW1613-4) and MW1613-11 (about 60 feet northeast of MW1613-4).

Groundwater BTEX concentrations at well MW1613-7 have been only a third as high as at MW1613-4, possibly due to the sporadic presence of mobile LNAPL. The BTEX concentration in April 1996 at well MW1613-7 was 753 $\mu\text{g/L}$, compared to 2080 $\mu\text{g/L}$ at well MW1613-4. It is possible that the product at MW1613-7 is heating oil, which characteristically has low BTEX concentrations. The closest potential heating oil source was the former 10,000-gallon UST. This location, however, is cross-gradient to well MW1613-7, and the potential LNAPL migration pathway is unclear.

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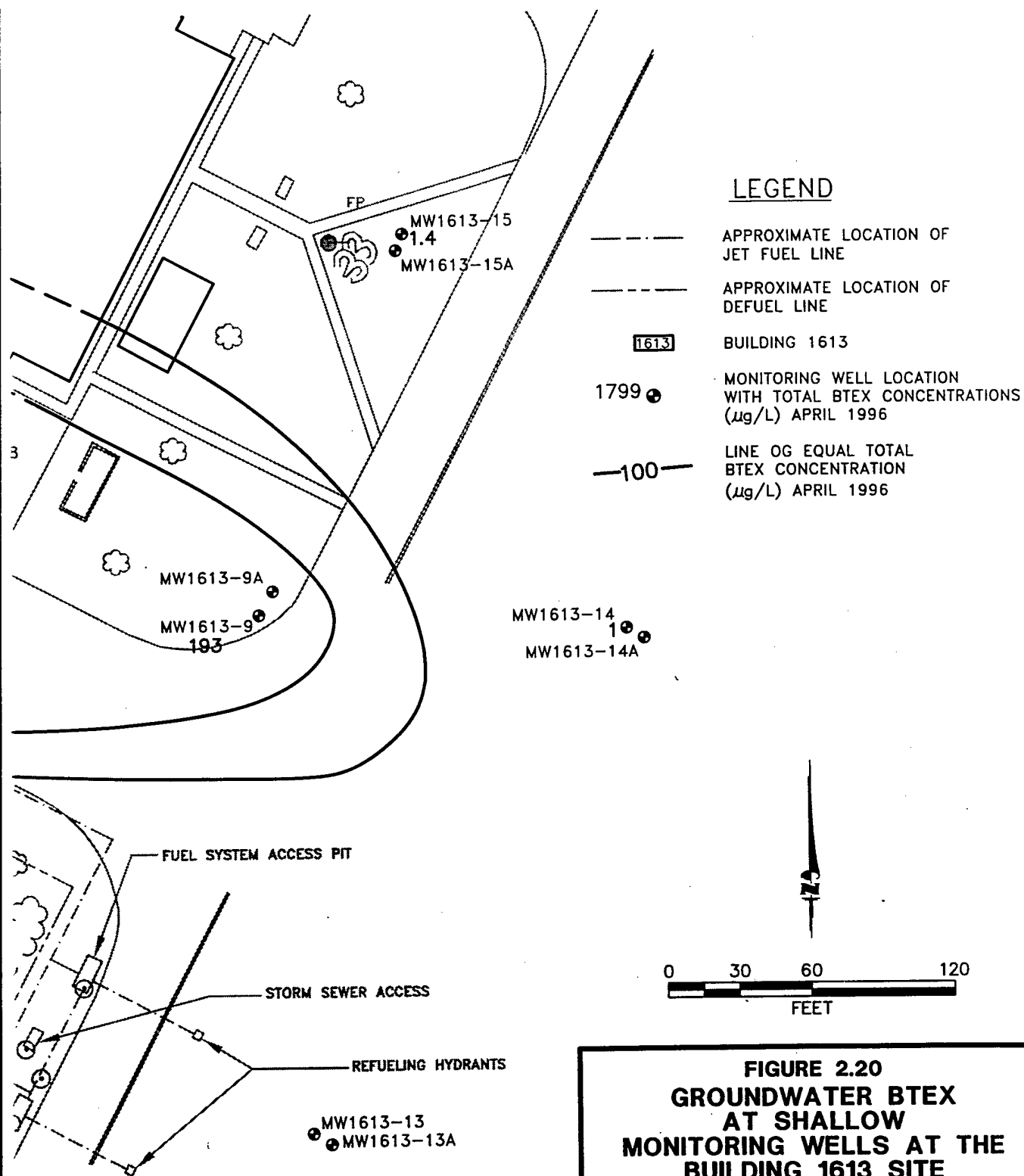


FIGURE 2.20
GROUNDWATER BTEX
AT SHALLOW
MONITORING WELLS AT THE
BUILDING 1613 SITE
APRIL 1996

Sites OU-4 and Building 1613
 RNA TS
 Shaw AFB, South Carolina

PARSONS
ENGINEERING SCIENCE, INC.

Denver, Colorado

Groundwater contamination has not migrated beyond the flightline located east of the source area. Historic BTEX concentrations at monitoring wells MW1613-13 to -15 (located roughly along a north to south line downgradient of the BTEX plume) have ranged from very low to below detection limits. In April 1996, the only BTEX detected in samples from these wells was 1.0 µg/L of benzene in the sample from MW1613-14 and 1.4 µg/L of xylenes in the sample from MW1613-15.

The groundwater contaminant plume also is defined vertically. A single detection of toluene (1.1 µg/L) was measured in well MW1613-3A, one of the six deep monitoring wells installed at the site. This toluene concentration was below the estimated quantitation limit for toluene, and may be the result of laboratory contamination. Therefore, it appears that groundwater BTEX contamination has not migrated to the base of the Shallow Aquifer, nor has it penetrated the clayey Sawdust Landing Member of the Black Mingo Formation that underlies the Shallow Aquifer at approximately 70 feet bgs.

The evaluation of non-BTEX contamination at the Building 1613 Site is not within the scope of the natural attenuation demonstration at the site; however, SVOC, pesticides/PCBs, and metal concentrations have been detected in site groundwater. Twelve SVOCs have been detected in groundwater samples collected from the Building 1613 Site. The two most frequently detected SVOCs were 2-methylnaphthalene and naphthalene at maximum concentrations of 340 µg/L (MW1613-12) and 140 µg/L (MW1613-4), respectively. Both naphthalene and 2-methylnaphthalene are commonly associated with fuel spills. Other SVOCs detected at the site were present in relatively low concentrations. Summary SVOC results are provided in Appendix C. No pesticides or PCBs were detected in any groundwater samples collected at the site. The sporadic detection of metal concentrations is not believed to have resulted from fueling operations within the Building 1613 Site (Rust E&I, 1996).

2.2 DEVELOPMENT OF CONCEPTUAL MODELS

A conceptual model is a three-dimensional representation of a hydrogeologic system based on available geological, hydrological, climatic, and geochemical data. A site-specific conceptual model is developed to provide an understanding of the mechanisms controlling contaminant fate and transport and to identify additional data requirements. The model describes known and suspected sources of contamination, types of contamination, affected media, contaminant migration pathways, and potential receptor exposure points. The model also provides a foundation for formulating decisions regarding additional data collection and potential remedial actions. The conceptual models for OU-4 and the Building 1613 Site will be used to aid in selecting additional data collection points and to identify appropriate data needs for modeling BTEX and chlorinated solvent attenuation using groundwater flow and solute transport models.

Successful conceptual model development involves:

- Defining the problem to be solved;
- Integrating available data, including
 - Local geologic and topographic data,
 - Hydraulic data,
 - Site stratigraphic data, and
 - Contaminant concentration and distribution data;
- Evaluating contaminant fate and transport characteristics;
- Identifying contaminant migration pathways;
- Identifying potential receptors and receptor exposure points; and

- Determining additional data requirements.

2.2.1 RNA and Groundwater Flow and Solute Transport Models

The positive effect of natural attenuation processes (e.g., advection, dispersion, sorption, and biodegradation) on reducing the actual mass of contamination dissolved in groundwater has been termed RNA. To estimate the impact of natural attenuation on the fate and transport of BTEX and CAH compounds dissolved in groundwater at a site, two important lines of evidence must be demonstrated (Wiedemeier *et al.*, 1995). The first is a documented loss of contaminants at the field scale. One way to show loss of contaminant mass is to use historical monitoring data to show that plume concentrations and extents decrease or remain stable over time. At some sites, dissolved concentrations of biologically recalcitrant tracers found in most fuel contamination can be used in conjunction with aquifer hydrogeologic parameters, such as groundwater seepage velocity and dilution, to demonstrate that a reduction in contaminant mass is occurring. The second line of evidence involves the use of geochemical data to show that areas with dissolved BTEX and CAH contamination can be correlated to areas with depleted electron acceptor (e.g., oxygen, nitrate, and sulfate) concentrations and increases in metabolic degradation byproduct concentrations (e.g., methane, ferrous iron, ethene, and chloride). With this site-specific information, groundwater flow and solute transport models can be used to simulate the fate and transport of dissolved BTEX and CAH compounds under the influence of natural attenuation.

Groundwater flow and solute transport models have proven useful for predicting plume migration and contaminant attenuation by natural biodegradation. Analytical and numerical models are available for modeling the fate and transport of BTEX and CAHs under the influence of advection, dispersion, sorption, and natural aerobic and anaerobic biodegradation. Analytical models derived from advection-dispersion equations [e.g., models such as those presented by Wexler (1992) and van Genuchten and Alves (1982)] may be useful. However, because BTEX and CAH biodegradation may be the result of

different processes in different locations, it may be necessary to use a numerical model to incorporate spatial variability into the fate and transport analysis.

An accurate estimate of the potential for natural biodegradation of CAHs and BTEX compounds in groundwater is important to consider when determining whether groundwater contamination presents a substantial threat to human health and the environment, and when deciding what type of remedial alternative will be most cost effective in eliminating or abating these threats. Over the past two decades, numerous laboratory and field studies have demonstrated that subsurface microorganisms can degrade a variety of hydrocarbons and chlorinated solvents (Lee, 1988; McCarty *et al.*, 1992). The following sections discuss the biodegradation of BTEX and CAHs.

2.2.2 Biodegradation of Dissolved BTEX Contamination

Numerous laboratory and field studies have shown that hydrocarbon-degrading bacteria can participate in the degradation of many of the chemical components of fuel hydrocarbons, including the BTEX compounds (e.g., Jamison *et al.*, 1975; Atlas, 1981, 1984, 1988; Gibson and Subramanian, 1984; Reinhard *et al.*, 1984; Young, 1984; Bartha, 1986; Wilson *et al.*, 1986, 1987, and 1990; Barker *et al.*, 1987; Baedeker *et al.*, 1988; Lee, 1988; Chiang *et al.*, 1989; Grbic-Galic, 1989 and 1990; Cozzarelli *et al.*, 1990; Leahy and Colewell, 1990; Altenschmidt and Fuchs, 1991; Alvarez and Vogel, 1991; Baedeker and Cozzarelli, 1991; Ball *et al.*, 1991; Bauman, 1991; Borden, 1991; Brown *et al.*, 1991; Edwards *et al.*, 1991 and 1992; Evans *et al.*, 1991a and 1991b; Haag *et al.*, 1991; Hutchins and Wilson, 1991; Hutchins *et al.*, 1991a and 1991b; Beller *et al.*, 1992; Bouwer, 1992; Edwards and Grbic-Galic, 1992; Thierrin *et al.*, 1992; Malone *et al.*, 1993; Davis *et al.*, 1994). Biodegradation of fuel hydrocarbons can occur when an indigenous population of hydrocarbon-degrading microorganisms is present in the aquifer and sufficient concentrations of electron acceptors and nutrients, including fuel hydrocarbons, are available to these organisms.

Microorganisms obtain energy for cell production and maintenance by facilitation of thermodynamically advantageous reduction/oxidation (redox) reactions involving the transfer of electrons from electron donors to available electron acceptors. This results in the oxidation of the electron donor and the reduction of the electron acceptor. Electron donors at OU-4 and the Building 1613 Site may include natural organic carbon and fuel hydrocarbon compounds. Fuel hydrocarbons are completely degraded or detoxified if they are utilized as the primary electron donor for microbial metabolism (Bouwer, 1992). Electron acceptors are elements or compounds that occur in relatively oxidized states, and include dissolved oxygen (DO), nitrate, ferric iron, sulfate, and carbon dioxide.

The driving force of BTEX degradation is electron transfer, which is quantified by the Gibbs free energy of the reaction (ΔG°_r) (Stumm and Morgan, 1981; Bouwer, 1994; Godsey, 1994). The value of ΔG°_r represents the quantity of free energy consumed or yielded to the system during the reaction. Table 2.11 lists the stoichiometry of the redox equations involving BTEX and the resulting ΔG°_r . Although thermodynamically favorable, most of the reactions involved in BTEX oxidation cannot proceed abiotically because of the lack of activation energy. Microorganisms are capable of providing the necessary activation energy; however, they will facilitate only those redox reactions that have a net yield of energy (i.e., $\Delta G^\circ_r < 0$). Microorganisms preferentially utilize electron acceptors while metabolizing fuel hydrocarbons (Bouwer, 1992). DO is utilized first as the prime electron acceptor. After the DO is consumed, anaerobic microorganisms typically use electron acceptors (as available) in the following order of preference: nitrate, ferric iron hydroxide, sulfate, and finally carbon dioxide. Because the biodegradation of fuel hydrocarbons should deplete the concentrations of these electron acceptors, construction of isopleth maps depicting their concentrations can provide evidence of whether biodegradation is occurring, and the degree to which it is occurring.

TABLE 2.11
COUPLED OXIDATION REACTIONS FOR BTEX COMPOUNDS
SITES OU-4 AND BUILDING 1613
RNA TS
SHAW AFB, SOUTH CAROLINA

Coupled Benzene Oxidation Reactions	ΔG°_r (kcal/mole Benzene)	ΔG°_r (kJ/mole Benzene)	Stoichiometric Mass Ratio of Electron Acceptor to Compound
$7.5O_2 + C_6H_6 \Rightarrow 6CO_{2,g} + 3H_2O$ <i>Benzene oxidation / aerobic respiration</i>	-765.34	-3202	3.07:1
$6NO_3^- + 6H^+ + C_6H_6 \Rightarrow 6CO_{2,g} + 6H_2O + 3N_{2,g}$ <i>Benzene oxidation / denitrification</i>	-775.75	-3245	4.77:1
$3.75NO_3^- + C_6H_6 + 7.5H^+ + 0.75H_2O \Rightarrow 6CO_2 + 3.75NH_4^+$ <i>Benzene oxidation / nitrate reduction</i>	-524.1	-2193	2.98:1
$60H^+ + 30Fe(OH)_{3,a} + C_6H_6 \Rightarrow 6CO_2 + 30Fe_2^{2+} + 78H_2O$ <i>Benzene oxidation / iron reduction</i>	-560.10	-2343	21.5:1 ^{a/}
$7.5H^+ + 3.75SO_4^{2-} + C_6H_6 \Rightarrow 6CO_{2,g} + 3.75H_2S^o + 3H_2O$ <i>Benzene oxidation / sulfate reduction</i>	-122.93	-514.3	4.61:1
$4.5H_2O + C_6H_6 \Rightarrow 2.25CO_{2,g} + 3.75CH_4$ <i>Benzene oxidation / methanogenesis</i>	-32.40	-135.6	0.77:1 ^{b/}

Coupled Toluene Oxidation Reactions	ΔG°_r (kcal/mole Toluene)	ΔG°_r (kJ/mole Toluene)	Stoichiometric Mass Ratio of Electron Acceptor to Compound
$9O_2 + C_6H_5CH_3 \Rightarrow 7CO_{2,g} + 4H_2O$ <i>Toluene oxidation / aerobic respiration</i>	-913.76	-3823	3.13:1
$7.2NO_3^- + 7.2H^+ + C_6H_5CH_3 \Rightarrow 7CO_{2,g} + 7.6H_2O + 3.6N_{2,g}$ <i>Toluene oxidation / denitrification</i>	-926.31	-3875	4.85:1
$72H^+ + 36Fe(OH)_{3,a} + C_6H_5CH_3 \Rightarrow 7CO_2 + 36Fe^{2+} + 94H_2O$ <i>Toluene oxidation / iron reduction</i>	-667.21	-2792	21.86:1 ^{a/}
$9H^+ + 4.5SO_4^{2-} + C_6H_5CH_3 \Rightarrow 7CO_{2,g} + 4.5H_2S^o + 4H_2O$ <i>Toluene oxidation / sulfate reduction</i>	-142.86	-597.7	4.7:1
$5H_2O + C_6H_5CH_3 \Rightarrow 2.5CO_{2,g} + 4.5CH_4$ <i>Toluene oxidation / methanogenesis</i>	-34.08	-142.6	0.78:1 ^{b/}

TABLE 2.11 (Continued)
COUPLED OXIDATION REACTIONS FOR BTEX COMPOUNDS
SITES OU-4 AND BUILDING 1613
RNA TS
SHAW AFB, SOUTH CAROLINA

Coupled Ethylbenzene Oxidation Reactions	ΔG°_r (kcal/mole Ethyl- benzene)	ΔG°_r (kJ/mole Ethyl- benzene)	Stoichiometric Mass Ratio of Electron Acceptor to Compound
$10.5 O_2 + C_6H_5C_2H_5 \Rightarrow 8 CO_{2,g} + 5 H_2O$ <i>Ethylbenzene oxidation / aerobic respiration</i>	-1066.13	-4461	3.17:1
$8.4 NO_3 + 8.4 H^+ + C_6H_5C_2H_5 \Rightarrow 8 CO_{2,g} + 9.2 H_2O + 4.2 N_{2,g}$ <i>Ethylbenzene oxidation / denitrification</i>	-1080.76	-4522	4.92:1
$84 H^+ + 42 Fe(OH)_{3,a} + C_6H_5C_2H_5 \Rightarrow 8 CO_2 + 42 Fe^{2+} + 110 H_2O$ <i>Ethylbenzene oxidation / iron reduction</i>	-778.48	-3257	22:1 ^{a/}
$10.5 H^+ + 5.25 SO_4^{2-} + C_6H_5C_2H_5 \Rightarrow 8 CO_{2,g} + 5.25 H_2S^\circ + 5 H_2O$ <i>Ethylbenzene oxidation / sulfate reduction</i>	-166.75	-697.7	4.75:1
$5.5 H_2O + C_6H_5C_2H_5 \Rightarrow 2.75 CO_{2,g} + 5.25 CH_4$ <i>Ethylbenzene oxidation / methanogenesis</i>	-39.83	-166.7	0.79:1 ^{b/}

Coupled m-Xylene Oxidation Reactions	ΔG°_r (kcal/mole m-xylene)	ΔG°_r (kJ/mole m-xylene)	Stoichiometric Mass Ratio of Electron Acceptor to Compound
$10.5 O_2 + C_6H_4(CH_3)_2 \Rightarrow 8 CO_{2,g} + 5 H_2O$ <i>m-Xylene oxidation / aerobic respiration</i>	-1063.25	-4448	3.17:1
$8.4 NO_3 + 8.4 H^+ + C_6H_4(CH_3)_2 \Rightarrow 8 CO_{2,g} + 9.2 H_2O + 4.2 N_{2,g}$ <i>m-Xylene oxidation / denitrification</i>	-1077.81	-4509	4.92:1
$84 H^+ + 42 Fe(OH)_{3,a} + C_6H_4(CH_3)_2 \Rightarrow 8 CO_2 + 42 Fe^{2+} + 110 H_2O$ <i>m-Xylene oxidation / iron reduction</i>	-775.61	-3245	22:1 ^{a/}
$10.5 H^+ + 5.25 SO_4^{2-} + C_6H_4(CH_3)_2 \Rightarrow 8 CO_{2,g} + 5.25 H_2S^\circ + 5 H_2O$ <i>m-Xylene oxidation / sulfate reduction</i>	-163.87	-685.6	4.75:1
$5.5 H_2O + C_6H_4(CH_3)_2 \Rightarrow 2.75 CO_{2,g} + 5.25 CH_4$ <i>m-Xylene oxidation / methanogenesis</i>	-36.95	-154.6	0.79:1 ^{b/}

^{a/} Mass of ferrous iron produced during microbial respiration.

^{b/} Mass of methane produced during microbial respiration.

Depending on the types and concentrations of electron acceptors present (e.g., nitrate, ferric iron, sulfate, carbon dioxide), pH conditions, and redox potential, anaerobic biodegradation can occur by denitrification, ferric iron reduction, sulfate reduction, or methanogenesis. Other, less common anaerobic degradation mechanisms such as manganese or nitrate reduction may dominate if the physical and chemical conditions in the subsurface favor use of these electron acceptors. Anaerobic destruction of BTEX compounds is associated with the accumulation of fatty acids, production of methane, solubilization of iron, and reduction of nitrate and sulfate (Cozzarelli *et al.*, 1990; Wilson *et al.*, 1990). Environmental conditions and microbial competition will ultimately determine which processes will dominate. Vrobesky and Chapelle (1994) show that the dominant terminal electron accepting process can vary both temporally and spatially in an aquifer with fuel hydrocarbon contamination.

2.2.3 Biodegradation of CAHs

Chlorinated solvents can be transformed, directly or indirectly, by biological processes (e.g., Bouwer *et al.*, 1981; Wilson and Wilson, 1985; Miller and Guengerich, 1982; Nelson *et al.*, 1986; Bouwer and Wright, 1988; Little *et al.*, 1988; Mayer *et al.*, 1988; Arciero *et al.*, 1989; Cline and Delfino, 1989; Freedman and Gossett, 1989; Folsom *et al.*, 1990; Harker and Kim, 1990; Alvarez-Cohen and McCarty, 1991a, 1991b; DeStefano *et al.*, 1991; Henry, 1991; McCarty *et al.*, 1992; Hartmans and de Bont, 1992; McCarty and Semprini, 1994; Vogel, 1994). CAHs may undergo biodegradation through three different pathways: use as an electron acceptor, use as an electron donor, or cometabolism, which is degradation resulting from exposure to a catalytic enzyme fortuitously produced during an unrelated process. At a given site where biodegradation is occurring, one or all of these processes may be operating, although at many sites the use of CAHs as electron acceptors appears to be the most important.

In a pristine aquifer, native organic carbon is utilized as an electron donor; where anthropogenic carbon (e.g., fuel hydrocarbons or less chlorinated CAHs) is present, it also will be utilized as an electron donor. Evaluation of the distribution of electron acceptors and electron donors can provide evidence of where and how CAH biodegradation is occurring. In addition, because CAHs may be used as electron acceptors or electron donors (in competition with other acceptors or donors), maps showing the distribution of these compounds also will provide evidence on the types of biodegradation processes acting at a site.

As with BTEX, the driving force behind redox reactions resulting in CAH degradation is electron transfer. Although thermodynamically favorable, most of the reactions involved in CAH reduction and oxidation cannot proceed abiotically because of the lack of activation energy. Microorganisms are capable of providing the necessary activation energy; however, they will facilitate only those redox reactions that have a net yield of energy. A more complete description of the main types of biodegradation reactions affecting CAHs is presented in the following subsections.

2.2.3.1 Electron Acceptor Reactions (Reductive Dechlorination)

Under anaerobic conditions, biodegradation of chlorinated solvents usually proceeds through a process called reductive dehalogenation. During this process, the halogenated hydrocarbon is used as an electron acceptor, not as a source of carbon, and a halogen atom is removed and replaced with a hydrogen atom. Figure 2.21 illustrates the transformation of chlorinated ethenes via reductive dehalogenation. In general, reductive dehalogenation occurs by sequential dechlorination. For the chlorinated ethenes, dechlorination progresses from PCE to TCE to DCE to VC to ethene. Likewise, for the chlorinated ethanes, dechlorination progresses from TCA to DCA to chloroethane to ethane. Depending upon environmental conditions, these dechlorination sequences may be interrupted, with other processes then acting upon the products. During reductive dehalogenation of TCE, all three isomers of DCE can theoretically be produced;

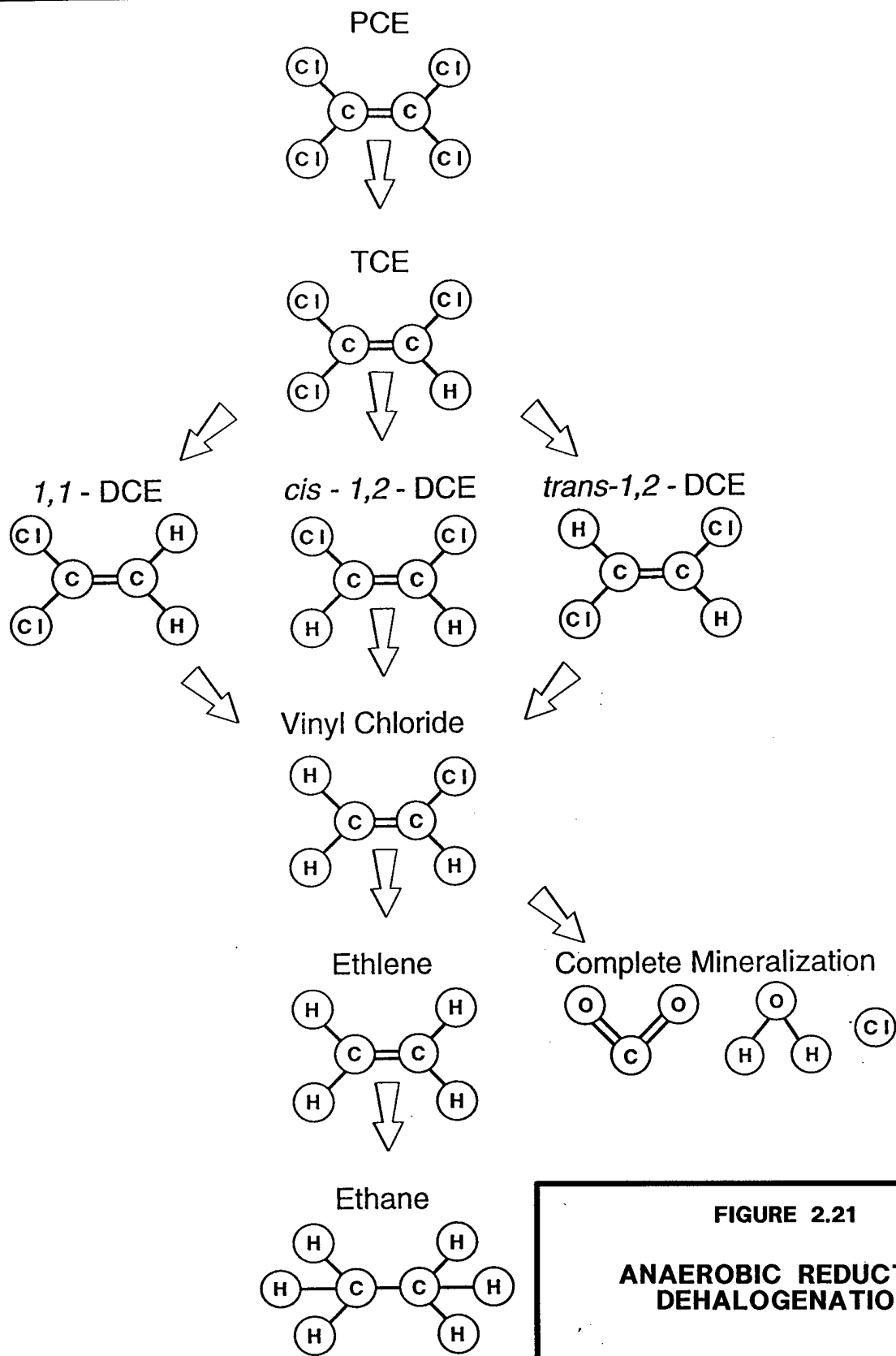


FIGURE 2.21

**ANAEROBIC REDUCTIVE
DEHALOGENATION**

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however, Bouwer (1994) reports that under the influence of biodegradation, *cis*-1,2-DCE is a more common intermediate than *trans*-1,2-DCE, and that 1,1-DCE is the least prevalent intermediate of the three DCE isomers. Reductive dehalogenation of chlorinated solvent compounds is associated with the accumulation of daughter products and an increase in chloride.

Reductive dehalogenation affects each of the chlorinated ethenes differently. PCE, TCE, and TCA are the most susceptible of these compounds to reductive dehalogenation because they are the most oxidized. Conversely, VC and chloroethane are the least susceptible to reductive dehalogenation because they are the least oxidized of these compounds. The rate of reductive dehalogenation also has been observed to decrease as the degree of chlorination decreases (Vogel and McCarty, 1985; Bouwer, 1994). Murray and Richardson (1993) have postulated that this rate decrease may explain the accumulation of VC in PCE and TCE plumes that are undergoing reductive dechlorination. Reductive dehalogenation has been demonstrated under nitrate- and sulfate-reducing conditions, but the most rapid biodegradation rates, affecting the widest range of CAHs, occur under methanogenic conditions (Bouwer, 1994).

Because CAH compounds are used as electron acceptors, there must be an appropriate source of carbon for microbial growth in order for reductive dehalogenation to occur (Bouwer, 1994). Potential carbon sources can include low-molecular-weight compounds (e.g., lactate, acetate, methanol, or glucose) present in natural organic matter, fuel hydrocarbons, or less-chlorinated compounds such as VC, DCE, chloroethane, or DCA.

2.2.3.2 Electron Donor Reactions

Under aerobic conditions some CAH compounds can be utilized as the primary substrate (i.e., electron donor) in biologically mediated redox reactions (McCarty and Semprini, 1994). In this type of reaction, the facilitating microorganism obtains energy and organic carbon from the degraded CAH. In contrast to reactions in which the CAH is used as an electron acceptor, only the least oxidized CAHs can be utilized as electron

donors in biologically mediated redox reactions. McCarty and Semprini (1994) describe investigations in which VC and 1,2-DCA were shown to serve as primary substrates. These authors also document that dichloromethane has the potential to function as a primary substrate in either aerobic or anaerobic environments. In addition, Bradley and Chapelle (1996) show evidence of mineralization of VC under iron-reducing conditions so long as there is sufficient bioavailable iron (III). Klier *et al.*, (1996) demonstrated aerobic mineralization of all 3 isomers of DCE. Murray and Richardson (1993) write that microorganisms are generally believed to be incapable of growth using TCE and PCE. Aerobic metabolism of VC, DCA, or DCE may be characterized by a loss of VC, DCA, or DCE relative mass or a decreasing molar ratio of VC, DCA, or DCE to other CAH compounds.

2.2.3.3 Cometabolism

When a CAH is biodegraded through cometabolism, it serves as neither an electron acceptor nor a primary substrate in a biologically mediated redox reaction. Instead, the degradation of the CAH is catalyzed by an enzyme or cofactor that is fortuitously produced by organisms for other purposes. The organism receives no known benefit from the degradation of the CAH; rather the cometabolic degradation of the CAH may in fact be harmful to the microorganism responsible for the production of the enzyme or cofactor (McCarty and Semprini, 1994).

Cometabolism is best documented in aerobic environments, although it potentially could occur under anaerobic conditions. Several aerobic degradation pathways for chlorinated ethenes are illustrated in Figure 2.22. It has been reported that under aerobic conditions chlorinated ethenes, with the exception of PCE, are susceptible to cometabolic degradation (Murray and Richardson, 1993; Vogel, 1994; McCarty and Semprini, 1994). Vogel (1994) further elaborates that the cometabolism rate increases as the degree of dechlorination decreases.

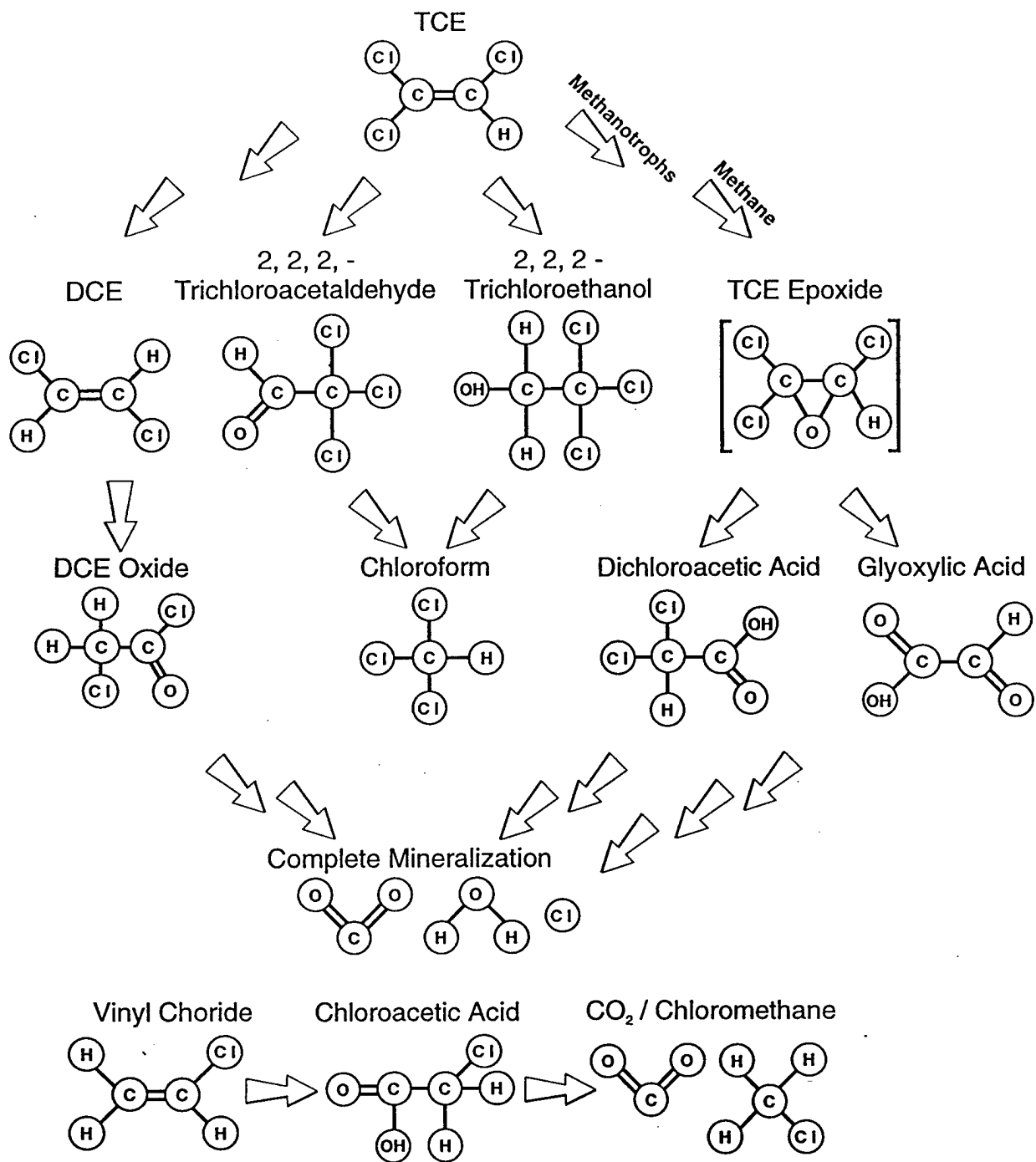


FIGURE 2.22

AEROBIC DEGRADATION PATHWAYS

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During the cometabolic process, TCE is indirectly transformed by bacteria as an organic carbon substrate is used to meet their energy requirements. Therefore, TCE does not enhance the degradation of carbon sources, nor will its cometabolism interfere with the use of electron acceptors involved in the oxidation of those carbon sources. It is likely that depletion of suitable substrates (organic carbon sources) may limit cometabolism of CAHs.

2.2.3.4 Behavior of Chlorinated Solvent Plumes

Chlorinated solvent plumes can exhibit three types of behavior depending on the amount of solvent, the amount of organic (native and/or anthropogenic) organic carbon in the aquifer, the distribution and concentration of natural electron acceptors, and the types of electron acceptors being utilized. Individual plumes may exhibit all three types of behavior in different portions of the plume. The different types of plume behavior are summarized below.

Type 1 behavior occurs where the primary substrate is anthropogenic carbon (e.g., BTEX or landfill leachate) and this anthropogenic carbon drives reductive dechlorination. When evaluating RNA for a plume exhibiting type 1 behavior the following questions must be answered:

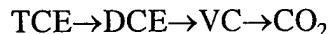
1. Does electron acceptor supply exceed demand (i.e., is the electron acceptor supply adequate)? Will the microorganisms degrading the CAH plume strangle before they starve [i.e., will they run out of CAHs (electron acceptors) before they run out of primary substrate (anthropogenic carbon)]?
2. What is the role of competing electron acceptors?
3. Are VC, DCE, and DCA oxidized or reduced?

Type 2 behavior dominates in areas that are characterized by relatively high native organic carbon concentrations, and this carbon source drives reductive dechlorination

(i.e., the primary substrate for microorganism growth is native organic carbon). When evaluating RNA for a type 2 chlorinated solvent plume, the same questions as those posed in the description of type 1 behavior must be answered.

Type 3 behavior dominates in areas that are characterized by low native and/or anthropogenic carbon concentrations where DO concentrations are greater than 1.0 mg/L. Under these conditions the plume is aerobic and reductive dechlorination will not occur. Thus there is no biodegradation of PCE, TCE, or TCA, and natural attenuation mechanisms for these compounds include advection, dispersion, and sorption only. However, VC, DCA, and DCE can be oxidized under these conditions.

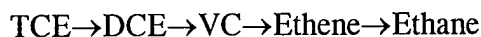
As mentioned above, a single chlorinated solvent plume can exhibit all three types of behavior in different portions of the plume. This can be beneficial for natural biodegradation of CAH plumes. For example Wiedemeier *et al.* (1996b) describe a plume at Plattsburgh AFB, New York that exhibits type 1 behavior in the source area and type 3 behavior downgradient from the source. The best scenario involves a plume in which TCE and DCE are reductively dechlorinated (type 1 or 2 behavior), then VC is oxidized (type 3 behavior), either aerobically or anaerobically (via iron reduction). Vinyl chloride is oxidized to carbon dioxide in this type of plume and does not accumulate. The following sequence of reactions occurs in this type of plume.



In general, the TCE, DCE, and VC are attenuated at approximately the same rate, and thus these reactions may be confused with simple dilution. Note that no ethene is produced during this reaction. Vinyl chloride is removed from the system much faster under these conditions than it is under VC-reducing conditions.

A less desirable scenario involves a plume in which all CAHs are reductively dechlorinated (type 1 or 2 behavior). Vinyl chloride is reduced to ethene which is

further reduced to ethane. The following sequence of reactions occur in this type of plume.



Under type 1 or 2 conditions, DCE and VC degrade more slowly than TCE, and thus they tend to accumulate. This is the type of reductive dechlorination described by Freedman and Gossett (1989).

2.2.4 Initial Conceptual Model

2.2.4.1 Initial Conceptual Model for OU-4

Geologic and hydrogeologic data for OU-4 were previously integrated to produce geologic cross-sections of the site (Figures 2.5 and 2.6). Although the cross-sections intersect at an angle of about 60 degrees, the downgradient portion of each section coincides with the local groundwater flow direction in the upper zone of the Shallow Aquifer. Each cross-section also traces a separate contaminant plume migration pathway.

Figure 2.7 is a groundwater contour map for the upper zone of the Shallow Aquifer for OU-4 prepared using March 1993 groundwater elevation data. Groundwater is present approximately 0 to 15 feet bgs. The groundwater flow direction is generally northeast; however, local topography contributes to local groundwater flow directions varying from north-northwest to east-northeast. Although groundwater elevations through the terrace portion of the site suggest a downward vertical gradient, a fining of grain size with depth as well as current contaminant distributions suggest that the lower zone of the Shallow Aquifer is not significantly impacted by site contamination. On the basis of available data, Parsons ES will model this site as an unconfined, fine-grained sand aquifer. This conceptual model will be modified as necessary as additional site hydrogeologic data become available.

Given available information, it appears that the CAH plume originating at OU-4 is a Type 1 behavior plume, with residual fuel hydrocarbons from fire training exercises serving as a source of carbon. This is supported by limited geochemical data for nitrate and sulfate showing reduced concentrations of these compounds throughout the dissolved plume. Reductive dehalogenation of the source solvents 1,1,1-TCA and TCA appears to be occurring based on the presence of 1,1-DCA and 1,2-DCE. These daughter products appear to be further biodegraded through reductive dehalogenation to chloroethane and VC. As described in Section 2.2.3, the *cis*- isomer is generated more frequently than the *trans*- isomer during reductive dehalogenation of TCE; however, this line of evidence could not be evaluated because the results reported in the Final RI (1995) did not distinguish between the two isomers. Section 2.2.3 also indicates that 1,1-DCE is not commonly produced as a result of the reductive dehalogenation of TCE. Therefore, the presence of 1,1-DCE suggests that 1,1,1-TCA is abiotically degraded through the process of dehydrohalogenation. This process is defined by the elimination of a hydrogen ion and a chloride ion, and the formation of a double carbon bond.

For the purposes of this demonstration, both CAHs and BTEX are the chemicals of concern in groundwater at OU-4 (Tables 2.6 and 2.7 and Figures 2.15 through 2.17) and will be the primary focus of this RNA study because of their regulatory importance. The effects of fate and transport processes on the dissolved CAHs will be further investigated using quantitative groundwater analytical data and analytical solute-transport models. Data collection and analysis requirements are discussed in Section 3 of this work plan.

2.2.4.2 Initial Conceptual Model for the Building 1613 Site

The Building 1613 Site hydrogeologic data were previously integrated to produce three hydrogeologic cross-sections of the site. Cross sections A-A', B-B', and C-C' (Figure 2.9, 2.10, and 2.11) show various stratigraphic intervals present at the site as determined from previous soil boring logs (Rust E&I, 1996a). Figure 2.12 is a

potentiometric map for shallow groundwater prepared using April 1, 1996 groundwater elevation data (Rust E&I, 1996b).

The water table is present at approximately 30 to 35 feet bgs in well to poorly graded sands with occasional silts and clays that are typical in the Duplin Aquifer at this depth. Groundwater flow is relatively uniform and flows to the east at an average gradient of 0.0032 ft/ft in the upper zone of the Shallow Aquifer. The site is best represented as an unconfined sand aquifer with occasional silty/clayey intervals. Vertical migration of site contaminants in groundwater is suspected to be minimal on the basis of insignificant vertical gradients and the lack of significant contaminant concentrations at depth in the aquifer.

Benzene is the primary chemical of interest in groundwater at the Building 1613 Site because of its solubility and relative toxicity. However, the combined effects of all the BTEX compounds on attenuation rates make site data for all of the BTEX compounds important. Therefore, the BTEX compounds will be the primary focus of this demonstration of RNA.

The dissolved BTEX plume is considered to be stable, owing to long-term monitoring data showing stability of plume concentrations and extents (Rust E&I, 1996b). This conclusion is further supported by the elimination of continuing spill sources (e.g., former USTs and line leaks) at the site. Nevertheless, dissolved BTEX compounds at the site are expected to continue to leach from contaminated soils containing fuel residual, to dissolve from mobile LNAPL into the groundwater, and to migrate downgradient as a dissolved contaminant plume. LNAPL dissolution will be evaluated using fuel/water partitioning models such as those described by Bruce *et al.* (1991) or Cline *et al.* (1991). Contaminant fate and transport will be evaluated with the Bioplume II numerical model.

The fate and transport of dissolved BTEX contamination at the site is affected by mass transport mechanisms (volatilization, dispersion, diffusion, and adsorption) and destructive attenuation mechanisms, such as biodegradation. Available groundwater geochemical data that can be used to support the contamination that biodegradation is occurring at the Building 1613 Site are summarized in Table 2.12. Data for nitrate and sulfate indicate that limited anaerobic biodegradation of BTEX through nitrate and sulfate reduction may be occurring at the site. Average background concentrations of nitrate (2.0 mg/L at wells MW1613-6, -10, -13, and -15) exceed source area concentrations of nitrate (0.8 mg/L at wells MW1613-4 and -5). Similarly, average background sulfate concentrations (1.1 mg/L at wells MW1613-6, -10, -13, and -15) exceed source area concentrations of sulfate (non-detect at wells MW1613-4 and -5). The decreased nitrate and sulfate concentrations in the source area coincide with elevated groundwater BTEX concentrations at the same location. This is a preliminary indication that biodegradation of BTEX compounds is occurring at the site.

Biodegradation also can be evaluated through changes in alkalinity. Groundwater alkalinity is a measure of the ability of groundwater to buffer changes in pH caused by the generation of biologically generated acids. Increased alkalinity in the areas of groundwater BTEX contamination can occur in response to increased carbon dioxide concentrations, which are a product of BTEX biodegradation (Morell and Hering, 1993). A definitive trend of increased alkalinities is not apparent at the Building 1613 Site; however, alkalinity concentrations in background wells were typically below detection limits, whereas alkalinity in the source area were typically between 6 to 20 mg/L. Additional analysis of these and other attenuation processes will be provided in the RNA TS report.

TABLE 2.12
GROUNDWATER GEOCHEMICAL ANALYTICAL DATA
BUILDING 1613 SITE
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Sample ID	Date Collected	Total Alkalinity (mg/L)	Chloride (mg/L)	Nitrate-Nitrite (mg/L)	Sulfate (mg/L)
MW1613-1	9/30/94	24	5.4	0.86	6.9
	12/15/94	7	NA ^{a/}	NA	NA
	3/21/95	5	4.3	0.95	<5
	7/19/95	9	4.8	1	1.9
	10/16/95	<5	4.6	0.6	2.5
	1/11/96	<5	4.5	1	1.5
	4/4/96	18	4.9	0.8	1
MW1613-2	9/30/94	<5	5	1.8	<25
	12/15/94	<5	NA	NA	NA
	3/21/95	<5	5.2	1.4	<5
	7/19/95	<5	5	2.2	<1
	10/16/95	<5	5	0.5	1
	1/11/96	<5	4.9	2.1	1.4
	4/1/96	<5	5.4	2.2	1.6
MW1613-3	9/30/94	<5	5.2	2.3	<5
	12/15/94	<5	NA	NA	NA
	3/21/95	<5	5.4	1.6	<5
	7/19/95	<5	5.2	2.8	<1
	10/16/95	<5	5.2	2.7	1.1
	1/11/96	<5	5.2	2.8	1.3
	4/1/96	<5	5.2	2.6	<1
MW1613-3A	6/20/94	<5	3.3	2.7	NA
	9/30/94	<5	4.5	2.9	<5
	12/15/94	<5	NA	3.1	NA
	3/21/95	<5	4.7	<0.05	<5
	7/19/95	<5	4.6	3	<1
	10/16/95	<5	5	3.2	<1
	1/11/96	<5	4.8	3.9	1.1
MW1613-4	4/1/96	<5	4.9	3	1.3
	9/30/94	11	<5	0.84	<5
	12/15/94	6	NA	NA	NA
	3/22/95	7	4.8	1.4 M ^{b/}	<5
	7/26/95	7	4.5	0.6	<1
	10/17/95	6	4.7	0.3	<1
	1/11/96	<5	4.6	1	<1
MW1613-4A	4/5/96	16	4.9	0.9	<1
	9/30/94	14	4.5	2.4	<20
	12/15/94	6	NA	NA	NA
	3/22/95	<5	4.7	2.6 M	<5
	7/19/95	<5	4.7	2.6	1.2
	10/17/95	5	4.7	2.7	1.4
	1/11/96	<5	4.7	2.1	1.3
MW1613-5	4/1/96	<5	4.8	2.7	1.1
	9/30/94	46	<5	NA	<5
	12/15/94	40	NA	NA	NA
	3/22/95	52	4.3	0.052 M	<5
	7/19/95	8	4.1	<0.1	<1
	10/17/95	8	4.4	<0.1	1
	1/11/96	8	4.5	<0.1	<1
	4/4/96	20	4.9	<0.1	<1

TABLE 2.12 (continued)
GROUNDWATER GEOCHEMICAL ANALYTICAL DATA
BUILDING 1613 SITE
SITES OU-4 AND BUILDING 1613
RNA TS
SHAW AFB, SOUTH CAROLINA

Sample ID	Date Collected	Total Alkalinity (mg/L)	Chloride (mg/L)	Nitrate-Nitrite (mg/L)	Sulfate (mg/L)
MW1613-6	9/30/94	8	3.9	2.3	< 5
	12/15/94	< 5	NA	NA	NA
	3/22/95	< 5	4.1	3.2 M	< 5
	7/19/95	< 5	3.9	3.2	2.3
	10/16/95	20	4.2	4.1	1.1
	1/11/96	< 5	4.1	3.7	1.2
	4/1/96	< 5	4.2	3.6	1.2
MW1613-7	9/30/94	7	3	0.76	< 5
	12/15/94	< 5	NA	NA	NA
	3/22/95	5	3.3	1.2 M	< 5
	7/26/95	< 5	3.2	1.3	< 1
	10/17/95	6	2.9	1.2	< 1
	1/11/96	< 5	3.6	1.4	< 1
	4/5/96	9	3.5	1	< 1
MW1613-8	9/30/94	8	3.6	< 0.05	< 5
	12/15/94	14	NA	NA	NA
	3/22/95	6	3.6	< 0.05	< 5
	7/19/95	10	3.9	< 0.1	< 1
	10/17/95	10	3.8	< 0.1	1
	1/11/96	< 5	3.8	< 0.1	< 1
	4/4/96	16	3.9	< 0.1	< 1
MW1613-9	9/30/94	10	4.3	0.26	< 5
	12/15/94	10	NA	NA	NA
	3/22/95	9	4.2	0.56 M	< 5
	7/20/95	14	3.5	0.5	< 1
	10/17/95	5	3.8	0.5	1.1
	1/8/96	8	3.7	0.1	< 1
	4/3/96	7	4.1	0.4	< 1
MW1613-9A	7/20/95	18	3.5	2.4	3.6
	10/16/95	10	3.4	0.5	1.6
	1/8/96	6	3.3	1.2	< 1
	4/3/96	< 5	3.8	2.2	< 1
MW1613-10	7/21/95	< 5	3.3	0.8	< 1
	10/16/95	< 5	3.6	1.2	1.3
	1/11/96	< 5	3.9	1.5	1.3
	4/1/96	< 5	4.4	1.7	1.8
MW1613-11	7/21/95	9	3.2	< 0.1	< 1
	10/17/95	10	3.4	< 0.1	< 1
	1/11/96	6	3.4	< 0.1	< 1
	4/4/96	16	3.6	< 0.1	< 1
MW1613-12	7/21/95	8	2.8	0.1	< 1
	10/16/95	5	3.1	0.1	< 1
	1/11/96	7	3.1	< 0.1	< 1
	4/4/96	20	3.6	< 0.1	< 1
MW1613-13	7/20/95	< 5	5.2	1.4	< 1
	10/17/95	< 5	5.2	1.1	< 1
	1/8/96	< 5	5	0.5	< 1
	4/2/96	< 5	5.5	1.2	< 1

TABLE 2.12 (concluded)
GROUNDWATER GEOCHEMICAL ANALYTICAL DATA
BUILDING 1613 SITE
SITES OU-4 AND BUILDING 1613
RNA TS
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Sample ID	Date Collected	Total Alkalinity (mg/L)	Chloride (mg/L)	Nitrate-Nitrite (mg/L)	Sulfate (mg/L)
MW1613-13A	7/27/95	14	4.4	1.9	6.4
	10/17/95	10	4.4	2.1	3.4
	1/8/96	10	4.3	1	1.5
	4/2/96	5	4.6	2.5	< 1
MW1613-14	7/26/95	8	3.2	0.9	< 1
	10/17/95	< 5	3.4	1.3	< 1
	1/8/96	< 5	3.2	0.5	< 1
	4/2/96	< 5	4	1.4	< 1
MW1613-14A	7/26/95	20	3.8	2	6
	10/17/95	12	3	2.1	2.4
	1/8/96	12	2.7	0.7	1.4
	4/2/96	< 5	2.9	2.1	< 1
MW1613-15	7/21/95	< 5	4.2	2	1.6
	10/16/95	< 5	3.6	1.9 M	2.5
	1/8/96	< 5	3.5	1.1	2
	4/3/96	< 5	4.2	18 ^{d/}	3.2
MW1613-15A	7/21/95	22	4.5	1.6	9.3
	10/16/95	24	4.1	1.6	3.5
	1/8/96	9	4.1	0.7 D ^{d/}	1.6
	4/3/96	< 5	4.1	1.7	1

^{a/} NA = Not Available.

^{b/} M = Duplicate injection precision was not met.

^{c/} Value suspect, exceeds order of magnitude.

^{d/} D = Percent difference of matrix spike duplicate exceeded established criteria.

2.2.5 Potential Pathways and Receptors

2.2.5.1 Potential Pathways and Receptors at OU-4

The potential pathway of current concern for groundwater at OU-4 is discharge to either Long Branch or the ephemeral tributary. On the basis of the groundwater flow direction, vertical hydraulic gradient, and depth to water, shallow groundwater appears to discharge to either the creeks or the adjoining flood plains. Furthermore, significant dissolved contaminant concentrations are regularly detected in the furthest downgradient monitoring wells: MW-115, MW-114, and MW-106. Minor concentrations of CAH and BTEX compounds have been detected in surface water and sediment samples associated with the Long Branch drainage system in the vicinity of OU-4.

Potential exposure to groundwater could also occur from the use of water obtained from supply wells placed in the Shallow Aquifer. However, the groundwater in the Shallow Aquifer currently is not used for a source of drinking water at the Base (Rust E&I, 1996a). The majority of Base potable water is withdrawn from the Black Creek Aquifer (Table 2.13). The active well nearest to OU-4 is well number 75, located about 4,000 feet south of OU-4 (Figure 2.23). At OU-4, contaminant migration from the Shallow Aquifer in the Duplin Formation to the Black Creek Aquifer would be restricted by the "100-foot clay."

2.2.5.2 Potential Pathways and Receptors at the Building 1613 Site

The Base property boundary nearest to the site is located approximately 2,000 feet to the north of the site. However, groundwater flow at the Building 1613 Site is to the east and the distance from the site to the eastern Base boundary is approximately one mile. The closest potable water well to the site is Base Well number 5, located about 3,000 feet northwest of the Building 1613 Site. This well is screened in the Black Creek Aquifer and does not influence groundwater flow in the Shallow Aquifer at the Building 1613 Site. The groundwater in the Shallow Aquifer currently is not used for a source of drinking

TABLE 2.13
SCREENED AQUIFERS FOR BASE WATER SUPPLY WELLS
SITES OU-4 AND BUILDING 1613
RNA TS
SHAW AFB, SOUTH CAROLINA

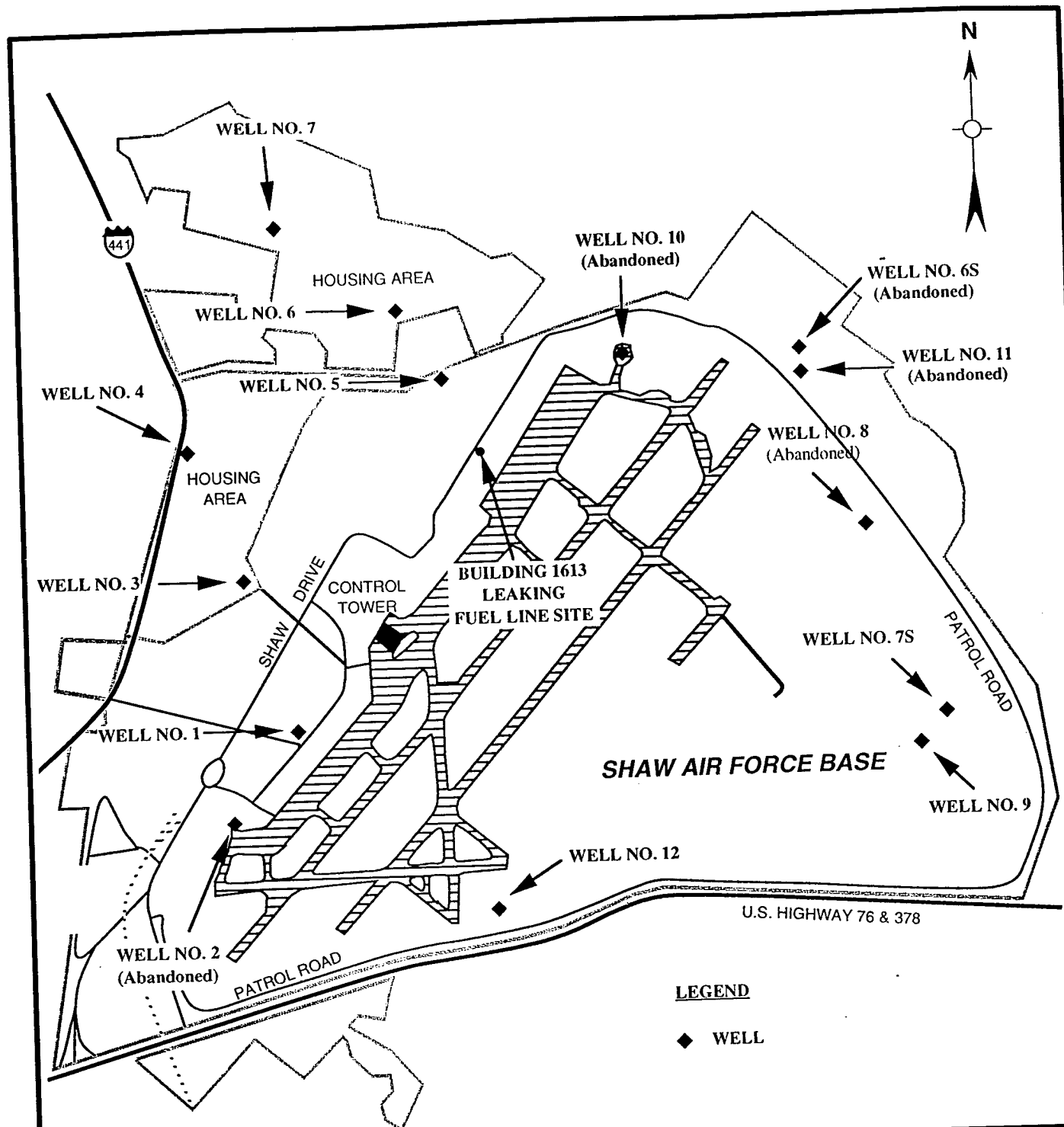
Base Well No.	Aquifer
1	Black Creek
2(A)	Black Creek
3	Black Creek
4	Black Creek and Tuscaloosa
5	Black Creek
6	Black Creek
6S(A)	Shallow Aquifer
7	Black Creek
7S	Black Creek
8(A)	Surficial
9	Black Creek
10	Black Creek
10(A)	Black Creek
11(A)	Not Available
12	Black Creek

Notes: A indicates abandoned well
S indicates shallow well

References:

1. Law Environmental, July 1989, "Final Remedial Action Plan for Site 1 - Fire Training Area, Shaw Air Force Base, Sumter, South Carolina"
2. Park, A. Drennen, June 1980, "Ground-Water Resources of Sumter and Florence Counties, SC"
3. SC Water Resource Commission (SCWRC), July 6, 1992, "Well Tabulations for Sumter County"

Source: RUST E&I, 1995b.



LEGEND

◆ WELL

FIGURE 2.23

BASE WATER SUPPLY WELLS

Sites OU-4 And Building 1613
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Source: RUST E&I, 1996a.

water at the Base (Rust E&I, 1996a). The majority of Base potable water is withdrawn from the Black Creek Aquifer (Table 2.12). The clayey deposits of the Sawdust Landing Member would inhibit any potential downward migration between the Shallow and Upper Black Creek Aquifers should contamination reach the deeper zones of the Shallow Aquifer.

The nearest possible surface water discharge for the Duplin Aquifer is the Long Branch, which is located approximately one mile east-northeast of the site. Therefore, based on the distance to the nearest surface water body, there is little potential for petroleum contaminants from the site to discharge to surface water.

Considering the distance from the site to the Base boundary and the closest potable water well, there is a minimal possibility that petroleum hydrocarbons from the site will impact potential receptors. Furthermore, current and anticipated future groundwater withdrawals at the Base are not expected to increase groundwater and contaminant migration rates toward potential future receptors (i.e., potable supply wells).

SECTION 3

COLLECTION OF ADDITIONAL DATA

To complete the demonstration and to assess the degree to which RNA of BTEX and CAHs is occurring at OU-4 and the Building 1613 Site, additional site-specific physical and chemical hydrogeologic data will be collected to supplement the available site data. Many of these measurements and analyses are commonly performed at hazardous waste sites; however, some of the data will be collected specifically to assess the potential for use of RNA for the CAHs and BTEX at OU-4 and the Building 1613 Site. The following information will be determined from the site investigation:

- Groundwater elevations at site monitoring wells;
- Mobile LNAPL composition, extent, and thickness;
- Concentration and extent of soil and groundwater contamination (analyses listed in Table 3.1);
- Subsurface geochemistry (analyses listed in Table 3.1);
- Locations of potential groundwater recharge and discharge areas;
- Hydraulic conductivity through slug tests;
- Stratigraphy of subsurface media; and
- Locations of preferential groundwater migration pathways and receptor exposure points (if present).

TABLE 3.1
ANALYTICAL PROTOCOLS FOR
GROUNDWATER, SURFACE WATER, PRODUCT, SOIL, AND SEDIMENT SAMPLES
SITES OU-4 AND BUILDING 1613
RNA TS
SHAW AFB, SOUTH CAROLINA

MATRIX Analyte	METHOD	FIELD (F) OR ANALYTICAL LABORATORY (L)
WATER		
Total Iron	Colorimetric, Hach Method 8008 (or similar)	F
Ferrous Iron (Fe ⁺²)	Colorimetric, Hach Method 8146 (or similar)	F
Ferric Iron (Fe ⁺³)	Difference between total and ferrous iron	F
Manganese	Colorimetric, Hach Method 8034 (or similar)	F
Sulfide	Colorimetric, Hach Method 8131 (or similar)	F
Sulfate	Colorimetric, Hach Method 8051 (or similar)	F
Nitrate	Titrimetric, Hach Method 8039 (or similar)	F
Nitrite	Titrimetric, Hach Method 8507 (or similar)	F
Redox Potential	A2580B, direct-reading meter	F
Oxygen	Direct-reading meter	F
pH	E150.1/SW9040, direct-reading meter	F
Conductivity	E120.1/SW9050, direct-reading meter	F
Temperature	E170.1, direct reading meter	F
Alkalinity (Carbonate [CO ₃ ⁻²] and Bicarbonate [HCO ₃ ⁻¹])	Titrimetric, Hach Method 8221 (or similar)	F
Carbon Dioxide	Titrimetric, Hach Method 1436-01	F
Nitrate	E353.1	L
Nitrite	E353.1	L
Chloride	Waters Capillary Electrophoresis Method N-601	L
Sulfate	Waters Capillary Electrophoresis Method N-601	L
Alkalinity	E310.1	L
Methane, Ethane, Ethene	RSKSOP-147 ^{a/}	L
Dissolved Organic Carbon	RSKSOP-102	L
VOCs (BTEX, CAHs)	RSKSOP-148	L
SURFACE WATER		
Redox Potential	A2580B, direct-reading meter	F
Oxygen	Direct-reading meter	F
pH	E150.1/SW9040, direct-reading meter	F
Conductivity	E120.1/SW9050, direct-reading meter	F
Temperature	E170.1, direct reading meter	F
VOCs (BTEX, CAHs)	RSKSOP-148	L
LNAPL		
Mass Fraction of BTEX and CAHs	GS/MS, Direct Injection SW8240B	L
SOIL/SEDIMENT		
Total Organic Carbon	RSKSOP-102 & RSKSOP-120	L
Moisture (Soils Only)	ASTM D-2216	L
VOCs (BTEX, CAHs)	RSKSOP-124, modified	L

^{a/}RSKSOP = Robert S. Kerr Laboratory standard operating procedure.

In general, analyses will be performed to allow an inference of which biodegradation processes are ongoing, as well as to provide information useful for solute transport modeling. Some inorganic groundwater chemical parameters (e.g., ferrous iron, DO, methane, or sulfate) are measured to evaluate if there is any ongoing degradation of native or anthropogenic carbon (e.g., BTEX). If such processes are ongoing, they may facilitate degradation of BTEX or CAHs via the pathways discussed in Sections 2.2.2 and 2.2.3, respectively. Chloride data also can be used as an indicator of dechlorination, which can result in increased chloride concentrations in CAH plume interiors. Carbon dioxide data may also indicate biodegradation, as it is the ultimate product of many of the biochemical reaction pathways. Oxidation/reduction potential (ORP) will be measured to help evaluate which biodegradation pathways are likely to be most significant for both CAH and BTEX compounds. ORP further serves as an indicator parameter for well purging, along with DO, temperature, pH, and conductivity. Methane, ethane, and ethene will be measured for evidence of complete dechlorination of CAHs (at OU-4), while trends in BTEX and CAH concentrations over time can be used to further evaluate the ongoing processes. At OU-4, soil analyses will be performed primarily to gain additional data on the magnitude and extent of potential continuing CAH sources. Additional analyses not listed in Table 3.1 may be performed at the discretion of the Parsons ES, USACE, or USEPA NRMRL scientists working at the site. Additional analytes that may be tested for are listed in Appendix A (e.g., dissolved hydrogen or volatile fatty acids).

Physical hydrogeologic parameters will be measured to further refine the site conceptual models and to aid in assembling and calibrating the groundwater flow portion of a site-specific transport model. To obtain these data, groundwater levels will be measured, and aquifer testing will be conducted. The following sections describe the procedures that will be followed when collecting additional site-specific data.

3.1 SITE MANAGEMENT

The following paragraphs outline site management issues pertaining to the field activities to be conducted at OU-4 and the Building 1613 Site. Base support, contingency plans, and waste management are discussed.

3.1.1 Base Support

The Base will provide the following support during field activities:

- **Provide Site Access to Field Team Members.** The Base point of contact (POC) will ensure daily access to the sites through arrangements with Shaw AFB security personnel.
- **Coordinate Badge and Vehicle Passes.** The Base POC will coordinate with Shaw AFB security personnel for the issue of personnel badges and vehicle passes for each field team member. Applicable forms will be completed by the Parsons ES field team members. Each field team member will be provided with a badge and vehicle pass (if needed).
- **Provide Scheduling Information.** The Base POC will notify Parsons ES and USACE of any Base activities that may adversely affect field activities and/or impact the sampling schedule.
- **Provide Base Notification.** The Base POC should ensure that all pertinent parties (e.g., military police, Base Commander's Office) are notified in advance of the drilling and sampling activities.
- **Provide Access to Office Equipment.** Parsons ES will need access to a telephone with long-distance capability and a copy machine to allow for efficient copying of chain-of-custody records and other field forms, as well as distribution of any memos pertaining to site coordination.

- **Assign Accumulation Points.** Any well purge fluids and decontamination rinseate or excavated soils generated during site work that are suspected of being hazardous will be properly contained and moved to predesignated accumulation points for proper disposal. The Base POC will specify the location for the discharge of purge fluids and decontamination rinseates to the Base groundwater treatment plant (GWTP), industrial wastewater treatment plant (IWTP), or sanitary sewer. The Base POC will also specify the location for the proper disposal of soil wastes.
- **Provide Underground Utility Clearance/Drilling Permits.** Before any work, each proposed intrusive sampling location at OU-4 (intrusive sampling at the Building 1613 Site will not occur) must be checked for underground utilities by Base personnel or utility representatives, or both. The Base POC will ensure that the field team has written approval before soil sampling. A copy of clearances will be kept at the site where soil sampling work will be conducted. Parsons ES will request clearance of locations at least 10 days before commencement of intrusive site work. The Base will issue digging or other appropriate permits prior to commencement of drilling operations.

3.1.2 Contingency Plans

This subsection describes steps that will be taken by Parsons ES to minimize delays during the investigations. Potential problems that could be encountered during the field effort include:

- Access and coordination difficulties;
- Equipment breakdowns;
- Conflicts with planned sampling locations;
- Abnormal site conditions (e.g., severe weather, unexpected Base operations); and/or

- Drilling permit delays.

3.1.2.1 Access and Coordination Contingencies

Anticipated support needs are outlined in Section 3.1.1. In the event that site access difficulties arise, the Base POC will be contacted to resolve the problem. The Base POC also will be notified if additional support needs arise during the field effort. The Parsons ES site manager and field team leader will be responsible for notifying the Base POC and/or other designated personnel (e.g., designated site escorts/contacts) of access or coordination difficulties.

3.1.2.2 Equipment Contingencies

In the event of operation problems with field equipment or testing instruments, the following actions will be taken:

- Contact the field team leader;
- Refer to the instrument's instruction book for troubleshooting procedures; and
- Contact the manufacturer and/or supplier.

If necessary, backup instruments will be obtained. However, any such decisions will be made by the Parsons ES site manager after consideration of other potential solutions. Equipment will be maintained and extra batteries and other standard replacement parts will be carried in order to avoid downtime due to minor problems.

3.1.2.3 Sampling Location Contingencies

During the field effort, certain chosen sampling locations may be inaccessible due to site conditions. When the conditions can be adjusted (e.g., unlocking a gate or moving a vehicle), the Parsons ES site manager and/or field team leader will contact the Base POC and/or site escort to arrange for access to the new sampling location.

3.1.2.4 Drilling Permit Delays

To ensure that drilling permits are issued prior to hand augering activities at OU-4, the following Base procedure will be followed. The proposed sampling location figure (Figure 3.1) indicating the locations and depths of the proposed soil sampling activities at site OU-4 will be provided to Base Civil Engineering and/or utility personnel by the Base POC at least 10 days prior to sampling activities. Civil Engineering and/or utility personnel will locate underground utility lines and buried structures that might be affected by any augering. No augering will be allowed until the permit is approved by all parties. The drilling permit will be effective only for the time period indicated by the final signature authority. Reauthorization from all organizations and the technical representative shall be required for any additional time required after expiration of the original permit period.

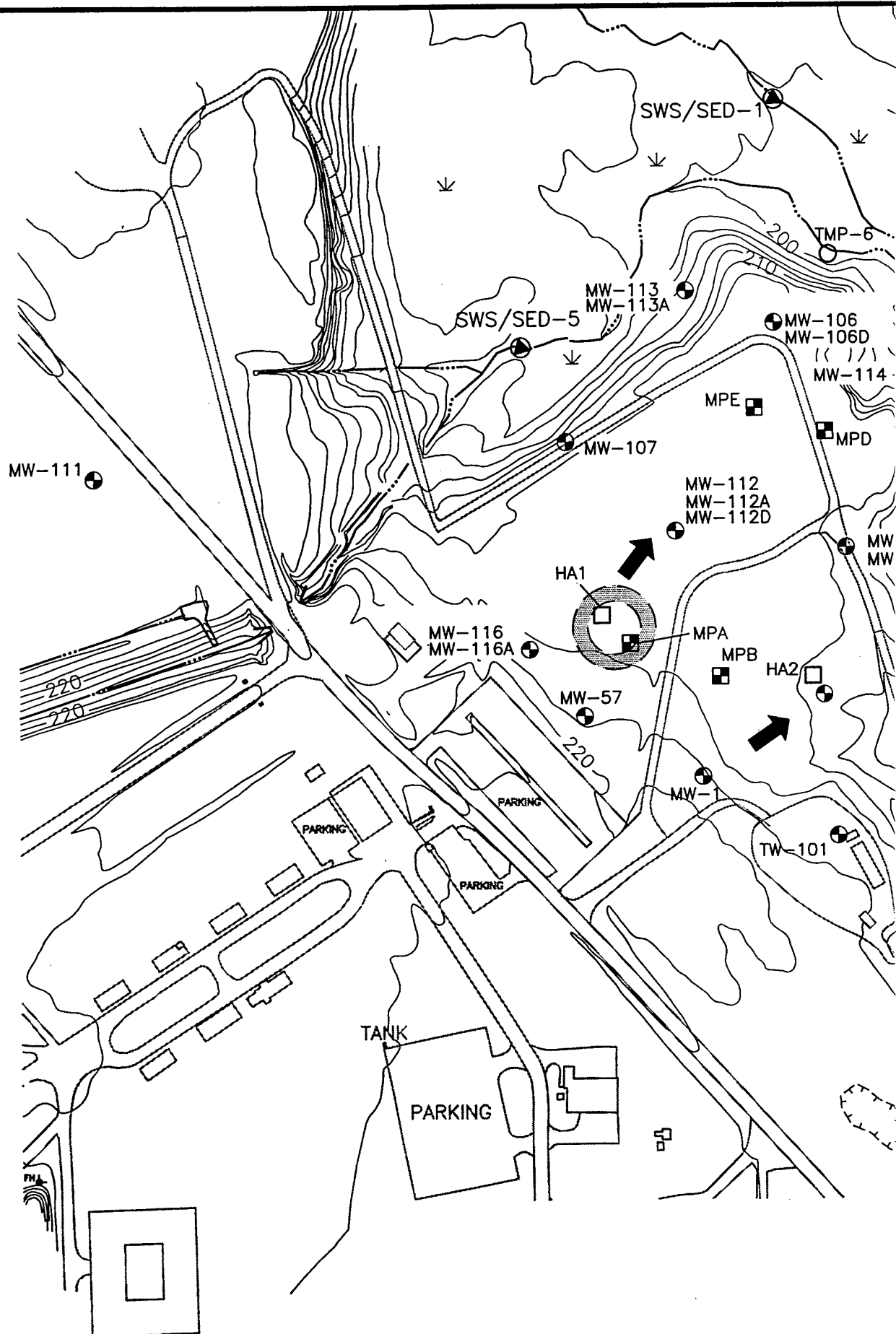
3.1.2.5 Site Health and Safety Plan

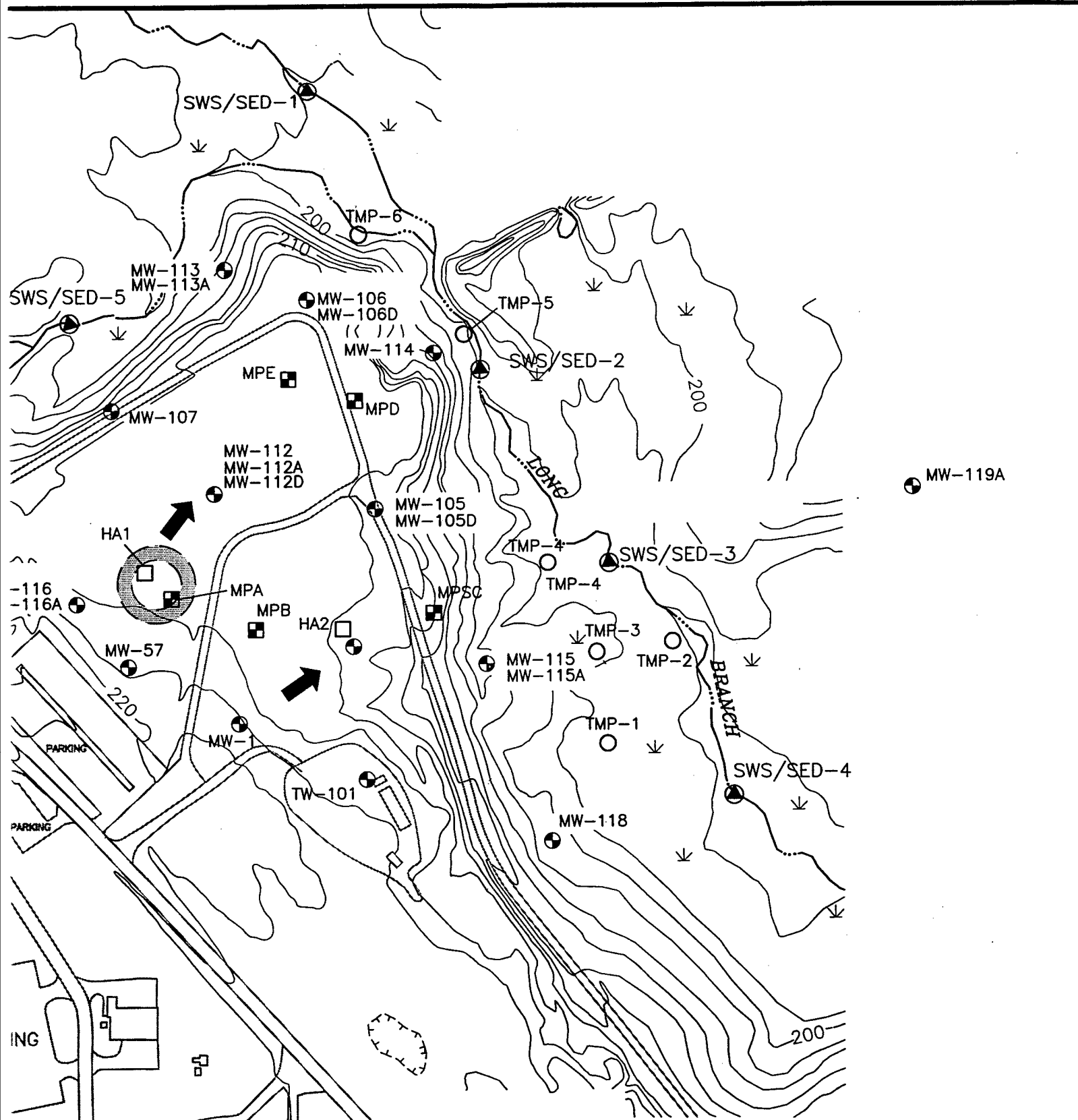
Parsons ES will provide a Health and Safety Plan (Parsons ES, 1996a) and a site-specific addendum for field investigations to be conducted at Shaw AFB. The documents will be provided to the Base POC for review prior to field mobilization, if requested by the Base POC. The plan includes the following information:

- An index of all hazardous materials to be introduced to the site;
- Plan for protecting personnel and property during the transport, storage and use of the materials;
- Procedures for spill response and disposal;
- Material safety data sheets (MSDSs) for materials listed in the index of the plan; and
- Approved labeling system to identify contents on all containers on site.

L:\45037\DRAWINGS\97DNO384, 04/24/97 at 12:51

REFERENCE: TOPOGRAPHIC BASE MAP PREPARED BY
AIR SURVEY CORPORATION, MARCH 1993.





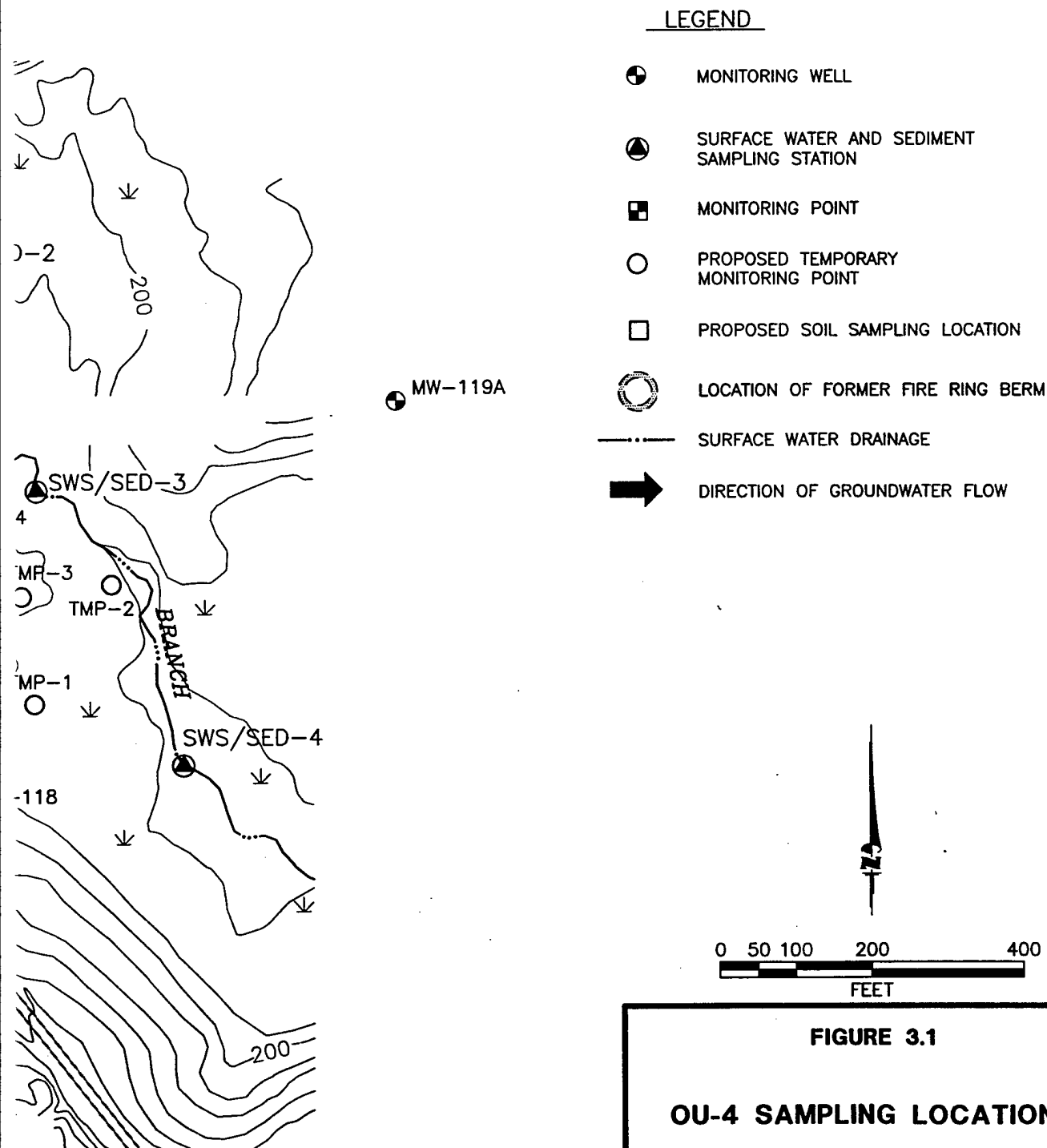


FIGURE 3.1

OU-4 SAMPLING LOCATIONS

Sites OU-4 And Building 1613
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3.1.3 Site Restoration and Waste Handling

After hand augering activities are complete, each sampling location will be restored as closely to its original condition as possible. A minimal quantity of soil will be generated as a result of augering activities at OU-4. Because a minimal volume of soils will be generated, headspace VOC readings of soil waste will be taken by a Parsons ES scientist. A portion of each sample will be used to measure the total ionizable VOC concentration in soil headspace using a photoionization detector (PID). Each headspace screening sample will be placed in a clean, sealed plastic bag or mason jar and allowed to equilibrate to the ambient temperature for at least 15 minutes. The PID probe will then be inserted into the bag or jar, and the maximum reading will be recorded in the field records. If headspace readings significantly above background readings are obtained, indicating the presence of vadose zone contamination, then the sample will be drummed and a sample will be submitted to a laboratory for analysis of VOCs using the method specified in Table 3.1. Waste soil with headspace readings below background values will be scattered around the site or as directed by Base personnel. Soil waste with headspace readings of greater than background will be spread in the former bermed burn pit or placed in 55-gallon drums for disposal by Base personnel.

If the Base POC determines that headspace screening of the soils is insufficient for proper disposal of wastes, all soils excavated during hand augering will be stored in labeled drums (provided by the Base) at a location designated by the Base. The soils will remain in the drums until analytical results from soil samples are received from the laboratory. If analysis indicate that soil contamination is not present, the soils will be redistributed by the Base at the site or at another location designated by the Base. If analyses indicate that soil contamination is present, the Base will make arrangements and recommendations for any additional analyses that may be required to characterize the waste for a selected disposal facility.

Groundwater removed from monitoring wells during development or purging or used for decontamination will be temporarily contained and transported to assigned

accumulation points. The water will then be disposed of by Parsons ES or the USACE to the Base GWTP. If the water cannot be accepted by the Base GWTP, the water will be disposed of by the Base using another acceptable means (e.g., the Base IWTP, or a licensed contractor will transport the wastewater to a treatment and/or disposal facility).

Precautions will be taken to prevent spills of hazardous material. In the event of a spill, the Base POC will be notified immediately. Spill response will be in accordance with Title 40 of the Code of Federal Regulations, Part 300 (40 CFR 300) and applicable state regulations.

3.2 BOREHOLE ADVANCEMENT, SOIL SAMPLING AND MONITORING POINT INSTALLATION

To further characterize site hydrogeologic conditions, additional shallow monitoring points were installed at Site OU-4 during preliminary site characterization activities. In addition, hand auger boreholes will be advanced during the site characterization activities to collect soil samples and install temporary monitoring points for the collection of groundwater grab samples. The following sections describe these activities as well as the proposed locations in more detail.

3.2.1 Monitoring Point Locations and Completion Intervals

Five monitoring points were installed using CPT at OU-4 with the CPT on April 2-4, 1997 during preliminary site characterization activities conducted by the USACE as part of this workplan. Monitoring point locations were selected to provide hydrogeologic and contaminant data necessary to define groundwater contamination in the source area and along the two primary contaminant flow paths at the site (Figure 3.1). The locations of the monitoring points were determined following a review of data gathered during previous site activities and were summarized in a sampling memo submitted to Mr. Mike Alcorn of Shaw Air Force Base (March 25, 1997). The sampling memo, which describes

the proposed monitoring point locations and the rationale for monitoring point installation, is included in Appendix D of this workplan. The methodologies used to install these monitoring wells will be described in detail in the TS report that will describe the results of site characterization activities, as outlined in Section 5. As described in Section 3.2.3, 6 temporary groundwater monitoring points will be installed using hand auger. Locations of these points are indicated on Figure 3.1.

Additional wells and/or monitoring points are not scoped for installation at the Building 1613 Site as a part of the RNA investigation. On the basis of data presented in Section 2.1.4.3, the groundwater BTEX plume has been defined to the west, east, and south of the Building 1613 Site source area. Shallow groundwater wells have not been placed beneath or north of Building 1614 (to the north of the source area) to define the northern extent of the groundwater plume; however, groundwater flow to the east suggests that contaminant advection or dispersion to the north is minimal. Toluene was detected in only one deep monitoring well at a concentration near the analytical method detection limit. Therefore, the groundwater BTEX plume is sufficiently defined in horizontal and vertical extent and the installation of additional monitoring wells is not necessary. All previously groundwater wells at the site will be sampled for the analytes listed in Table 3.1.

3.2.2 Soil Sampling Procedures

Soil samples will be collected at OU-4 with a hand auger at locations shown on Figure 3.1. At each location, one or two soil samples will be collected within the vadose zone from depths deemed to have the highest potential for contamination on the basis of field observation and screening. These samples will be collected to evaluate the current magnitude of CAH and BTEX contamination in the source areas that are undergoing remediation and to evaluate impact to the wetland soils downgradient from OU-4. No additional soil data will be collected at the Building 1613 Site.

A Parsons ES field scientist will be responsible for collecting the soil samples, maintaining a detailed descriptive log of all subsurface materials recovered during hand augering, and properly labeling and storing samples. During borehole advancement, soil samples for visual description will be collected at a frequency sufficient to identify the depths of significant stratigraphic contacts or other soil properties. Soil samples will be obtained using a hand auger with extension rods to sample as deep as 10 feet bgs. An example geologic borehole log form that will be used to log augering activities is presented in Figure 3.2.

A portion of each sample will be used to measure the total ionizable VOC concentration in soil headspace using a photoionization detector (PID), as per Section 3.1.3. If headspace readings significantly above background readings are obtained, indicating the presence of vadose zone contamination, then the sample will be drummed and a sample will be submitted to a laboratory for analysis of VOCs using the method specified in Table 3.1. Each laboratory soil sample will be placed in an analyte-appropriate sample container and hand-delivered to the USEPA field laboratory personnel for analysis. If USEPA personnel have not mobilized to the site, then the samples will be shipped on ice to the NRMRL via overnight courier.

Soil samples for TOC analysis may also be collected from selected hand-auger locations in uncontaminated or minimally contaminated areas cross-gradient or downgradient from the groundwater contaminant plume.

Boreholes will be sealed with hydrated bentonite chips, pellets, or grout to eliminate any creation or enhancement of contaminant migration pathways to the groundwater.

3.2.3 Temporary Monitoring Point Installation

Temporary groundwater monitoring points will be installed at 6 locations between the escarpment and Long Branch to determine the downgradient extent of the shallow groundwater contamination beneath the wetlands associated with Long Branch. Approximate locations for the 6 points are illustrated on Figure 3.1; however, if fuel

GEOLOGIC BORING LOG

Sheet 1 of 1

BORING NO.: _____ CONTRACTOR: _____ DATE SPUD: _____
 CLIENT: AFCEE RIG TYPE: _____ DATE CMPL.: _____
 JOB NO.: 722450 DRLG METHOD: _____ ELEVATION: _____
 LOCATION: SHAW AFB BORING DIA.: _____ TEMP: _____
 GEOLOGIST: _____ DRLG FLUID: _____ WEATHER: _____
 COMMENTS: _____

Elev (ft)	Depth (ft)	Pro- file	US CS	Geologic Description	Sample		Penet Res	PID(ppm)	TLV(ppm)	TOTAL BTX(ppm)	TPH (ppm)
					No.	Depth (ft)					
	1										
	5										
	10										
	15										
	20										
	25										
	30										
	35										

NOTES

bgs - Below Ground Surface
 GS - Ground Surface
 TOC - Top of Casing
 NS - Not Sampled
 SAA - Same As Above

SAMPLE TYPE

D - DRIVE
 C - CORE
 G - GRAB

▼ Water level drilled

FIGURE 3.2

GEOLOGIC BORING LOG

Sites OU-4 And Building 1613
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seeps or other signs of contamination are noted between the escarpment and Long Branch, monitoring points will be installed at these locations rather than those indicated on Figure 3.1.

Temporary monitoring points will be constructed of a sacrificial drive point attached to a length of 0.5-inch-diameter stainless steel mesh that will function as the well screen. The mesh will in turn be connected to 0.375-inch Teflon[®] tubing. To install the temporary monitoring points, a Geoprobe[®] rod with the monitoring point assembly threaded through the interior will be manually driven through the bottom of a hole augered to the water table. When the probe rods are removed, the sacrificial tip, screen assembly, and tubing will remain in place. Following sampling, the tubing will be extracted as far as possible and discarded. Any remaining hole will be abandoned as described in Section 3.2.2.

3.2.4 Equipment Decontamination During Temporary Monitoring Point Installation and Soil Sampling Activities

Prior to arriving at the site and when collecting soil samples for laboratory analysis of VOCs, the sampling device will be disassembled and decontaminated with Alconox[®] and potable water. The hand auger and extension rods and other soil sampling equipment will then be rinsed with deionized water and a solvent (methanol or isopropanol) and air-dried. Prior to collection of samples for TOC analysis, the sampling device will be rinsed with potable water and scrubbed with a stiff brush, as necessary, to remove soil particles from previous sampling intervals.

All rinseate will be collected for transportation and proper disposal with decontamination and development waters (Section 3.1.3). Alternate methods of rinseate disposal will be considered by the Parsons as recommended by Base personnel. Precautions will be taken to minimize any impact to the surrounding area that might result from decontamination operations.

3.2.5 Monitoring Point Development and Records

The monitoring points installed at OU-4 on April 2-4, 1997 will be developed prior to sampling to remove fine sediments and introduced fluids from the portion of the formation adjacent to the screened interval. Development of these 0.5-inch inside diameter (ID) polyvinyl chloride (PVC) monitoring points will be accomplished using a peristaltic pump provided by the USEPA NRMRL or Parsons ES. Monitoring point development will occur a minimum of 24 hours prior to sampling. Development will continue until a minimum of 5 times the standing water volume in the monitoring point (to include the well screen and casing plus saturated annulus, assuming 30-percent porosity) have been removed, and the water pH, temperature, and specific conductance have stabilized. If the development water is still turbid after removal of the minimum number of casing volumes, development will continue until the water becomes clear or the turbidity of the water produced has been stable after the removal of several additional casing volumes. In low-yield wells that go dry during development, development activity will be staged over a period of time to allow water to refill the well bore. In the event that the minimum number of casing volumes cannot be removed, the water volume recovered and the deficiency will be noted in the development records.

A development record will be maintained for each monitoring point. The development record will be completed in the field by the field scientist. Figure 3.3 is an example of a development record used for similar well installations. Development records will include at a minimum:

- Monitoring point number;
- Date and time of development;
- Development method;
- Monitoring point depth;

MONITORING WELL DEVELOPMENT RECORD

Job Number: 722450 37020

Job Name: AFCEE-RNA

Location Shaw Air Force Base

by _____ Date: _____

Well Identification _____

Measurement Datum _____

Pre-Development Information

Time (Start): _____

Water Level: _____

Total Depth of Well: _____

Water Characteristics

Color _____ Clear Cloudy

Odor: None Weak Moderate Strong

Any Films or Immiscible Material _____

pH _____ Temperature (°C) _____

Specific Conductance (μS/cm) _____

Dissolved Oxygen (mg/L) _____

Redox (mV) _____

Interim Water Characteristics

Gallons Removed _____

pH _____

Temperature (°C) _____

Specific Conductance (μS/cm) _____

Dissolved Oxygen (mg/L) _____

Redox (mV) _____

Post-Development Information

Time (Finish): _____

Water Level: _____

Total Depth of Well: _____

Approximate Volume Removed: _____

Water Characteristics

Color _____ Clear Cloudy

Odor: None Weak Moderate Strong

Any Films or Immiscible Material _____

pH _____ Temperature (°C) _____

Specific Conductance (μS/cm) _____

Dissolved Oxygen (mg/L) _____

Redox (mV) _____

Comments:

FIGURE 3.3

MONITORING POINT DEVELOPMENT RECORD

Sites OU-4 And Building 1613
RNA TS
Shaw AFB, South Carolina

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- Volume of water produced;
- Description of water produced;
- Post-development water level and monitoring point depth; and
- Field analytical measurements, including pH and specific conductivity.

Development waters will be collected and held for proper disposal to the Base GWTP. Alternate methods of water disposal will be considered by the Parsons ES scientist as recommended by Base personnel.

3.2.6 Datum Survey

The horizontal location of all soil sampling locations and monitoring points relative to established Base coordinates will be measured by a surveyor. Horizontal coordinates will be measured to the nearest 0.5 foot using a State Plane Lambert Coordinate System. The elevation of the ground surface and the top of monitoring point casings will also be measured to the nearest 0.01 foot.

3.3 GROUNDWATER SAMPLING PROCEDURES

This section describes the procedures for collection of groundwater quality samples. Groundwater samples will be collected from selected previously installed monitoring wells, and from all newly installed, temporary and permanent groundwater monitoring points. All of the groundwater locations shown in Figures 3.1 and 1.4 for site OU-4 and Site the Building 1613 Site, respectively, will be sampled. In order to maintain a high degree of QC during this sampling event, the procedures described in the following sections will be followed.

3.3.1 Groundwater Sampling Strategy

Groundwater samples will be collected from previously installed monitoring wells and from monitoring points installed during this project (Figures 3.1 and 1.4). At OU-4, the existing wells to be sampled will include TW-101, MW-105, MW-106, MW-

107, MW-111, MW-112, MW-113, MW-114, MW-115, MW-116, MW-117, and MW-118 in the upper portion of the Shallow Aquifer; and MW-112A, MW-115A, and MW-116A in the lower portion of the Shallow Aquifer. At the Building 1613 Site, the existing wells to be sampled will include monitoring wells 1613-1, through 16-13-15, and 1613-3A, 1613-4A, 1613-9A, 1613-13A, 1613-14A, and 1613-15A. In addition, all newly installed monitoring points at site OU-4 will be sampled.

Sampling will be conducted by qualified scientists and technicians from Parsons ES and the USEPA NRMRL who are trained in the performance of groundwater sampling, records documentation, and chain-of-custody procedures. In addition, sampling personnel will have thoroughly reviewed this work plan prior to sample acquisition and will have a copy of the work plan available onsite for reference.

3.3.2 Preparation for Sampling

All equipment to be used for sampling will be assembled and properly cleaned and calibrated (if required) prior to arriving in the field. In addition, all record-keeping materials will be gathered prior to leaving the office.

3.3.2.1 Equipment Cleaning

All portions of sampling and test equipment that will contact the sample matrix will be thoroughly cleaned before each use. This includes hand augers water level probe and cable, test equipment for onsite use, and other equipment or portions thereof that will contact the samples. Based on the types of sample analyses to be conducted, the following cleaning protocol will be used:

- Wash with potable water and phosphate-free laboratory detergent (HP-II detergent solutions, as appropriate);
- Rinse with potable water;
- Rinse with isopropyl alcohol;

- Rinse with distilled or deionized water; and
- Air dry the equipment prior to use.

Any deviations from these procedures will be documented in the field scientist's field notebook and on the Groundwater Sampling Record (Figure 3.4).

If precleaned disposable sampling equipment is used, the cleaning protocol specified above will not be required. Laboratory-supplied sample containers will be cleaned and sealed by the laboratory. The type of container provided and the method of container decontamination will be documented in the laboratory's permanent record of the sampling event.

3.3.2.2 Equipment Calibration

As required, field analytical equipment will be calibrated according to the manufacturers' specifications prior to field use. This applies to equipment used for onsite measurements of DO, pH, electrical conductivity, alkalinity, redox potential, sulfate, nitrate, ferrous iron (Fe^{2+}), and other field parameters listed in Table 3.1.

3.3.3 Well and Monitoring Point Sampling Procedures

Special care will be taken to prevent contamination of the groundwater and extracted samples. The primary way in which sample contamination can occur is through cross-contamination due to insufficient cleaning of equipment between wells and monitoring points. To prevent such contamination, the water level probe and cable used to determine static water levels and total well depths will be thoroughly cleaned before and after field use and between uses at different sampling locations according to the procedures presented in Section 3.3.2.1. In addition to the use of properly cleaned equipment, dedicated high-density polyethylene (HDPE) tubing will be used at each monitoring point sampling location where a peristaltic pump is used for purging and sampling. Positive displacement pumps (such as the Grundfos® Redi-Flo II®) will be utilized for purging existing site monitoring wells. At the Building 1613 Site, a

GROUNDWATER SAMPLING RECORD

Sampling Location Shaw Air Force Base

Sampling Dates 5/12/97 - 5/23/97

GROUND WATER SAMPLING RECORD - MONITORING WELL _____

(number)

REASON FOR SAMPLING: ☒ Regular Sampling; ☐ Special Sampling;

DATE AND TIME OF SAMPLING: _____, 1997 _____ a.m./p.m.

SAMPLE COLLECTED BY: RTH/CM/CH of Parsons ES

WEATHER: _____

DATUM FOR WATER DEPTH MEASUREMENT (Describe): _____

MONITORING WELL CONDITION:

☐ LOCKED:

☐ UNLOCKED

WELL NUMBER (IS - IS NOT) APPARENT

STEEL CASING CONDITION IS: _____

INNER PVC CASING CONDITION IS: _____

WATER DEPTH MEASUREMENT DATUM (IS - IS NOT) APPARENT

☐ DEFICIENCIES CORRECTED BY SAMPLE COLLECTOR

☐ MONITORING WELL REQUIRED REPAIR (describe): _____

Check-off

1 ☐ EQUIPMENT CLEANED BEFORE USE WITH _____
Items Cleaned (List): _____

2 ☐ PRODUCT DEPTH _____ FT. BELOW DATUM
Measured with: _____

WATER DEPTH _____ FT. BELOW DATUM
Measured with: _____

3 ☐ WATER-CONDITION BEFORE WELL EVACUATION (Describe):
Appearance: _____
Odor: _____
Other Comments: _____

4 ☐ WELL EVACUATION:
Method: _____
Volume Removed: _____
Observations: Water (slightly - very) cloudy
Water level (rose - fell - no change)
Water odors: _____
Other comments: _____

FIGURE 3.4

GROUNDWATER SAMPLING RECORD

Sites OU-4 And Building 1613
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Monitoring Well No. _____ (Cont'd)

SAMPLE EXTRACTION METHOD:

```
[ ] Pump, type: __
```

[] Other, describe: _____

Sample obtained is [X] GRAB; [] COMPOSITE SAMPLE

ON-SITE MEASUREMENTS:

Measured with: _____

Measured with: _____

Measured with: _____

Measured with: _____

Measured with: _____

Measured with: _____

Measured with: _____

Measured with: _____

Measured with: _____

SAMPLE CONTAINERS (material, number, size): _____

ON-SITE SAMPLE TREATMENT:

Method _____ Containers: _____

Containers: _____

Containers: _____

[] Preservatives added:

Containers: _____

Containers: _____

Containers: _____

Containers: _____

CONTAINER HANDLING:

[] **Container Lids Taped**

[] Containers Placed in I

OTHER COMMENTS: _____

FIGURE 3.4 (Continued)

GROUNDWATER SAMPLING RECORD

Sites OU-4 And Building 1613

RNA TS

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properly decontaminated positive displacement pump or a disposable bailer may be used for purging; as an additional precaution against cross contamination, a new disposable bailer will be used to collect groundwater samples from monitoring wells at that site. A peristaltic pump with dedicated HDPE tubing or a disposable bailer (on two-inch ID wells) will be used to sample wells at site OU-4. A clean pair of new, disposable nitrile or latex gloves will be worn each time a different well or monitoring point is sampled. The following paragraphs present the procedures to be followed for groundwater sample collection from groundwater monitoring wells and monitoring points. These activities will be performed in the order presented below. Exceptions to this procedure will be noted in the sampler's field notebook and the groundwater sampling form.

3.3.3.1 Preparation of Location

Prior to starting the sampling procedure, the area around the existing wells and new monitoring points will be cleared of foreign materials, such as brush, rocks, and debris. These procedures will prevent sampling equipment from inadvertently contacting debris around the monitoring well/point. In addition, the sampling location will be inspected for the integrity of the protective cover, lock, external surface seal, concrete pad, cap, datum reference, and internal surface seal.

3.3.3.2 Water Level and Total Depth Measurements

Prior to removing any water from the monitoring well or monitoring point, the static water level will be measured. An electric water level probe (or oil/water interface probe) will be used to measure the depth to groundwater below the datum to the nearest 0.01 foot. After measuring the static water level, the water level probe will be slowly lowered to the bottom of the monitoring well/point, and the depth will be measured to the nearest 0.01 foot. Based on these measurements, the volume of water to be purged from the monitoring well/point will be calculated. If mobile LNAPL is encountered, the thickness of the LNAPL layer will be measured, and the total depth of the

well/point will not be measured to minimize contamination of equipment and the water column with LNAPL.

3.3.3.3 Purging Before Sampling

The volume of water contained within the monitoring well/point casing at the time of sampling will be calculated, and three times the calculated volume will be removed from the well/monitoring point. Purge waters will be handled in accordance with the procedures outlined in Section 3.1.3.

Monitoring points and shallow monitoring wells at OU-4 will be purged with a peristaltic pump and dedicated HDPE tubing. At temporary points, the Teflon[®] tubing that forms the well casing will be attached directly to the peristaltic pump instead of HDPE tubing. All monitoring wells at the Building 1613 Site and the three deep monitoring wells at OU-4 will be purged with a positive displacement pump.

3.3.3.4 Sample Extraction

HDPE tubing and a peristaltic pump will be used to extract groundwater samples from the monitoring wells and CPT-installed points at OU-4. The tubing will be lowered through the casing into the water gently to prevent splashing. The sample will be transferred directly into the appropriate sample container. The water will be carefully poured down the inner walls of the sample bottle to minimize aeration of the sample. At the temporary monitoring points, the peristaltic pump will be attached directly to the Teflon[®] tubing. A new disposable bailer will be used for sample extraction at each well at the Building 1613 Site.

If a monitoring well/monitoring point is evacuated to a dry state during purging, the monitoring well/monitoring point will be allowed to recharge, and the sample will be collected as soon as sufficient water is present in the monitoring well or monitoring point to obtain the necessary sample quantity. Sample compositing or sampling over a lengthy period by accumulating small volumes of water at different times to obtain a sample of sufficient volume will not be allowed.

Unless other instructions are given by the analytical laboratory, sample containers will be completely filled so that no air space remains in the container. Excess water collected during sampling will be handled according to the procedures outlined in Section 3.1.3.

3.3.4 Onsite Groundwater Parameter Measurement

As indicated on Table 3.1, many of the groundwater chemical parameters will be measured onsite by USEPA NRMRL or Parsons ES personnel. Some of the measurements will be made with direct-reading meters, while others will be made using of a Hach[®] portable colorimeter in accordance with specific Hach[®] analytical procedures. These procedures will be described in the following subsections.

All glassware or plasticware used in the analyses will have been cleaned prior to sample collection by thoroughly washing with a solution of Alconox[®] and water, and rinsing with deionized water and ethanol to prevent interference or cross contamination between measurements. If concentrations of an analyte are above the range detectable by the titrimetric method, the analysis will be repeated by diluting the groundwater sample with double-distilled water until the analyte concentration falls to a level within the range of the method. All rinseate and sample reagents accumulated during groundwater analysis will be collected in glass containers fitted with screw caps. These waste containers will be clearly labeled as to their contents and carefully stored for later transfer to the approved disposal facility.

3.3.4.1 Dissolved Oxygen Measurements

DO measurements will be made using a meter with a downhole oxygen sensor or a sensor in a flow-through cell. Measurements will be taken before and following groundwater sample acquisition. When DO measurements are taken in monitoring wells/points that have not yet been sampled, the existing monitoring wells/points will be purged until DO levels stabilize. DO measurements will be recorded on the groundwater sampling record (Figure 3.4)

3.3.4.2 pH, Temperature, and Specific Conductance

Because the pH, temperature, and specific conductance of a groundwater sample can change significantly within a short time following sample acquisition, these parameters will be measured in the field in unfiltered, unpreserved, "fresh" water collected by the same technique as the samples taken for laboratory analyses. The measurements will be made in a clean glass container separate from those intended for laboratory analysis, and the measured values will be recorded in the groundwater sampling record (Figure 3.4).

3.3.4.3 Carbon Dioxide Measurements

Carbon dioxide (CO₂) is a byproduct of biological reactions and can be used to evaluate the bioactivity of the groundwater system. CO₂ concentrations in groundwater will be measured in the field by experienced USEPA NRMRL or Parsons ES scientists via titrimetric analysis using CHEMetrics® Method 4500 (0 to 250 mg/L as CO₂), or equivalent.

3.3.4.4 Alkalinity Measurements

Alkalinity in groundwater helps buffer the groundwater system against acids generated through both aerobic and anaerobic biodegradation processes. Alkalinity of the groundwater sample will be measured in the laboratory (Table 3.1), or may be measured in the field by experienced USEPA NRMRL or Parsons ES scientists via titrimetric analysis using USEPA-approved Hach® Method 8221 (0 to 5,000 mg/L as calcium carbonate), or equivalent.

3.3.4.5 Nitrate- and Nitrite-Nitrogen Measurements

Nitrate-nitrogen concentrations are of interest because nitrate can act as an electron acceptor during hydrocarbon biodegradation under anaerobic soil or groundwater conditions. Nitrate-nitrogen is also a potential nitrogen source for hydrocarbon-degrading bacteria biomass formation. Nitrite-nitrogen is an intermediate byproduct in both ammonia nitrification and in nitrate reduction in anaerobic environments.

Nitrate- and nitrite-nitrogen concentrations in groundwater will be measured in the laboratory (Table 3.1), or may be measured in the field by experienced NRMRL or Parsons ES scientists via colorimetric analysis using a Hach® DR/700 Portable Colorimeter. Nitrate concentrations in groundwater samples will be analyzed after preparation with Hach® Method 8039 (0 to 30.0 mg/L nitrate), or equivalent. Nitrite concentrations in groundwater samples will be analyzed after preparation with USEPA-approved Hach® Method 8507 (0 to 0.35 mg/L nitrite), or equivalent.

3.3.4.6 Sulfate and Sulfide Sulfur Measurements

Sulfate in groundwater is a potential electron acceptor for fuel-hydrocarbon biodegradation in anaerobic environments, and sulfide is resultant after sulfate reduction. Sulfate will be measured in the laboratory (Table 3.1), or USEPA NRMRL or Parsons ES scientists may measure sulfate and sulfide concentrations via colorimetric analysis with a Hach® DR/700 Portable Colorimeter after appropriate sample preparation. USEPA-approved Hach® Methods 8051 (0 to 70.0 mg/L sulfate) and 8131 (0.60 mg/L sulfide), or equivalents, will be used to prepare samples and analyze sulfate and sulfide concentrations, respectively.

3.3.4.7 Total Iron, Ferrous Iron, and Ferric Iron Measurements

Iron is an important trace nutrient for bacterial growth, and different states of iron can affect the oxidation/reduction potential of the groundwater and act as an electron acceptor for biological metabolism under anaerobic conditions. Iron concentrations will be measured in the field via colorimetric analysis with a Hach® DR/700 Portable Colorimeter after appropriate sample preparation. Hach® Method 8008, or equivalent, for total soluble iron (0 to 3.0 mg/L ferric + ferrous iron) and Hach® Method 8146, or equivalent, for ferrous iron (0 to 3.0 mg/L) will be used to prepare and quantitate the samples. Ferric iron will be quantitated by subtracting ferrous iron levels from total iron levels.

3.3.4.8 Manganese Measurements

Manganese is a potential electron acceptor in anaerobic environments. Manganese concentrations will be quantitated in the field using colorimetric analysis with a Hach® DR/700 Portable Colorimeter. USEPA-approved Hach® Method 8034 (0 to 20.0 mg/L), or equivalent, will be used to prepare the samples for quantitation of manganese concentrations.

3.3.4.9 Oxidation/Reduction Potential

The ORP of groundwater is an indicator of the relative tendency of a solution to accept or transfer electrons. Redox reactions in groundwater are usually biologically mediated; therefore, the redox potential of a groundwater system depends upon and influences rates of biodegradation. ORPs can be used to provide real-time data on the location of the contaminant plume, especially in areas undergoing anaerobic biodegradation. The ORP of a groundwater sample taken inside the contaminant plume should be somewhat lower than that of a sample taken in an upgradient location.

The ORP of a groundwater sample can change significantly within a short time following sample acquisition and exposure to atmospheric oxygen. Therefore, this parameter will be measured in the field in unfiltered, unpreserved, "fresh" water collected by the same technique as the samples taken for laboratory analyses. The measurements will be made as quickly as possible in a clean glass container separate from those intended for laboratory analysis.

3.4 MOBILE LNAPL SAMPLING

If a sufficient thickness of mobile LNAPL is detected in a monitoring well at the Building 1613 Site, a sample of mobile LNAPL will be obtained using a disposable Teflon® bailer attached to nylon rope. The bailer will be gently lowered into the well in an attempt to minimize agitation. After the mobile LNAPL sample has been collected into the bailer and the bailer has been retrieved, any water accumulated in the bailer will be drained, and the LNAPL sample will be slowly poured into appropriate

bottles. Sample packaging, labeling, and handling is described in the following section.

3.5 SURFACE WATER AND SEDIMENT SAMPLING

Five surface water and sediment samples will be collected from Long Branch and the ephemeral tributary previously sampled by Rust E&I (1995b). The stations to be sampled will include SWS/SED-1 through SWS/SED-5. Surface water samples will be analyzed for VOCs, and sediment samples will be analyzed for VOCs and TOC using the methods specified in Table 3.1.

Samples will be collected so as not to cause cross-contamination. Background samples will be collected first. Sampling will continue with the furthest downstream station and proceed upstream to avoid sample contamination. The surface water sample at each location will be collected before the sediment sample in order to minimize the amount of suspended solids in the water sample. Samples will be taken from the creek along the bank nearest the source of contamination.

Surface water samples will be collected by submerging unpreserved sample containers in the ditch. If the water level is too shallow, a hole may be dug in the sediment to create room in the channel for containers to be submerged. The sediment will be allowed to settle before water samples are collected. Sample bottles that contain preservative will be filled by collecting surface water from the ditch using a decontaminated beaker and transferring the sample into the preserved bottle. Temperature, pH, DO and specific conductance will be measured at each surface water sampling point and recorded in the field logbook. Sediment samples will be collected from the upper 6 inches of ditch bottom sediment using a stainless steel hand trowel. During sediment collection, the amount of sediment disturbance will be minimized.

Surface water and sediment samples will be handled and transported in the same manner as groundwater and soil samples. All surface water and sediment samples will be placed in an analyte-appropriate sample container and hand-delivered to the USEPA

field laboratory personnel for analysis. Unless other instructions are given by the analytical laboratory, sample containers will be completely filled so that no air space remains in the container.

3.6 HANDLING OF SAMPLES FOR LABORATORY ANALYSIS

This section describes the handling of samples from the time of sampling until the samples are delivered to USEPA field laboratory.

3.6.1 Sample Preservation

The USEPA laboratory support personnel will add any necessary chemical preservatives prior to sealing the sample containers. Samples will be prepared for transportation to the analytical laboratory by placing the samples in a cooler containing ice to maintain a shipping temperature of as close to 4 degrees centigrade (°C) as possible. Samples will be delivered promptly to USEPA field laboratory personnel, who will be responsible for shipment of appropriate samples to the NRMRL in Ada, Oklahoma for analysis.

3.6.2 Sample Container and Labels

Sample containers and appropriate container lids will be provided by the USEPA field laboratory (see Appendix A). The sample containers will be filled as described in Sections 3.2.2 and 3.3.3.4, and the container lids will be tightly closed. The sample label will be firmly attached to the container side, and the following information will be legibly and indelibly written on the label:

- Facility name;
- Sample station identification;
- Sample type (e.g., groundwater, soil, surface water, sediment);

- Sampling date;
- Sampling time;
- Preservatives added;
- Sample collector's initials; and
- Analyses requested.

3.6.3 Sample Shipment

After the samples are sealed and labeled, they will be packaged for transport to the onsite USEPA field laboratory. The packaged samples will be delivered by hand to the USEPA field laboratory. Delivery will occur as soon as possible after sample acquisition.

The following packaging and labeling procedures will be followed:

- Package sample so that it will not leak, spill, or vaporize from its container;
- Cushion samples to avoid breakage; and
- Add ice to container to keep samples cool.

USEPA personnel will be responsible for repackaging and overnight shipment of samples to the NRMRL in Ada, Oklahoma.

3.6.4 Chain-of-Custody Control

Chain-of-custody documentation for the shipment of samples from the USEPA field laboratory to the NRMRL analytical laboratory in Ada, Oklahoma, will be the responsibility of the USEPA field personnel.

3.6.5 Sampling Records

In order to provide complete documentation of the sampling event, detailed records will be maintained by the field scientist. At a minimum, these records will include the following information:

- Sample location (facility name);
- Sample station identification;
- Sample location map or detailed sketch;
- Date and time of sampling;
- Sampling method;
- Field observations of sample appearance and odor;
- Weather conditions;
- Water level prior to purging (groundwater samples only);
- Total monitoring well/point depth (groundwater samples only);
- Sample depth (soil samples only);
- Purge volume (groundwater samples only);
- Water level after purging (groundwater samples only);
- Monitoring well/point condition (groundwater samples only);
- Stream width, depth, and flow rate (surface water and sediment samples only);
- Discharge pipe, sewer, or tributary locations (surface water and sediment samples only);

- Sampler's identification;
- Field measurements of pH, temperature, DO, and specific conductivity (groundwater and surface water samples only); and
- Any other relevant information.

Groundwater sampling information will be recorded on a groundwater sampling form. Figure 3.4 shows an example of the groundwater sampling record. Soil sampling information will be recorded in the field log book.

3.6.6 Laboratory Analyses

Laboratory analyses will be performed on all groundwater and soil samples as well as the QA/QC samples described in Section 4. The analytical methods for this sampling event are listed in Table 3.1. Prior to sampling, USEPA NRMRL personnel will provide a sufficient number of analyte-appropriate sample containers for the samples to be collected. All containers, preservatives, and shipping requirements will be consistent with USEPA protocol or those listed in Appendix A of this plan.

USEPA laboratory support personnel will specify the necessary QC samples and prepare appropriate QC sample containers. For samples requiring chemical preservation, preservatives will be added to containers by the laboratory or USEPA NRMRL field personnel. Containers, ice chests with adequate padding, and cooling media will be provided by USEPA NRMRL laboratory personnel. Sampling personnel will fill the sample containers and return the samples to the field laboratory.

3.7 AQUIFER TESTING

Slug tests will be conducted on newly installed monitoring wells at each site to estimate the hydraulic conductivity of unconsolidated deposits at the sites. This information is required to accurately estimate the velocity of groundwater and

contaminants in the shallow saturated zone. A slug test is a single-well hydraulic test used to determine the hydraulic conductivity of an aquifer in the immediate vicinity of the tested well. Slug tests can be used for both confined and unconfined aquifers that have a transmissivity of less than 7,000 square feet per day (ft²/day). Slug testing can be performed using either a rising head or a falling head test; at this site, both methods will be used in sequence.

3.7.1 Definitions

- **Hydraulic Conductivity (K).** A quantitative measure of the ability of porous material to transmit water; defined as the volume of water that will flow through a unit cross-sectional area of porous or fractured material per unit time under a unit hydraulic gradient.
- **Transmissivity (T).** A quantitative measure of the ability of an aquifer to transmit water. It is the product of the hydraulic conductivity and the saturated thickness.
- **Slug Test.** Two types of testing are possible: rising head and falling head tests. A slug test consists of adding a slug of water or a solid cylinder of known volume to the well to be tested or removing a known volume of water or cylinder and measuring the rate of recovery of water level inside the well. The slug of a known volume acts to raise or lower the water level in the well.
- **Rising Head Test.** A test used in an individual well within the saturated zone to estimate the hydraulic conductivity of the surrounding formation by lowering the water level in the well and measuring the rate of recovery of the water level. The water level may be lowered by pumping, bailing, or removing a submerged slug from the well.
- **Falling Head Test.** A test used in an individual well to estimate the hydraulic conductivity of the surrounding formation by raising the water level in the well

by insertion of a slug or quantity of water, and then measuring the rate of drop in the water level.

3.7.2 Equipment

The following equipment will be used to conduct a slug test:

- Teflon[®], PVC, or metal slugs;
- Nylon or polypropylene rope;
- Electric water level indicator;
- Pressure transducer/sensor;
- Field logbook/forms; and
- Automatic data recording instrument (such as the Hermit Environmental Data Logger[®], In-Situ, Inc. Model SE1000B, or equivalent).

3.7.3 General Test Methods

Aquifer hydraulic conductivity tests (slug tests) are accomplished by either removal of a slug or quantity of water (rising head) or introduction of a slug (falling head), and then allowing the water level to stabilize while taking water level measurements at closely spaced time intervals.

Because hydraulic testing will be completed on existing wells, it will be assumed that the wells were properly developed and that water levels have stabilized. Slug testing will proceed only after multiple water level measurements over time show that static water levels are in equilibrium. During the slug test, the water level change should be influenced only by the introduction (or removal) of the slug volume. Other factors, such as inadequate well development or extended pumping may lead to inaccurate results; in addition, slug tests will not be performed on wells with free product. The field scientist will determine when static equilibrium has been reached in

the well. The pressure transducer, slugs, and any other downhole equipment will be decontaminated prior to and immediately after the performance of each slug test using the procedures described in Section 3.3.2.1.

3.7.4 Falling Head Test

The falling head test is the first step in the two-step slug testing procedure. The following steps describe procedures to be followed during performance of the falling head test.

1. Decontaminate all downhole equipment prior to initiating the test.
2. Open the well. Where wells are equipped with watertight caps, the well should be unsealed at least 24 hours prior to testing to allow the water level to stabilize. The protective casing will remain locked during this time to prevent vandalism.
3. Prepare the aquifer slug test data form (Figure 3.5) with entries for:
 - Borehole/well number,
 - Project number,
 - Project name,
 - Aquifer testing team,
 - Climatic data,
 - Ground surface elevation,
 - Top of well casing elevation,
 - Identification of measuring equipment being used,
 - Static water level, and

Aquifer Slug Test Data Sheet

Location Shaw AFBJob No. 722450 37020

Water Level

Measuring Datum

Weather

Comments

Client AFCÉEField Scientist RTH/CM/CH

Total Well Depth

Elevation of Datum

Temp

Well ID

Date _____

[illegible]

FIGURE 3.5

**AQUIFER TEST
DATA FORM**

Sites OU-4 And Building 1613
RNA TS
Shaw AFB, South Carolina

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- Date.
4. Measure the static water level in the well to the nearest 0.01 foot.
 5. Lower the decontaminated pressure transducer into the well and allow the displaced water to return to its static level. This can be determined by periodic water level measurements until the static water level in the well is within 0.01 foot of the original static water level.
 6. Lower the decontaminated slug into the well to just above the water level in the well.
 7. Turn on the data logger and quickly lower the slug below the water table, being careful not to disturb the pressure transducer. Follow the owner's manual for proper operation of the data logger.
 8. Terminate data recording when the water level stabilizes in the well. The well will be considered stabilized for termination purposes when it has recovered 80 to 90 percent from the initial displacement.

3.7.5 Rising Head Test

After completion of the falling head test, the rising head test will be performed. The following steps describe the rising head slug test procedure.

1. Measure the water level in the well to the nearest 0.01 foot to ensure that it has returned to the static water level.
2. Initiate data recording and quickly withdraw the slug from the well. Follow the owner's manual for proper operation of the data logger.
3. Terminate data recording when the water level stabilizes in the well, and remove the pressure transducer from the well and decontaminate. The well

will be considered stabilized for termination purposes when it has recovered 80 to 90 percent from the initial displacement.

3.7.6 Slug Test Data Analysis

Data obtained during slug testing will be analyzed using AQTESOLVTM and the method of Hvorslev (1951) for confined aquifers or the method of Bouwer and Rice (1976) and Bouwer (1989) for unconfined conditions.

SECTION 4

QUALITY ASSURANCE/QUALITY CONTROL

Field QA/QC procedures will include collection of field duplicates/replicates and rinseate, field, and trip blanks; decontamination of all equipment that contacts the sample medium before and after each use; use of analyte-appropriate containers; and chain-of-custody procedures for sample handling and tracking. All samples to be transferred to the USEPA laboratory for analysis will be clearly labeled to indicate sample number, location, matrix (e.g., groundwater), and analyses requested. Samples will be preserved in accordance with the analytical methods to be used, and water sample containers will be packaged in coolers with ice to maintain a temperature of as close to 4°C as possible.

All field sampling activities will be recorded in a bound, sequentially paginated field notebook in permanent ink. All sample collection entries will include the date, time, sample locations and numbers, notations of field observations, and the sampler's name and signature. Field QC samples will be collected in accordance with the program described below, and as summarized in Table 4.1.

QA/QC sampling will include collection and analysis of duplicate groundwater and surface water samples, replicate soil and sediment samples, rinseate blanks, field/trip blanks, and matrix spike samples. Internal laboratory QC analyses will involve the analysis of laboratory control samples (LCSs) and laboratory method blanks (LMBs). QA/QC objectives for each of these samples, blanks, and spikes are described below.

TABLE 4.1
QA/QC SAMPLING PROGRAM
SITES OU-4 AND BUILDING 1613
RNA TS
SHAW AFB, SOUTH CAROLINA

QA/QC Sample Types	Frequency to be Collected and/or Analyzed	Analytical Methods
Duplicates/Replicates	5 Groundwater and 1 Soil Samples (10%)	VOCs
Rinseate Blanks	3 Samples (5% of Groundwater Samples)	VOCs
Field Blanks	3 Samples (5% of Groundwater Samples)	VOCs
Trip Blanks	One per shipping cooler containing VOC samples	VOCs
Matrix Spike Samples	Once per sampling event	VOCs
Laboratory Control Sample	Once per method per medium	Laboratory Control Charts (Method Specific)
Laboratory Method Blanks	Once per method per medium	Laboratory Control Charts (Method Specific)

Duplicate groundwater/surface water and replicate soil/sediment samples will be collected at a frequency of 1 for every 10 or fewer samples of similar matrix. Each duplicate water sample will be collected concurrent with, and by the same method, as the primary sample. Replicated soil and sediment samples will be collected by mixing a single soil sample interval to obtain a homogeneous sample, and then dividing the soil sample into the primary and replicate soil sample containers. For samples to be analyzed for VOCs, mixing of the soil will be minimized to prevent the loss of volatiles. Duplicate samples will be analyzed for VOCs and geochemical analyses.

One rinseate sample will be collected for every 20 or fewer groundwater samples collected. Because both peristaltic pumps and disposable bailers may be used for this sampling event, the rinseate samples will alternately consist of a sample representing both methods. The peristaltic pump sample will consist of a sample of distilled water pumped through a section of clean tubing and subsequently transferred into a sample container provided by the laboratory. The disposable bailer sample will consist of a sample of distilled water poured into a new disposable bailer and subsequently transferred into a sample container provided by the laboratory. Rinseate samples will be analyzed for VOCs only.

One field blank will be collected for every 20 or fewer groundwater samples to assess the effects of ambient conditions in the field. The field blank will consist of a sample of distilled water poured into a laboratory-supplied sample container while sampling activities are underway. The field blank will be analyzed for VOCs.

A trip blank will be analyzed to assess the effects of ambient conditions on sampling results during the transportation of samples. The trip blank will be prepared by the laboratory. A trip blank will be transported inside each cooler which contains samples for VOC analysis. Trip blanks will be analyzed for VOCs.

Matrix spikes will be prepared in the laboratory and used to establish matrix effects for samples analyzed for VOCs. LCSs and LMBs will be prepared internally by the laboratory and will be analyzed each day samples from the sites are analyzed. Samples will be reanalyzed in cases where the LCS or LMB are out of the control limits. Control charts for LCSs and LMBs will be developed by the laboratory and monitored for the analytical methods used (see Table 3.1).

SECTION 5

DATA ANALYSIS AND REPORT

Once the data collected during the field effort are assembled, they will be analyzed using a variety of methods. For example, isopleth maps of BTEX and CAHs, degradation products, and primary and alternate electron acceptors and donors will be used to evaluate the occurrence and mechanisms of biodegradation at the site, using the relationships discussed in Section 2. Site contaminant data also will be used to determine rates of contaminant mass loss and to determine rates of biodegradation. Site data also will be used to estimate contaminant flux through specified areas. Where possible, the data also will be applied to estimate the impacts of other ongoing or planned remedial actions at OU-4 and the Building 1613 Site.

After the data evaluation and analysis, numerical and/or analytical groundwater models will be used to evaluate the fate and transport of fuel hydrocarbons and chlorinated solvents dissolved in groundwater at both sites. The contaminant fate and transport modeling effort has three primary objectives: 1) predict the future extent and concentration of dissolved contaminant plumes by modeling the effects of advection, dispersion, sorption, and biodegradation; 2) assess the possible exposure of potential downgradient receptors to contaminant concentrations that exceed levels intended to be protective of human health and the environment; and 3) to provide technical support for selection of RNA as the best remedial alternative at regulatory negotiations, as appropriate.

Based upon model predictions of contaminant concentrations and distribution through time, and upon potential exposure pathways, the potential risk to human health

and the environment will be assessed. If it is shown that RNA of BTEX compounds and CAHs at OU-4 and the Building 1613 Site is sufficient to reduce the potential risk to human health and the environment to acceptable levels, Parsons ES will recommend implementation of the RNA with LTM option. If RNA is chosen, Parsons ES will prepare site-specific LTM plans that will specify the location of point-of-compliance monitoring wells and sampling frequencies.

If RNA alone is deemed inappropriate for use at these sites, institutional controls such as groundwater or land use restrictions will be evaluated to determine if they will be sufficient to reduce the risk to human health and the environment to acceptable levels. If institutional controls are inappropriate, remedial options that could reduce risks to acceptable levels will be evaluated, and appropriate remedial options will be recommended. Potential remedial options include, but are not limited to: free product recovery (e.g., bioslurping), groundwater pump-and-treat, enhanced biological treatment, air sparging, and *in situ* reactive barrier walls. The expected reduction in dissolved BTEX and CAHs or in the contaminant sources that should result from remedial activities will be used to produce new input files for the groundwater models. The models will then be used to predict the BTEX and CAH plume and risk reduction that should result from remedial actions.

A report detailing the results of the modeling and remedial option evaluation will be prepared. This report will follow the outline presented in Table 5.1 and will contain an introduction, site descriptions, identification of remediation objectives, description of remediation alternatives, an analysis of remediation alternatives, and the suggested remedial approach for each site. This report will also contain the results of the site characterization activities described herein.

TABLE 5.1 (concluded)
EXAMPLE REPORT OUTLINE
SITES OU-4 AND BUILDING 1613
RNA TS
SHAW AFB, SOUTH CAROLINA

COMPARATIVE ANALYSIS OF REMEDIAL ALTERNATIVES

- Remedial Alternatives Evaluation Criteria
 - Long-Term Effectiveness
 - Implementability (Technical, Administrative)
 - Cost (Capital, Operating, Present Worth)
- Factors Influencing Alternatives Development
 - Program Objectives
 - Contaminant Properties
 - Site-Specific Conditions
- Brief Description of Remedial Alternatives
 - Intrinsic Remediation with Long-Term Monitoring
 - Other Alternatives
- Evaluation of Alternatives
- Recommended Remedial Approach

LONG-TERM MONITORING PLAN

- Overview
- Monitoring Networks
- Groundwater and Surface Water Sampling

CONCLUSIONS AND RECOMMENDATIONS

APPENDICES: Supporting Data and Documentation

- Site-Specific Model Input and Results

TABLE 5.1
EXAMPLE REPORT OUTLINE
SITES OU-4 AND BUILDING 1613
RNA TS
SHAW AFB, SOUTH CAROLINA

INTRODUCTION

Scope and Objectives

Site Background

SITE CHARACTERIZATION ACTIVITIES

Sampling and Aquifer Testing Procedures

PHYSICAL CHARACTERISTICS OF THE STUDY AREA

Surface Features

Regional Geology and Hydrogeology

Site Geology and Hydrogeology

Climatological Characteristics

NATURE AND EXTENT OF CONTAMINATION

Source Characterization

Soil, Sediment, and Source Chemistry (if source is located)

Mobile LNAPL

Residual Contamination

Total Organic Carbon

Groundwater and Surface Water Chemistry

Dissolved Contamination

Groundwater Geochemistry

Discussion of Results

Evidence of Biodegradation

Calculation of Biodegradation Rates

GROUNDWATER FLOW AND SOLUTE TRANSPORT MODELING

Model Description

Conceptual Model Design and Assumptions

Initial Model Setup

Model Calibration

Sensitivity Analysis

Model Results

Conclusions

SECTION 6

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APPENDIX A

APPENDIX A: ANALYTICAL METHODS, DATA USE, AND PACKAGING REQUIREMENTS FOR SOIL AND GROUNDWATER SAMPLES

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Soil	Aromatic and chlorinated hydrocarbons (benzene, toluene, ethylbenzene, and xylene [BTEX]; chlorinated compounds)	SW8260A	Handbook method	Data are used to determine the extent of soil contamination, the contaminant mass present, and the potential need for source removal.	Each soil sampling round	Sample volume approximately 100 ml; subsample and extract in the field using methanol or appropriate solvent; cool to 4°C	Fixed-base
Soil	Total hydrocarbons, volatile and extractable	GC method SW8015 [modified]	Handbook method; reference is the California LUFT manual	Data are used to determine the extent of soil contamination, the contaminant mass present, and the need for source removal.	Each sampling round	Collect 100 g of soil in a glass container with Teflon-lined cap; cool to 4°C	Fixed-base
Soil	Total organic carbon (TOC)	SW9060 modified for soil samples	Procedure must be accurate over the range of 0.5–15 percent TOC	The rate of migration of petroleum contaminants in groundwater is dependent upon the amount of TOC in the saturated zone soil.	At initial sampling	Collect 100 g of soil in a glass container with Teflon-lined cap; cool to 4°C	Fixed-base
Soil	Moisture	ASTM D-2216	Handbook method	Data are used to correct soil sample analytical results for moisture content (e.g., report results on a dry weight basis).	Each soil sampling round	Use a portion of soil sample collected for another analysis	Fixed-base
Soil	Grain size distribution	ASTM D422	Procedure provides a distribution of grain size by sieving	Data are used to infer hydraulic conductivity of aquifer, and are used in calculating sorption of contaminants.	One time during life of project	Collect 250 g of soil in a glass or plastic container; preservation is unnecessary	Fixed-base

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Aromatic and chlorinated hydrocarbons (BTEX, trimethylbenzene isomers, chlorinated compounds)	SW8260A	Handbook method; analysis may be extended to higher molecular weight alkyl benzenes	Method of analysis for BTEX and chlorinated solvents/byproducts, which are the primary target analytes for monitoring natural attenuation; method can be extended to higher molecular weight alkyl benzenes; trimethylbenzenes are used to monitor plume dilution if degradation is primarily anaerobic.	Each sampling round	Collect water samples in a 40 mL VOA vial; cool to 4°C; add sulfuric acid to pH 2	Fixed-base
Water	Total hydrocarbons, volatile and extractable	GC method SW8015 [modified]	Handbook method; reference is the California LUFT manual	Data used to monitor the reduction in concentrations of total fuel hydrocarbons (in addition to BTEX) due to natural attenuation; data also used to infer presence of an emulsion or surface layer of petroleum in water sample, as a result of sampling.	One time per year or as required by regulations	Volatile hydrocarbons—collect water samples in a 40 mL VOA vial; cool to 4°C; add hydrochloric acid to pH 2 Extractable hydrocarbons—collect 1 L of water in a glass container; cool to 4°C; add hydrochloric acid to pH 2	Fixed-base
Water	Polycyclic aromatic hydrocarbons (PAHs) (optional)	GC/mass spectroscopy method SW8270; high-performance liquid chromatography method SW8310	Analysis needed only for several samples per site	PAHs are components of fuel and are typically analyzed for regulatory compliance; data on their concentrations are not used currently in the evaluation of natural attenuation.	At initial sampling and at site closure or as required by regulations	Collect 1 L of water in a glass container; cool to 4°C	Fixed-base

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Ferrous (Fe^{2+})	Colorimetric A3500-Fe D	Field only	May indicate an anaerobic degradation process due to depletion of oxygen, nitrate, and manganese.	Each sampling round	Collect 100 ml of water in a glass container, acidify with hydrochloric acid per method	Field
Water	Ferrous (Fe^{2+})	Colorimetric HACH Method # 8146	Alternate method; field only	Same as above.	Each sampling round	Collect 100 ml of water in a glass container	Field
Water	Total Iron	Colorimetric HACH Method # 8008	Field only		Each sampling round	Collect 100 mL of water in a glass container	Field
Water	Manganese	Colorimetric HACH Method # 8034	Field only		Each sampling round	Collect 100 mL of water in a glass container	Field
Water	Chloride	Mercuric nitrate titration A4500- Cl^- C	Ion chromatography (IC) method E300 or method SW9050 may also be used	General water quality parameter used as a marker to verify that site samples are obtained from the same groundwater system.	Each sampling round	Collect 250 mL of water in a glass container	Field
Water	Chloride	HACH Chloride test kit model 8-P	Silver nitrate titration	Same as above.	Each sampling round	Collect 100mL of water in a glass container	Field
Water	Oxygen	Dissolved oxygen meter	Refer to method A4500 for a comparable laboratory procedure	The oxygen concentration is a data input to the Bioplume model; concentrations less than 1 mg/L generally indicate an anaerobic pathway.	Each sampling round	Collect 300 mL of water in biochemical oxygen demand bottles; analyze immediately, alternately, measure dissolved oxygen <i>in situ</i>	Field
Water	Conductivity	E120.1/SW9050, direct reading meter	Protocols/Handbook methods	General water quality parameter used as a marker to verify that site samples are obtained from the same groundwater system.	Each sampling round	Collect 100–250 mL of water in a glass or plastic container	Field

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Alkalinity	HACH Alkalinity test kit model AL AP MG-L, method 8221	Phenolphthalein method	General water quality parameter used (1) as a marker to verify that all site samples are obtained from the same groundwater system and (2) to measure the buffering capacity of groundwater.	Each sampling round	Collect 100mL of water in glass container	Field
Water	Alkalinity	A2320, titrimetric; E310.2 or E150.1, colorimetric	Handbook method	Same as above.	Each sampling round	Collect 250 mL of water in a glass or plastic container; analyze within 6 hours	Field
Water	Nitrate (NO_3^{-1}) and Nitrite (NO_2^{-1})	IC method E300 or method SW9056; colorimetric, method E353.2	Method E300 is a Handbook method; method SW9056 is an equivalent procedure	Substrate for microbial respiration if oxygen is depleted.	Each sampling round	Collect up to 40 mL of water in a glass or plastic container; cool to 4°C; analyze within 48 hours	Fixed-base
Water	Nitrate (NO_3^{-1})	HACH method # 8039 for high range method # 8192 for low range	Colorimetric	Same as above.	Each sampling round	Collect 100mL of water in a glass container	Field
Water	Nitrite (NO_2^{-1})	HACH method #8040	Colorimetric	Substrate for microbial respiration if oxygen is depleted.	Each sampling round	Collect 100mL of water in a glass container	Field
Water	Sulfate (SO_4^{-2})	IC method E300 or method SW9056	Method E300 is a Handbook method; method SW9056 is an equivalent procedure	Substrate for anaerobic microbial respiration.	Each sampling round	Collect up to 40 mL of water in a glass or plastic container; cool to 4°C	Fixed-base
Water	Sulfate (SO_4^{-2})	HACH method # 8051	Colorimetric	Same as above.	Each sampling round	Collect up to 40 mL of water in a glass or plastic container; cool to 4°C	Field

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Dissolved sulfide (S ²⁻)	HACH method # 8131	Colorimetric	Product of sulfate-based anaerobic microbial respiration; analyze in conjunction with sulfate analysis.	Each sampling round	Collect 100 mL of water in a glass container; analyze immediately	Field
Water	Carbon dioxide	HACH test kit model CA-23, method 8223 or CHEMetrics Method R-1910	Titrimetric; alternate method	The presence of free carbon dioxide dissolved in groundwater is unlikely because of the carbonate buffering system of water, but if detected, the carbon dioxide concentrations should be compared with background to determine whether they are elevated; elevated concentrations of carbon dioxide could indicate biodegradation of BTEX.	Each sampling round	Collect 100 mL of water in a glass container	Field
Water	Methane	Kampbell <i>et al</i> , 1989 or SW3810 modified.	Method published and used by the U.S. Environmental Protection Agency (EPA) National Risk Management Research Laboratory	The presence of methane suggests BTEX degradation via an anaerobic pathway utilizing carbon dioxide (carbonate) as the electron acceptor (methanogenesis).	Each sampling round	Collect water samples in 50 ml glass serum bottles with butyl gray/Teflon-lined caps; add H ₂ SO ₄ to pH 2; cool to 4°C	Fixed-base

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Total fuel carbon (optional)	Purge and trap GC method SW8020 modified to measure all volatile aromatic hydrocarbons present in the sample	A substitute method for measuring total volatile hydrocarbons; reports amount of fuel as carbon present in the sample; method available from the U.S. EPA Robert S. Kerr Laboratory	Data used to monitor the reduction in concentrations of total fuel hydrocarbons (in addition to BTEX) due to natural attenuation.	At initial sampling and at site closure	Collect 40 mL of water in glass vials with Teflon-lined caps; add sulfuric acid to pH 2; cool to 4°C	Fixed-base
Water	Dissolved organic carbon (DOC) (optional)	A5310 C	An oxidation procedure whereby carbon dioxide formed from DOC is measured by an infrared spectrometer. The minimum detectable amount of DOC is 0.05 mg/L	An indirect index of microbial activity.	Each sampling round	Collect 100 mL of water in an amber glass container with Teflon-lined cap; preserve with sulfuric acid to pH less than 2; cool to 4°C	Fixed-base
Water	TOC	E415.1 or RSKSOP-102	Handbook method; sample sparged with nitrogen in lab		Each sampling round	Collect 100 mL of water in glass containers with Teflon-lined caps; add H ₂ SO ₄ to pH 2; cool to 4°C	
Water	pH	E150.1/SW9040, direct reading meter	Protocols/Handbook methods	Aerobic and anaerobic processes are pH-sensitive.	Each sampling round	Collect 100–250 mL of water in a glass or plastic container; analyze immediately	Field
Water	Temperature	E170.1	Field only	Well development.	Each sampling round	N/A	Field

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Redox potential	A2580 B	Measurements are made with electrodes; results are displayed on a meter; samples should be protected from exposure to atmospheric oxygen	The redox potential of groundwater influences and is influenced by the nature of the biologically mediated degradation of contaminants; the redox potential of groundwater may range from more than 200 mV to less than -400 mV	Each sampling round	Collect 100-250 mL of water in a glass container, filling container from bottom; analyze immediately	Field

NOTES:

1. "HACH" refers to the HACH Company catalog, 1990.
2. "A" refers to *Standard Methods for the Examination of Water and Wastewater*, 18th edition, 1992.
3. "E" refers to *Methods for Chemical Analysis of Water and Wastes*, U.S. Environmental Protection Agency, March 1979.
4. "Protocols" refers to the AFCEE *Environmental Chemistry Function Installation Restoration Program Analytical Protocols*, 11 June 1992.
5. "Handbook" refers to the AFCEE *Handbook to Support the Installation Restoration Program (IRP) Remedial Investigations and Feasibility Studies (RI/FS)*, September 1993.
6. "SW" refers to the *Test Methods for Evaluating Solid Waste, Physical, and Chemical Methods*, SW-846, U.S. Environmental Protection Agency, 3rd edition, 1986.

7. "ASTM" refers to the *American Society for Testing and Materials*, current edition.
8. "RSKSOP" refers to Robert S. Kerr (*Environmental Protection Agency Laboratory Standard Operating Procedure*).
9. "LUFT" refers to the state of California *Leaking Underground Fuel Tank Field Manual*, 1988 edition.
10. *International Journal of Environmental Analytical Chemistry*, Volume 36, pp. 249-257, "Dissolved Oxygen and Methane in Water by a Gas Chromatography Headspace Equilibration Technique," by D. H. Kampbell, J. T. Wilson, and S. A. Vandegrift.

APPENDIX B

ADDITIONAL SITE DATA

APPENDIX B

GROUNDWATER MONITORING INSTALLATION DETAIL

PROJECT: <u>OU#4/FORMER FIRE TRAINING AREA #1</u>		JOB NO <u>81863.150</u>	
LOCATION: <u>SAFB, SUMTER, SC</u>		INSTALLATION NO <u>MW-112A</u>	
CLIENT: <u>US ARMY CORPS OF ENGINEERS</u>		TYPE OF INSTALLATION <u>2-IN. SCH</u>	
CONTRACTOR: <u>AE DRILLING</u>		<u>40 PVC MONITORING WELL</u>	
DRILLER: <u>B. BARNES</u> CERTIFICATION NO: <u>562</u>		BORING NO. <u>MW-112A</u>	
RUST E&I FIELD REPRESENTATIVE: <u>FRANK FARMER</u>		LOCATION <u>OU #4</u>	
		INSTALLATION DATE <u>2/4/93</u>	

SURVEY DATUM: <u>NGVD</u>			
GROUND SURFACE ELEVATION: <u>215.78</u>			

SUMMARIZE SOIL CONDITIONS, BACKFILL AND SEALS (NOT TO SCALE)

Interlayered Well Graded and Poorly Graded Sand (SW/SP)

NEAT CEMENT/ BENTONITE GROUT

Well Graded Sand (SW)

BENTONITE

Poorly Graded Sand (SP)

FILTERPACK SAND

TOP OF PROTECTIVE CASING (CAP OPEN)
EL. ≈218 STICKUP ≈2.0 ft.

TOP OF WELL CASING OR RISER PIPE
EL. 217.92 STICKUP 2.14 ft.

TYPE OF SURFACE SEAL Concrete Pad

THICKNESS OF SURFACE SEAL Approx. 6 in.

TYPE OF PROTECTIVE CASING Anodized Aluminum

INSIDE DIAMETER 4.0 in. Square

TOTAL LENGTH 5.0 ft.

BOTTOM OF PROTECTIVE CASING
EL. ≈213 DEPTH ≈3.0 ft.

TYPE OF WELL CASING OR RISER PIPE SCH 40 PVC

INSIDE DIAMETER 2.0 in.

APPROXIMATE DIAMETER OF BOREHOLE Approx. 6.5 in.

TOP OF SCREENED INTERVAL
EL. 136.68 DEPTH 79.64 ft.

TYPE OF SCREEN Continuous Slot PVC

SCREEN GAUGE OR SIZE OF OPENINGS 0.010 in.

INSIDE DIAMETER 2.0 in.

TYPE OF BACKFILL AROUND POINT FX-50

BOTTOM OF SCREENED INTERVAL
EL. 126.60 DEPTH 89.18 ft.

BOTTOM OF WELL
EL. 126.08 DEPTH 89.70 ft.

BOTTOM OF BOREHOLE
EL. 125.78 DEPTH 90.00 ft.

• FIGURES ABOVE REFER TO DEPTH IN FEET • ALL DEPTHS ARE REFERENCED TO GROUND SURFACE

<u>81.51 ft.</u> LENGTH OF RISER PIPE	+	<u>10.33 ft.</u> LENGTH OF POINT	=	<u>91.84 ft.</u> TOTAL
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BENTONITE SEALS

GROUNDWATER MONITORING INSTALLATION DETAIL

GROUNDWATER MONITORING INSTALLATION DETAIL

PROJECT: <u>OU#4/FORMER FIRE TRAINING AREA #1</u>		JOB NO <u>81863.150</u>	
LOCATION: <u>SAFB, SUMTER, SC</u>		INSTALLATION NO <u>MW-116</u>	
CLIENT: <u>US ARMY CORPS OF ENGINEERS</u>		TYPE OF INSTALLATION <u>2-IN. SCH</u>	
CONTRACTOR: <u>AE DRILLING</u>		<u>40 PVC MONITORING WELL</u>	
DRILLER: <u>LEE REEVES/ BILL BARNES</u> CERTIFICATION NO: <u>562</u>		BORING NO. <u>MW-116</u>	
RUST E&I FIELD REPRESENTATIVE: <u>FRANK FARMER</u>		LOCATION <u>OU #4</u>	
		INSTALLATION DATE <u>2/1/93</u>	

SURVEY DATUM: <u>NGVD</u>			
GROUND SURFACE ELEVATION: <u>217.20</u>			

SUMMARIZE SOIL CONDITIONS, BACKFILL AND SEALS (NOT TO SCALE)

Poorly Graded Sand (SP)

BENTONITE

FINE SAND

FILTERPACK SAND

TOP OF PROTECTIVE CASING (CAP OPEN)
EL. ~219 STICKUP ~2.0 ft.

TOP OF WELL CASING OR RISER PIPE
EL. 219.46 STICKUP 2.26 ft.

TYPE OF SURFACE SEAL Concrete Pad

THICKNESS OF SURFACE SEAL Approx. 6 in.

TYPE OF PROTECTIVE CASING Anodized Aluminum

INSIDE DIAMETER 4.0 in. Square

TOTAL LENGTH 5.0 ft.

BOTTOM OF PROTECTIVE CASING
EL. ~214 DEPTH ~3.0 ft.

TYPE OF WELL CASING OR RISER PIPE SCH 40 PVC

INSIDE DIAMETER 2.0 in.

APPROXIMATE DIAMETER OF BOREHOLE Approx. 10 in.

TOP OF SCREENED INTERVAL
EL. 208.87 DEPTH 8.33 ft.

TYPE OF SCREEN Continuous Wrap PVC

SCREEN GAUGE OR SIZE OF OPENINGS 0.010 in.

INSIDE DIAMETER 2.0 in.

TYPE OF BACKFILL AROUND POINT FX-50

BOTTOM OF SCREENED INTERVAL
EL. 194.36 DEPTH 22.84 ft.

BOTTOM OF WELL
EL. 193.85 DEPTH 23.35 ft.

BOTTOM OF BOREHOLE
EL. 190.20 DEPTH 27.0 ft.

10.31 ft. + 15.30 ft. = 25.61 ft.
 LENGTH OF RISER PIPE LENGTH OF POINT TOTAL

BENTONITE SEALS

393020

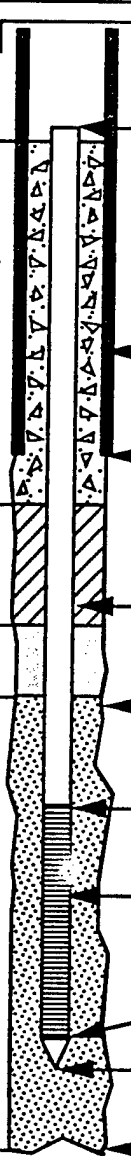
GROUNDWATER MONITORING INSTALLATION DETAIL

PROJECT: <u>OU#4/FORMER FIRE TRAINING AREA #1</u>		JOB NO <u>81863.150</u>
LOCATION: <u>SAFB, SUMTER, SC</u>		INSTALLATION NO <u>MW-116A</u>
CLIENT: <u>US ARMY CORPS OF ENGINEERS</u>		TYPE OF INSTALLATION <u>2-IN. SCH</u>
CONTRACTOR: <u>AE DRILLING</u>		<u>40 PVC MONITORING WELL</u>
DRILLER: <u>LEE REEVES/ BILL BARNES</u> CERTIFICATION NO: <u>562</u>		BORING NO. <u>MW-116A</u>
RUST E&I FIELD REPRESENTATIVE: <u>FRANK FARMER</u>		LOCATION <u>OU #4</u>
		INSTALLATION DATE <u>1/29/93</u>

SURVEY DATUM: <u>NGVD</u>			
GROUND SURFACE ELEVATION: <u>217.14</u>			

SUMMARIZE SOIL CONDITIONS, BACKFILL AND SEALS (NOT TO SCALE)

Mainly Poorly Graded Sand (SP)	NEAT CEMENT/ BENTONITE GROUT
49.0 ft.	
Well Graded Sand (SW)	72.77 ft.
78.0 ft.	BENTONITE
	79.0 ft.
Poorly Graded Sand (SP)	FINE SAND
	81.65 ft.
	FILTERPACK SAND



TOP OF PROTECTIVE CASING (CAP OPEN)	EL. <u>~219</u>	STICKUP <u>~2.0 ft.</u>
TOP OF WELL CASING OR RISER PIPE	EL. <u>219.48</u>	STICKUP <u>2.34 ft.</u>
TYPE OF SURFACE SEAL	<u>Concrete Pad</u>	
THICKNESS OF SURFACE SEAL	<u>6.23 ft.</u>	
TYPE OF PROTECTIVE CASING	<u>Anodized Aluminium</u>	
INSIDE DIAMETER	<u>4.0 in. Square</u>	
TOTAL LENGTH	<u>5.0 ft.</u>	
BOTTOM OF PROTECTIVE CASING	EL. <u>~214</u>	DEPTH <u>~3.0 ft.</u>
TYPE OF WELL CASING OR RISER PIPE	<u>SCH 40 PVC</u>	
INSIDE DIAMETER	<u>2.0 in.</u>	
APPROXIMATE DIAMETER OF BOREHOLE	<u>Approx. 6.5 in.</u>	
TOP OF SCREENED INTERVAL	EL. <u>131.94</u>	DEPTH <u>85.20 ft.</u>
TYPE OF SCREEN	<u>Continuous Wrap PVC</u>	
SCREEN GAUGE OR SIZE OF OPENINGS	<u>0.010 in.</u>	
INSIDE DIAMETER	<u>2.0 in.</u>	
TYPE OF BACKFILL AROUND POINT	<u>FX-50</u>	
BOTTOM OF SCREENED INTERVAL	EL. <u>122.40</u>	DEPTH <u>94.74 ft.</u>
BOTTOM OF WELL	EL. <u>121.89</u>	DEPTH <u>95.25 ft.</u>
BOTTOM OF BOREHOLE	EL. <u>120.14</u>	DEPTH <u>97.00 ft.</u>

• FIGURES ABOVE REFER TO DEPTH IN FEET

• ALL DEPTHS ARE REFERENCED TO GROUND SURFACE

<u>87.26 ft.</u> LENGTH OF RISER PIPE	+	<u>10.33 ft.</u> LENGTH OF POINT	=	<u>97.59 ft.</u> TOTAL
				BENTONITE SEALS 

GROUNDWATER MONITORING INSTALLATION DETAIL

PROJECT: <u>OU#4/FORMER FIRE TRAINING AREA #1</u>		JOB NO <u>81863.150</u>	
LOCATION: <u>SAFB, SUMTER, SC</u>		INSTALLATION NO <u>MW-117</u>	
CLIENT: <u>US ARMY CORPS OF ENGINEERS</u>		TYPE OF INSTALLATION <u>2-IN. SCH</u>	
CONTRACTOR: <u>AE DRILLING</u>		<u>40 PVC MONITORING WELL</u>	
DRILLER: <u>LEE REEVES/ BILL BARNES</u> CERTIFICATION NO: <u>562</u>		BORING NO. <u>MW-117</u>	
RUST E&I FIELD REPRESENTATIVE: <u>FRANK FARMER</u>		LOCATION <u>OU #4</u>	
		INSTALLATION DATE <u>2/5/93</u>	

SURVEY DATUM: <u>NGVD</u>		TOP OF PROTECTIVE CASING (CAP OPEN) EL. <u>≈216</u> STICKUP <u>≈2.5 ft.</u>	
GROUND SURFACE ELEVATION: <u>213.89</u>		TOP OF WELL CASING OR RISER PIPE EL. <u>216.42</u> STICKUP <u>2.53 ft.</u>	
SUMMARIZE SOIL CONDITIONS, BACKFILL AND SEALS (NOT TO SCALE)			TYPE OF SURFACE SEAL <u>Concrete Pad</u>
			THICKNESS OF SURFACE SEAL <u>Approx. 1.5 ft.</u>
			TYPE OF PROTECTIVE CASING <u>Anodized Aluminum</u>
			INSIDE DIAMETER <u>4.0 in. Square</u>
			TOTAL LENGTH <u>≈3.0 ft.</u>
			BOTTOM OF PROTECTIVE CASING EL. <u>≈211</u> DEPTH <u>≈2.5 ft.</u>
			TYPE OF WELL CASING OR RISER PIPE <u>SCH 40 PVC</u>
			INSIDE DIAMETER <u>2.0 in.</u>
			APPROXIMATE DIAMETER OF BOREHOLE <u>Approx. 10 in.</u>
			TOP OF SCREENED INTERVAL EL. <u>207.44</u> DEPTH <u>6.45 ft.</u>
			TYPE OF SCREEN <u>Continuous Slot PVC</u>
			SCREEN GAUGE OR SIZE OF OPENINGS <u>0.010 in.</u>
			INSIDE DIAMETER <u>2.0 in.</u>
			TYPE OF BACKFILL AROUND POINT <u>FX-50</u>
			BOTTOM OF SCREENED INTERVAL EL. <u>192.99</u> DEPTH <u>20.90 ft.</u>
BOTTOM OF WELL EL. <u>192.48</u> DEPTH <u>21.41 ft.</u>			
BOTTOM OF BOREHOLE EL. <u>188.39</u> DEPTH <u>25.50 ft.</u>			

8.70 ft. LENGTH OF RISER PIPE	+	15.24 ft. LENGTH OF POINT	=	23.94 ft. TOTAL
				BENTONITE SEALS

• FIGURES ABOVE REFER TO DEPTH IN FEET • ALL DEPTHS ARE REFERENCED TO GROUND SURFACE

GROUNDWATER MONITORING INSTALLATION DETAIL

PROJECT: <u>OU#4/FORMER FIRE TRAINING AREA #1</u>		JOB NO <u>81863.150</u>	
LOCATION: <u>SAFB, SUMTER, SC</u>		INSTALLATION NO <u>MW-118</u>	
CLIENT: <u>US ARMY CORPS OF ENGINEERS</u>		TYPE OF INSTALLATION <u>2-IN. SCH 40 PVC MONITORING WELL</u>	
CONTRACTOR: <u>AE DRILLING</u>		BORING NO. <u>MW-118</u>	
DRILLER: <u>T. BURNETTE</u> CERTIFICATION NO: <u>387</u>		LOCATION <u>OU #4</u>	
RUST E&I FIELD REPRESENTATIVE: <u>FRANK FARMER</u>		INSTALLATION DATE <u>2/15/93</u>	

SURVEY DATUM: <u>NGVD</u>		GROUND SURFACE ELEVATION: <u>201.12</u>	
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SUMMARIZE SOIL CONDITIONS, BACKFILL AND SEALS (NOT TO SCALE)

Poorly Graded Sand (SP)

8.5 ft. Clayey Sand (SC)

9.0 ft. Poorly Graded Sand (SP)

TOP OF PROTECTIVE CASING (CAP OPEN)
EL. ~203 STICKUP ~2.0 ft.

TOP OF WELL CASING OR RISER PIPE
EL. 203.51 STICKUP 2.39 ft.

TYPE OF SURFACE SEAL Concrete Pad
THICKNESS OF SURFACE SEAL Approx. 6 in.

TYPE OF PROTECTIVE CASING Anodized Aluminum
INSIDE DIAMETER 4.0 in square
TOTAL LENGTH Approx. 2.25 ft.

BOTTOM OF PROTECTIVE CASING
EL. ~200.87 DEPTH ~0.25 ft.

TYPE OF WELL CASING OR RISER PIPE SCH 40 PVC
INSIDE DIAMETER 2.0 in.

APPROXIMATE DIAMETER OF BOREHOLE Approx. 10 in.

TOP OF SCREENED INTERVAL
EL. 200.27 DEPTH 0.85 ft.

TYPE OF SCREEN Continuous Wrap PVC
SCREEN GAUGE OR SIZE OF OPENINGS 0.010 in.
INSIDE DIAMETER 2.0 in.

TYPE OF BACKFILL AROUND POINT Morie #00N

BOTTOM OF SCREENED INTERVAL
EL. 190.76 DEPTH 10.36 ft.

BOTTOM OF WELL
EL. 190.24 DEPTH 10.88 ft.

BOTTOM OF BOREHOLE
EL. 189.12 DEPTH 12.00 ft.

• FIGURES ABOVE REFER TO DEPTH IN FEET

• ALL DEPTHS ARE REFERENCED TO GROUND SURFACE

<u>2.96 ft.</u> LENGTH OF RISER PIPE	+	<u>10.31 ft.</u> LENGTH OF POINT	=	<u>13.27 ft.</u> TOTAL
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BENTONITE SEALS

GROUNDWATER MONITORING INSTALLATION DETAIL

PROJECT: <u>OU#4</u>		JOB NO <u>81961.230</u>	
LOCATION: <u>SAFB, SOUTH CAROLINA</u>		INSTALLATION NO <u>MW-119A</u>	
CLIENT: <u>US ARMY CORPS OF ENGINEERS</u>		TYPE OF INSTALLATION <u>2-IN. SCH 40 PVC MONITORING WELL</u>	
CONTRACTOR: <u>AE DRILLING</u>		BORING NO. <u>MW-119A</u>	
DRILLER: <u>P. O'DONNELL</u> CERTIFICATION NO: <u>519</u>		LOCATION <u>SEE SITE PLAN</u>	
RUST E&I FIELD REPRESENTATIVE: <u>B. E. CULP</u>		INSTALLATION DATE <u>5/17/94</u>	

SURVEY DATUM: <u>NGVD</u>			
GROUND SURFACE ELEVATION: <u>203.59</u>			

SUMMARIZE SOIL CONDITIONS, BACKFILL AND SEALS (NOT TO SCALE)

Silty Sand (SM)	10.0
Well Graded Sand (SW)	20.0
Silty Sand (SM)	45.0
Poorly Graded Sand (SP)	50.5
Silty Sand (SM)	61.0
Clayey Sand (SC)	

TOP OF PROTECTIVE CASING (CAP OPEN)	EL. <u>205.84 ft.</u>	STICKUP <u>2.25 ft.</u>
TOP OF WELL CASING OR RISER PIPE	EL. <u>205.89 ft.</u>	STICKUP <u>2.30 ft.</u>
THICKNESS OF SURFACE SEAL	<u>56.46 ft.</u>	
TYPE OF PROTECTIVE CASING	<u>Annodized Aluminum</u>	
INSIDE DIAMETER	<u>4.0 inch</u>	
TOTAL LENGTH	<u>5.0 feet</u>	
BOTTOM OF PROTECTIVE CASING	EL. <u>200.89 ft.</u>	DEPTH <u>2.70 ft.</u>
APPROXIMATE DIAMETER OF BOREHOLE	<u>7 3/4 inch</u>	
TYPE OF WELL CASING OR RISER PIPE	<u>Schedule 40 PVC</u>	
INSIDE DIAMETER	<u>2.0 inch</u>	
TOP OF WELL POINT	EL. <u>122.91 ft.</u>	DEPTH <u>59.92</u>
TYPE OF WELL POINT	<u>Schedule 40 PVC</u>	
SCREEN GAUGE OR SIZE OF OPENINGS	<u>.010 inch</u>	
INSIDE DIAMETER	<u>2.0 inch</u>	
TYPE OF BACKFILL AROUND POINT	<u>FX 50</u>	
BOTTOM OF WELL POINT	EL. <u>133.29 ft.</u>	DEPTH <u>70.30 ft.</u>
BOTTOM OF BOREHOLE	EL. <u>126.59 ft.</u>	DEPTH <u>77.00 ft.</u>

• FIGURES ABOVE REFER TO DEPTH IN FEET

• ALL DEPTHS ARE REFERENCED TO GROUND SURFACE

<u>62.27 ft.</u> LENGTH OF RISER PIPE	+ =	<u>10.33 ft.</u> LENGTH OF POINT	=	<u>72.60 ft.</u> TOTAL
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BENTONITE SEALS

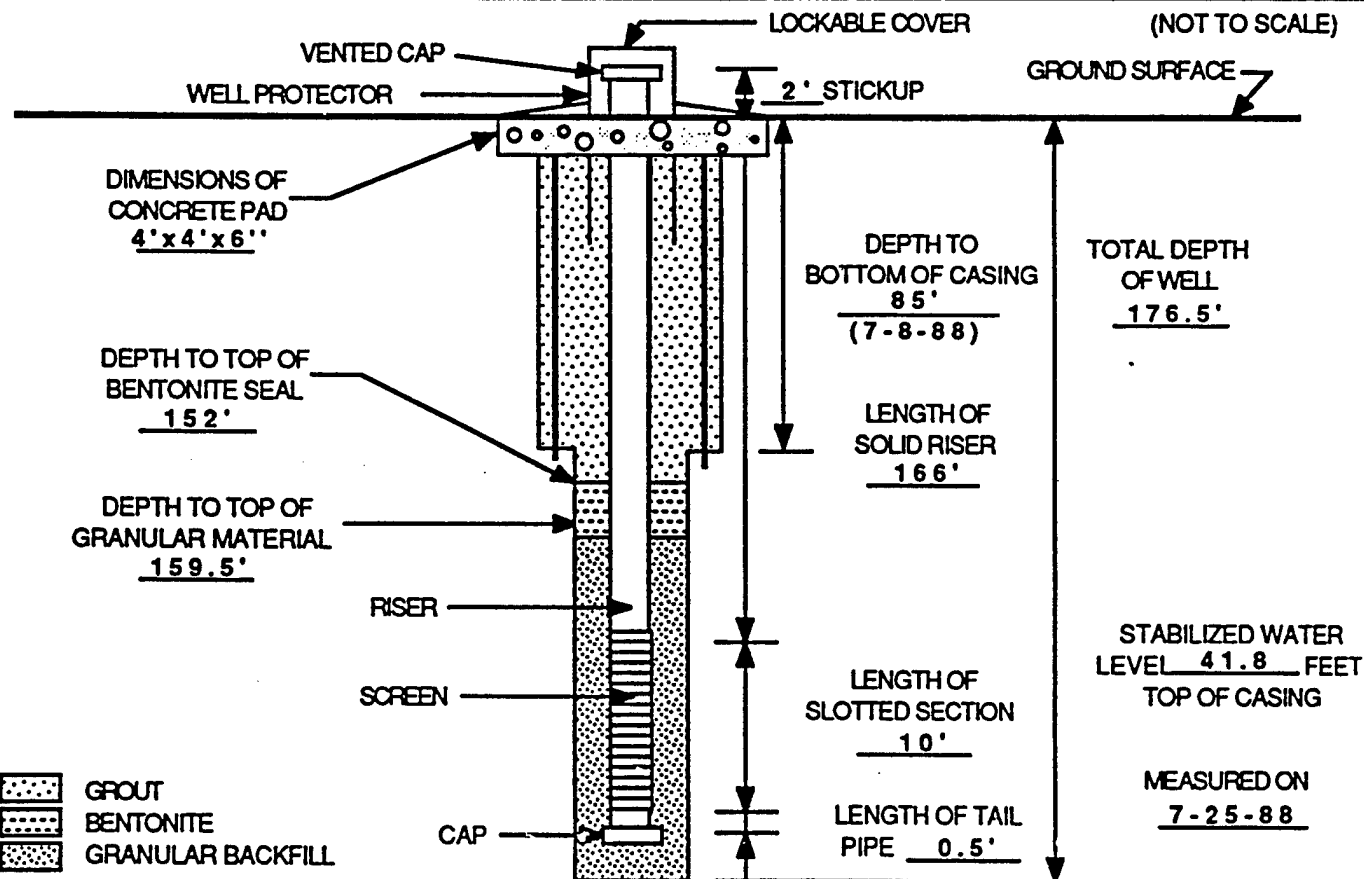
TYPE III MONITORING WELL INSTALLATION DIAGRAM

LAW ENVIRONMENTAL, INC.
GOVERNMENT SERVICES DIVISION
KENNESAW, GEORGIA

WELL NO. MW-105D
JOB NO. 11-8509-01
DATE 7-13-88 TIME 1900
WELL LOCATION SHAW AFB SITE 1, ADJACENT MW-105

GROUND SURFACE ELEVATION ~ 213.16'
TOP OF SCREEN ELEVATION 49.16'
REFERENCE POINT ELEVATION 215.16'
TYPE SAND PACK SC#89-M GRADATION GP
SAND PACK MANUFACTURER BECKER SAND & GRAVEL
SCREEN MATERIAL PVC-CONTINUOUS WRAP
MANUFACTURER JOHNSON
RISER MATERIAL PVC
MANUFACTURER BRAINARD KILMAN
RISER DIAMETER 2" ID
DRILLING TECHNIQUE (above casing) MUD ROTARY
BIT SIZE AND TYPE 9 7/8" TRICONE
DRILLING TECHNIQUE (below casing) MUD ROTARY
BIT SIZE AND TYPE 5 7/8" TRICONE

BENTONITE TYPE QUIK GEL
MANUFACTURER NL BAROID DIV.
CEMENT TYPE PORTLAND TYPE I
MANUFACTURER GIANT CEMENT CO.
BOREHOLE DIAMETER 10" OUTER, 6" INNER
SCREEN DIAMETER 2" ID SLOT SIZE 0.010
LAW ENVIRONMENTAL, INC.
FIELD REPRESENTATIVE MUNGIN-DAVIS
DRILLING CONTRACTOR LAW ENGINEERING, INC.
AMOUNT BENTONITE USED 6 BAGS
AMOUNT CEMENT USED 29 BAGS
AMOUNT SAND USED 10 GALLONS
STATIC WATER DEPTH (after dev.) 42.20' (TOC)
TYPE OF CASING PVC - 6"



QA / QC

INSTALLED BY: R. BANKS INSTALLATION OBSERVED BY: QM-D
DISCREPANCIES: STICK UP 2' BEFORE INSTALLATION OF BLADDER PUMP

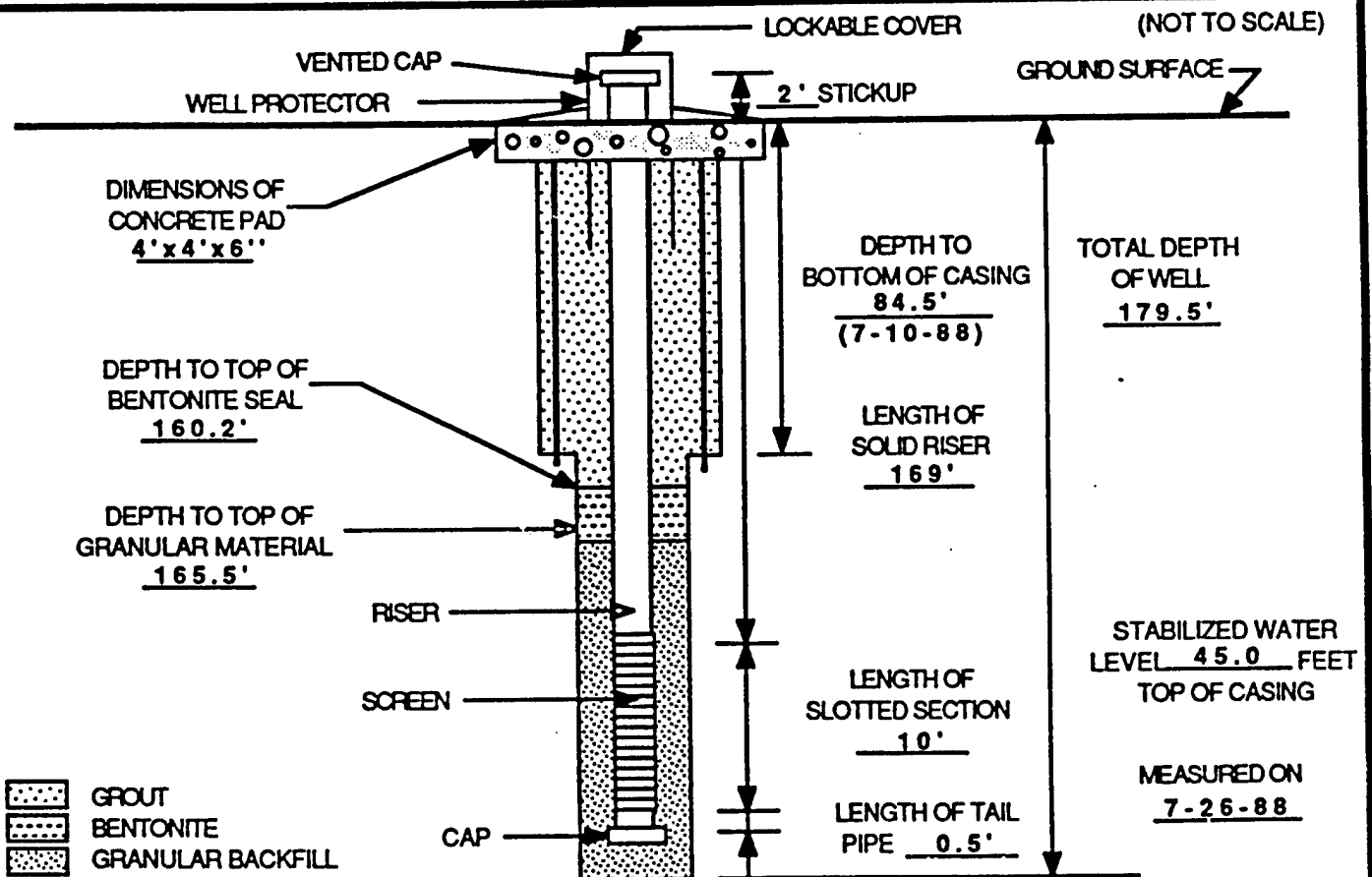
TYPE III MONITORING WELL INSTALLATION DIAGRAM

LAW ENVIRONMENTAL, INC.
GOVERNMENT SERVICES DIVISION
KENNESAW, GEORGIA

WELL NO. MW-106D
JOB NO. 11-8509-01
DATE 7-21-88 TIME 1600
WELL LOCATION SHAW AFB SITE 1, ADJACENT MW-106

GROUND SURFACE ELEVATION ~ 217.02'
TOP OF SCREEN ELEVATION 50.02'
REFERENCE POINT ELEVATION 219.02'
TYPE SAND PACK SC#89-M GRADATION GP
SAND PACK MANUFACTURER BECKER SAND & GRAVEL
SCREEN MATERIAL PVC-CONTINUOUS WRAP
MANUFACTURER JOHNSON
RISER MATERIAL PVC
MANUFACTURER BRAINARD KILMAN
RISER DIAMETER 2" ID
DRILLING TECHNIQUE (above casing) MUD ROTARY
BIT SIZE AND TYPE 9 7/8" TRICONE
DRILLING TECHNIQUE (below casing) MUD ROTARY
BIT SIZE AND TYPE 5 7/8" TRICONE

BENTONITE TYPE QUIK GEL
MANUFACTURER NL BAROID DIV.
CEMENT TYPE PORTLAND TYPE I
MANUFACTURER GIANT CEMENT CO.
BOREHOLE DIAMETER 10" OUTER, 6" INNER
SCREEN DIAMETER 2" ID SLOT SIZE 0.010
LAW ENVIRONMENTAL, INC.
FIELD REPRESENTATIVE MUNGIN-DAVIS, ZAUNER
DRILLING CONTRACTOR LAW ENGINEERING, INC.
AMOUNT BENTONITE USED 8 BAGS
AMOUNT CEMENT USED 26 BAGS
AMOUNT SAND USED 20 GALLONS
STATIC WATER DEPTH (after dev.) 46.14' (TOC)
TYPE OF CASING PVC - 6"



QA / QC

INSTALLED BY: C. IVEY INSTALLATION OBSERVED BY: QM-D
DISCREPANCIES: STICK UP 2' BEFORE INSTALLATION OF BLADDER PUMP

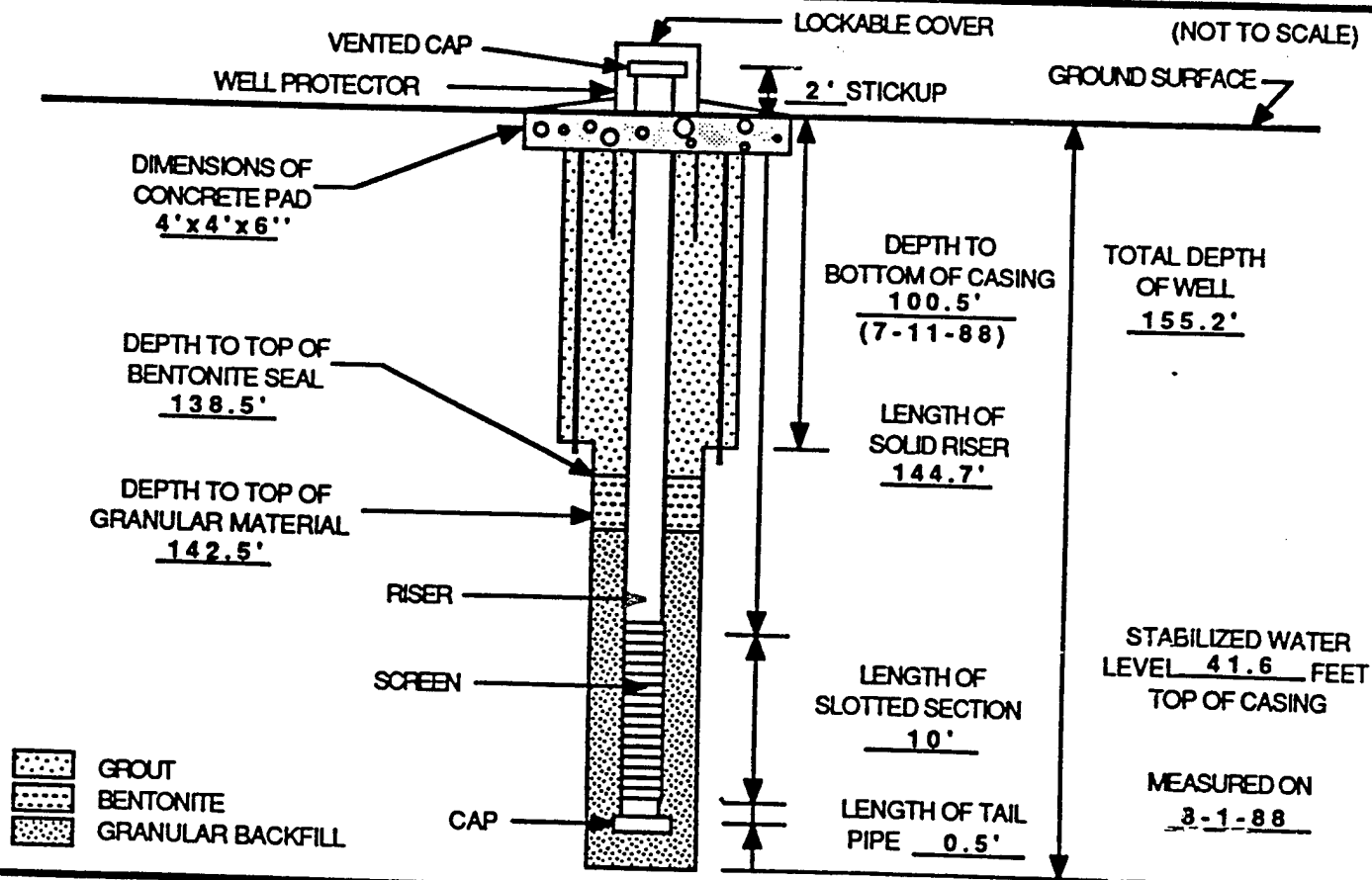
TYPE III MONITORING WELL INSTALLATION DIAGRAM

LAW ENVIRONMENTAL, INC.
GOVERNMENT SERVICES DIVISION
KENNESAW, GEORGIA

WELL NO. MW-112D
JOB NO. 11-8509-01
DATE 7-24-88 TIME 1145
WELL LOCATION SHAW AFB SITE 1, ADJACENT MW-112

GROUND SURFACE ELEVATION ~ 215.72'
TOP OF SCREEN ELEVATION 73.02'
REFERENCE POINT ELEVATION 217.72'
TYPE SAND PACK SC#89-M GRADATION GP
SAND PACK MANUFACTURER BECKER SAND & GRAVEL
SCREEN MATERIAL PVC-CONTINUOUS WRAP
MANUFACTURER JOHNSON
RISER MATERIAL PVC
MANUFACTURER BRAINARD KILMAN
RISER DIAMETER 2" ID
DRILLING TECHNIQUE (above casing) MUD ROTARY
BIT SIZE AND TYPE 9 7/8" TRICONE
DRILLING TECHNIQUE (below casing) MUD ROTARY
BIT SIZE AND TYPE 5 7/8" TRICONE

BENTONITE TYPE QUIK GEL
MANUFACTURER NL BAROID DIV.
CEMENT TYPE PORTLAND TYPE I
MANUFACTURER GIANT CEMENT CO.
BOREHOLE DIAMETER 10" OUTER, 6" INNER
SCREEN DIAMETER 2" ID SLOT SIZE 0.010
LAW ENVIRONMENTAL, INC.
FIELD REPRESENTATIVE MUNGIN-DAVIS, ZAUNER
DRILLING CONTRACTOR LAW ENGINEERING, INC.
AMOUNT BENTONITE USED 7 BAGS
AMOUNT CEMENT USED 29 BAGS
AMOUNT SAND USED 15 GALLONS
STATIC WATER DEPTH (after dev.) 44.09' (TOC)
TYPE OF CASING PVC - 6" & 10"

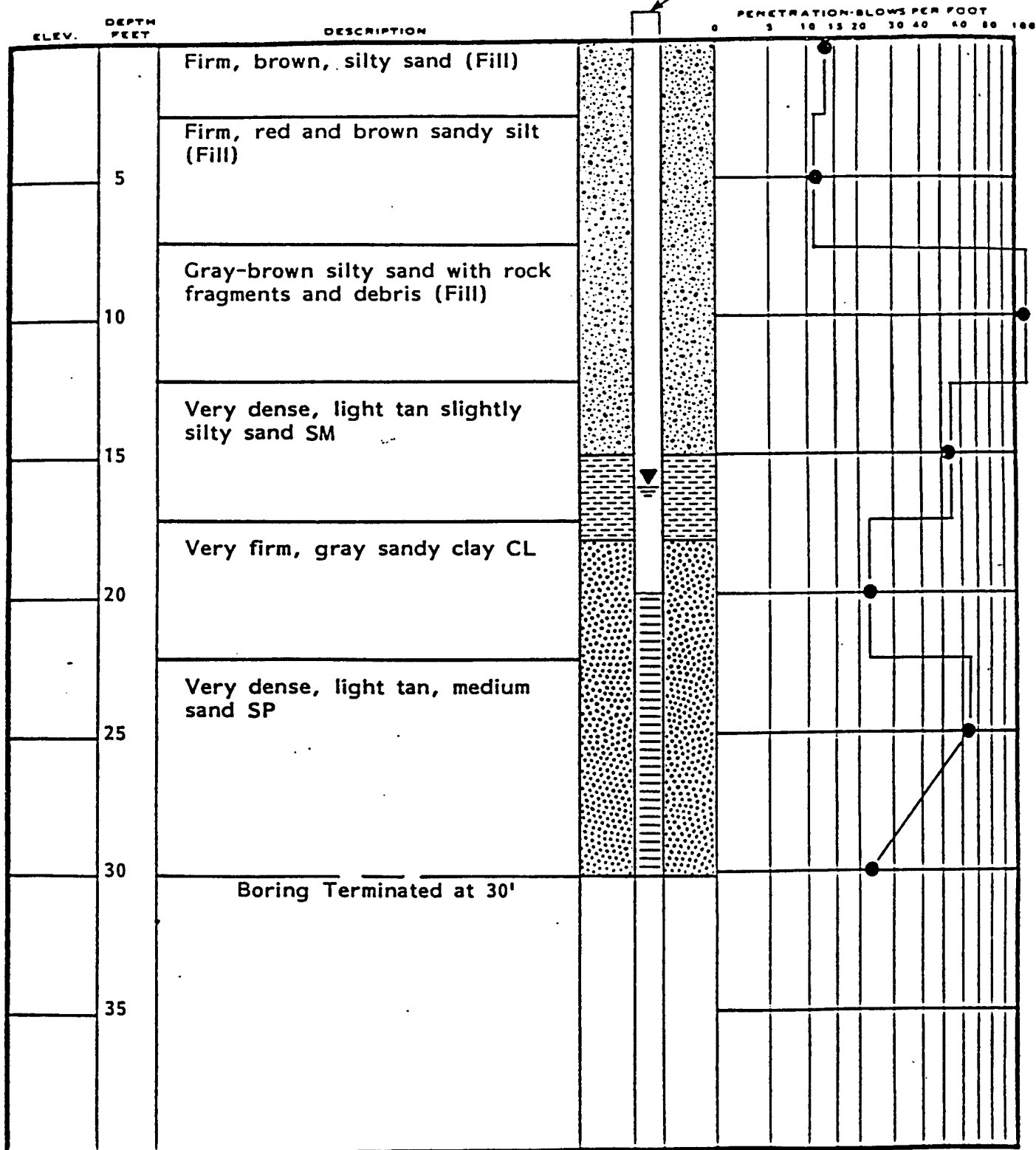


QA / QC

INSTALLED BY: C. IVEY INSTALLATION OBSERVED BY: QM-D
DISCREPANCIES: STICK UP 2' BEFORE INSTALLATION OF BLADDER PUMP

TEST BORING RECORD

2.5' Stick-up



REMARKS:

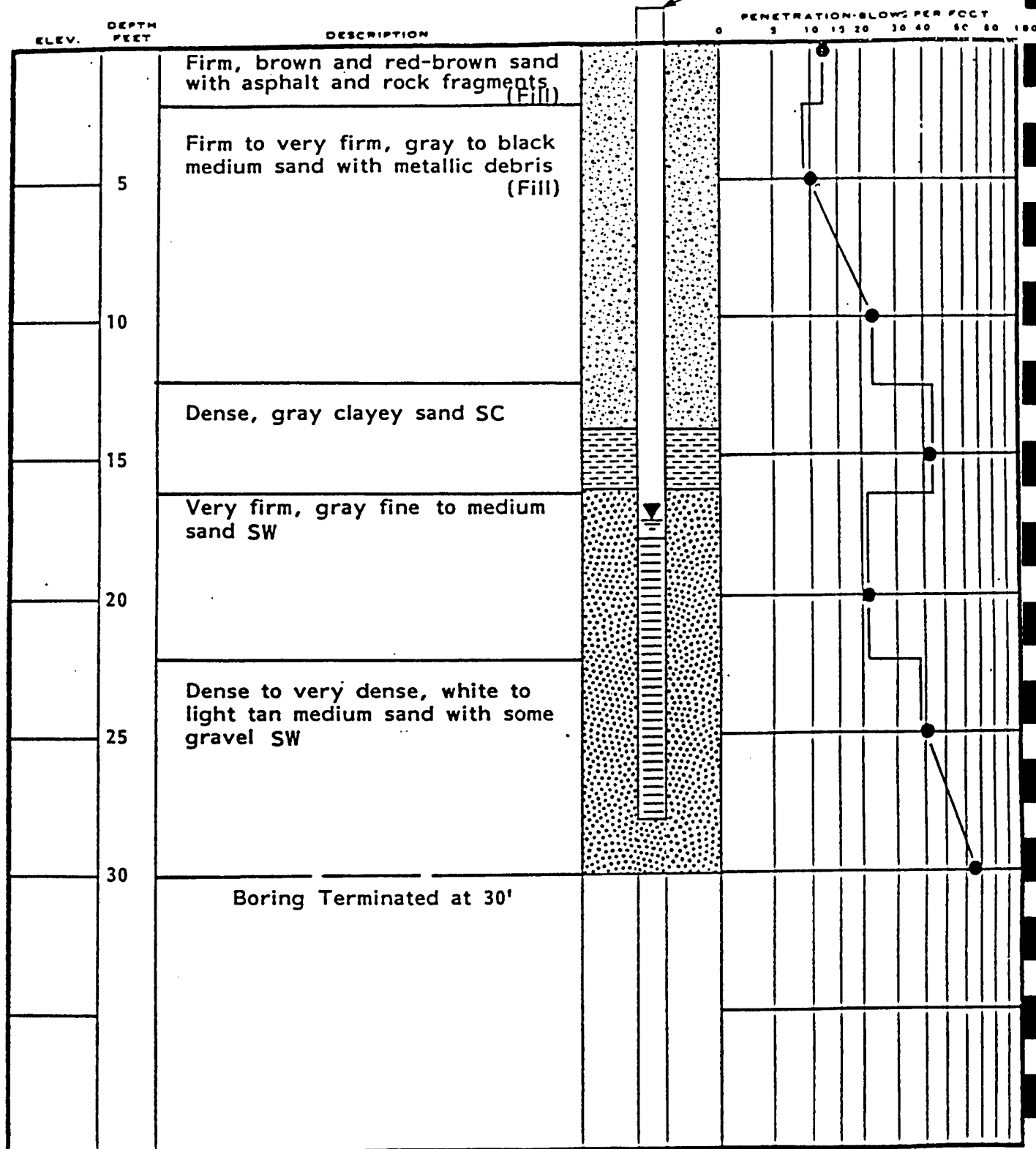
2" PVC casing

Elevation not surveyed

Water level measured 11/19/86

DRILLED BY R. BanksLOGGED BY M. Bond/BabcockCHECKED BY J. WilsonBORING NUMBER PZ-101DATE STARTED 11/8/86DATE COMPLETED 11/8/86JOB NUMBER 602-2

2' Stick-up



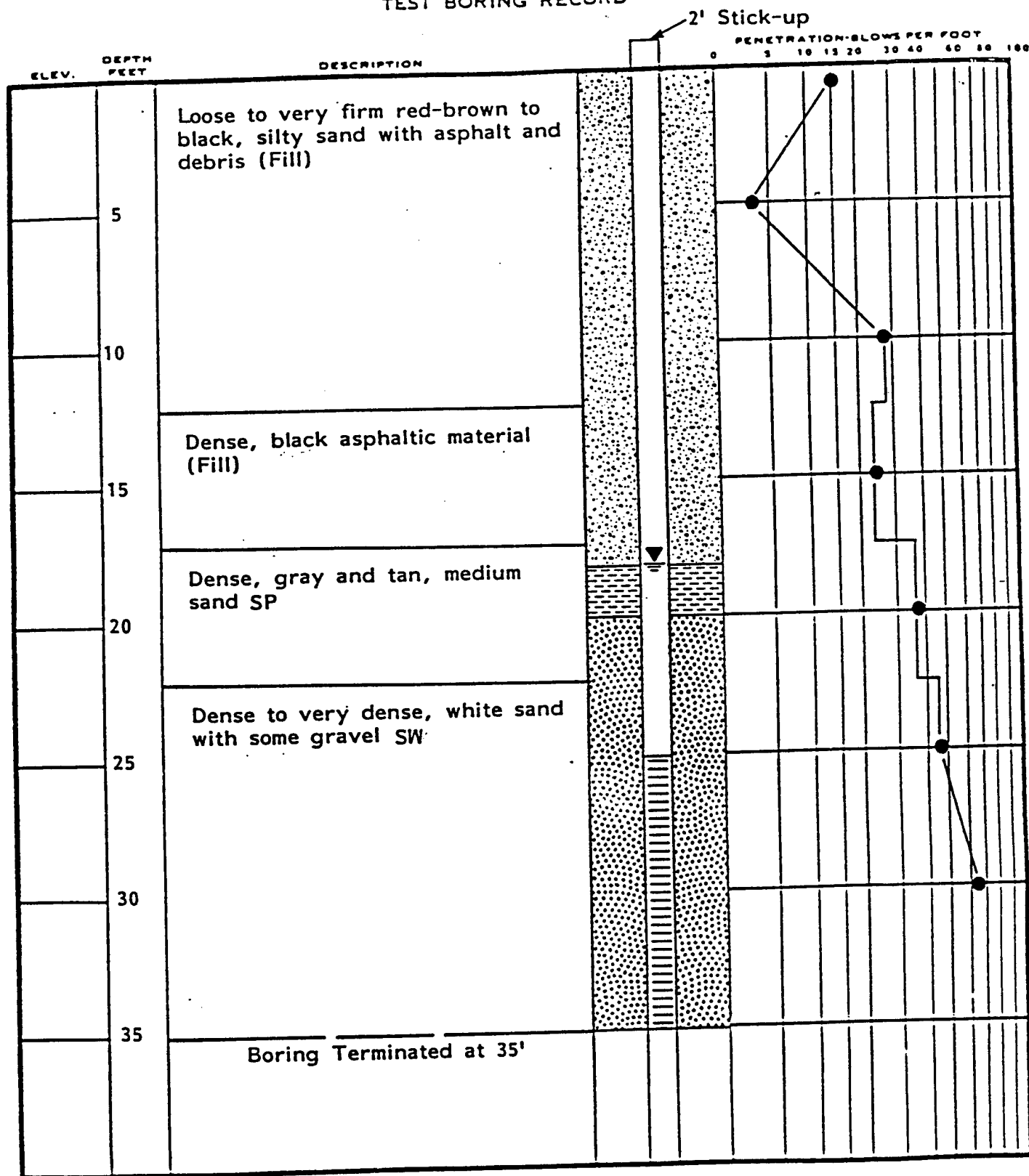
REMARKS:

2" PVC casing
Elevation not surveyed
Water level measured 11/19/86

DRILLED BY R. Banks
LOGGED BY M. Bond
CHECKED BY J. Wilson

BORING NUMBER PZ-102
DATE STARTED 11/11/86
DATE COMPLETED 11/11/86
JOB NUMBER 602-2

TEST BORING RECORD



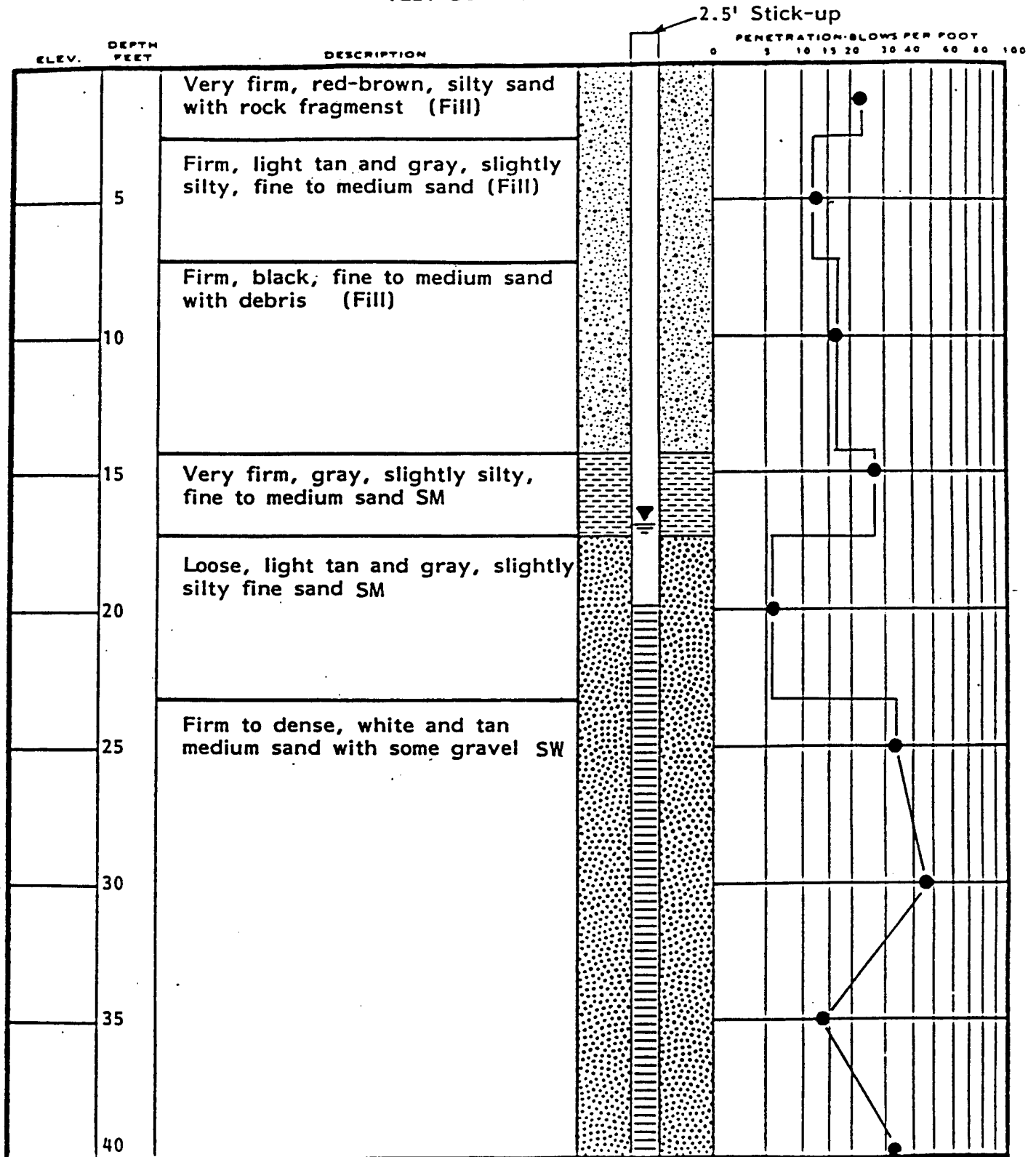
REMARKS:

2" PVC casing
Elevation not surveyed
Water level measured 11/19/86

DRILLED BY R. Banks
LOGGED BY M. Bond
CHECKED BY J. Wilson

BORING NUMBER PZ-103
DATE STARTED 11/11/87
DATE COMPLETED 11/11/87
JOB NUMBER 602-2

TEST BORING RECORD



REMARKS:

Sheet 1 of 2
 4" PVC casing
 Elevation not surveyed
 Water level measured 11/19/86

DRILLED BY R. Banks
 LOGGED BY M. Bond
 CHECKED BY J. Wilson

BORING NUMBER TW-101
 DATE STARTED 11/9/86
 DATE COMPLETED 11/9/86
 JOB NUMBER 602-2

[illegible][illegible]

Sheet 2 of 2

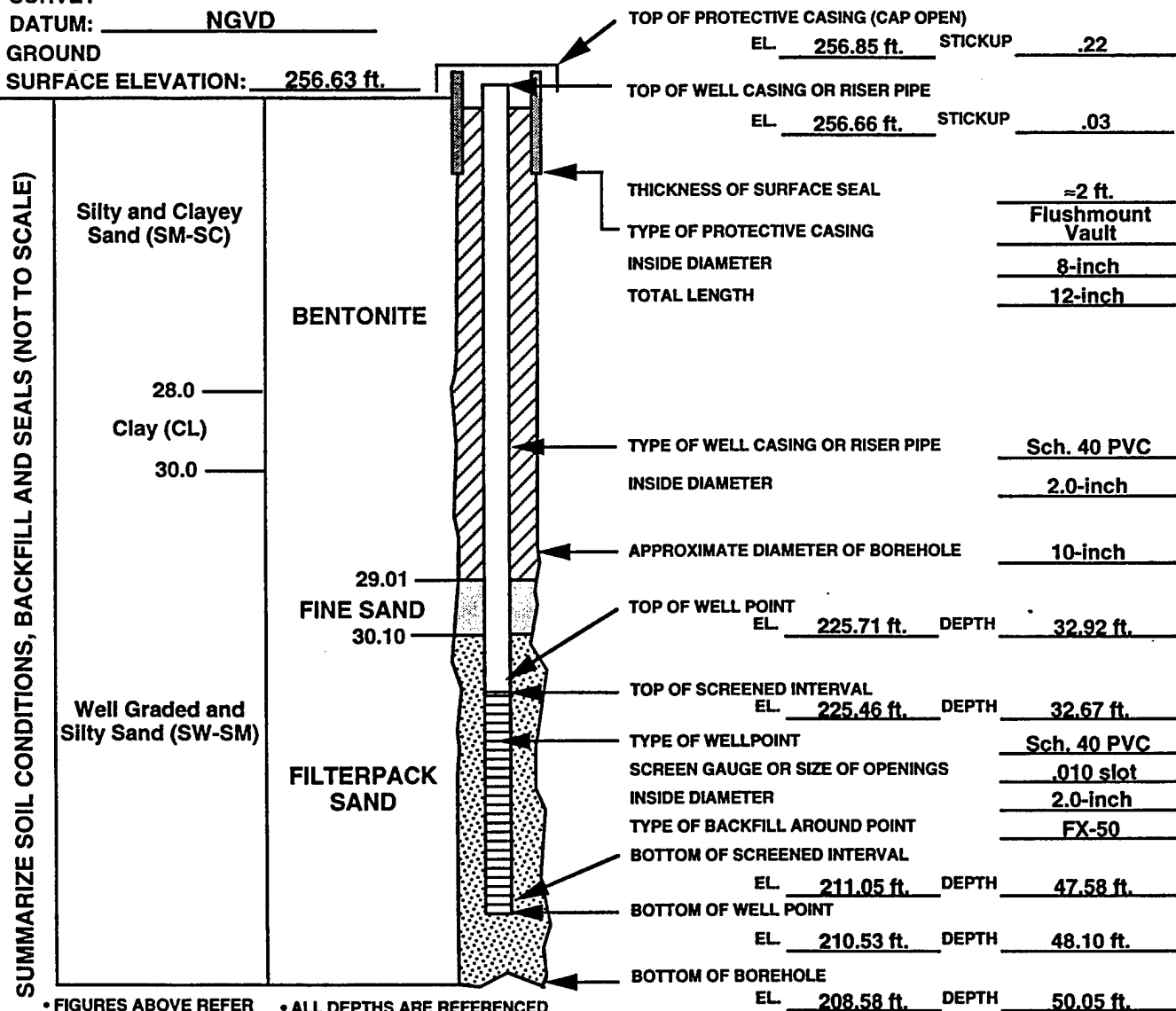
BORING NUMBER TW-101
DATE STARTED 11/9/86
DATE COMPLETED 11/9/86
JOB NUMBER 602-2

APPENDIX C

GROUND WATER MONITORING INSTALLATION DETAIL

PROJECT: <u>MULTI-SITES GROUP II EXPANDED ASSESSMENT</u>	JOB NO <u>87650.230</u>
LOCATION: <u>SAFB, SOUTH CAROLINA</u>	INSTALLATION NO <u>MW1613-1</u>
CLIENT: <u>US ARMY CORPS OF ENGINEERS</u>	TYPE OF INSTALLATION <u>2.0-IN. SCH. 40 PVC MONITORING WELL</u>
CONTRACTOR: <u>AE DRILLING</u>	BORING NO. <u>MW1613-1</u>
DRILLER: <u>T. HIGHTOWER</u> CERTIFICATION NO: <u>1088</u>	LOCATION <u>SEE SITE PLAN</u>
RUST FIELD REPRESENTATIVE: <u>B. E. CULP</u>	INSTALLATION DATE <u>6/7/94</u>

SURVEY
DATUM: NGVD
GROUND
SURFACE ELEVATION: 256.63 ft.



• FIGURES ABOVE REFER TO DEPTH IN FEET

• ALL DEPTHS ARE REFERENCED TO GROUND SURFACE

$$\begin{array}{rcl}
 \underline{32.92 \text{ ft.}} & + & \underline{15.18 \text{ ft.}} \\
 \text{LENGTH OF RISER PIPE} & & \text{LENGTH OF POINT} \\
 & = & \underline{48.10 \text{ ft.}} \\
 & & \text{TOTAL}
 \end{array}$$

BENTONITE SEALS



GROUND WATER MONITORING INSTALLATION DETAIL

PROJECT: <u>MULTI-SITES GROUP II EXPANDED ASSESSMENT</u>		JOB NO <u>87650.230</u>	
LOCATION: <u>SAFB, SOUTH CAROLINA</u>		INSTALLATION NO <u>MW1613-2</u>	
CLIENT: <u>US ARMY CORPS OF ENGINEERS</u>		TYPE OF INSTALLATION <u>2.0-IN. SCH. 40 PVC MONITORING WELL</u>	
CONTRACTOR: <u>AE DRILLING</u>		BORING NO. <u>MW1613-2</u>	
DRILLER: <u>T. HIGHTOWER</u> CERTIFICATION NO: <u>1088</u>		LOCATION <u>SEE SITE PLAN</u>	
RUST FIELD REPRESENTATIVE: <u>B. E. CULP</u>		INSTALLATION DATE <u>6/9/94</u>	

SURVEY DATUM: <u>NGVD</u>	
GROUND SURFACE ELEVATION: <u>256.37 ft.</u>	

SUMMARIZE SOIL CONDITIONS, BACKFILL AND SEALS (NOT TO SCALE)

The diagram shows a vertical cross-section of a monitoring well. From top to bottom, the layers are: Sandy Clay and Clayey Sand (CL-SC) with a thickness of 13.0 ft; Silty and Clayey Sands (SM-SC) with a thickness of 33.0 ft; Well Graded Sand (SW) with a thickness of 27.86 ft. The well casing is shown with a top of casing at elevation 256.41 ft and a top of well casing at elevation 256.20 ft. The casing has a thickness of surface seal of approximately 2 ft and is a flushmount vault with an 8-inch inside diameter and a total length of 12 inches. The well casing is made of Sch. 40 PVC with a 2.0-inch inside diameter. The approximate diameter of the borehole is 10 inches. The well point is at elevation 228.19 ft, with a depth of 28.18 ft. The screened interval is from elevation 227.96 ft to 213.65 ft, with a depth of 28.41 ft. The well point is made of Sch. 40 PVC with a screen gauge or size of openings of .010 slot and a 2.0-inch inside diameter. The backfill around the point is FX-50. The bottom of the screened interval is at elevation 213.65 ft, with a depth of 42.72 ft. The bottom of the well point is at elevation 213.03 ft, with a depth of 43.34 ft. The bottom of the borehole is at elevation 211.41 ft, with a depth of 45.0 ft.

• FIGURES ABOVE REFER TO DEPTH IN FEET • ALL DEPTHS ARE REFERENCED TO GROUND SURFACE	TOP OF PROTECTIVE CASING (CAP OPEN) EL. <u>256.41 ft.</u> STICKUP <u>.04</u> TOP OF WELL CASING OR RISER PIPE EL. <u>256.20 ft.</u> STICKUP <u>-.17</u> THICKNESS OF SURFACE SEAL <u>~2 ft.</u> TYPE OF PROTECTIVE CASING <u>Flushmount Vault</u> INSIDE DIAMETER <u>8-inch</u> TOTAL LENGTH <u>12-inch</u> TYPE OF WELL CASING OR RISER PIPE <u>Sch. 40 PVC</u> INSIDE DIAMETER <u>2.0-inch</u> APPROXIMATE DIAMETER OF BOREHOLE <u>10-inch</u> TOP OF WELL POINT EL. <u>228.19 ft.</u> DEPTH <u>28.18 ft.</u> TOP OF SCREENED INTERVAL EL. <u>227.96 ft.</u> DEPTH <u>28.41 ft.</u> TYPE OF WELLPOINT <u>Sch. 40 PVC</u> SCREEN GAUGE OR SIZE OF OPENINGS <u>.010 slot</u> INSIDE DIAMETER <u>2.0-inch</u> TYPE OF BACKFILL AROUND POINT <u>FX-50</u> BOTTOM OF SCREENED INTERVAL EL. <u>213.65 ft.</u> DEPTH <u>42.72 ft.</u> BOTTOM OF WELL POINT EL. <u>213.03 ft.</u> DEPTH <u>43.34 ft.</u> BOTTOM OF BOREHOLE EL. <u>211.41 ft.</u> DEPTH <u>45.0 ft.</u>
--	---

<u>27.86 ft.</u> LENGTH OF RISER PIPE	+	<u>15.31 ft.</u> LENGTH OF POINT	=	<u>43.17 ft.</u> TOTAL
				BENTONITE SEALS

GROUND WATER MONITORING INSTALLATION DETAIL

PROJECT: <u>MULTI-SITES GROUP II EXPANDED ASSESSMENT</u>		JOB NO <u>87650.230</u>	
LOCATION: <u>SAFB, SOUTH CAROLINA</u>		INSTALLATION NO <u>MW1613-3A</u>	
CLIENT: <u>US ARMY CORPS OF ENGINEERS</u>		TYPE OF INSTALLATION <u>2.0-IN. SCH.</u>	
CONTRACTOR: <u>AE DRILLING</u>		<u>40 PVC MONITORING WELL</u>	
DRILLER: <u>P. O'DONNELL</u> CERTIFICATION NO: <u>519</u>		BORING NO. <u>MW1613-3A</u>	
RUST FIELD REPRESENTATIVE: <u>B. E. CULP</u>		LOCATION <u>SEE SITE PLAN</u>	
		INSTALLATION DATE <u>6/2/94</u>	

SURVEY DATUM: <u>NGVD</u>	
GROUND SURFACE ELEVATION: <u>255.67 ft.</u>	

SUMMARIZE SOIL CONDITIONS, BACKFILL AND SEALS (NOT TO SCALE)

• FIGURES ABOVE REFER TO DEPTH IN FEET

• ALL DEPTHS ARE REFERENCED TO GROUND SURFACE

59.64 ft.	+	15.25 ft.	=	74.89 ft.
LENGTH OF RISER PIPE		LENGTH OF POINT		TOTAL

BENTONITE SEALS

GROUND WATER MONITORING INSTALLATION DETAIL

PROJECT: <u>MULTI-SITES GROUP II EXPANDED ASSESSMENT</u>		JOB NO <u>87650.230</u>	
LOCATION: <u>SAFB, SOUTH CAROLINA</u>		INSTALLATION NO <u>MW1613-4</u>	
CLIENT: <u>US ARMY CORPS OF ENGINEERS</u>		TYPE OF INSTALLATION <u>2.0-IN. SCH.</u>	
CONTRACTOR: <u>AE DRILLING</u>		<u>40 PVC MONITORING WELL</u>	
DRILLER: <u>T. HIGHTOWER</u> CERTIFICATION NO: <u>1088</u>		BORING NO. <u>MW1613-4</u>	
RUST FIELD REPRESENTATIVE: <u>B. E. CULP</u>		LOCATION <u>SEE SITE PLAN</u>	
		INSTALLATION DATE <u>6/8/94</u>	

SURVEY DATUM: <u>NGVD</u>	
GROUND SURFACE ELEVATION: <u>252.39 ft.</u>	

SUMMARIZE SOIL CONDITIONS, BACKFILL AND SEALS (NOT TO SCALE)	Clayey Sand and Sandy Clay (SC-CL)	7.0 ft.	BENTONITE	TOP OF PROTECTIVE CASING (CAP OPEN)	EL. <u>252.55 ft.</u>	STICKUP <u>.16</u>
				TOP OF WELL CASING OR RISER PIPE	EL. <u>252.29 ft.</u>	STICKUP <u>-0.10</u>
				THICKNESS OF SURFACE SEAL	<u>≈2 ft.</u>	
				TYPE OF PROTECTIVE CASING	<u>Flushmount Vault</u>	
				INSIDE DIAMETER	<u>8-inch</u>	
				TOTAL LENGTH	<u>12-inch</u>	
				TYPE OF WELL CASING OR RISER PIPE	<u>Sch. 40 PVC</u>	
				INSIDE DIAMETER	<u>2.0-inch</u>	
				APPROXIMATE DIAMETER OF BOREHOLE	<u>10-inch</u>	
				TOP OF WELL POINT	EL. <u>226.58 ft.</u>	DEPTH <u>25.81 ft.</u>
				TOP OF SCREENED INTERVAL	EL. <u>226.62 ft.</u>	DEPTH <u>25.77 ft.</u>
				TYPE OF WELLPOINT	<u>Sch. 40 PVC</u>	
				SCREEN GAUGE OR SIZE OF OPENINGS	<u>.010 slot</u>	
				INSIDE DIAMETER	<u>2.0-inch</u>	
				TYPE OF BACKFILL AROUND POINT	<u>FX-50</u>	
		BOTTOM OF SCREENED INTERVAL	EL. <u>211.92 ft.</u>	DEPTH <u>40.47 ft.</u>		
		BOTTOM OF WELL POINT	EL. <u>211.36 ft.</u>	DEPTH <u>41.03 ft.</u>		
		BOTTOM OF BOREHOLE	EL. <u>205.89 ft.</u>	DEPTH <u>46.50 ft.</u>		

• FIGURES ABOVE REFER TO DEPTH IN FEET	• ALL DEPTHS ARE REFERENCED TO GROUND SURFACE
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<u>25.71 ft.</u> LENGTH OF RISER PIPE	+	<u>15.22 ft.</u> LENGTH OF POINT	=	<u>40.93 ft.</u> TOTAL
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BENTONITE SEALS	
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GROUNDWATER MONITORING INSTALLATION DETAIL

PROJECT: <u>MULTI-SITES GROUP II EXPANDED ASSESSMENT</u>		JOB NO <u>87650.241</u>	
LOCATION: <u>SAFB, SOUTH CAROLINA</u>		INSTALLATION NO <u>MW1613-4A</u>	
CLIENT: <u>US ARMY CORPS OF ENGINEERS</u>		TYPE OF INSTALLATION <u>2-IN. SCH</u>	
CONTRACTOR: <u>AE DRILLING</u>		<u>40 PVC MONITORING WELL</u>	
DRILLER: <u>P. O'DONNELL</u> CERTIFICATION NO: <u>519</u>		BORING NO. <u>MW1613-4A</u>	
RUST E&I FIELD REPRESENTATIVE: <u>S. ZENGER</u>		LOCATION <u>SEE SITE PLAN</u>	
SURVEY DATUM: <u>NGVD</u>		INSTALLATION DATE <u>9/13/94</u>	

GROUND SURFACE ELEVATION: <u>252.65 ft.</u>		TOP OF PROTECTIVE CASING (CAP OPEN) EL. <u>252.65 ft.</u> STICKUP <u>0.0 ft.</u>	
		TOP OF WELL CASING OR RISER PIPE EL. <u>252.19 ft.</u> STICKUP <u>-0.46 ft.</u>	
		TYPE OF SURFACE SEAL <u>Concrete Pad</u> THICKNESS OF SURFACE SEAL <u>5.0 in.</u>	
		TYPE OF PROTECTIVE CASING <u>Flushmount Vault</u> INSIDE DIAMETER <u>8.0 in.</u> TOTAL LENGTH <u>12 in.</u>	
		APPROXIMATE DIAMETER OF BOREHOLE <u>8.0 in.</u>	
		TYPE OF WELL CASING OR RISER PIPE <u>Schedule 40 PVC</u> INSIDE DIAMETER <u>2.0 in.</u>	
		TOP OF WELL POINT EL. <u>192.64 ft.</u> DEPTH <u>60.01 ft.</u>	
		TYPE OF WELLPOINT <u>Continuous Slot PVC</u> SCREEN GAUGE OR SIZE OF OPENINGS <u>0.010 in.</u> INSIDE DIAMETER <u>2.0 in.</u>	
		TYPE OF BACKFILL AROUND POINT <u>FX -50</u> BOTTOM OF SCREENED INTERVAL EL. <u>183.05 ft.</u> DEPTH <u>69.45 ft.</u>	
		BOTTOM OF WELLPOINT EL. <u>182.65 ft.</u> DEPTH <u>70.0 ft.</u>	
		BOTTOM OF BOREHOLE EL. <u>180.65 ft.</u> DEPTH <u>72.0 ft.</u>	

SUMMARIZE SOIL CONDITIONS, BACKFILL AND SEALS (NOT TO SCALE)

Clayey Sand, Sandy Clay and Poorly Graded Sand (SC, CL, SP)	VOLCLAY® GROUT
30.0 ft.	
Poorly Graded Sand (SP)	
51.0 ft.	FINE SAND
56.0 ft.	57.9 ft.
Silty Sand (SM)	
59.0 ft.	FILTERPACK SAND
Interlayered Clay and Poorly Graded Sand (CL-SP)	

The diagram shows a vertical cross-section of the well. From top to bottom, it shows: a concrete pad at the surface, a flushmount vault casing, a riser pipe, and a wellpoint. The wellpoint is located 70.0 ft below the ground surface. The casing is 12 inches long. The riser pipe is 59.67 ft long. The wellpoint is 10.33 ft long. The total depth of the well is 72.0 ft. The well is surrounded by backfill (FX-50) and filterpack sand. The soil layers are: Clayey Sand, Sandy Clay and Poorly Graded Sand (SC, CL, SP) from 0 to 30.0 ft; Poorly Graded Sand (SP) from 30.0 to 51.0 ft; Silty Sand (SM) from 51.0 to 56.0 ft; and Interlayered Clay and Poorly Graded Sand (CL-SP) from 56.0 to 59.0 ft. The well is installed in the Silty Sand (SM) layer. The wellpoint is located in the Interlayered Clay and Poorly Graded Sand (CL-SP) layer. The wellpoint is 70.0 ft below the ground surface. The casing is 12 inches long. The riser pipe is 59.67 ft long. The wellpoint is 10.33 ft long. The total depth of the well is 72.0 ft. The well is surrounded by backfill (FX-50) and filterpack sand. The soil layers are: Clayey Sand, Sandy Clay and Poorly Graded Sand (SC, CL, SP) from 0 to 30.0 ft; Poorly Graded Sand (SP) from 30.0 to 51.0 ft; Silty Sand (SM) from 51.0 to 56.0 ft; and Interlayered Clay and Poorly Graded Sand (CL-SP) from 56.0 to 59.0 ft. The well is installed in the Silty Sand (SM) layer. The wellpoint is located in the Interlayered Clay and Poorly Graded Sand (CL-SP) layer. The wellpoint is 70.0 ft below the ground surface. The casing is 12 inches long. The riser pipe is 59.67 ft long. The wellpoint is 10.33 ft long. The total depth of the well is 72.0 ft. The well is surrounded by backfill (FX-50) and filterpack sand.

• FIGURES ABOVE REFER TO DEPTH IN FEET

• ALL DEPTHS ARE REFERENCED TO GROUND SURFACE

59.67 ft.	+ 10.33 ft.	= 70.0 ft.
LENGTH OF RISER PIPE	LENGTH OF POINT	TOTAL

VOLCLAY® GROUT	
FINE SAND	
FILTERPACK SAND	

GROUND WATER MONITORING INSTALLATION DETAIL

PROJECT: <u>MULTI-SITES GROUP II EXPANDED ASSESSMENT</u>		JOB NO <u>87650.230</u>	
LOCATION: <u>SAFB, SOUTH CAROLINA</u>		INSTALLATION NO <u>MW1613-5</u>	
CLIENT: <u>US ARMY CORPS OF ENGINEERS</u>		TYPE OF INSTALLATION <u>2.0-IN. SCH.</u>	
CONTRACTOR: <u>AE DRILLING</u>		<u>40 PVC MONITORING WELL</u>	
DRILLER: <u>L. REEVES</u> CERTIFICATION NO: <u>1055</u>		BORING NO. <u>MW1613-5</u>	
RUST FIELD REPRESENTATIVE: <u>B. E. CULP</u>		LOCATION <u>SEE SITE PLAN</u>	
SURVEY DATUM: <u>NGVD</u>		INSTALLATION DATE <u>6/15/94</u>	
GROUND SURFACE ELEVATION: <u>252.72 ft.</u>			

SUMMARIZE SOIL CONDITIONS, BACKFILL AND SEALS (NOT TO SCALE)	Clayey Sand and Sandy Clay (SC-CL) 9.0 ft.	BENTONITE	TOP OF PROTECTIVE CASING (CAP OPEN)	EL. <u>252.77 ft.</u> STICKUP <u>.05</u>		TOP OF WELL CASING OR RISER PIPE	EL. <u>252.42 ft.</u> STICKUP <u>-0.30</u>
				THICKNESS OF SURFACE SEAL		<u>=2 ft.</u>	
				TYPE OF PROTECTIVE CASING		<u>Flushmount Vault</u>	
				INSIDE DIAMETER		<u>8-inch</u>	
				TOTAL LENGTH		<u>12-inch</u>	
				TYPE OF WELL CASING OR RISER PIPE		<u>Sch. 40 PVC</u>	
				INSIDE DIAMETER		<u>2.0-inch</u>	
				APPROXIMATE DIAMETER OF BOREHOLE		<u>10-inch</u>	
				TOP OF WELL POINT		EL. <u>228.22 ft.</u> DEPTH <u>24.50 ft.</u>	
				TOP OF SCREENED INTERVAL		EL. <u>227.88 ft.</u> DEPTH <u>24.84 ft.</u>	
				TYPE OF WELLPOINT		<u>Sch. 40 PVC</u>	
				SCREEN GAUGE OR SIZE OF OPENINGS		<u>.010 slot</u>	
				INSIDE DIAMETER		<u>2.0-inch</u>	
				TYPE OF BACKFILL AROUND POINT		<u>FX-50</u>	
				BOTTOM OF SCREENED INTERVAL		EL. <u>212.89 ft.</u> DEPTH <u>39.83 ft.</u>	
		BOTTOM OF WELL POINT	EL. <u>212.20 ft.</u> DEPTH <u>40.52 ft.</u>				
		BOTTOM OF BOREHOLE	EL. <u>207.62 ft.</u> DEPTH <u>45.10 ft.</u>				

• FIGURES ABOVE REFER TO DEPTH IN FEET • ALL DEPTHS ARE REFERENCED TO GROUND SURFACE	<u>24.90 ft.</u> LENGTH OF RISER PIPE + <u>15.32 ft.</u> LENGTH OF POINT = <u>40.22 ft.</u> TOTAL BENTONITE SEALS
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GROUNDWATER MONITORING INSTALLATION DETAIL

PROJECT: <u>MULTI-SITES GROUP II EXPANDED ASSESSMENT</u>		JOB NO <u>87650.241</u>	
LOCATION: <u>SAFB, SOUTH CAROLINA</u>		INSTALLATION NO <u>MW1613-6</u>	
CLIENT: <u>US ARMY CORPS OF ENGINEERS</u>		TYPE OF INSTALLATION <u>2-IN. SCH</u>	
CONTRACTOR: <u>AE DRILLING</u>		<u>40 PVC MONITORING WELL</u>	
DRILLER: <u>M. KING</u> CERTIFICATION NO: <u>1089</u>		BORING NO. <u>MW1613-6</u>	
RUST E&I FIELD REPRESENTATIVE: <u>B. E. CULP</u>		LOCATION <u>SEE SITE PLAN</u>	
SURVEY DATUM: <u>NGVD</u>		INSTALLATION DATE <u>9/22/94</u>	

GROUND SURFACE ELEVATION: <u>265.72 ft.</u>		TOP OF PROTECTIVE CASING (CAP OPEN) EL. <u>265.72 ft.</u> STICKUP <u>0.0</u>	
		TOP OF WELL CASING OR RISER PIPE EL. <u>265.05 ft.</u> STICKUP <u>-0.67</u>	
		TYPE OF SURFACE SEAL <u>Concrete Pad</u>	
		THICKNESS OF SURFACE SEAL <u>5.0 in.</u>	
		TYPE OF PROTECTIVE CASING <u>Flushmount Vault</u>	
		INSIDE DIAMETER <u>8.0 in.</u>	
		TOTAL LENGTH <u>12.0 in.</u>	
		APPROXIMATE DIAMETER OF BOREHOLE <u>9.0 in.</u>	
		TYPE OF WELL CASING OR RISER PIPE <u>Sch. 40 PVC</u>	
		INSIDE DIAMETER <u>2.0 in.</u>	
		TOP OF WELL POINT EL. <u>235.56 ft.</u> DEPTH <u>30.16 ft.</u>	
		TYPE OF WELLPOINT <u>Continuous Slot PVC</u>	
		SCREEN GAUGE OR SIZE OF OPENINGS <u>0.010 in.</u>	
		INSIDE DIAMETER <u>2.0 in.</u>	
		TYPE OF BACKFILL AROUND POINT <u>FX -50</u>	
		BOTTOM OF SCREENED INTERVAL EL. <u>211.30 ft.</u> DEPTH <u>54.42 ft.</u>	
		BOTTOM OF WELLPOINT EL. <u>210.78 ft.</u> DEPTH <u>54.94 ft.</u>	
		BOTTOM OF BOREHOLE EL. <u>208.22 ft.</u> DEPTH <u>57.5 ft.</u>	

SUMMARIZE SOIL CONDITIONS, BACKFILL AND SEALS (NOT TO SCALE)

Clayey Sand and Clay and Sandy Clay (SC-CL)	BENTONITE HOLEPLUG
20.0 ft.	
Poorly Graded Sand (SP)	36.75 ft. FINE SAND
	38.42 ft.
48.0 ft.	FILTERPACK SAND
Well Graded Sand (SW)	

• FIGURES ABOVE REFER TO DEPTH IN FEET • ALL DEPTHS ARE REFERENCED TO GROUND SURFACE

<u>39.60 ft.</u> LENGTH OF RISER PIPE	+	<u>15.34 ft.</u> LENGTH OF POINT	=	<u>54.94 ft.</u> TOTAL
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BENTONITE SEALS	
FINE SAND	
FILTERPACK SAND	

GROUNDWATER MONITORING INSTALLATION DETAIL

PROJECT: <u>MULTI-SITES GROUP II EXPANDED ASSESSMENT</u>		JOB NO <u>87650.241</u>	
LOCATION: <u>SAFB, SOUTH CAROLINA</u>		INSTALLATION NO <u>MW1613-7</u>	
CLIENT: <u>US ARMY CORPS OF ENGINEERS</u>		TYPE OF INSTALLATION <u>2-IN. SCH</u>	
CONTRACTOR: <u>AE DRILLING</u>		<u>40 PVC MONITORING WELL</u>	
DRILLER: <u>M. KING</u> CERTIFICATION NO: <u>1089</u>		BORING NO. <u>MW1613-7</u>	
RUST E&I FIELD REPRESENTATIVE: <u>B. E. CULP</u>		LOCATION <u>SEE SITE PLAN</u>	
SURVEY DATUM: <u>NGVD</u>		INSTALLATION DATE <u>9/23/94</u>	

GROUND SURFACE ELEVATION: <u>253.07 ft.</u>		TOP OF PROTECTIVE CASING (CAP OPEN) EL. <u>253.07 ft.</u> STICKUP <u>0.0</u>	
		TOP OF WELL CASING OR RISER PIPE EL. <u>252.63 ft.</u> STICKUP <u>-0.44</u>	
		TYPE OF SURFACE SEAL <u>Concrete Pad</u>	
		THICKNESS OF SURFACE SEAL <u>5.0 in.</u>	
		TYPE OF PROTECTIVE CASING <u>Flushmount Vault</u>	
		INSIDE DIAMETER <u>8.0 in.</u>	
		TOTAL LENGTH <u>12.0 in.</u>	
		APPROXIMATE DIAMETER OF BOREHOLE <u>9.0 in.</u>	
		TYPE OF WELL CASING OR RISER PIPE <u>Sch. 40 PVC</u>	
		INSIDE DIAMETER <u>2.0 in.</u>	
		TOP OF WELL POINT EL. <u>226.86 ft.</u> DEPTH <u>26.21 ft.</u>	
		TYPE OF WELLPOINT <u>Continuous Slot PVC</u>	
		SCREEN GAUGE OR SIZE OF OPENINGS <u>0.010 in.</u>	
		INSIDE DIAMETER <u>2.0 in.</u>	
		TYPE OF BACKFILL AROUND POINT <u>FX-50</u>	
		BOTTOM OF SCREENED INTERVAL EL. <u>212.21 ft.</u> DEPTH <u>40.86 ft.</u>	
		BOTTOM OF WELLPOINT EL. <u>211.59 ft.</u> DEPTH <u>41.48 ft.</u>	
		BOTTOM OF BOREHOLE EL. <u>210.07 ft.</u> DEPTH <u>43.0 ft.</u>	

SUMMARIZE SOIL CONDITIONS, BACKFILL AND SEALS (NOT TO SCALE)	Sandy Clay 2.0 ft.	BENTONITE HOLEPLUG							
	Poorly Graded Sand (SP) 13.8 ft.								
	Clay (CL) 18.0 ft.								
	20.50 ft. FINE SAND 22.01 ft.								
	Poorly Graded Sand and Well Graded Sand (SP-SW)								
FILTERPACK SAND									

• FIGURES ABOVE REFER TO DEPTH IN FEET

• ALL DEPTHS ARE REFERENCED TO GROUND SURFACE

<u>26.12 ft.</u> LENGTH OF RISER PIPE	+	<u>15.36 ft.</u> LENGTH OF POINT	=	<u>41.48 ft.</u> TOTAL
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BENTONITE SEALS

GROUNDWATER MONITORING INSTALLATION DETAIL

PROJECT: <u>MULTI-SITES GROUP II EXPANDED ASSESSMENT</u>		JOB NO <u>87650.241</u>	
LOCATION: <u>SAFB, SOUTH CAROLINA</u>		INSTALLATION NO <u>MW1613-8</u>	
CLIENT: <u>US ARMY CORPS OF ENGINEERS</u>		TYPE OF INSTALLATION <u>2-IN. SCH</u>	
CONTRACTOR: <u>AE DRILLING</u>		<u>40 PVC MONITORING WELL</u>	
DRILLER: <u>M. KING</u> CERTIFICATION NO: <u>1089</u>		BORING NO. <u>MW1613-8</u>	
RUST E&I FIELD REPRESENTATIVE: <u>B. E. CULP</u>		LOCATION <u>SEE SITE PLAN</u>	
		INSTALLATION DATE <u>9/27/94</u>	

SURVEY DATUM: <u>NGVD</u>	
GROUND SURFACE ELEVATION: <u>253.82 ft.</u>	

SUMMARIZE SOIL CONDITIONS, BACKFILL AND SEALS (NOT TO SCALE)	Clayey Sand and Well Graded Sand (SC-SW)	BENTONITE HOLEPLUG		TOP OF PROTECTIVE CASING (CAP OPEN) EL. <u>253.82 ft.</u> STICKUP <u>0.0</u>	
	13.0 ft.			TOP OF WELL CASING OR RISER PIPE EL. <u>253.42 ft.</u> STICKUP <u>-0.40</u>	
	Silty Sand (SM)			TYPE OF SURFACE SEAL <u>Concrete Pad</u>	
	23.0 ft.			THICKNESS OF SURFACE SEAL <u>5.0 in.</u>	
	Clayey Sand and Clay with Sand (SC-CL)			TYPE OF PROTECTIVE CASING <u>Flushmount Vault</u>	
	22.14 ft. FINE SAND			INSIDE DIAMETER <u>8.0 in.</u>	
	23.21 ft.			TOTAL LENGTH <u>12.0 in.</u>	
	33.0 ft.			APPROXIMATE DIAMETER OF BOREHOLE <u>9.0 in.</u>	
	Poorly Graded Sand (SP)			TYPE OF WELL CASING OR RISER PIPE <u>Sch. 40 PVC</u>	
	22.14 ft.			INSIDE DIAMETER <u>2.0 in.</u>	
23.21 ft.		FILTERPACK SAND		TOP OF WELL POINT EL. <u>227.44 ft.</u> DEPTH <u>26.38 ft.</u>	
33.0 ft.				TYPE OF WELLPOINT <u>Continuous Slot PVC</u>	
Poorly Graded Sand (SP)				SCREEN GAUGE OR SIZE OF OPENINGS <u>0.010 in.</u>	
22.14 ft.				INSIDE DIAMETER <u>2.0 in.</u>	
23.21 ft.				TYPE OF BACKFILL AROUND POINT <u>FX-50</u>	
33.0 ft.		BOTTOM OF SCREENED INTERVAL EL. <u>212.85 ft.</u> DEPTH <u>40.97 ft.</u>			
Poorly Graded Sand (SP)		BOTTOM OF WELLPOINT EL. <u>212.27 ft.</u> DEPTH <u>41.55 ft.</u>			
22.14 ft.		BOTTOM OF BOREHOLE EL. <u>210.32 ft.</u> DEPTH <u>43.5 ft.</u>			
23.21 ft.					

• FIGURES ABOVE REFER TO DEPTH IN FEET

• ALL DEPTHS ARE REFERENCED TO GROUND SURFACE

26.32 ft.	+	15.32 ft.	=	41.55 ft.
LENGTH OF RISER PIPE		LENGTH OF POINT		TOTAL

BENTONITE SEALS

GROUNDWATER MONITORING INSTALLATION DETAIL

PROJECT: <u>MULTI-SITES GROUP II EXPANDED ASSESSMENT</u>		JOB NO <u>87650.241</u>	
LOCATION: <u>SAFB, SOUTH CAROLINA</u>		INSTALLATION NO <u>MW1613-9</u>	
CLIENT: <u>US ARMY CORPS OF ENGINEERS</u>		TYPE OF INSTALLATION <u>2-IN. SCH</u>	
CONTRACTOR: <u>AE DRILLING</u>		<u>40 PVC MONITORING WELL</u>	
DRILLER: <u>M. KING</u> CERTIFICATION NO: <u>1089</u>		BORING NO. <u>MW1613-9</u>	
RUST E&I FIELD REPRESENTATIVE: <u>B. E. CULP</u>		LOCATION <u>SEE SITE PLAN</u>	
SURVEY DATUM: <u>NGVD</u>		INSTALLATION DATE <u>9/26/94</u>	

GROUND SURFACE ELEVATION: <u>251.40 ft.</u>		TOP OF PROTECTIVE CASING (CAP OPEN) EL. <u>251.40 ft.</u> STICKUP <u>0.0</u>	
		TOP OF WELL CASING OR RISER PIPE EL. <u>250.90 ft.</u> STICKUP <u>-0.50</u>	
		TYPE OF SURFACE SEAL <u>Concrete Pad</u> THICKNESS OF SURFACE SEAL <u>5.0 in.</u>	
		TYPE OF PROTECTIVE CASING <u>Flushmount Vault</u> INSIDE DIAMETER <u>9.0 in.</u> TOTAL LENGTH <u>12.0 in.</u>	
		APPROXIMATE DIAMETER OF BOREHOLE <u>9.0 in.</u>	
		TYPE OF WELL CASING OR RISER PIPE <u>Sch. 40 PVC</u> INSIDE DIAMETER <u>2.0 in.</u>	
		TOP OF WELL POINT EL. <u>225.28 ft.</u> DEPTH <u>26.12 ft.</u>	
		TYPE OF WELLPOINT <u>Continuous Slot PVC</u> SCREEN GAUGE OR SIZE OF OPENINGS <u>0.010 in.</u> INSIDE DIAMETER <u>2.0 in.</u>	
		TYPE OF BACKFILL AROUND POINT <u>FX-50</u> BOTTOM OF SCREENED INTERVAL EL. <u>210.68 ft.</u> DEPTH <u>40.72 ft.</u>	
		BOTTOM OF WELLPOINT EL. <u>210.08 ft.</u> DEPTH <u>41.30 ft.</u>	
		BOTTOM OF BOREHOLE EL. <u>209.38 ft.</u> DEPTH <u>42.0 ft.</u>	

SUMMARIZE SOIL CONDITIONS, BACKFILL AND SEALS (NOT TO SCALE)

Silty Sand (SM) 2.0 ft.	BENTONITE HOLEPLUG
Clayey Sand (SC) 6.5 ft.	
Sandy Clay (CL) 11.0 ft.	
Silty Sand (SM) 25.3 ft.	
Sandy Clay and Clay (CL) 33.0 ft.	FINE SAND 21.75 ft. 22.80 ft.
Poorly Graded Sand (SP)	
FILTERPACK SAND	

• FIGURES ABOVE REFER TO DEPTH IN FEET

• ALL DEPTHS ARE REFERENCED TO GROUND SURFACE

25.49 ft.	+	15.31 ft.	=	40.80 ft.
LENGTH OF RISER PIPE		LENGTH OF POINT		TOTAL

BENTONITE SEALS

GROUNDWATER MONITORING INSTALLATION DETAIL (Flush Mount)

PROJECT: <u>Pre-Remedial Design Field Activities Bldg 706 & 1613</u>		JOB NO. <u>33822.200</u>	
LOCATION: <u>SAFB, South Carolina</u>		INSTALLATION NO. <u>MW1613-9A</u>	
CLIENT: <u>USACE</u>		TYPE OF INSTALLATION <u>2 inch Monitoring Well</u>	
CONTRACTOR: <u>AE Drilling</u>		BORING NO. <u>MW1613-9A</u>	
DRILLER: <u>D. Gentillucci</u> CERTIFICATION NO: <u>1189</u>		LOCATION <u>See Site Plan</u>	
RUST FIELD REPRESENTATIVE: <u>B. E. Culp</u>		INSTALLATION DATE <u>6/28/95</u>	

SURVEY DATUM: <u>NGVD</u>		GROUND SURFACE ELEVATION: <u>251.00 ft.</u>	
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SUMMARIZE SOIL CONDITIONS, BACKFILL AND SEALS (NOT TO SCALE)

2 ---	Silty sand (SM)		
6.5 ---	Clayey sand (SC)		
11.0 ---	Sandy clay		
25.3 ---	Silty sand (SM)		
33 ---	Sandy clay and clay (CL)		
40 ---	Poorly graded sand (SP)		
	Well graded sand with gravel		

TOP OF PROTECTIVE VAULT

INSIDE DIAMETER 8.00 in.

TYPE OF SURFACE SEAL Concrete Pad

THICKNESS OF SURFACE SEAL 12.00 in.

TOP OF WELL CASING OR RISER PIPE

EL. 250.88 ft. STICKUP -0.12 ft.

TYPE OF WELL CASING OR RISER PIPE SCH 40 PVC

INSIDE DIAMETER 2.00 in.

APPROXIMATE DIAMETER OF BOREHOLE 8.00 in.

TOP OF WELL POINT

EL. 196.43 ft. DEPTH 54.57 ft.

TYPE OF SCREEN Slotted Sch 40 PVC

SCREEN GAUGE OR SIZE OF OPENINGS 0.01 in.

INSIDE DIAMETER 2.00 in.

TYPE OF BACKFILL AROUND SCREEN FX-50

BOTTOM OF SCREENED INTERVAL

EL. 186.71 ft. DEPTH 64.29 ft.

BOTTOM OF WELL

EL. 186.08 ft. DEPTH 64.92 ft.

BOTTOM OF BOREHOLE

EL. 184.00 ft. DEPTH 67.00 ft.

*NOT TO SCALE

• FIGURES ABOVE REFER TO DEPTH IN FEET

• ALL DEPTHS ARE REFERENCED TO GROUND SURFACE

55.05 ft.	9.72 ft.	0.63 ft.	
LENGTH OF RISER PIPE	LENGTH OF SCREEN	LENGTH OF CAP/PLUG	
			= 65.40 ft.
			TOTAL

GROUT
FINE SAND
FILTER PACK
CONCRETE

GROUNDWATER MONITORING INSTALLATION DETAIL (Flush Mount)

PROJECT: Pre-Remedial Design Field Activities Bldg 706 & 1613		JOB NO. 33822 . 200	
LOCATION: SAFB, South Carolina		INSTALLATION NO. MW1613-10	
CLIENT: USACE		TYPE OF INSTALLATION 2 inch Monitoring Well	
CONTRACTOR: AE Drilling		BORING NO. MW1613-10	
DRILLER: K. Warren CERTIFICATION NO: 750		LOCATION See Site Plan	
RUST FIELD REPRESENTATIVE: T. Campbell		INSTALLATION DATE 7-6-95	

SURVEY DATUM: NGVD		TOP OF PROTECTIVE VAULT	
GROUND SURFACE ELEVATION: 264.79 ft.		INSIDE DIAMETER 8.00 in.	
		TYPE OF SURFACE SEAL Concrete Pad	
		THICKNESS OF SURFACE SEAL 12.00 in.	

SUMMARIZE SOIL CONDITIONS, BACKFILL AND SEALS (NOT TO SCALE)

10 ---	Silty sand (SM)
14 ---	Clayey sand (SC)
23 ---	Silty sand (SM)
28 ---	Sandy clay (CL)
Well graded sand (SW)	

TOP OF WELL CASING OR RISER PIPE	EL. 264.44 ft.	STICKUP	-0.35 ft.
TYPE OF WELL CASING OR RISER PIPE	SCH 40 PVC		
INSIDE DIAMETER	2.00 in.		
APPROXIMATE DIAMETER OF BOREHOLE	10.00 in.		
TOP OF WELL POINT	EL. 231.09 ft.	DEPTH	33.70 ft.
TYPE OF SCREEN	Slotted Sch 40 PVC		
SCREEN GAUGE OR SIZE OF OPENINGS	0.01 in.		
INSIDE DIAMETER	2.00 in.		
TYPE OF BACKFILL AROUND SCREEN	FX-50		
BOTTOM OF SCREENED INTERVAL	EL. 216.25 ft.	DEPTH	48.54 ft.
BOTTOM OF WELL	EL. 215.75 ft.	DEPTH	49.04 ft.
BOTTOM OF BOREHOLE	EL. 211.79 ft.	DEPTH	53.00 ft.

• FIGURES ABOVE REFER TO DEPTH IN FEET

• ALL DEPTHS ARE REFERENCED TO GROUND SURFACE

*NOT TO SCALE

$\frac{45.04 \text{ ft.}}{\text{LENGTH OF RISER PIPE}} + \frac{14.84 \text{ ft.}}{\text{LENGTH OF SCREEN}} + \frac{0.50 \text{ ft.}}{\text{LENGTH OF CAP/PLUG}} = \frac{60.38 \text{ ft.}}{\text{TOTAL}}$	GROUT FINE SAND FILTER PACK CONCRETE	
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GROUNDWATER MONITORING INSTALLATION DETAIL (Flush Mount)

PROJECT: <u>Pre-Remedial Design Field Activities Bldg 706 & 1613</u>		JOB NO. <u>33822.200</u>	
LOCATION: <u>SAFB, South Carolina</u>		INSTALLATION NO. <u>MW1613-11</u>	
CLIENT: <u>USACE</u>		TYPE OF INSTALLATION <u>2 inch Monitoring Well</u>	
CONTRACTOR: <u>AE Drilling</u>		BORING NO. <u>MW1613-11</u>	
DRILLER: <u>K. Warren</u> CERTIFICATION NO: <u>750</u>		LOCATION <u>See Site Plan</u>	
RUST FIELD REPRESENTATIVE: <u>T. Campbell</u>		INSTALLATION DATE <u>7-12-95</u>	

SURVEY DATUM: <u>NGVD</u>			
GROUND SURFACE ELEVATION: <u>253.47 ft.</u>			

SUMMARIZE SOIL CONDITIONS, BACKFILL AND SEALS (NOT TO SCALE)

Well graded sand with silt (SW-ML)		Bentonite Hole Plug	
10.00 ---			
Silty sand (SM)			
18.60 ---			
Sandy clay (SC)			
24.10 ---			
Well graded sand with clay (SW-CL)			
29 ---			
Poorly graded sand			

TOP OF PROTECTIVE VAULT

INSIDE DIAMETER 5.00 in.

TYPE OF SURFACE SEAL Concrete Pad

THICKNESS OF SURFACE SEAL 16.00 in.

TOP OF WELL CASING OR RISER PIPE
EL. 252.84 ft. **STICKUP** -0.63 ft.

TYPE OF WELL CASING OR RISER PIPE SCH 40 PVC

INSIDE DIAMETER 2.00 in.

APPROXIMATE DIAMETER OF BOREHOLE 8.00 in.

TOP OF WELL POINT
EL. 229.27 ft. **DEPTH** 24.20 ft.

TYPE OF SCREEN Slotted Sch 40 PVC

SCREEN GAUGE OR SIZE OF OPENINGS 0.01 in.

INSIDE DIAMETER 2.00 in.

TYPE OF BACKFILL AROUND SCREEN FX-50

BOTTOM OF SCREENED INTERVAL
EL. 214.52 ft. **DEPTH** 38.95 ft.

BOTTOM OF WELL
EL. 213.92 ft. **DEPTH** 39.55 ft.

BOTTOM OF BOREHOLE
EL. 210.47 ft. **DEPTH** 43.00 ft.

***NOT TO SCALE**

• FIGURES ABOVE REFER TO DEPTH IN FEET

• ALL DEPTHS ARE REFERENCED TO GROUND SURFACE

<u>35.04 ft.</u>	<u>14.75 ft.</u>	<u>0.60 ft.</u>	<u>50.39 ft.</u>
LENGTH OF RISER PIPE	LENGTH OF SCREEN	LENGTH OF CAP/PLUG	TOTAL

GROUT FINE SAND FILTER PACK CONCRETE

GROUNDWATER MONITORING INSTALLATION DETAIL (Flush Mount)

PROJECT: <u>Pre-Remedial Design Field Activities Bldg 706 & 1613</u>		JOB NO. <u>33822.200</u>	
LOCATION: <u>SAFB, South Carolina</u>		INSTALLATION NO. <u>MW1613-12</u>	
CLIENT: <u>USACE</u>		TYPE OF INSTALLATION <u>2 inch Monitoring Well</u>	
CONTRACTOR: <u>AE Drilling</u>		BORING NO. <u>MW1613-12</u>	
DRILLER: <u>K. Warren</u> CERTIFICATION NO: <u>750</u>		LOCATION <u>See Site Plan</u>	
RUST FIELD REPRESENTATIVE: <u>T. Campbell</u>		INSTALLATION DATE <u>6/29/95</u>	

SURVEY DATUM: <u>NGVD</u>		TOP OF PROTECTIVE VAULT	
GROUND SURFACE ELEVATION: <u>254.23 ft.</u>		INSIDE DIAMETER <u>8.00 in.</u>	
SUMMARIZE SOIL CONDITIONS, BACKFILL AND SEALS (NOT TO SCALE)		TYPE OF SURFACE SEAL <u>Concrete Pad</u>	
		THICKNESS OF SURFACE SEAL <u>12.00 in.</u>	
		TOP OF WELL CASING OR RISER PIPE	
		EL. 254.04 ft. STICKUP -0.19 ft.	
		TYPE OF WELL CASING OR RISER PIPE <u>SCH 40 PVC</u>	
		INSIDE DIAMETER <u>2.00 in.</u>	
		APPROXIMATE DIAMETER OF BOREHOLE <u>10.00 in.</u>	
		TOP OF WELL POINT	
		EL. 232.04 ft. DEPTH 22.19 ft.	
		TYPE OF SCREEN <u>Slotted Sch 40 PVC</u>	
SCREEN GAUGE OR SIZE OF OPENINGS <u>0.01 in.</u>			
INSIDE DIAMETER <u>2.00 in.</u>			
TYPE OF BACKFILL AROUND SCREEN <u>FX-50</u>			
BOTTOM OF SCREENED INTERVAL			
EL. 217.38 ft. DEPTH 36.85 ft.			
BOTTOM OF WELL			
EL. 216.68 ft. DEPTH 37.55 ft.			
BOTTOM OF BOREHOLE			
EL. 214.23 ft. DEPTH 40.00 ft.			

• FIGURES ABOVE REFER TO DEPTH IN FEET

• ALL DEPTHS ARE REFERENCED TO GROUND SURFACE

*NOT TO SCALE

$\frac{30.00 \text{ ft.}}{\text{LENGTH OF RISER PIPE}} + \frac{14.66 \text{ ft.}}{\text{LENGTH OF SCREEN}} + \frac{0.70 \text{ ft.}}{\text{LENGTH OF CAP/PLUG}} = \frac{45.36 \text{ ft.}}{\text{TOTAL}}$	GROUT FINE SAND FILTER PACK CONCRETE
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GROUNDWATER MONITORING INSTALLATION DETAIL (Flush Mount)

PROJECT: <u>Pre-Remedial Design Field Activities Bldg 706 & 1613</u>		JOB NO. <u>33822.200</u>	
LOCATION: <u>SAFB, South Carolina</u>		INSTALLATION NO. <u>MW1613-13</u>	
CLIENT: <u>USACE</u>		TYPE OF INSTALLATION <u>2.0 inch Monitoring Well</u>	
CONTRACTOR: <u>AE Drilling</u>		BORING NO. <u>MW1613-13</u>	
DRILLER: <u>K. Warren</u> CERTIFICATION NO: <u>750</u>		LOCATION <u>See Site Plan</u>	
RUST FIELD REPRESENTATIVE: <u>T. Campbell</u>		INSTALLATION DATE <u>6/28/95</u>	

SURVEY DATUM: <u>NGVD</u>		GROUND SURFACE ELEVATION: <u>251.88 ft.</u>	
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SUMMARIZE SOIL CONDITIONS, BACKFILL AND SEALS (NOT TO SCALE)

Sandy Clay (SC)	
2 --- Silty sand (SM)	
6 --- Well graded sand (SW)	
24 --- Sandy clay (CL)	
28 --- Well graded sand (SW)	
33 --- Sandy clay (CL)	

TOP OF PROTECTIVE VAULT	
INSIDE DIAMETER	<u>8.00 in.</u>
TYPE OF SURFACE SEAL	<u>Concrete Pad</u>
THICKNESS OF SURFACE SEAL	<u>12.00 in.</u>
TOP OF WELL CASING OR RISER PIPE	
EL. <u>251.20 ft.</u>	STICKUP <u>-0.68 ft.</u>
TYPE OF WELL CASING OR RISER PIPE	
INSIDE DIAMETER	<u>SCH 40 PVC 2.00 in.</u>
APPROXIMATE DIAMETER OF BOREHOLE	
<u>10.00 in.</u>	
TOP OF WELL POINT	
EL. <u>228.47 ft.</u>	DEPTH <u>23.41 ft.</u>
TYPE OF SCREEN	
<u>Slotted Sch 40 PVC</u>	
SCREEN GAUGE OR SIZE OF OPENINGS	
<u>0.01 in.</u>	
INSIDE DIAMETER	
<u>2.00 in.</u>	
TYPE OF BACKFILL AROUND SCREEN	
<u>FX-50</u>	
BOTTOM OF SCREENED INTERVAL	
EL. <u>213.77 ft.</u>	DEPTH <u>38.11 ft.</u>
BOTTOM OF WELL	
EL. <u>213.14 ft.</u>	DEPTH <u>38.74 ft.</u>
BOTTOM OF BOREHOLE	
EL. <u>209.88 ft.</u>	DEPTH <u>42.00 ft.</u>

• FIGURES ABOVE REFER TO DEPTH IN FEET • ALL DEPTHS ARE REFERENCED TO GROUND SURFACE

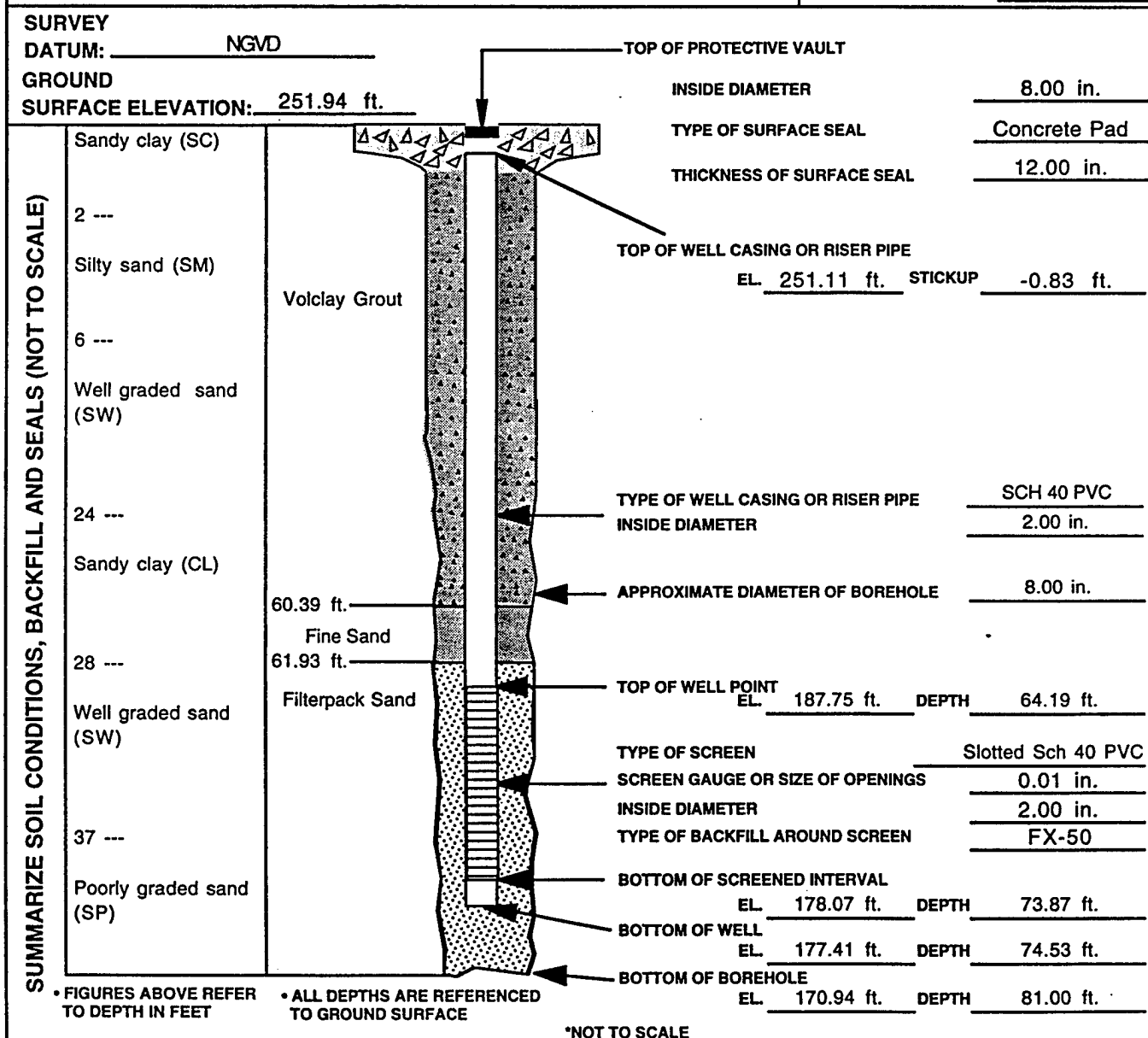
*NOT TO SCALE

<u>30.00 ft.</u> LENGTH OF RISER PIPE	<u>14.70 ft.</u> LENGTH OF SCREEN	<u>0.63 ft.</u> LENGTH OF CAP/PLUG
+ + +		
<u>45.33 ft.</u> TOTAL		

GROUT
FINE SAND
FILTER PACK
CONCRETE

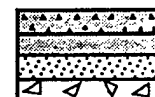
GROUNDWATER MONITORING INSTALLATION DETAIL (Flush Mount)

PROJECT: <u>Pre-Remedial Design Field Activities Bldg 706 & 1613</u>	JOB NO. <u>33822 . 200</u>
LOCATION: <u>SAFB, South Carolina</u>	INSTALLATION NO. <u>MW1613-13A</u>
CLIENT: <u>USACE</u>	TYPE OF INSTALLATION <u>2 .0 inch Monitoring Well</u>
CONTRACTOR: <u>AE Drilling</u>	BORING NO. <u>MW1613-13A</u>
DRILLER: <u>P. O'Donnell</u> CERTIFICATION NO: <u>519</u>	LOCATION <u>See Site Plan</u>
RUST FIELD REPRESENTATIVE: <u>B.E. Culp</u>	INSTALLATION DATE <u>7/26/95</u>



$$\frac{70.08 \text{ ft.}}{\text{LENGTH OF RISER PIPE}} + \frac{9.68 \text{ ft.}}{\text{LENGTH OF SCREEN}} + \frac{0.66 \text{ ft.}}{\text{LENGTH OF CAP/PLUG}} = \frac{80.42 \text{ ft.}}{\text{TOTAL}}$$

GROUT
 FINE SAND
 FILTER PACK
 CONCRETE



GROUNDWATER MONITORING INSTALLATION DETAIL (Flush Mount)

PROJECT: <u>Pre-Remedial Design Field Activities Bldg 706 & 1613</u>		JOB NO. <u>33822 . 200</u>	
LOCATION: <u>SAFB, South Carolina</u>		INSTALLATION NO. <u>MW1613-14</u>	
CLIENT: <u>USACE</u>		TYPE OF INSTALLATION <u>2.0 inch Monitoring Well</u>	
CONTRACTOR: <u>AE Drilling</u>		BORING NO. <u>MW1613-14</u>	
DRILLER: <u>K. Warren</u> CERTIFICATION NO: <u>750</u>		LOCATION <u>See Site Plan</u>	
RUST FIELD REPRESENTATIVE: <u>T. Campbell</u>		INSTALLATION DATE <u>7/14/95</u>	

SURVEY DATUM: <u>NGVD</u>		GROUND SURFACE ELEVATION: <u>251.63 ft.</u>	
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SUMMARIZE SOIL CONDITIONS, BACKFILL AND SEALS (NOT TO SCALE)

Silty Sand (SM) 3.5 Clayey Sandy (SC) and Sandy Clay (CL)	Bentonite Hole Plug
18.4 Silty Sand with Clay (SM-CL)	
23.0 Sandy Clay (CL)	20 ft. Fine Sand
28.0 Well Graded Sand (SW)	
34.4 Well Graded Sand With Clay (SW-CL)	
38 Interlayered Clay, Clay Sand And Poorly Graded Sand (CL-SC-SP)	Filterpack Sand

TOP OF PROTECTIVE VAULT

INSIDE DIAMETER 5.00 in.

TYPE OF SURFACE SEAL Concrete Pad

THICKNESS OF SURFACE SEAL 12.00 in.

TOP OF WELL CASING OR RISER PIPE
EL. 250.88 ft. **STICKUP** -0.75 ft.

TYPE OF WELL CASING OR RISER PIPE SCH 40 PVC

INSIDE DIAMETER 2.00 in.

APPROXIMATE DIAMETER OF BOREHOLE 10.00 in.

TOP OF WELL POINT
EL. 227.36 ft. **DEPTH** 24.27 ft.

TYPE OF SCREEN Slotted Sch 40 PVC

SCREEN GAUGE OR SIZE OF OPENINGS 0.01 in.

INSIDE DIAMETER 2.00 in.

TYPE OF BACKFILL AROUND SCREEN FX-50

BOTTOM OF SCREENED INTERVAL
EL. 212.63 ft. **DEPTH** 39.00 ft.

BOTTOM OF WELL
EL. 212.01 ft. **DEPTH** 39.62 ft.

BOTTOM OF BOREHOLE
EL. 208.63 ft. **DEPTH** 43.00 ft.

• FIGURES ABOVE REFER TO DEPTH IN FEET • ALL DEPTHS ARE REFERENCED TO GROUND SURFACE

*NOT TO SCALE

<u>30.01 ft.</u> LENGTH OF RISER PIPE	<u>14.73 ft.</u> LENGTH OF SCREEN	<u>0.62 ft.</u> LENGTH OF CAP/PLUG	= <u>45.36 ft.</u> TOTAL
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GROUT FINE SAND FILTER PACK CONCRETE	
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GROUNDWATER MONITORING INSTALLATION DETAIL (Flush Mount)

PROJECT: <u>Pre-Remedial Design Field Activities Bldg 706 & 1613</u>		JOB NO. <u>33822.200</u>	
LOCATION: <u>SAFB, South Carolina</u>		INSTALLATION NO. <u>MW1613-14A</u>	
CLIENT: <u>USACE</u>		TYPE OF INSTALLATION <u>2.0 inch Monitoring Well</u>	
CONTRACTOR: <u>AE Drilling</u>		BORING NO. <u>MW1613-14A</u>	
DRILLER: <u>P. O'Donnell</u> CERTIFICATION NO: <u>519</u>		LOCATION <u>See Site Plan</u>	
RUST FIELD REPRESENTATIVE: <u>B.E. Culp</u>		INSTALLATION DATE <u>6/21/95</u>	

SURVEY DATUM: <u>NGVD</u>		TOP OF PROTECTIVE VAULT	
GROUND SURFACE ELEVATION: <u>251.68 ft.</u>		INSIDE DIAMETER <u>12.00 in.</u>	
SUMMARIZE SOIL CONDITIONS, BACKFILL AND SEALS (NOT TO SCALE)		TYPE OF SURFACE SEAL <u>Concrete pad</u>	
		THICKNESS OF SURFACE SEAL <u>12.00 in.</u>	
		TOP OF WELL CASING OR RISER PIPE EL. <u>251.01 ft.</u> STICKUP <u>-0.67 ft.</u>	
		TYPE OF WELL CASING OR RISER PIPE <u>SCH 40 PVC</u>	
		INSIDE DIAMETER <u>2.00 in.</u>	
		APPROXIMATE DIAMETER OF BOREHOLE <u>8.00 in.</u>	
		TOP OF WELL POINT EL. <u>191.90 ft.</u> DEPTH <u>59.78 ft.</u>	
		TYPE OF SCREEN <u>Slotted Sch 40 PVC</u>	
		SCREEN GAUGE OR SIZE OF OPENINGS <u>0.01 in.</u>	
		INSIDE DIAMETER <u>2.00 in.</u>	
TYPE OF BACKFILL AROUND SCREEN <u>FX-50</u>			
BOTTOM OF SCREENED INTERVAL EL. <u>182.23 ft.</u> DEPTH <u>69.45 ft.</u>			
BOTTOM OF WELL EL. <u>181.56 ft.</u> DEPTH <u>70.12 ft.</u>			
BOTTOM OF BOREHOLE EL. <u>176.68 ft.</u> DEPTH <u>75.00 ft.</u>			

• FIGURES ABOVE REFER TO DEPTH IN FEET		• ALL DEPTHS ARE REFERENCED TO GROUND SURFACE	
*NOT TO SCALE			
$\frac{65.03 \text{ ft.}}{\text{LENGTH OF RISER PIPE}} + \frac{9.67 \text{ ft.}}{\text{LENGTH OF SCREEN}} + \frac{0.67 \text{ ft.}}{\text{LENGTH OF CAP/PLUG}} = \frac{75.37 \text{ ft.}}{\text{TOTAL}}$		GROUT FINE SAND FILTER PACK CONCRETE	

GROUNDWATER MONITORING INSTALLATION DETAIL (Flush Mount)

PROJECT: Pre-Remedial Design Field Activities Bldg 706 & 1613		JOB NO. 33822.200	
LOCATION: SAFB, South Carolina		INSTALLATION NO. MW1613-15	
CLIENT: USACE		TYPE OF INSTALLATION 2.0 inch Monitoring Well	
CONTRACTOR: AE Drilling		BORING NO. MW1613-15	
DRILLER: K. Warren CERTIFICATION NO: 750		LOCATION See Site Plan	
RUST FIELD REPRESENTATIVE: T. Campbell		INSTALLATION DATE 6/30/95	

SURVEY DATUM: NGVD		GROUND SURFACE ELEVATION: 251.51 ft.	
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SUMMARIZE SOIL CONDITIONS, BACKFILL AND SEALS (NOT TO SCALE)

Silty sand (SM)	10.4 ---						
Well graded sand (SP)	24.5 ---						
Clayey sand (SC)	33 ---						
Clay with sand (CL-SP)	38 ---						
Poorly graded sand (SP)							

TOP OF PROTECTIVE VAULT
 TOP OF WELL CASING OR RISER PIPE
 EL. 251.26 ft. STICKUP -0.25 ft.

INSIDE DIAMETER 8.00 in.
 TYPE OF SURFACE SEAL Concrete Pad
 THICKNESS OF SURFACE SEAL 12.00 in.

TYPE OF WELL CASING OR RISER PIPE SCH 40 PVC
 INSIDE DIAMETER 2.00 in.
 APPROXIMATE DIAMETER OF BOREHOLE 10.00 in.

TOP OF WELL POINT EL. 227.82 ft. DEPTH 23.69 ft.

TYPE OF SCREEN Slotted Sch 40 PVC
 SCREEN GAUGE OR SIZE OF OPENINGS 0.01 in.
 INSIDE DIAMETER 2.00 in.
 TYPE OF BACKFILL AROUND SCREEN FX-50

BOTTOM OF SCREENED INTERVAL EL. 213.13 ft. DEPTH 38.38 ft.

BOTTOM OF WELL EL. 212.48 ft. DEPTH 39.03 ft.

BOTTOM OF BOREHOLE EL. 209.01 ft. DEPTH 42.50 ft.

• FIGURES ABOVE REFER TO DEPTH IN FEET

• ALL DEPTHS ARE REFERENCED TO GROUND SURFACE

*NOT TO SCALE

$\frac{42.50 \text{ ft.}}{\text{LENGTH OF RISER PIPE}} + \frac{14.69 \text{ ft.}}{\text{LENGTH OF SCREEN}} + \frac{0.65 \text{ ft.}}{\text{LENGTH OF CAP/PLUG}} = \frac{57.84 \text{ ft.}}{\text{TOTAL}}$	GROUT FINE SAND FILTER PACK CONCRETE
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GROUNDWATER MONITORING INSTALLATION DETAIL (Flush Mount)

PROJECT: <u>Pre-Remedial Design Field Activities Bldg 706 & 1613</u>	JOB NO. <u>33822 . 200</u>
LOCATION: <u>SAFB, South Carolina</u>	INSTALLATION NO. <u>MW1613-15A</u>
CLIENT: <u>USACE</u>	TYPE OF INSTALLATION <u>2 inch Monitoring Well</u>
CONTRACTOR: <u>AE Drilling</u>	BORING NO. <u>MW1613-15A</u>
DRILLER: <u>P. O'Donnell</u> CERTIFICATION NO: <u>519</u>	LOCATION <u>See Site Plan</u>
RUST FIELD REPRESENTATIVE: <u>B.E. Culp</u>	INSTALLATION DATE <u>7/6/95</u>

SURVEY DATUM: <u>NGVD</u>		GROUND SURFACE ELEVATION: <u>251.50 ft.</u>			
SUMMARIZE SOIL CONDITIONS, BACKFILL AND SEALS (NOT TO SCALE)	Silt sand (SM)		TOP OF PROTECTIVE VAULT INSIDE DIAMETER <u>8.00 in.</u> TYPE OF SURFACE SEAL <u>Concrete pad</u> THICKNESS OF SURFACE SEAL <u>12.00 in.</u> TOP OF WELL CASING OR RISER PIPE EL <u>251.36 ft.</u> STICKUP <u>-0.14 ft.</u>		
	10.4 --- Well graded sand (SP)		TYPE OF WELL CASING OR RISER PIPE <u>SCH 40 PVC</u> INSIDE DIAMETER <u>2.00 in.</u>		
	24.5 --- Clayey sand (SC)		APPROXIMATE DIAMETER OF BOREHOLE <u>8.00 in.</u>		
	33 --- Clay with sand (CL-SP)		TOP OF WELL POINT EL <u>197.40 ft.</u> DEPTH <u>54.10 ft.</u>		
	38 --- Poorly graded sand with clay (SP-CL)		TYPE OF SCREEN <u>Slotted Sch 40 PVC</u> SCREEN GAUGE OR SIZE OF OPENINGS <u>0.01 in.</u> INSIDE DIAMETER <u>2.00 in.</u> TYPE OF BACKFILL AROUND SCREEN <u>FX-50</u>		
	50 ---		BOTTOM OF SCREENED INTERVAL EL <u>187.71 ft.</u> DEPTH <u>63.79 ft.</u>		
			BOTTOM OF WELL EL <u>187.06 ft.</u> DEPTH <u>64.44 ft.</u>		
			BOTTOM OF BOREHOLE EL <u>184.50 ft.</u> DEPTH <u>67.00 ft.</u>		
	* FIGURES ABOVE REFER TO DEPTH IN FEET		* ALL DEPTHS ARE REFERENCED TO GROUND SURFACE		
	*NOT TO SCALE				

$$\begin{array}{rclcl}
 \frac{60.03 \text{ ft.}}{\text{LENGTH OF RISER PIPE}} & + & \frac{9.69 \text{ ft.}}{\text{LENGTH OF SCREEN}} & + & \frac{0.65 \text{ ft.}}{\text{LENGTH OF CAP/PLUG}} & = & \frac{70.37 \text{ ft.}}{\text{TOTAL}}
 \end{array}$$

GROUT
 FINE SAND
 FILTER PACK
 CONCRETE



SUMMARY OF SVOCs IN GROUNDWATER
BUILDING 1613 SITE
DEMONSTRATION OF REMEDIATION BY NATURAL ATTENUATION
SHAW AFB, SOUTH CAROLINA

Sample ID	Date Collected	2,4-Dimethyl-phenol (mg/L)	bis(2-Ethyl-hexyl)phthalate (mg/L)	2-Methyl-naphthalene (mg/L)	4-Methyl-phenol (mg/L)	Acena-phthene (mg/L)	Di-n-butyl phthalate (mg/L)	Di-n-octyl phthalate (mg/L)	Fluor-anthene (mg/L)	Fluorene (mg/L)	Naphthalene (mg/L)	Phenanthrene (mg/L)	Phenol (mg/L)
MW1613-1	3/21/95	<10	10	13	<10	<10	<10	<10	<10	<10	17	<10	<10
	7/19/95	<10	11 K	10	<10	<10	<10	<10	<10	<10	19	<10	<10
	10/16/95	<10	8 J/K	18	<10	<10	<10	<10	<10	<10	34	<10	<10
	1/11/96	<10	12 K	<10	<10	<10	15 K	<10	<10	<10	<10	<10	<10
	4/4/96	<10	<10	16 M	<10	<10	<10	<10	<10	<10	33 M	<10	<10
MW1613-2	10/16/95	<10	10 K	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
	4/1/96	<10	8.5 J/M	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
MW1613-4	7/26/95	<40	<40	96	<40	<40 R	<40	<40	<40	<40	86	<40	<40
	10/17/95	<10	21 /KJI	160 /JI	<10	<10	<10	<10	<10	<10	140 J/I	<10	<10
	1/11/96	<10	<10	110	<10	<10	<10	<10	<10	<10	56	<10	<10
MW1613-4A	1/11/96	<10	9.8 J/K	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
MW1613-5	9/30/94	5.2 J	<10	58	<10	3.8 J	24 B/L	<10	3.1 J	<10	110	<10	22
	7/19/95	<10	<10	29	<10	<10	<10	<10	<10	<10	60	<10	<10
	10/17/95	<10	17 K	34	<10	<10	<10	10 K	<10	<10	76	<10	<10
	1/11/96	<10	<10	39	<10	<10	<10	<10	<10	<10	68	<10	9.7 J
	4/4/96	<10	<10	43 M	<10	<10	<10	<10	<10	<10	82 M	<10	<10
MW1613-7	12/15/94	<11	<11	29	<11	<11	<11	<11	<11	<11	18 &	<11	<11
	7/26/95	<20	<20	19 J/I	72 J/I	<20 R	<20	<20	<20	<20	32 J/I	<20	32 J/I
	10/17/95	<10	54 /KJI	98 J/I	<10	<10	<10	<10	<10	<10	75 J/I	<10	<10
	1/11/96	<20	38 K	190	<20	<20	<20	<20	<20	<20	70	<20	<20
	4/5/96	<10	8.5 J/K	120	<10	<10	<10	<10	<10	<10	47	<10	<10
MW1613-8	10/17/95	<10	<10	9.4 J	<10	<10	<10	<10	<10	<10	22	<10	<10
	1/11/96	<10	<10	12	<10	<10	<10	<10	<10	<10	19	<10	<10
	4/4/96	<10	<10	16 M	<10	<10	<10	<10	<10	<10	26 M	<10	<10
MW1613-9	1/8/96	<10	<10	7.6 J	<10	<10	<10	<10	<10	<10	5.9 J	<10	<10
	4/3/96	<10	<10	7.4 J	<10	<10	<10	<10	<10	<10	8 J	<10	<10

SUMMARY OF SVOCs IN GROUNDWATER
BUILDING 1613 SITE
DEMONSTRATION OF REMEDIATION BY NATURAL ATTENUATION
SHAW AFB, SOUTH CAROLINA

Sample ID	Date Collected	2,4-Dimethyl-phenol (mg/L)	bis(2-Ethyl-hexyl)phthalate (mg/L)	2-Methyl-naphthalene (mg/L)	4-Methyl-phenol (mg/L)	Acena-phthene (mg/L)	Di-n-butyl phthalate (mg/L)	Di-n-octyl phthalate (mg/L)	Fluor-anthene (mg/L)	Fluorene (mg/L)	Naphthalene (mg/L)	Phenanthrene (mg/L)	Phenol (mg/L)
MW1613-9A	10/16/95	<10	10 K	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
MW1613-11	7/21/95	<10	<10	55	<10	<10	<10	<10	<10	<10	85	<10	<10
	10/17/95	<10	<10	16	<10	<10	<10	<10	<10	<10	40	<10	<10
	1/11/96	<10	<10	36	<10	<10	<10	<10	<10	<10	52	<10	<10
MW1613-12	4/4/96	9.9 J/M	8.6 JKM	57 M	7.8 J/M	<10	<10	<10	<10	<10	65 M	10 M	<10
	7/21/95	<40	<40	340	<40	<40	<40	<40	<40	17 J	95	25 J	<40
	10/17/95	<20	<20	250 J/I	<20	<20	<20	<20	<20	26 J/I	81 J/I	64 J/I	<20
	1/11/96	<10	<10	89	<10	<10	<10	<10	<10	<10	26	<10	<10
MW1613-14	4/4/96	<10	<10	92 M	<10	<10	<10	<10	<10	<10	65 M	10 M	<10
	7/26/95	<10	<10	<10	<10	<10	29 K	<10	<10	<10	<10	<10	<10
MW1613-14A	7/26/95	<10	<10	<10	<10	<10	40 /KJI	<10	<10	<10	<10	<10	<10

B = Detected in method blank.

I = Recovery above upper limit due to sample matrix interference.

J = Estimated value less than quantitation limit.

K = _____ ?

M = Duplicate injection was not met.

& = Recovery outside of control limits.

APPENDIX D

MEMORANDUM

March 25, 1997

To: Mike Alcorn, Shaw AFB
From: Todd Herrington, Parsons ES *T.H.*
Subject: Proposed CPT/LIF push locations and monitoring points installation
locations for Building 1613 Site and Fire Training Area 01

I have prepared a draft write-up about the proposed CPT/LIF sampling locations at Building 1613 and Fire Training Area 1. This write-up includes figures and a table describing sampling locations and intervals at each site. The write-up, figures, and table should be enough information for you to obtain dig clearances and to arrange for appropriate potable water sources (for CPT tanks) and wastewater disposal facilities (waste water will be generated from the steam cleaning of CPT/LIF push rods) to be used during the field work. If you need information not contained in the sampling write-up, please call Mr. Dave Moutoux or myself at (303) 831-8100 or Ms. Cathy Older at the USACE in Kansas City at (816) 426-3553. Cathy is aware that you may have a need for additional information. Furthermore, Cathy mentioned that the CPT truck probably will not be available at Shaw AFB until Tuesday, April 1. This should still work well with the overall sampling schedule.

Overall, eight CPT/LIF push locations are proposed for the Building 1613 site at depths ranging from 0 to 60 feet bgs. Five CPT/LIF push locations at depths ranging from 0 to 25 feet bgs and 5 monitoring points screened across or below the water table are proposed for Fire Training Area 1. The monitoring points will be constructed of 0.5-inch to 1.0-inch ID PVC (depending on availability of materials). Because CPT/LIF is a direct push technology, no soil wastes should be generated during site investigation activities.

3/25/97

Page 1

PROPOSED FIELD WORK AT FIRE TRAINING AREA 1 AND BUILDING 1613

The objective of field work for the week of March 31, 1997 will be to explore for residual and mobile LNAPL hydrocarbon contamination using cone penetrometry (CPT) in conjunction with laser induced fluorescence (LIF) testing at the Building 1613 site and the Fire Training Area 1. In addition, monitoring points will be installed at Fire Training Area 1 with the CPT apparatus. Proposed sampling locations for CPT/LIF and monitoring point installation are shown on Figures 1 and 2. Table 1 lists sampling requirements for each site. The data to be collected as part of this field effort is intended to supplement a full-scale natural attenuation field study to be conducted in May 1997 by Parsons ES.

The following sections describe the procedures that will be followed when performing field investigations and collecting site-specific data.

1.1 CONE PENETROMETRY

Subsurface conditions at the site will be characterized using CPT coupled with LIF. Cone penetrometry is an expeditious and effective means of analyzing the stratigraphy of a site by measuring resistance against the conical probe of the penetrometer as it is pushed into the subsurface. Stratigraphy is determined from a correlation of the point stress at the probe tip and frictional stress on the side of the cone. Soil cores also are collected to correlate the CPT readings to the lithologies present at the site.

CPT will be conducted using the U.S. Army Corps of Engineers (USACE's) cone penetrometer truck. This equipment consists of an instrument probe that is forced into the ground using a hydraulic load frame mounted on a heavy truck, with the weight of the truck providing the necessary reaction mass. The penetrometer equipment is housed in a stainless steel, dual-compartment body mounted on a 43,000-pound, triple-axle Kenworth® truck chassis powered by a turbo-charged diesel engine. The weight of the truck and equipment is used as ballast to achieve the overall push capability of 39,000 pounds. This push capacity may be limited in tight soils by the structural bending capacity of the 1.40-inch outside-diameter (OD) push rods, rather than by the weight of the truck. The current 39,000-pound limitation is intended to minimize the possibility of push-rod buckling. Penetration force is supplied by a pair of large hydraulic cylinders bolted to the truck frame.

The penetrometer probe is of standard dimensions, having a 1.40-inch OD, a 60-degree conical point with sacrificial tip, and an 8.0-inch-long by 1.40-inch OD friction sleeve. Inside the probe, two load cells independently measure the vertical resistance against the conical tip and the side friction along the sleeve. Each load cell is a cylinder of uniform cross-section that is instrumented with four strain gauges in a full-bridge

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circuit. Forces are sensed by the load cells, and the data are transmitted from the probe assembly via a cable running through the push tubes. The analog data are digitized, recorded, and plotted by computer in the penetrometry truck. A grout tube also runs down the push cylinder to allow the emplacement of cement grout in order to seal the CPT hole. The USACE CPT is not equipped to monitor pore pressure; therefore, the location of the water table will not be measured using the CPT apparatus. However, evaluation of point and sleeve stresses can often provide an estimated depth to groundwater. The penetrometer is usually advanced vertically into the soil at a constant rate of 2 cm/s, although this rate must sometimes be reduced, such as when hard layers are encountered. Penetration, dissipation, and resistivity data will be used to determine lithologic layering as it is encountered in the field.

The known propensity of aromatic hydrocarbons to fluoresce under ultraviolet wavelengths has allowed the use of LIF technology, in conjunction with CPT technology, to detect soil characteristics and hydrocarbon contamination simultaneously. The LIF is not capable of detecting chlorinated solvents. The LIF is only useful for more grossly contaminated areas with mobile LNAPL or significant residual contamination concentrations. The lower range of detection is greater than 100 mg/kg total hydrocarbons. The LIF system has a 0.25-inch sapphire window in the side of the cone that allows a laser to scan the soil for fluorescent compounds as the LIF penetrometer rod pushes through soil. Assuming that aromatic hydrocarbons are simultaneously solvenated with other fuel-hydrocarbon constituents, the magnitude of aromatic fluorescence is indicative of hydrocarbon contamination in a soil matrix. Fiber optic cables connected to the laser spectrometer and a 6-pair electrical conductor connected to the CPT data acquisition system, are routed through the interior of the push tubes to the CPT probe.

The basic components of the LIF instrument are a nitrogen laser, a fiber optic probe, a monochromator for wavelength resolution of the return fluorescence, a photomultiplier tube to convert photons into an electrical signal, a digital oscilloscope for waveform capture, and a control computer. The fiber optic probe for the cone penetrometer consists of delivery and collection optical fibers, a protective sheath, a fiber optic mount within the cone, and a 0.25-inch sapphire window.

The results of each CPT/LIF push will be available 2 or 3 minutes after the completion of each hole. Graphs showing cone resistance, sleeve friction, soil classification, fluorescence intensity, and wavelength will be plotted by USACE personnel at the conclusion of each penetration and used, as necessary, to place monitoring points at Fire Training Area 1.

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1.1.1 CPT/LIF Testing Strategy

The purpose of the CPT/LIF testing at the site is to determine subsurface stratigraphy and to better define the areal and vertical extent of residual fuel hydrocarbons in the unsaturated zone and free-phase hydrocarbons in the site groundwater. The CPT will be pushed from ground surface to below fluorescing contamination, refusal, or up to 60 feet bgs, depending on contaminant distribution and subsurface conditions. In order to define the edges of mobile/residual LNAPL contamination, CPT/LIF points will be placed at the locations shown on Figures 1 and 2. The majority of the points will be used to tighten data gaps along fuel transfer lines at Building 1613 and in soils at Fire Training Area 1.

Base personnel will coordinate with the USACE to identify the location of all utility lines, USTs, fuel lines, and any other underground infrastructure prior to any CPT activities. All necessary digging permits will be obtained by Base and the USACE personnel prior to mobilizing to the field.

1.1.2 CPT Locations and Datum Survey

The horizontal location of all CPT/LIF testing locations will be flagged or marked with paint (as on asphalt). The distance of the CPT/LIF push and/or monitoring point to the nearest land feature (preferably an adjacent monitoring well) will be measured with a hand-held measuring tape to within 1 foot. A survey will be performed during May, 1997 field work to establish the actual coordinates to established Base coordinates.

1.1.3 Site Restoration

After sampling is complete, each CPT location will be restored as closely to its original condition as possible. Any test holes remaining open after extraction of the penetrometer rod will be sealed with hydrated bentonite chips, pellets, or grout to eliminate the creation or enhancement of contaminant migration pathways to the groundwater. Soil sampling using the CPT creates minor volumes of soil waste.

1.1.4 Equipment Decontamination Procedures

The CPT push rods will be cleaned with potable water using the USACE CPT steam-cleaning system (rod cleaner) as the rods are withdrawn from the ground. A vacuum system located beneath the CPT truck will be used to recover rinseate. Use of this system results in nearly 100-percent recovery of steam-cleaning rinseate from the rod cleaner. Rinseate is generated only as the rods move past the cleaner, thereby minimizing liquid waste generation. Care will be taken not to apply the pressurized steam to the LIF module, which will be decontaminated by hand. Rinseate will be collected in 55-gallon

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drums. USACE personnel will arrange for final disposal of the containerized rinseate with the Base.

Potable water to be used in CPT equipment cleaning, decontamination, or grouting will be obtained from one of the Base water supplies. Water use approval will be verified by contacting the appropriate facility personnel. Precautions will be taken to minimize any impact on the surrounding area that might result from decontamination operations.

1.2 PERMANENT MONITORING POINT INSTALLATION

Five groundwater monitoring points will be installed at Fire Training Area 1 to supplement the existing site monitoring wells. No monitoring points will be installed at Building 1613 during the field efforts conducted the week of March 31, 1997. The following sections describe the proposed monitoring point locations and completion intervals, monitoring point installation, monitoring point development, and equipment decontamination procedures.

1.2.1 Monitoring Point Locations and Completion Intervals

The locations of five proposed groundwater monitoring points are identified for Fire Training Area 1 on Figure 1. Proposed completion intervals are included on Table 1.

1.2.2 Monitoring Point Installation Procedures

This section describes the procedures to be used for installation of new groundwater monitoring points. All new monitoring points will be constructed of 0.75-inch OD/0.5-inch ID polyvinyl chloride (PVC) casing placed with a CPT pushrod using equipment described in Section 1.1.

1.2.2.1 Pre-Placement Activities

All necessary digging, drilling, and groundwater monitoring point installation permits will be obtained prior to mobilizing to the field. In addition, all utility lines will be located, and proposed drilling locations will be cleared prior to any intrusive activities. Responsibilities for these permits and clearances are discussed in Section 1.1.1.

Water to be used in monitoring point installation and equipment cleaning will be obtained from one of the Base water supplies. Water use approval will be verified by contacting the appropriate facility personnel. The field scientist will make the final determination as to the suitability of water for these activities.

1.2.2.2 Groundwater Monitoring Point Installation

1.2.2.2.1 Monitoring Point Materials Decontamination

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Monitoring point completion materials will be inspected by the field scientist and determined to be clean and acceptable prior to use. If not factory sealed, casing, screen, and casing plugs and caps will be cleaned prior to use with a high-pressure, steam/hot-water cleaner using approved water. Materials that cannot be cleaned to the satisfaction of the field scientist will not be used.

1.2.2.2.2 Monitoring Point Screen and Casing

Groundwater monitoring points will be installed by attaching 0.75-inch OD/0.5-inch ID PVC casing and screen to a sacrificial tip and threading the casing/screen through the penetrometer pushrod. As the pushrod is pressed into the ground, new 0.75-inch OD/0.5-inch ID PVC casing will be continuously attached until the desired depth is reached and a fully cased monitoring point is created. Data collection devices such as CPT and LIF will not be used during monitoring point placement; however, a CPT test will be performed at each monitoring point location prior to monitoring point placement in order to select desired screen depths.

Monitoring point casing and screens will be constructed of flush-threaded, Schedule 40 PVC. The screens will be factory slotted with 0.01-inch openings. Casing joints will not be glued. The PVC top cap for monitoring points completed at or below grade will not be vented in order to minimize the potential for surface water entering the point.

USACE personnel will verify and record the total depth of the monitoring point, the lengths of all casing sections, and the depth to the top of all monitoring point completion materials. All lengths and depths will be recorded to the nearest 0.1 foot.

1.2.2.3 Above-Grade and At-Grade Well Completion

Each monitoring point will be completed with an at-grade protective cover. In areas where pavement is present, the at-grade cover will be cemented in place using concrete blended to the existing pavement; otherwise, a concrete pad will be installed around the monitoring point. The concrete immediately surrounding the monitoring point will be sloped gently away from the protective casing to facilitate runoff during precipitation events.

1.2.3 Site Restoration

After monitoring point installation and sampling is complete, each site will be restored around the finished monitoring point as closely as possible to its original condition. Both clean and contaminated development waters and sampling purge waters will be stored in

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55-gallon drums or buckets. Development water will be disposed of as specified by Base personnel.

STARTING DATE: 04/25/95	DATE LAST REV: 6/19/96	DRAFT CHCK BY: K. WOOD	INITIATOR: K. CURTIS	DWG NO 7612
DRAWN BY: D. ACULAR	DRAWN BY: R. KNIGHT	ENGR CHCK BY: K. CURTIS	PROJ MGR: STURDEVANT	PROJ NO: 761

079 96:06 Dec. 31, 1996 KLM

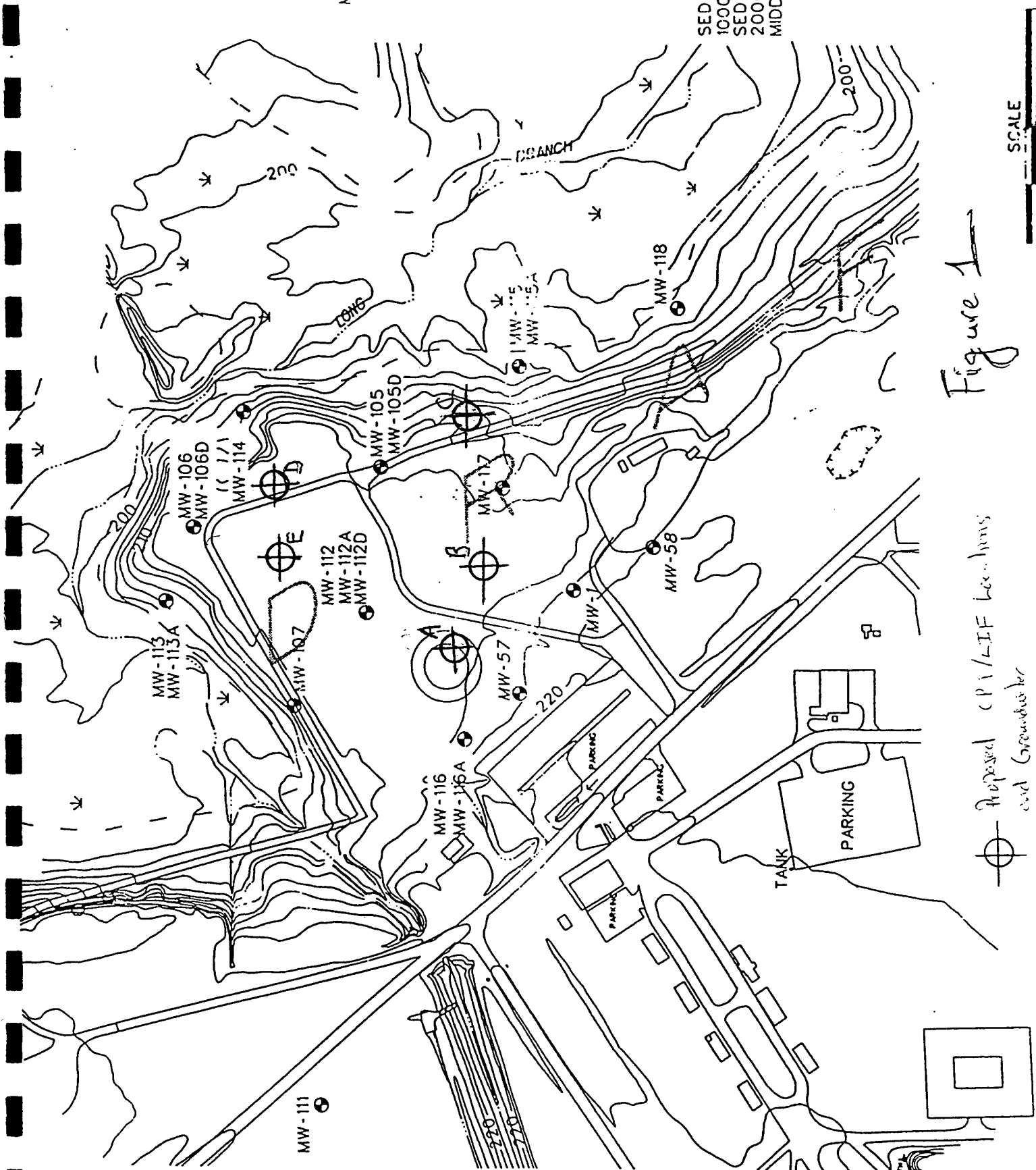
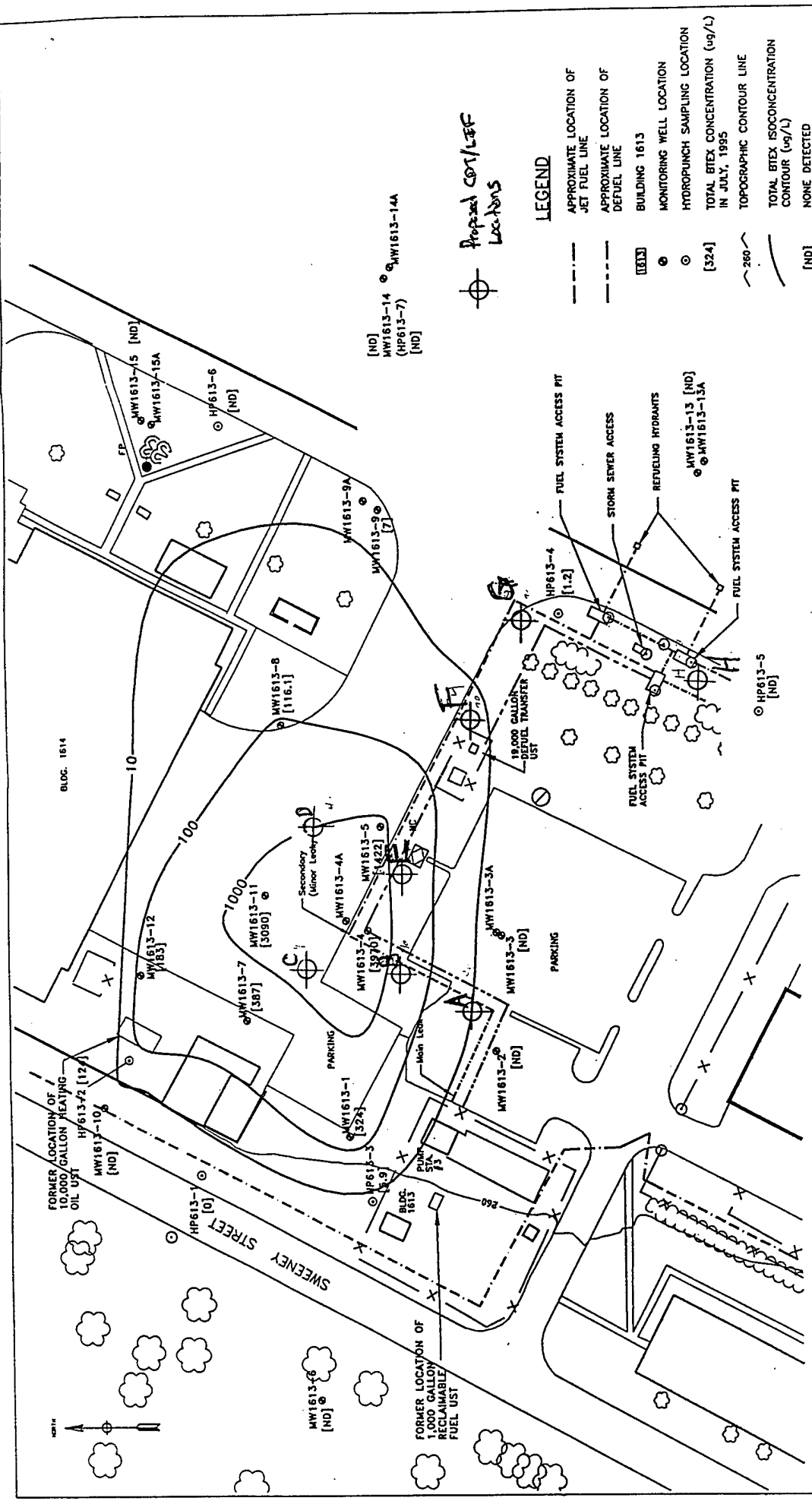


Figure 1

Proposed CP/LIF locations
and groundwater

SCALE



Proposed Cor/Lef Locations

LEGEND

- APPROXIMATE LOCATION OF JET FUEL LINE
- APPROXIMATE LOCATION OF DEFUEL LINE
- 1613 BUILDING 1613
- MONITORING WELL LOCATION
- HYDRANT PUNCH SAMPLING LOCATION
- [324] TOTAL BTX CONCENTRATION (ug/L) IN JULY, 1995
- ~ 250 TOPOGRAPHIC CONTOUR LINE
- TOTAL BTX ISOCONCENTRATION CONTOUR (ug/L)
- [ND] NONE DETECTED

[ND] MW1613-14
[ND] (HP613-7)
[ND] MW1613-14A

TOTAL BTX IN UPPER DUPLIN AQUIFER
JULY 1995
BUILDING 1613 SITE
MULTI-SITES GROUP II
SAFB, SOUTH CAROLINA
N:\87650\7650HG76.DWG 09/25/95

RUST ENVIRONMENT & INFRASTRUCTURE

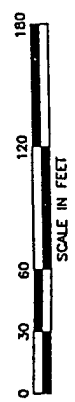


TABLE 1
PROPOSED SAMPLING LOCATIONS AND CRITERIA FOR
FIRE TRAINING AREA 01 AND BUILDING 1613 SITE

MARCH 31 - APRIL 4, 1997

Site	Proposed Location	Proposed Screen Length	~ Top of Screen	~ Bottom of Screen	Collect CPT/LIF Data?	Install Monitoring Point?	Reason For Location/Installation Notes
Fire Training Area 01	A	10 feet	8 feet bgs	18 feet bgs	Yes	Yes	Collect groundwater data from suspected source area. Screen the 10' monitoring point across the water table. Add an additional 5' of screen if CPT logs suggests that silts or clays exist that might inhibit development and sampling of the point.
Fire Training Area 01	B	10 feet	8 feet bgs	18 feet bgs	Yes	Yes	Collect downgradient groundwater data that is important biodegradation rate estimation. Screen the 10' monitoring point across the water table. Add an additional 5' of screen if CPT logs suggests that many silts or clays exist that might inhibit development and sampling of the point.

TABLE 1
PROPOSED SAMPLING LOCATIONS AND CRITERIA FOR
FIRE TRAINING AREA 01 AND BUILDING 1613 SITE (Continued)

MARCH 31 - APRIL 4, 1997

Site	Proposed Location	Proposed Screen Length	~Top of Screen	~Bottom of Screen	Collect CPT/LIF Data?	Install Monitoring Point?	Reason For Location/Installation Notes
Fire Training Area 01	C	10 feet	4 feet bgs	14 feet bgs	Yes	Yes	Collect groundwater data point near the plume front. The vertical location of screen should be placed in the most permeable section of the upper surface of the aquifer as based on CPT logs. Top of screen should be placed as near to the water table as possible, although is not necessary to screen above the water table at this point.
Fire Training Area 01	D	10 feet	13 feet bgs	23 feet bgs	Yes	Yes	SAA
Fire Training Area 01	E	10 feet	13 feet bgs	23 feet bgs	Yes	Yes	SAA
Building 1613 Site	A	NA	NA	NA	Yes	No	Collect CPT/LIF data from surface to approximately 5 feet below the water table to monitor for mobile and residual LNAPL. Therefore, push depth should be approximately 0 to 40 feet bgs. Adjust depth of CPT/LIF push, as necessary to make it to 5 feet below the water table.

TABLE 1
PROPOSED SAMPLING LOCATIONS AND CRITERIA FOR
FIRE TRAINING AREA 01 AND BUILDING 1613 SITE (Continued)

MARCH 31 - APRIL 4, 1997

Site	Proposed Location	Proposed Screen Length	~Top of Screen	~Bottom of Screen	Collect CPT/LIF Data?	Install Monitoring Point?	Reason For Location/Installation Notes
Building 1613 Site	B	NA	NA	NA	Yes	No	Collect CPT/LIF data from surface to the top of the lower confining clay layer. These pushes will help monitor for mobile and residual LNAPL in vadose zone and for any unusual stratigraphy that may be causing large groundwater elevation discrepancies (as observed in nested wells at MW1613-3 and MW1613-4). Therefore, the CPT/LIF push depth should be from ground surface to the lower confining clay layer (approximately 0 to 60 feet bgs). Do not push through the lower sawdust landing member of the black mingo formation which is comprised of clay or clay with poorly graded sand.
Building 1613 Site	C	NA	NA	NA	Yes	No	Collect CPT/LIF data from surface to approximately 10 feet bgs to monitor for mobile and residual LNAPL. Therefore, push depth should be approximately 0 to 40 feet bgs. Adjust depth of CPT/LIF push, as necessary to make it to 5 feet below the water table.

TABLE 1
PROPOSED SAMPLING LOCATIONS AND CRITERIA FOR
FIRE TRAINING AREA 01 AND BUILDING 1613 SITE (Continued)

MARCH 31 - APRIL 4, 1997

Site	Proposed Location	Proposed Screen Length	~Top of Screen	~Bottom of Screen	Collect CPT/LIF Data?	Install Monitoring Point?	Reason For Location/Installation Notes
Building 1613 Site	D	NA	NA	NA	Yes	No	SAA
Building 1613 Site	E	NA	NA	NA	Yes	No	Collect CPT/LIF data from surface to the top of the lower confining clay layer. These pushes will help monitor for mobile and residual LNAPL in vadose zone and for any unusual stratigraphy that may be causing large groundwater elevation discrepancies (as observed in nested wells at MW1613-3 and MW1613-4). Therefore, the CPT/LIF push depth should be from ground surface to the lower confining clay layer (approximately 0 to 60 feet bgs). Do not push through the lower sawdust landing member of the black mingo formation which is comprised of clay or clay with poorly graded sand.
Building 1613 Site	F	NA	NA	NA	Yes	No	SAA

TABLE 1
PROPOSED SAMPLING LOCATIONS AND CRITERIA FOR
FIRE TRAINING AREA 01 AND BUILDING 1613 SITE (Concluded)

MARCH 31 - APRIL 4, 1997

Site	Proposed Location	Proposed Screen Length	~Top of Screen	~Bottom of Screen	Collect CPT/LIF Data?	Install Monitoring Point?	Reason For Location/Installation Notes
Building 1613 Site	G	NA	NA	NA	Yes	No	NOTE! This point is optional, depending on time constraints. Collect CPT/LIF data from surface to approximately 5 feet below the water table to monitor for mobile and residual LNAPL. Therefore, push depth should be approximately 0 to 40 feet bgs. Adjust depth of CPT/LIF push, as necessary to make push extend 5 feet below the water table.
Building 1613 Site	H	NA	NA	NA	Yes	No	SAA