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1.0 INTRODUCTION

This report presents the Corrective Action Plan (CAP) developed by Baker Environmental, Inc. (Baker), for the remediation of petroleum contamination at the Campbell Street Fuel Farm (CSFF) and related underground storage tank (UST) AS-143. This CAP has been prepared for the Department of the Navy's Naval Facilities Engineering Command Atlantic Division (LANTDIV).

1.1 Site Location

The CSFF and Building AS-143 and its associated UST, are located along Campbell Street at the Marine Corps Air Station (MCAS), New River, Jacksonville, North Carolina. The location of the site is shown on Figure 1-1.

As shown on Figure 1-2, the CSFF is located on the northwest corner of the White Street and Campbell Street intersection. Building AS-143 is located on the northeast corner of the intersection. The CSFF is situated near the MCAS flightline and is proximate to several buildings associated with flightline operations.

1.2 Site Description

The CSFF contains four aboveground storage tanks (ASTs), each with capacities of 215,000 gallons, and are used to store JP-5 aviation fuel. ASTs CSFF-9 and CSFF-10 are located within an oval concrete dike; ASTs CSFF-11 and CSFF-12 are surrounded by a rectangular concrete dike wall. Several surface water catch-basins are located within the diked areas and are connected by underground drain piping. The drain piping exits the diked areas and runs into an oil/water separator located within the southwest portion of the fuel farm.

The ASTs are connected by aboveground 6-inch fuel transfer lines which run into a filter building prior to entering the pumping station. The transfer line exits the fuel farm underground in the southeast corner. The fuel system currently used at the CSFF was installed in 1985.

An oval truck access roadway is located on the western side of the site. Fuel deliveries to the fuel farm are made by civilian tanker trucks. Military tanker trucks use the loading rack south of the filter building for transporting fuel between the fuel farm and the flightline.

The site is primarily grass-covered and enclosed by a chainlink fence. A wooded area is located north of the CSFF. To the west is an abandoned railroad line and several athletic fields. South of the site is Campbell Street. In the area immediately south and east of the site, the CSFF is bounded by a surface water drainage channel 6 to 8 feet in depth; the network of drainage channels in the vicinity of the site is shown on Figure 1-2.

Building AS-143 is located east of White Street across from the CSFF. UST AS-143 is located north of Building AS-143 as shown on Figure 1-2. This 10,000-gallon tank, installed in 1961, contains unleaded gasoline that is used solely for Government-owned vehicles. North of the UST is a concrete containment system for tanker unloading operations for UST AS-143. Fluids that may be released during unloading operations are contained and then passed to an oil/water separator. The location of the oil/water separator is shown on Figure 1-2.

1.3 Purpose of CAP

The purpose of this CAP is to describe and provide supporting documentation for the corrective action alternative selected for the remediation of petroleum contaminated soils and groundwater at the CSFF and Building AS-143 sites.

The specific objectives of this CAP are to: (1) provide background assessment information; (2) provide measures to adequately protect human health and the environment; (3) present the corrective action to be undertaken at the site; (4) outline a monitoring plan to evaluate the progress of the corrective action, and (5) comply with applicable Federal and State regulations.

This CAP has been prepared based on the North Carolina Department of Environment, Health, and Natural Resources (DEHNR), "Groundwater Section Guidelines for the Investigation and Remediation of Soils and Groundwater." The guidelines, developed by the DEHNR Division of Environmental Management - Groundwater Section, was published in March 1993.

1.4 Site History

The following sections discuss the history of the CSFF and the results of previous assessment activities performed at the site.

1.4.1 CSFF Construction History

The CSFF consists of four steel ASTs installed in 1985. Each AST has capacities of 215,000 gallons and are used to store JP-5 aviation fuel.

The ASTs are replacement tanks for a system of eight USTs of varying capacities reportedly used prior to 1985 at the CSFF. Six of the eight USTs were used to store JP-5. Three of these six USTs had capacities of 120,000-gallons, 106,000-gallons, and 100,000-gallons; the other three USTs had capacities of 50,000-gallons, each. Capacities of the other two USTs are unknown. Seven of the USTs and associated piping systems were removed and replaced by the existing AST system in 1985. One aviation gasoline (AVGAS) UST was filled with sand and has remained in place; this UST is directly behind the filter building that services the loading rack inside the fuel farm. An accurate location of the AVGAS UST has not been determined.

Some of the contaminated soil generated by the excavation and removal of the old USTs still remains on site. This soil was stockpiled on site due to problems involving the inability of the contractor to transport these soils to a disposal facility. The subcontractor also transported petroleum contaminated soils from other UST removal projects to the CSFF site. As a result, a soil mound (shown on Figure 1-2) is present in the center of the fuel farm.

The flightline for the air station is supplied with fuel from the CSFF via an underground pipeline. The underground pipeline runs south along White Street, as shown on Figure 1-3, then turns to the east and connects to the aircraft direct refueling stations, approximately 1.0 mile southeast of the CSFF.

The underground pipeline currently in use was installed in 1985 as a replacement for the previous system. The previous underground pipeline was allowed to drain before being abandoned in place. For most of its length, the current, active pipeline is adjacent to the original, abandoned pipeline system. The approximate locations of the abandoned and currently used pipelines are shown on Figure 1-3. The possibility of small amounts of JP-5 remaining in the abandoned line still exists.

1.4.2 Previous Assessment Activities

Four groundwater monitoring wells, from a previous hydrogeologic assessment, are located in the vicinity of the CSFF and UST AS-143. The location of these wells are shown on Figure 1-4.

Information regarding the reason for installation, date installed, well construction details, etc., was not obtainable for this CAP. Fluid levels in these four monitoring wells have been monitored on several occasions. No free product has been reported in any of the four wells.

In December 1991, Baker conducted the first phase of field activities at the CSFF. Field activities included the installation of seven Type II shallow monitoring wells, three Type III deep monitoring wells, four soil borings and 15 hydropunch penetrometers (hydropunches). The locations of the wells, soil borings, and hydropunches sampled during this phase are presented on Figure 1-4. Specific field activities and well installation data are described in the Final Site Assessment Report, submitted to LANTDIV in August 1992.

During the first phase of assessment activities, Baker identified several areas impacted by petroleum contamination. However, the full extent of soil and groundwater contamination was not completely defined.

A second phase of field activities was performed at the CSFF from November 16, 1992 through December 7, 1992. The services performed during the second phase of assessment activities included: installation of 18 Type II shallow monitoring wells, three Type III deep monitoring wells, eight soil borings, one six-inch monitoring well, and an aquifer test. The locations of the wells and borings are shown on Figure 1-4. Specific field activities and well installation data are described in the Draft Site Assessment Report, submitted to LANTDIV on February 15, 1993.

Summaries of the well construction details for monitoring wells installed during the first and second phase of assessment activities are provided on Tables 1-1 and 1-2, respectively. All monitoring wells were surveyed and referenced to the mean sea level elevations.

1.4.2.1 Site Geologic Conditions

Information collected during the soil boring and monitoring well installation activities was used to develop three hydrogeologic cross-sections. The location of these cross-sections are shown on Figure 1-5. The three cross-sections, identified as A-A', B-B', and C-C', are shown on Figures 1-6, 1-7, and 1-8, respectively.

In general, all three cross-sections indicate that the site overlies a clay and/or silt layer that extends downward from the ground surface. This clay/silt is fairly continuous across the site.

It is underlain by a silty sand layer which grades downward into a fine sand. This sand begins approximately 12 feet below ground surface and extends to about 22 feet. At approximately 40 feet below ground surface, a layer of white, fine gravel, limey mud/clay with bits of limestone shell fragments was encountered. This layer is believed to be the beginning of the Castle Hayne Formation.

1.4.2.2 Site Hydrogeologic Conditions

This is the River Bend Formation of the Castle Hayne Aquifer. by whom?

Groundwater beneath the site lies approximately 6 to 7 feet below ground surface. Tables 1-3 and 1-4 summarize the fluid level measurements and elevations from the CSFF obtained on December 7 and 30, 1992, respectively. As shown on Tables 1-3 and 1-4, 0.02 feet of free product was detected in monitoring well MW-13 on December 30, 1992.

Based on the data from December 30, 1992, shallow groundwater appears to flow south across the site as shown on Figure 1-9. Based on the December 30, 1992 measurements, the average horizontal groundwater gradient in the shallow groundwater zone is calculated at 7.5×10^{-3} .

The six deep monitoring wells, DW-1 through DW-6, were used to evaluate the groundwater gradient in the deeper portion of the aquifer. Based on December 30, 1992 measurements, the direction of groundwater migration in this zone is to the east, as shown on Figure 1-10. The groundwater gradient calculated for this zone is 1.7×10^{-3} .

The aquifer test performed on December 5, 1992, and other in-situ hydraulic conductivity tests performed at the site, determined an average hydraulic conductivity for the site of 4.6×10^{-1} feet/day (1.6×10^{-4} cm/sec) (Baker, 1993). Using the average hydraulic conductivity value calculated from the aquifer test, a groundwater gradient of 7.5×10^{-3} , and an effective porosity of 0.28 (Fetter, 1980), the average groundwater flow velocity is 4.5 feet/year.

1.4.2.3 Subsurface Soil Contamination

During the two separate phases of assessment activities, selected soil samples from the soil borings were analyzed for Total Petroleum Hydrocarbon (TPH). Several soil samples from the first phase of assessment activities were also analyzed for pH, flashpoint, and lead using the Toxicity Characteristic Leaching Procedure (TCLP). The analytical results of the December 1991 and December 1992 soil sampling activities are summarized on Tables 1-5 and 1-6, respectively.

Soil samples were analyzed for TPH during both phases of assessment activities using EPA Method 8015/5030 (low to medium range petroleum) and EPA Method 8015/3550 (medium to high range petroleum). These analytical methods provide a method of identifying the source of petroleum contaminant. As shown on Tables 1-5 and 1-6, soil contamination at the site consisted of weathered jet fuel, jet fuel, gasoline, and motor oil. This is most likely the result of releases from the USTs formerly located at the site, and recent, periodic releases of JP-5 from the daily operations of the fuel farm.

The highest TPH concentrations were found at soil boring locations MW-13, SB-11, and DW-2, which are located on the eastern base of the soil mound. Highest TPH concentrations in this area ranged from 147,000 mg/kg (medium to high) in boring MW-13 (2.0 to 4.0 feet) to 1,900 mg/kg (medium to high) in boring SB-11 (3.0 to 4.0 feet).

In the vicinity of UST AS-143, the highest soil TPH concentration was detected in soil boring DW-6. This soil boring had a TPH concentration of 204 mg/kg (medium to high) at 2.0 to 4.0 feet below ground surface. The remaining borings around UST AS-143 identified low concentrations of TPH. This indicates that the area of concern is limited to soils in direct contact with the northeast side of the AS-143 UST.

Analytical results from the remaining soil borings, sampled in December 1991 and December 1992, indicate low TPH values (in both the low to medium and medium to high ranges) in a scattered pattern about the fuel farm. These low concentrations can be related to the day-to-day handling of jet fuel. TPH concentration obtained from the selected soil samples are depicted on Figure 1-11 (low to medium range) and Figure 1-12 (medium to high range).

1.4.2.4 Groundwater Contamination

During the two separate phases of assessment activities, groundwater samples were collected from hydropunch penetrometers and monitoring wells. These groundwater samples were analyzed for various chemical parameters. The analytical results for the samples collected by the hydropunch procedure are summarized on Table 1-7. The analytical results of the January 1992 and December 1992 sampling activities are summarized on Tables 1-8 and 1-9, respectively.

Several analytical methods were used to evaluate the condition of the groundwater. These methods include the following:

- EPA Method 601 - Purgeable halocarbons
- EPA Method 602 - Purgeable aromatics, also referred as volatile organics compounds (VOCs)
- EPA Method 625 - Base neutral/acid extractables, also referred as polynuclear aromatic hydrocarbons (PAHs)
- EPA Method 7421 - Total lead

Of these analytical methods, only EPA Method 602, VOCs, was used to analyze all groundwater samples. Based on these analyses, Figure 1-13 was developed to depict total VOC and benzene concentration distribution in the groundwater.

As shown on Figure 1-13, groundwater has been adversely impacted in several isolated areas. This is evidenced by samples which have exceeded the North Carolina Water Quality Standard (WQS) of 1.0 µg/L for benzene. Groundwater samples from monitoring wells MW-4, DW-2, and MW-16, and hydropunch HP-10, had benzene concentrations of 2.47 µg/L, 2.05 µg/L, 69.5 µg/L, and 1.17 µg/L, respectively. This plume is estimated to begin at the base of the soil mound and extend southeast (downgradient). Total VOC concentrations for these wells are less than 100 µg/L, with the exception of monitoring well MW-16, which had a concentration of 792.9 µg/L. This concentration may be related to the buried return line for the oil/water separator in close proximity to this well.

On the east side of the CSFF, groundwater from monitoring well MW-3 and hydropunch HP-12 had benzene levels of 2.79 µg/L and 4.47 µg/L, respectively. This impacted area is located directly over the JP-5 pipeline as it exits the fuel farm. Total VOCs for these two locations are below 5 µg/L.

Several monitoring wells near UST AS-143 also show evidence of petroleum contaminated groundwater. RW-1, installed directly beside the UST, had a reported benzene concentration of 26.7 µg/L. A small contaminant plume was defined by benzene detections in hydropunch HP-15, and monitoring wells MW-24 and MW-25, which are all downgradient of the UST.

Monitoring well MW-21, which had no detected concentrations of benzene, did have the highest total VOC level of the entire site, 9,825.9 µg/L. This well is also downgradient of UST AS-143 and coincides with total VOC values of 1,789 µg/L and 4,034 µg/L for monitoring wells MW-24 and MW-25.

A benzene concentration of 7.85 µg/L was detected in monitoring well MW-8. Since it is upgradient from all other contamination sources, it appears that this area was affected by contamination from the off-loading area within the fuel farm. This is substantiated by the high level of total VOCs at this location, while nearby wells have dramatically lower values.

Monitoring well DW-2 was the deep monitoring well detected to have the highest levels of petroleum contamination. As shown on Table 1-8, 2.05 µg/L of benzene was detected in this well. The constituent detected with the highest concentration was naphthalene (258 µg/L). Other deep monitoring wells that had detectable concentrations of petroleum constituents were DW-3 (total VOC concentration of 0.94 µg/L and DW-6 (total VOC concentration of 12.39 µg/L).

Free product was detected in one monitoring well, MW-13, which is located at the toe of the soil mound, north of the filter building. On December 30, 1992, 0.02 feet of free product was observed in the monitoring well.

HP-15
MW-24
MW-25
RW-1

2.0 OBJECTIVES

This section discusses the remediation objectives of the CAP and the proposed cleanup levels.

2.1 Remediation Objectives

Soil and groundwater contamination have been identified at several areas of the site. The extent of the soil and groundwater contaminant plume has been essentially defined. The results of the risk assessment conducted for this site suggest that the contaminants present at the site do not pose an immediate health risk and that the likelihood of contamination from the site affecting human receptors is minimal. This is because the contamination is present in the shallow aquifer. Potable supply wells obtain water from the deeper Castle Hayne aquifer.

Based upon the assessment activities performed at the CSFF, three areas of the site were identified as areas where soil and/or groundwater remediation may be required. These areas are:

- The mounded soil area located in the center of the CSFF (in the vicinity of monitoring wells MW-4 and MW-13 and soil boring SB-11): Free product (0.02 feet in monitoring well MW-13) and soil and groundwater contamination that exceeded state standards were identified in this area.
- The area south of the tanker loading facility (in the vicinity of monitoring wells MW-12 and MW-16): This area has groundwater contamination that exceeded the state standards.
- The UST and associated piping at Building AS-143: This area has groundwater contamination present that exceeded WQS criteria.

In general, the cleanup goals of the remediation approach are as follows:

- Remove measurable free product from the water table in the vicinity of the soil mound.
- Reduce TPH concentrations in the area of the soil mound to State approved levels. These levels will be based on the DEHNR Site Sensitivity Evaluation (SSE) format.

- Reduce groundwater contaminant concentrations in both the CSFF area and the AS-143 UST area to levels acceptable with the North Carolina WQSs.

2.2 Remediation Endpoints

The groundwater remediation endpoints are based on State guidelines and established WQSs. The WQSs will be used as the initial groundwater remediation endpoints. Based on the results of the risk assessment, it was determined that the impact the petroleum contaminants to human and ecological receptors at the fuel farm were minimal. With this consideration, if it is determined that attaining the WQSs is not practical, remediation activities will continue until contaminant concentrations reach asymptotic conditions. Table 2-1 summarizes the maximum concentration of groundwater contaminants in comparison to established State WQSs.

Using the State WQSs and soil SSE procedure, remediation endpoints were evaluated and established to address each phase of petroleum contamination to comply with State regulations. The remediation endpoints are:

Groundwater: Groundwater was impacted at this site from direct contamination and from leaching of petroleum constituents from contaminated soils. Groundwater remediation was evaluated using the State WQSs. If it is determined that attaining the WQSs is not practical, remediation activities will continue until contaminant concentrations reach asymptotic conditions.

Soil: Using the SSE, an evaluation score of 75 was calculated. Because the site has no contaminated water supply wells within 1,500 feet and has a sufficient potable water supply, the CSFF was classified as a Category E site. With this consideration, the site has a soil remediation level of 180 mg/kg TPH. A copy of the SSE used to determine the remediation endpoint for soil is provided in Appendix A.

Product: The presence of free product was detected in one monitoring well, MW-13 (0.02 feet). The remediation endpoint for free product will be less than 0.01 feet of free product present on the water table.

2.3 Remediation Schedule

The achieve the remediation goals established in this CAP, the excavation of petroleum contaminated soils and the recovery and treatment of groundwater will be required. To perform these tasks, it will be necessary for the U.S. Government to procure several contractors. This procurement process will extend the amount of time required to complete the remediation activities.

Other concerns will also influence the remediation schedule for the site. The CSFF is an active area and is vital to the operation of the flightline activities. Therefore, remediation activities must be completed in a manner that is non-disruption of the CSFF operations.

The following schedule provides a general time frame for the completion of major tasks associated with implementing the remediation plan.

June 1994

- Acceptance of CAP by North Carolina DEHNR.
- U.S. Navy submits National Pollutant Discharge Elimination System (NPDES) permit application for the site remediation system.
- Procure contractor to design remediation system.

September 1994

- Procure contractor to construct and install remediation system.

November 1994

- Begin excavation of contaminated soils in the mounded area at CSFF.
- Dispose of excavated soils at State permitted facility.
- Contractor procure necessary remediation equipment for groundwater recovery and treatment.
- Initiate groundwater monitoring program.

December 1994

- Excavation activities completed in the mounded area. Restore excavated areas with clean backfill and revegetate disturbed areas.
- Begin excavation activities in area of monitoring wells MW-12 and MW-16 for installation of interceptor trench.
- Install subsurface trenching to connect CSFF with AS-143 site.
- Continue groundwater monitoring program as necessary.

January 1995

- Install groundwater recovery and treatment equipment at the CSFF and UST AS-143 sites.
- Continue groundwater monitoring program as necessary.

February 1995

- Complete installation of groundwater recovery and treatment system.
- Activate groundwater recovery and treatment system.
- Continue groundwater monitoring program as necessary.

February 1996

- Continue operation of the groundwater remediation system.
- System shut-down and post operational monitoring will begin once remediation goals have been met.

The actual length of time to achieve the remediation endpoints is unknown. It is anticipated that the remediation system will be in operation for a minimum of one year.

3.0 EXPOSURE ASSESSMENT

This section discusses the results of the preliminary exposure assessment performed for the CSFF during the earlier site assessment activities. The topics that will be addressed in this section are: (1) evaluation of contaminant levels; (2) fate and transport of petroleum in the environment; (3) identification of human exposure pathways; and (4) the identification of receptors.

3.1 Evaluation of Contaminant Levels

3.1.1 Soil Contamination

The soil analytical data identified TPH concentrations in 67 of the 96 soil samples. The detected TPH concentrations for these samples ranged from 0.07 mg/kg (SB-5, 4 to 6 feet) to 14,700 mg/kg (MW-13, 2 to 4 feet). Six soil samples (from SB-9, SB-11, SB-12, MW-13, and DW-6) exceeded the DEHNR remediation level of 180 mg/kg for TPH in soil, established by the SSE.

3.1.2 Groundwater Contamination

Three different analytical methods were applied to evaluate the organic chemical concentrations in the groundwater at CSFF. EPA Methods 601, 602, and 625 were used to detect purgeable halocarbons, VOCs, and PAHs, respectively.

All 52 groundwater samples were analyzed for VOCs, four samples were analyzed for purgeable halocarbons, and two samples were analyzed for PAHs. Of the groundwater samples analyzed for purgeable halocarbons, none of the four samples contained detectable concentrations of halocarbons. For the two groundwater samples analyzed for PAHs, only monitoring well DW-2 had detectable concentrations. Four PAHs were identified: acenaphthene (46 µg/L), fluorene (36 µg/L), naphthalene (258 µg/L), and phenanthrene (11 µg/L). All four PAHs are constituents of petroleum fuels and are noncarcinogenic. At the present time there are no Federal Maximum Contaminant Levels (MCLs) or North Carolina WQSs for these constituents.

As presented on Tables 1-7, 1-8, and 1-9, VOCs analyzed using EPA Method 602 had been detected in all but 16 of the 52 groundwater samples obtained from the hydropunches and

monitoring wells. EPA Method 602 utilizes the gas chromatograph (GC) to identify compounds. The GC procedure identifies compounds based upon their retention times. Due to the similarities in solubilities of certain compounds, some tend to elute at the same time, making it difficult to differentiate compound identities by this method of analysis. This is the case for 1,3-dichlorobenzene and 1,4-dichlorobenzene; toluene and ethylene dibromide (EDB); and m-,p-xylenes and chlorobenzene. As a result the laboratory reported the concentration of these aforementioned pairs as a combined value during Phase I activities. Since all of the chemical have State and Federal standards, a conservative resolution to this issue of combined values would be to attribute all of the contamination to the chemical constituent with the most stringent standard. This is the approach that has been taken for this qualitative risk assessment. Laboratory results from the Phase II activities were able to differentiate these compounds.

The following is a summary, by compound, of the purgeable aromatic compounds identified at the CSFF:

- Benzene was detected in 14 of the 52 groundwater samples collected. The detected concentrations ranged from 0.20 µg/L in MW-2 to 73 µg/L in MW-24. Only five of the samples exceeded the Federal MCL of 5.0 µg/L. Twelve of the 14 samples, ranging in concentrations of 1.05 µg/L in HP-14 to 73 µg/L in MW-24, exceeded the State WQS of 1.0 µg/L.
- Toluene/EDB was detected in 12 of the 52 groundwater samples collected. The detected concentrations ranged from 0.23 µg/L in HP-11 to 762 µg/L in MW-24. The MCL of toluene is 1,000 µg/L; none of the groundwater samples exceeded this concentration. The MCL for EDB is 0.05 µg/L and the State WQS is 0.0005 µg/L, all 12 groundwater samples exceeded the State and Federal standards for EDB.
- Ethylbenzene was detected in 10 of the 52 groundwater samples. The detected concentrations ranged from 0.36 µg/L in DW-2 to 661 µg/L in MW-21. None of the concentrations exceeded ethylbenzene's MCL of 700 µg/L. Three samples exceeded the State WQS of 26 µg/L.
- Xylenes (total) were detected in 25 of the 52 groundwater samples collected. The detected concentrations ranged from 0.21 µg/L in HP-1 to 5,083 µg/L in MW-21.

Xylenes (total) have an MCL of 10,000 µg/L; none of the groundwater samples exceeded this concentration. Three samples exceeded the State WQS of 400 µg/L.

- 1,2-dichlorobenzene was detected in 14 of the 52 groundwater samples. The detected concentrations ranged from 0.57 µg/L in HP-15 to 486 µg/L in MW-21. The MCL for 1,2-dichlorobenzene is 600 µg/L; none of the detected concentrations exceeded this standard. The State of North Carolina has established a standard of 620 µg/L for this chemical.
- 1,3- and 1,4-dichlorobenzene were detected in 14 of the 52 groundwater samples. The detected concentrations ranged from 0.78 µg/L in HP-15 to 3,060 µg/L in MW-21. Currently there is only a MCL for 1,4-dichlorobenzene of 75 µg/L. None of the concentrations exceeded the state standard of 620 µg/L for 1,3-dichlorobenzene. Eleven samples contained concentrations that surpassed the state level of 1.8 µg/L for 1,4-dichlorobenzene.

Table 2-1 summarizes the analytical data from both phases of field activities and compares this information with State WQSs.

3.2 Fate and Transport of Petroleum in the Environment

Petroleum products are complex mixtures of hydrocarbons; more than one hundred compounds can be found in a typical fuel (EPRI, 1989). Each constituent has different chemical and physical properties that control the ultimate fate and transport of the petroleum products in the soil. In general, when petroleum hydrocarbons are released into unsaturated soils, they tend to migrate vertically under the force of gravity, with some slight lateral spread (Schwendeman, 1989). This migration pathway may be interrupted by adsorption to soil particles, inhibition by a geologic formation (i.e., low transmissive capability) or by cultural features (i.e., pipe channels or foundations). The subsurface transport of contaminants is also controlled by complex interactions between chemical, physical, and biological processes. Some conditions which affect migration are:

- Soil texture
- Soil uniformity or non-uniformity
- Soil layer configuration
- Depth to water table

- Soil structure
- Flow stability
- Soil moisture

The major constituents of JP-5 jet fuel are presented in Table 3-1. Table 3-2 presents the concentrations of water soluble components of JP-5 jet fuel detected in a mixture of 1 part JP-5 to 1,000 parts water. The chemicals, toluene, ethylbenzene, xylenes, naphthalene and methylnaphthalene, account for approximately 75 percent of the water soluble constituents of JP-5.

The physical and chemical properties of a compound are responsible for its mobility in the environment. These properties, in conjunction with site conditions, determine whether a chemical will readily volatilize into the air or be transported via advection or diffusion through the soil, groundwater, and surface water. These characteristics also describe the tendency of a chemical to adsorb onto soil/sediment particles. Environmental mobility can correspond to either an increased or decreased potential to affect human health.

Persistence of a chemical in the environment is also important in the potential risk and depends on factors such as the microbial content of soil and water, organic carbon content, the concentration of the chemical, climate, and the ability of the microbes to degrade the chemical under site conditions. In addition, chemical degradation (e.g., hydrolysis), photochemical degradation and certain fate processes such as sorption may contribute to the elimination or retention of a particular compound in a given medium.

The environmental mobility of a chemical is influenced primarily by its physical and chemical properties and the site chemistry. The following sections evaluate the properties of the chemicals or groups of chemicals detected, with emphasis on potential environmental mobility and persistence.

The following text summarizes physical and chemical properties for the primary constituents of JP-5 which directly affect the persistence and mobility of these constituents identified at the CSFF. Table 3-3 presents the physical and chemical properties associated with the chemicals detected at the site including: specific gravity; vapor pressure; water solubility; octanol/water partition coefficient; organic carbon adsorption coefficient, Henry's law constant; and mobility index. A discussion of the environmental significance of each of these properties follows.

Specific Gravity

Specific gravity is the ratio of the weight of a given volume of pure chemical at a specified temperature to the weight of the same volume of water at a given temperature. Its primary use is to determine whether a constituent will have a tendency to "float" or "sink" (as an immiscible liquid) in water only if it exceeds its corresponding water solubility. Specific gravity of a constituent must be assessed along with the constituent's water solubility to produce a qualitative estimation of movement in the water column. For example, the maximum groundwater analytical results for the constituent benzene was 73 µg/L. The specific gravity for the compound is 0.879 g/cm³ suggesting that the chemical would float in the saturated zone. However, its water solubility of 1,780 mg/L is roughly 24,000 times greater than its maximum detected value. Under these circumstances, the chemical will tend not to float but disperse throughout the aquifer.

Vapor Pressure

Vapor pressure provides an indication of the rate at which a chemical may volatilize. It is of primary significance at environmental interfaces such as surface soil/air and surface water/air. Volatilization is not as important when evaluating groundwater and subsurface soils. Vapor pressures for monocyclic aromatics and chlorinated ethenes or ethanes are generally higher than vapor pressures for semivolatiles. Chemicals with higher vapor pressures are expected to enter the atmosphere much more readily than chemicals with lower vapor pressures.

Water Solubility

The rate at which a chemical is leached from soil by infiltrating precipitation and its behavior in a water column is a function of its water solubility. More soluble chemicals are usually more readily leached than less soluble chemicals. For example, the water solubilities presented in Table 3-3 indicate that the volatile organic chemicals, (monocyclic aromatics), are usually several orders-of-magnitude more soluble than certain semivolatile compounds.

Octanol/Water Partitioning Coefficient

The octanol/water partition coefficient (K_{ow}) is a measure of the equilibrium partitioning of chemicals between octanol and water. The coefficient is also useful in characterizing the sorption of compounds by organic soils where experimental values are not available.

Organic Carbon Adsorption Coefficient

The organic carbon adsorption coefficient (K_{oc}) indicates the tendency of a chemical to adhere to soil particles containing some amount of organic carbon. Chemicals with high soil/sediment adsorption coefficients generally have low water solubilities and vice versa. For example, chemicals such as the semivolatiles are relatively immobile in the environment with respect to the volatile organics and are preferentially bound to the soil. These compounds are not as inherently likely to experience aqueous transport to the extent of compounds with higher water solubilities. Erosional properties of surface soils and the presence of dissolved organic macromolecules in groundwaters may enhance the mobility of these bound soil chemicals.

Henry's Constant

Both vapor pressure and water solubility are of use in determining volatilization rates from surface water bodies and from groundwater. These two parameters can be used to estimate an equilibrium concentration of a constituent in the water phase and in the air directly above the water. This can be expressed as Henry's Constant. As a rule, constituents having a Henry's Constant exceeding 10^{-3} volatilize readily from surface water bodies. Therefore, the constituents detected at the facility will tend to leave the water column at atmospheric pressure (i.e., shallow, unconfined aquifer or surface waters).

Mobility Indices

A quantitative assessment of mobility has been developed that uses water solubility (S), vapor pressure (VP) and organic carbon partition coefficient (K_{oc}) (Laskowski, 1983). This value is referred to as the Mobility Index (MI). It is defined as:

$$MI = \log((S \times VP)/K_{oc})$$

A scale to evaluate MI is presented by Ford and Gurba (1984):

<u>Relative MI</u>	<u>Mobility Description</u>
> 5	extremely mobile
0 to 5	very mobile
-5 to 0	slightly mobile
-10 to -5	immobile
< -10	very immobile

The MIs for the chemicals selected using prevalence criteria are also presented in Table 3-3.

The following paragraphs summarize the general fate and transport data for JP-5 constituents at the site.

Volatile Organic Compounds (VOCs)

VOCs (i.e. benzene) tend to be relatively mobile in environmental media as indicated by their presence in groundwater. Their inherent mobility and their relatively high MIs result from high water solubilities, high vapor pressures, low K_{ow} and K_{oc} values.

Benzene does not tend to persist in environmental media because photolysis, oxidation, and biodegradation figure significantly in their removal, and they are seldom detected in surface soils where volatilization and other removal processes predominate. Benzene has a soil half-life of 16 days and a groundwater half-life of 128 days (Howard et al., 1991).

Polynuclear Aromatic Hydrocarbons (PAHs)

The PAH is generally less mobile than the VOC benzene. Naphthalene (-2.5) is slightly mobile by virtue of its water solubility and vapor pressure.

PAHs also tend to be more persistent environmentally. Photolysis and biodegradation figure to be the most significant removal processes. Naphthalene has a half-life of approximately 48 days in soil, and 252 days in groundwater (Howard et al., 1991).

3.3 Identification of Human Exposure Pathways

Groundwater ingestion, the potential inhalation of volatile organic chemicals from groundwater and soil, soil dermal contact and soil ingestion would most likely be the major exposure pathways of concern at this site. Since there are no identified drinking water sources within 1/4-mile radius of the site in the surficial aquifer, and all drinking water on the base is supplied by the deeper Castle Hayne Aquifer, no groundwater exposure pathways are considered to exist.

The CSFF is enclosed by a chain-link fence which limits access to the site. The fuel farm is primarily grass-covered; therefore, the potential for soil dispersion due to fugitive dust is not considered to exist and no exposure to contaminated soils is expected. Exposure to any of the contaminated soils would be contingent upon site disturbance via construction and remediation activities. In the event that soil remediation is required, there could be an exposure route due to inhalation from volatilization of the TPHs found in the soils. Since this would be an occupational exposure, the receptor analysis for these exposure pathways should be considered as part of the site remediation design plan. It is not expected that soil ingestion or dermal contact exposure pathways are likely to exist, although a potential exposure pathway due to inhalation during remediation may occur.

3.4 Identification of Receptors

No actual or potential human receptors have been identified that would be exposed to groundwater at this site since the surficial water-bearing layer is not used as a drinking water source. One water supply well is located approximately 1/4-mile south-southwest of the site. The well is screened in the deeper Castle Hayne Formation and has a maximum pumping rate of approximately 110 gallons per minute (gpm). The locations of water supply wells located in the vicinity of the CSFF are shown on Figure 3-1.

Receptors identified that could be exposed to contaminated soils are limited to the workers performing site remediation activities. No other receptors have been identified on site because the area is mostly grass-covered and, therefore, limits exposure pathways from contaminated soils.

3.5 Risk Evaluation

From a qualitative perspective, the contaminants do not appear to represent or pose a public health risk as there appear to be no opportunities for exposure to contaminants in any media, except during remediation activities. It would be during this time that soil contamination at the site could pose an immediate human health risk. It should be noted that some of the chemical constituents do exceed State (2L) and Federal groundwater and drinking water standards. A potential risk could exist if the shallow groundwater was used as a potable source. However, since there are no identified wells within the 1/4-mile of the site that use the shallow aquifer, the contaminated groundwater does not represent an immediate health threat. This potential risk could be controlled by following appropriate health and safety procedures designed for the remediation/construction site. A summary of the potential risk associated with the site is provided on Table 3-4.

4.0 EVALUATION OF REMEDIAL ALTERNATIVES

This section of the CAP discusses the type and extent of soil and groundwater contamination in the vicinity of CSFF and UST AS-143, and evaluates applicable remediation alternatives for soil and groundwater remediation. A remediation alternative consists of a combination of technologies or a single technology capable of addressing the site-specific contamination at the site. Several different types of soil and groundwater remediation alternatives have been screened for the CSFF site. Each alternative that was selected as suitable was further evaluated based upon site conditions, contaminant type, and costs. A site-specific alternative was then selected to address the contamination present.

4.1 Remedial Options

4.1.1 Soil Remediation Technologies

The objectives for the remediation of soils are to remove contaminated soils that exceed the soil remediation endpoint established by the SSE and to reduce or eliminate the effects that excessively contaminated soils have on the groundwater. The determination of the SSE score is presented in Appendix A.

Table 4-1 presents demonstrated technologies for soil remediation including an evaluation of each of technology based on applicability to the site, feasibility, and costs. Based on this evaluation, several technologies appear to be potentially applicable to the CSFF site. These soil remediation technologies are indicated, briefly discussed, and further evaluated below. As a result, the most applicable technologies will be recommended.

4.1.1.1 In-Situ Leaching

In-situ leaching is a process which involves extracting contaminants from soil by "washing" or "flushing," using water or more typically, a water-surfactant mixture. The process involves injecting or spraying a solution onto the area of contamination; the solution then percolates downward through the soil, adsorbing hydrocarbons from the soil. The mixture leaches through the soil under the influence of gravity until it reaches the groundwater table. The leached solution is then collected and pumped to the surface for removal or on-site treatment and reinjection. The use of this technology for soil remediation at a site is dependent on the

nature of the contamination and the permeability of the site soils. Costs to perform this type of remediation can range from \$150 to \$200 per cubic yard of soil.

The major advantage of in-situ leaching is that the contaminant source area can be remediated in-situ (i.e., without excavation). System application is fairly simple and a variety of solutions can be used. The major disadvantage is that it is very dependent upon site geologic conditions. Also, a disadvantage is the necessity of using this technique in conjunction with a recovery system which would require the treatment and/or disposal of recovered liquids.

Evaluation/Recommendation: The type and low permeability of soils at shallow depths reduces the effectiveness of this technology. The shallow depth to groundwater at the site is also not favorable for this alternative. The low permeability of the soils would reduce the ability of the treated fluids to "flush" out contaminants. Remediation using this method may require an extended period of time. This option may be expensive as compared to other alternatives, and may not be the best alternative for this site. Therefore, in-situ leaching is not considered an applicable technology for the CSFF site.

4.1.1.2 In-Situ Bioremediation

In-situ bioremediation is a process which relies on naturally occurring or genetically altered microorganisms to break down or transform contaminants to less hazardous compounds. The use of this technology may require the addition of nutrients and oxygen to the soil to enhance the biodegradation process. These additives are typically mixed into a water source which is introduced to the subsurface by leaching through the soil under the influence of gravity.

When this method is used in conjunction with groundwater remediation efforts, groundwater is typically extracted from the subsurface, mixed with nutrients and an oxygen source, and reintroduced into the subsurface via an infiltration gallery or injection system located upgradient of the contaminated area. The typical costs for remediation using this type of alternative is \$75 per cubic yard.

Major advantages to this method include: it will remediate the source area in-situ; it does not require treatment or disposal of water; it is unobtrusive and is not labor intensive. The major disadvantage to this method is (depending on the nature of the contaminant and host soil) the time span needed to reduce the contaminant concentration to an acceptable level.

Evaluation/Recommendation: The amount of silt and clay in the soil at the CSFF site reduces the effectiveness of this technology. The low permeability of the soils and shallow depth to groundwater at the site further reduces the suitability of this method. This option has high capital costs and may require a lengthy period of time for to reduce contaminant concentrations to the desired levels. Therefore, this technology is not recommended for the CSFF site.

4.1.1.3 Vacuum Extraction

Vacuum extraction (or in-situ venting) is a method that vents soil by volatilizing the contaminants in the soil from a liquid phase to a vapor phase, with removal of the vapor phase contaminants from the soil atmosphere. The process involves application of a vacuum through a network of wells. The vapors are drawn through the soil air spaces to the wells, where they are captured and brought to the surface. Once the contaminant-saturated vapors are brought to the surface, additional treatment may be required. This technology may be enhanced through injection of volatile-free air into the zone of contamination. The use of this technology for soil remediation at the site also appears to be an option given the moderate hydraulic conductivity of the soils, the shallow depth to groundwater, and the apparently limited area of contamination. Costs for implementing the vacuum extraction technique may range from \$50 to \$75 per cubic yard.

The major advantage of this method is that it removes the volatile components of hydrocarbon contaminated soil (which contribute to groundwater contamination) in-situ. Disadvantages include that it will not impact the nonvolatile components of hydrocarbon contaminated soil and it requires vapor phase treatment of groundwater off-gases.

Evaluation/Recommendation: Because the petroleum contamination in the vicinity of Building AS-143 is supposedly gasoline, vacuum extraction technology may be feasible in this portion of the site. However the low permeability of the soils reduces the effectiveness of this technology. Due to these low permeability soils, the extraction points would require close spacing and result in increased installation and operation costs. This technology is not recommended due to its costs and unsuitable soil conditions.

4.1.1.4 Excavation

Excavation of hydrocarbon contaminated soil (>180 mg/kg TPH) would eliminate the source of groundwater contamination. The excavated material could be handled in the following ways:

- Disposal-excavated material transported to an authorized off-site landfill.
- "Landfarming" - spreading the soil on the surface and mixing it to increase volatilization and biodegradation of the contaminant. This activity could be performed at an off-site bioremediation facility located near the activity.
- Low temperature thermal reduction (LTTR) - excavated soil placed into an apparatus where the contaminants are driven from the soil through enhanced volatilization by the application of heat. This activity may be performed at an off-site facility or a mobile unit may be brought on site. For the later case, the treated soil could be used for backfill.

Evaluation/Recommendation: Excavation with treatment either off site at an bioremediation facility or a LTTR facility, or on site treatment using a mobile LTTR unit are the recommended technologies for this site. This type of treatment would be effective on the low permeable soils present at the site. Excavation with treatment would effectively reduce elevated levels of petroleum contamination and reduce further migration of contaminants into the water table.

Excavation activities could be completed within a one month period if soils are hauled off-site. The cost of off-site disposal is \$28 per ton at nearby bioremediation and LTTR facilities. With transportation and backfilling expenses, the overall cost for the alternative would range from \$50 to \$70 per cubic yard.

Although feasible alternatives, landfarming and landfill disposal were not selected based upon site requirements and suitability to the U.S. Navy. The use of a landfill would not eliminate future liability associated with the contamination.

4.1.2 Free Product Recovery

Free product was detected in only one portion of the site. This area was the eastern edge of the soil mound located north of the tanker loading area. Monitoring well MW-13 had 0.02 feet of free product present in December, 1992.

Excavation of this portion of the soil mound is proposed to address the soil contamination present in this area (soil borings MW-13 and SB-11 had the highest TPH concentrations detected at the site, 14,700 mg/kg and 1,900 mg/kg, respectively). It is anticipated that the saturated soils associated with this free product will be removed at that time. No active free product recovery system is recommended at this time. Any remaining free product that may be present at the site will be addressed by the proposed groundwater recovery system.

4.1.3 Groundwater Recovery Technologies

As discussed in Section 3.0, several petroleum constituents exceeded established WQSS established by the State. Based on these standards it will be necessary to remediate the groundwater present at the site. Several potential technologies that may be applicable for the recovery of groundwater have been screened based on capability and limitations and are presented on Table 4-2. The technologies which appear to be potentially applicable to the CSFF site will be evaluated (with respect to advantages and disadvantages) in the following subsections. Please note that generic recovery technologies and not specific variations on each type of technology have been included in the following discussions.

4.1.3.1 Well Points

Well point technology consists of installation of a number of small diameter recovery wells on the perimeter of the free phase product plume. This technology is best suited for sandy soil conditions.

Evaluation/Recommendation: This option may have high initial capital costs to cover well installation and recovery equipment costs. Due to the geologic setting present, this method may not be the best alternative for this site.

4.1.3.2 Recovery Wells

Recovery wells are a conventional, demonstrated technology, which is useful with sandy aquifers. A typical recovery well would likely be 6 to 12 inches in diameter and extend 10 feet to 20 feet into the water table. The distance between the wells and the flow rates would be dependent on geologic conditions. A considerable quantity of groundwater would also be generated by this process depending on the geologic conditions.

Evaluation/Recommendation: The results of an eight-hour aquifer test performed at the site during the second phases of assessment activities, indicate that a single recovery well cannot generate a significant radius of influence at the site. The low permeability of the soils would require several recovery wells be installed at the site, with a close spacing pattern to effectively remediate the groundwater at the site. The costs associated with installing and maintaining each recovery well with the necessary equipment does not make this option suitable for the CSFF site.

4.1.3.3 Interceptor Trenches

An interceptor trench is excavated downgradient of a plume for the purpose of intercepting and preventing further migration of free phased product. The trench is dug to a depth several feet below the water table and should be long enough to intercept the full lateral extent of the plume. The trench must also be perpendicular to local groundwater flow direction. As the product plume migrates, free product accumulates in the trench and can be recovered manually or with pumps. An impermeable liner can be placed on the downstream side of the trench to eliminate free product from moving past the trench. Sumps or wells may also be installed in the trench to increase the rate of recovery (EPA, 1990).

Evaluation/Recommendation: This is an effective technology at sites which have silt or clay soils present. The shallow groundwater present at the site adds to the suitability of this approach. This option can inhibit the migration of the product plume. It is a recommended option for remediation at this site.

4.1.4 Fluid Disposal Alternatives

Several methods of treated groundwater disposal were evaluated. These disposal methods include:

- Disposal via infiltration galleries
- Disposal by injection well system
- Disposal to a wastewater treatment plant
- Disposal to a surface water or drainage ditch

Each disposal method was evaluated based upon cost (design, installation, maintenance, and monitoring), feasibility, and consideration to the impact to future land uses in the area. Each disposal alternative and associated evaluation are described below.

4.1.4.1 Infiltration Gallery

An infiltration gallery is an area where a permeable media, such as gravel or sand, is installed within an area of low permeability soils. The design of an infiltration gallery is similar to a trench or septic drainage field. The increased surface area of the gallery permits the infiltration of water into the soils. The treated water is discharged over the media and allowed to infiltrate into the underlying soils.

In North Carolina the gallery must operate as a "closed loop" system, (i.e. fluids introduced into the subsurface will be captured through the recovery portion of the remediation system). The installation requires documentation (computer models, results of previous pilot studies, published reports, etc.) that both supports the effectiveness of the proposed process and demonstrates that applicable water, air, or land quality will not be contravened. The level of treatment of the contaminated groundwater, prior to discharge into a gallery located outside the contaminant plume, must not contain concentrations of contaminants in excess of those specified in the groundwater quality standards (15A NCAC 2L.0202). If the treated water is infiltrated within the contaminant plume, the water shall not contain more than 5% of the concentration of contaminants in the groundwater influent.

Evaluation/Recommendation: The infiltration gallery is an acceptable method of fluid disposal in low permeability soils. However, given the soil conditions of the site, the shallow

groundwater conditions, and the available land space and usages in the area, the use of a infiltration gallery is not recommended.

4.1.4.2 Injection Well

An injection well is a well used to pump fluids into underlying geologic zones or aquifers. According to North Carolina regulations the injection well must be constructed and operated such that: (1) the injected liquid does not exit the well bore above or below the demonstrated vertical extent of the contaminant plume, (2) operation of the remediation system will not result in a contravention of groundwater quality standards at the compliance boundary (15A NCAC 2C.0107), and (3) they are operated as a "closed loop" system.

The level of treatment of the contaminated groundwater, prior to discharge into an injection well located outside the contaminant plume, must not contain concentrations of contaminants in excess of those specified in the groundwater quality standards (15A NCAC 2L.0202). If the treated water is infiltrated within the contaminant plume, the water shall not contain more than 5% of the concentration of contaminants in the groundwater influent.

Evaluation/Recommendation: Given the state requirements that the injected liquid does not exit the well bore above or below the demonstrated vertical extent of the contaminant plume, the suitability of injection wells at the site is not feasible. The shallow groundwater and low permeability of the shallow soils are not suitable for this alternative.

4.1.4.3 Wastewater Treatment Plant

This fluid disposal option uses existing sanitary sewer lines to receive treated groundwater discharge. The groundwater is treated, discharged into the sewer line, and then further treated at a municipal wastewater treatment facility. Discharge into the sewer lines is not possible without authorization from the wastewater treatment facility.

Evaluation/Recommendation: MCB Camp Lejeune operates several wastewater treatment plants. The CSFF area is serviced by the Camp Geiger Wastewater Treatment Plant. Sewage lines for the wastewater treatment plant are located in the vicinity. However, the capacity of the lines in this area are reportedly near capacity. The MCB does not want to increase the flow within the lines by receiving waste streams from remediation systems. Therefore, this disposal alternative is not acceptable.

4.1.4.4 Surface Water and Drainage Ditches

This disposal option results in treated groundwater being discharged to a surface water or drainage ditch. To utilize this option, a NPDES General Permit is required. This general permit is not acceptable for contaminants other than petroleum. Design and operation of the remediation systems that utilize this option must be accordance with 15A NCAC 2B.0100 (Wastewater Discharged to Surface Water). Major permitting considerations include (but are not limited to) types and concentrations of contaminants and daily volume of discharge.

Evaluation/Recommendation: Although there may be significant delays in receiving a NPDES permit, this alternative is the most suitable for the CSFF site. Several drainage ditches are located in the immediate vicinity of the CSFF and Building AS-143. The anticipated low flow rates of the remediation system (2 to 4 gpm) will not impact the carrying capacity of the drainage ditches. In addition, the treated groundwater will not adversely impact the quality of the water within the ditches.

4.2 Selected Remediation and Disposal Alternatives

Three areas of the site require soil and/or groundwater remediation. These areas consist of:

- The soil mound located in the center of the CSFF.
- The area south of the tanker loading area along Campbell Street.
- The UST located at Building AS-143.

Based upon the results of the two phases of site assessment activities performed at the site, and the evaluation of potential remediation technologies, the following remediation alternatives were selected for each of the areas designated above:

- The soil mound: The soils in the eastern portion of the mound (in the vicinity of soil borings SB-11 and MW-13) should be excavated. The excavated soils may be treated off site at either a permitted LTTR facility or bioremediation facility located near MCB Camp Lejeune.

Upon completion of the excavation of the eastern portion of the mound, the remaining soil mound should be sampled and analyzed. If the results are below the remediation requirements, the soils may be used as backfill.

No free product recovery is recommended at this time. It is anticipated that free product and saturated soils will be removed during the excavation activities. Any free product or contaminated groundwater that is present in this area after the excavation activities are completed will be recovered by the proposed groundwater recovery system for the other portions of the site.

- The area south of the tanker loading area (in the vicinity of monitoring wells MW-12 and MW-16): Based upon the assessment activities performed in this area, it appears that elevated soil and groundwater contamination is present in this area. Unfortunately numerous subsurface utilities are also present, as shown on Figure 4-1, which will impact the remediation alternatives that are available.

The recommended approach for this portion of the site is to excavate an interceptor trench from the western side of the loading facility access driveway and extend the trench westward toward monitoring well MW-16. This activity will assist in removing soils with elevated levels of petroleum contamination and create a hydraulic barrier to reduce the migration of contaminated groundwater. The installation of the trench is not intended to excavate all petroleum contaminated soils above 180 mg/kg, but to assist in groundwater recovery operations.

The groundwater recovered from the trench will be treated and discharged to the drainage ditch located east of Building AS-143. The water collected from the interceptor trench would be combined with groundwater generated from recovery operations located at Building AS-143.

- Building AS-143: The UST located at Building AS-143 is scheduled for removal in August, 1994. Petroleum contaminated soils generated during UST removal activities should be disposed at an off-site permitted facility. It is recommended that the UST system be replaced with a system that is within current UST requirements.

It is recommended that a groundwater interceptor trench is constructed within this area of the site. The trench would use the natural flow direction of the groundwater to

intercept and recover contaminated groundwater in this portion of the site. The existing recovery well, RW-1, would be used as a recovery sump to remove groundwater from the trench.

After the groundwater is recovered from the trench, it is recommended that the groundwater undergo a treatment process and then be discharged to the drainage stream located east of Building AS-143.

The treatment process for the recovered groundwater would consist of an oil/water separator, followed by a low-profile air stripper, and finally a carbon adsorption treatment. Filters will also be installed within the system to reduce the potential of sediments or metals fouling the system.

The oil/water separator is recommended to remove any free product that still may be present in the soils and that may eventually migrate to the interceptor trenches. Because of the low flow rates anticipated from the combined discharge of the interceptor trenches (2 to 4 gpm) and the low concentrations of organic compounds present, it is anticipated that a low-profile air stripper be used to reduce organic concentrations. A carbon adsorption unit would be used to treat groundwater after the air stripper and prior to discharge. Although it is anticipated that the air stripper will adequately reduce organic concentrations, the carbon adsorption unit will "polish" the treated water before discharge to the drainage ditch.

5.0 PROPOSED CORRECTIVE ACTION

This section of the CAP presents a discussion of the proposed remediation alternative for the CSFF and Building AS-143. The following subsections discuss the design of the remediation alternative; remediation construction concerns; and proposed system monitoring approach.

The recommended corrective action for the site is the removal of petroleum contaminated soils in the center of the CSFF, and the recovery and treatment of petroleum contaminated groundwater in the southern portion of the CSFF and vicinity of Building AS-143. Both remediation alternatives are discussed below.

5.1 Soil Excavation

Petroleum contaminated soils with TPH concentrations above 180 mg/kg will be excavated from the center area of the CSFF. It is anticipated that the excavation activities to obtain the soil remediation endpoint will also be able to achieve the free product groundwater remediation endpoint of less than 0.01 feet.

Due to the origin of the soil mound, additional soil sampling should be performed to verify TPH concentrations. This information will aid in evaluating the amount of soil to be removed. The proposed soil sampling locations are shown on Figure 5-1. The shallow soil samples may be obtained using hand augering methods.

The corrective action will include excavating the soil in the immediate vicinity of the soil mound, as depicted on Figure 5-1. Final limits of the excavation will be established in the field using visual observations and field testing procedures outlined in Section 5.1.1. The excavated soils should be transported to either an off-site LTTR facility or a bioremediation facility. The excavated area may then be backfilled with clean soil and revegetated. If the limits of the excavation are as shown on Figure 5-1, it is estimated that 1,700 cubic yards of soil will be removed. The actual quantity may vary, depending on conditions encountered during excavation activities.

5.1.1 Excavation and On-Site Testing

The area delineated on Figure 5-1 will be excavated to the top of the groundwater surface. Contaminated soils will be loaded into dump trucks and transported to the disposal facility.

As the excavation activities progress into lower contaminated areas, the excavated soils will be temporarily stockpiled as contaminated soil until further verified by laboratory testing. This soil will be stored in the area southeast of the soil mound and covered in a temporary containment area, as shown on Figure 5-2, to prevent contamination of stormwater runoff and underlying soils. If necessary, temporary shoring will be provided around any exposed utilities. The excavation will continue until field testing indicates that TPH levels in the excavation walls are below 180 mg/kg. It is anticipated that the extent of the excavation will not include roadway areas of the site that are asphalt or concrete covered.

Field testing will be performed using the EnSys RIS Test System. This is an EPA test approved as SW-846 Draft Method 4030. More information on the field testing method is provided in Appendix B. The field testing will enable the remediation contractor to differentiate contaminated and non-contaminated soil. Utilizing field testing methods will also provide same day sampling results at a cost savings compared to laboratory testing. The final extent of the soil excavation will be confirmed and supplemented with laboratory testing.

It is anticipated that the excavation activities will damage or destroy the three existing monitoring wells located in the vicinity of the soil mound. Therefore, these three monitoring wells MW-13, MW-17 and DW-5 will be properly abandoned prior to initiating excavation activities.

5.1.2 Off-Site Treatment

Due to the close proximity of off-site soil recycling companies, such as McGill Environmental Systems in Rose Hill, North Carolina and American Soils Corporation in New Bern, North Carolina, off-site treatment is recommended for the disposal of soils generated during excavation activities. The contaminated soils that require treatment will be placed into trucks with covers, and hauled to the disposal facility.

5.1.3 Site Restoration

The open excavation area will be backfilled with a certified clean fill, or with fill from an approved base borrow area. All temporary shoring will be removed upon being supported with fill material. The fill will be placed in lifts and compacted. Topsoil will be placed on top of the clean fill and graded to match the surrounding terrain, and the disturbed area will be revegetated. The temporary soil stockpiling containment structure will be decontaminated

and dismantled. The components of the containment structure will be properly disposed. General site clean up and equipment demobilization will occur upon completion of all remediation activities.

5.2 UST Removal

The UST located at Building AS-143 is scheduled for removal in August 1994. Petroleum contaminated soils generated during UST removal activities should be properly disposed at an off-site permitted facility. A replacement UST will be installed, along with clean backfill, in the same location. During the design phase of the remedial activities, removal and replacement of the UST should be verified.

5.3 Groundwater Recovery

5.3.1 Trench Installation

As discussed in Section 4.0, interceptor trenches will be used to recover groundwater. Interceptor trenches were selected over other remediation alternatives due to the shallow depth to groundwater and the low permeability of the soils. The interceptor trenches will create an area of higher permeability. As groundwater is removed from the trench, groundwater from the adjacent silt and clay soils will migrate into the trench and the cycle is repeated.

A recovery well will be installed within the center of the interceptor trench to be installed in the vicinity of monitoring well MW-12. The interceptor trench which will be installed in the vicinity of Building AS-143 shall be excavated to connect with the existing six-inch well (RW-1) previously installed.

The proposed locations of the interceptor trenches are shown on Figure 5-1. The actual length of the trenches will depend upon soil and groundwater conditions encountered during their construction. If soil concentration above 180 mg/kg TPH, or free product is detected, the length of the trenches may be extended. However, the actual length of the trench will depend upon site conditions such as subsurface utilities, disruption of CSFF services, traffic concerns, etc.. Soils generated during excavation activities will be disposed at an off-site permitted facility.

Both trenches will be three feet wide with a depth of 12 feet. The trench located within the CSFF will be excavated to 14 feet at the recovery well location to allow for additional room within the well for the pump.

The interceptor trenches shall be backfilled with gravel suitable for the well screen and geologic conditions. The gravel backfill shall extend 1/2 foot above the well screen. A geotextile fabric will be placed over the gravel fill to prevent shallow backfill soils from migrating into the gravel zone.

The recovery wells will be completed below grade within a lockable vault box or manhole that is capable of containing the necessary pump controls. A schematic of a typical interceptor trench is shown on Figure 5-3.

5.3.2 Subsurface Trenching

Subsurface trenching connecting the recovery wells with the air compressor and remediation system will be required. Compressed air and recovered groundwater lines will be placed within a 4-inch PVC pipe. The piping will be installed within the subsurface trenches and covered with compacted backfill.

A portion of this trench will pass beneath White Street to connect the two groundwater interceptor trenches. Additional concerns to the integrity of the piping, traffic control, and worker safety will be required to perform this task.

5.3.3 Pneumatic Pumping System

5.3.3.1 Pneumatic Pump

A pneumatic pump will be installed within each recovery well. The pneumatic pump will be designed to recover free product and petroleum contaminated groundwater. The pump must be constructed of a material that is resistant to petroleum products (JP-5). All fittings and product return lines associated with the pump must also be resistant to petroleum products.

Several companies manufacture pumps that meet the product recovery requirements for this site. Examples of such manufacturers are QED Environmental Systems, Inc. (QED) of Ann

Arbor, Michigan, and Ejector Systems of Chicago, Illinois. Pneumatic pump information supplied by Ejector Systems is provided in Appendix C.

5.3.3.2 Air Compressor

The pneumatic pumps for both recovery wells will be powered by a single air compressor. The air compressor will be an electric type of sufficient horsepower to operate both pumps and be equipped with an appropriate size receiver tank.

5.3.3.3 Equipment Storage Building

A prefabricated equipment storage building will be constructed to house both the recovery pump control panel, the electric air compressor, the oil/water separator, product storage tank, air stripper, and carbon adsorption unit. The storage building will be constructed and equipped at the factory for immediate installation and operation at the site. The building shall already be internally wired and constructed on a skid mounted platform for movement to other facilities once remediation is completed at the CSFF.

A chain-link fence will enclose the equipment storage building for added security. The fence will have a gate constructed on the two opposite sides to permit access to the equipment storage building. Each gate will be constructed to swing a minimum of 90 degrees so equipment may be replaced or repaired if needed.

5.4 Groundwater Treatment

Aquifer testing performed at the site during the second phase of assessment activities (Baker 1993), indicate that low flow rates are anticipated for the treatment system. Based upon the aquifer test results, it is estimated that the flow rate for the system will be less than 4 gallons per minute (gpm). The treatment system will be designed to treat a maximum flow rate of 10 gpm.

Based on this maximum flow rate of 10 gpm, the treatment system will have the following processes for treating groundwater:

- The pneumatic pumps will recover groundwater and direct it to the treatment system. The groundwater will first pass through an oil/water separator.

- Effluent from the oil/water separator will be sent to a low profile, low flow air stripper.
- Effluent from the air stripper will be sent to a suspended solid/iron removal filter. The suspended solids/iron removal filter will consist of a series of replaceable filter plates, or a cartridge type filter system. This filtration system is necessary to remove suspended solids prior to the carbon adsorption system.
- Effluent from the filter will be pumped through two liquid granular activated carbon (GAC) adsorbers installed in series. The GAC will reduce any remaining volatile and semivolatile compounds in the groundwater to within acceptable discharge requirements.
- The treated groundwater will be pumped to the drainage ditch located east of the site as shown on Figure 5-1.

Several companies manufacture equipment for the treatment of petroleum contaminated groundwater. Information from one such company, Ejector Systems, for the equipment discussed below is provided in Appendix C.

The proposed treatment equipment will be located within the storage building. The equipment will be preassembled by the manufacturer and ready to place into service with a minimum amount of field construction time. All electrical components will have an explosion-proof rating. A schematic of the proposed recovery system is shown on Figure 5-4.

5.5 Remediation Construction Concerns

Logistical and construction issues associated with the implementation of the recommended remedial actions should be addressed prior to initiation of construction activities. These include site access, construction worker health and safety, utility clearance, and temporary soil stockpiling, and are addressed below.

5.5.1 Site Access

The remediation contractor will have to make arrangements with the Activity for daily access to the site, and for access to the site outside normal working hours.

5.5.2 Construction Worker Health and Safety

The contractor will be required to prepare a site-specific Health and Safety Plan (HASP) to provide for the safety of construction workers during construction activities. The plan will include but is not limited, to the following items:

- An outline of the tasks to be conducted at the site and the associated physical and health hazards of these tasks.
- The potential risks to the health and safety of the construction worker.
- The physical and chemical properties of the contaminants at the site.
- Measures to detect the presence of contamination.
- Standard operating procedures for protection against hazards and a contingency plan for responding to accidents.

The HASP should be reviewed by all construction workers at the site, and should be updated as activities or conditions warrant. Only workers with the appropriate health and safety training will be permitted to work at the site.

5.5.3 Utility Clearance

A primary concern during site preparation and actual remediation activities will be locating and identifying all underground utilities in the work area. The MCB Camp Lejeune Public Works Department will provide utility clearance for those areas that will be disturbed prior to construction. A plan of the study area with approximate subsurface utility locations is provided on Figure 4-1.

5.5.4 Equipment Installation Considerations

The installation of the equipment recommended for the groundwater recovery and treatment system will include conventional construction techniques such as: installation of underground piping in utility trenches, installation of an equipment storage building, and installation of the necessary electric service, power panels and controls. The main components necessary for the groundwater treatment and recovery system is as follows:

- Installation of groundwater interceptor trench.
- Installation groundwater recovery pneumatic pumps.
- Installation of subsurface trenching to connect pumps with treatment system.
- Installation of an equipment storage building which will contain the air compressor, oil/water separator, air stripper, carbon adsorption unit, and control board.

Figures 5-1 and 5-4 show the site plan and process schematic of the recommended system, respectively. Construction considerations for the major components of the system are discussed below.

The equipment storage building will be located north of Building AS-143. This location is proposed due to the available space and close proximity of the drainage ditch. The equipment storage building will contain the remediation equipment such as: air compressor, oil/water separator, air stripper, carbon adsorption unit, and control board.

The equipment storage building will be located in a manner that will not interfere with MCB Camp Lejeune activities and will be designed to permit easy access for construction and service vehicles. The storage building will be secured with locking door. A chain-link fence will surround the building as an additional safety precaution.

Electric service of sufficient capacity will be brought to a pole or pad mounted transformer next to the equipment storage building. The power distribution and controls for the equipment should have an explosion-proof rating.

5.5.5 System Startup and Operation

The groundwater recovery system should operate continuously 24 hours a day, seven days a week. Startup of the groundwater recovery system will be the responsibility of a contractor selected by the U.S. Navy. The contractor will be required to initially operate the equipment during the initial startup. During this startup period, the contractor will be responsible for making any necessary equipment adjustments or repairs. The contractor will also be required to provide a detailed system operation and maintenance (O&M) manual to the Activity.

5.5.6 Temporary Soil Stockpiling

Temporary soil stockpiling will be necessary during trenching or excavation activities. A method to temporarily stockpile soils is shown on Figure 5-2. Excavated soils must be sampled before being used as clean backfill. A minimum of one composite sample for every 100 cubic yards (c.y.) of stockpiled soil will be obtained to evaluate the condition of the soils. If the soil contains TPH concentrations above 180 mg/kg it will be removed from the site and disposed at a state permitted LTTR or bioremediation facility.

Soils will be collected and analyzed for the following analytical parameters:

- Percent moisture (EPA Method 160)
- Total organic halogens (EPA Method 9020)
- TPH (EPA Method 418.1)
- VOCs (EPA Method 8020)
- Toxicity characteristic leaching procedure (TCLP) metals (these include arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver)
- Polychlorinated biphenols (PCBs) (EPA Method 8080)

A minimum of one composite sample will be collected for every 100 cubic yard of soil to be disposed.

5.5.7 Effect of CAP on Activity Personnel

The implementation of the remediation alternative will affect Activity personnel who work in the area. These personnel will be notified by their supervisor of the planned corrective action, and what effects it may have on their daily routine. Workers will be notified of the potential physical hazards posed during the construction and implementation of the remediation alternatives. Examples of such hazards are open trenches and excavations, exposed underground utilities, exposure to odors during excavation and the movement of construction vehicles.

In addition, workers will receive instruction on the potential hazards associated with the operation of the groundwater recovery system. These hazards include air emissions from the air stripper.

5.6 System Monitoring

An outline of the monitoring plan, including sampling frequency, sample locations, parameters to be measured, levels to be reported, and data submittal requirements, is presented for the selected remediation alternative in the following sections. Reporting requirements are discussed in Sections 5.5.2 and 5.5.3. Standard operating procedures (SOPs) suggested for the monitoring requirements are listed in Section 5.5.4, and included in Appendix D.

5.6.1 CAP Monitoring Requirements

Under the proposed remediation alternative, soil excavation and groundwater treatment will be performed to remediate the petroleum contamination. The monitoring plan has been designed to confirm that the designated remediation endpoints for soil and groundwater contamination have been met and that the remediation system is operating effectively. The components of the monitoring plan (sampling locations, sampling frequency, and method of analysis) are summarized on Table 5-1.

5.6.1.1 Soil Monitoring

Soil samples will be obtained periodically from the excavation and screened in the field to determine the condition of the soils. Once the full extent of the excavation has been reached,

confirmatory soil samples shall be obtained from the side walls of the excavation. One soil sample shall be taken every 50 feet along the excavation wall with a minimum of one sample per side of the excavation. Based upon Figure 5-1, it is estimated that 8 soil samples will be obtained to confirm the condition of the soils not excavated. Each soil sample selected for laboratory analysis will be analyzed for TPH using EPA Method 8015 (5030/3550). The laboratory detection limit will be a no greater than 10.0 mg/kg.

If soils above 180 mg/kg are detected along the excavation wall, additional soils shall be excavated until the soil remediation endpoint is reached. Additional soil samples will be obtained to confirm the condition of the soil.

5.6.1.2 Groundwater Monitoring

Groundwater monitoring will be conducted on a quarterly basis following the initiation of remediation activities, and then performed on a quarterly basis to monitor groundwater quality. Samples will be collected from existing monitoring wells MW-3, MW-11, MW-12, MW-14, MW-16, MW-21, MW-23, MW-24, MW-25, DW-2 and DW-6. The purpose of the monitoring activities are to evaluate the organic concentrations within the groundwater and the effectiveness of the remediation system.

Groundwater samples from the selected monitoring wells will be analyzed for volatile organics using EPA Method 602. In addition, groundwater samples from monitoring wells DW-2 and DW-6 will also be analyzed for PAHs using EPA method 625. The laboratory detection limit for the volatile organic and PAH analyses will be a no greater than 0.001 mg/L.

Fluid level measurements will be obtained monthly from the monitoring wells which will be sampled, and the following additional wells: MW-9, MW-10, MW-15, MW-22, and the two recovery wells within the interceptor trenches. Fluid level measurements shall include thickness of free product in addition to groundwater elevations. This information shall be used to evaluate the effectiveness of the remediation system and determine if adjustments in flow rates may be required.

5.6.1.3 System Effluent Monitoring

The discharge flow rate of the treatment system will be monitored weekly as specified by the NPDES permit requirements. In addition, effluent samples shall be obtained monthly and analyzed for toluene, benzene, and methyl teryl butyl ether using EPA Method 602.

5.6.1.4 Post-Operational Monitoring

Post-operational monitoring will be conducted at the site after the remediation goals for soil and groundwater contamination have been met. The post-operational monitoring may begin after soil and groundwater remediation endpoints have been met for one full year.

Post-operational monitoring will include sampling the selected monitoring wells for the presence of volatile organics and TPH. The groundwater sampling activities will be performed quarterly for one year after the operation of the groundwater treatment system has been terminated.

Groundwater samples will be obtained from the same monitoring wells that were sampled during the operational monitoring period. The groundwater samples will be obtained quarterly until the post-operational monitoring period is terminated.

If during the year of post-operational monitoring the groundwater remediation endpoints are exceeded, the operation of the groundwater treatment system may be resumed.

5.7 Monthly Reporting Requirements

MCB Camp Lejeune will submit monthly reports to the DEHNR regional office. These monthly reports will summarize the results of the groundwater and effluent monitoring activities performed at the site. The following information will be included in the monitoring reports:

- The results of all monitoring data, including monitoring well gauging, free product levels (if detected), effluent analytical results, and groundwater analytical results if quarterly sampling occurred during that month.
- Remediation system performance and air emissions monitoring results.

- If applicable for the reporting period, a description of the circumstances or events that caused mechanical problems with the remediation system, including dates and times of nonoperation, and actions taken or planned to correct the problem.

In addition to the monthly monitoring reports, MCB Camp Lejeune personnel will report to the DEHNR Regional Office any unpermitted or unusual discharge that may enter or affect State waters, or may endanger public health. Such reporting shall be made within 24 hours from the time the Activity becomes aware of the discharge or release.

5.8 Annual Reporting Requirements

In addition to the monthly monitoring reports, an annual report will be submitted to the DEHNR. The annual report will include monitoring results, evaluate the effectiveness of the remediation alternative and its progress toward achieving the cleanup endpoints. The first report shall be submitted within 12 months of initiation of remediation activities, and yearly thereafter, if necessary.

5.9 Field Monitoring Procedures and QA/QC Considerations

Example standard operating procedures (SOPs) for the collection of samples and field data have been included in this CAP in Appendix D. These examples may be used as guidelines to implement the monitoring plan:

- F102 Soil and Rock Sample Acquisition
- F104 Groundwater Acquisition
- F201 On-site Water Quality Testing
- F202 Water Level, Water-Product Level, and Well Depth Measurements
- F203 Photoionization Detector (PID)
- F204 Flame Ionization Detector (FID)
- F301 Sample Preservation and Handling
- F302 Chain-of-Custody
- F304 QA/QC Samples
- F502 Decontamination of Sampling and Monitoring Equipment

5.10 Completion of Corrective Action and Site Restoration

The corrective action will be complete after demonstrating that the site-specific remediation endpoints (180 mg/kg TPH in soils and specified organic concentrations in groundwater) have been met for twelve consecutive months. A request may then be submitted to the State to end remediation activities, and begin post operational monitoring.

Post operational monitoring will be conducted quarterly for a one year period after shut down of the groundwater treatment system. If levels of volatile organic concentrations in groundwater greater than the specified endpoints (or agreed upon asymptotic concentrations with the State) are detected during the post operational monitoring, the remediation system will again be activated and the operational treatment system monitoring plan implemented.

Site restoration activities will commence after all confirmatory sampling results have been evaluated to verify that contamination exceeding the remediation endpoint is removed.

Following equipment demobilization and removal of all subsurface remediation equipment and piping, the disturbed area(s) will be graded to match the previously existing ground cover. Finally, general site cleanup activities will be performed.

5.11 Cost Estimate

A cost estimate was prepared for the proposed remediation alternative (Appendix E). The estimate includes labor and equipment costs for: site preparation, soil excavation and disposal, recovery trench installation, pipe subsurface trenching, remediation equipment (i.e., air stripper, pumps, filters, carbon adsorbers) and system operation and monitoring. Although UST AS-143 is scheduled to be removed in August, 1994, an estimate for its removal was included for future reference. All assumptions are listed in Appendix E. The estimated cost to install and operate the system is \$463,592.

6.0 PERMITS

Because of the remediation alternative selected for the site; soil excavation, groundwater extraction and treatment, and discharge to a drainage ditch, several permits are required from the State of North Carolina. These permits include:

- NPDES permit
- Air quality permit/registration
- Well construction permit
- Certificate of approval

6.1 NPDES Permit

Because the treatment system shall be discharging to a drainage ditch, a NPDES permit will be required. The permit shall require weekly monitoring of the discharge rate of the treatment system. In addition, monthly chemical sampling of the system effluent shall be required. The chemical analyses to be performed, effluent limitations, and other monitoring requirements are summarized on Table 6-1.

6.2 Air Quality Permit

The treatment system shall utilize a low profile air stripper. This stripper will generate volatile emissions into the atmosphere. As required by the State of North Carolina, the air stripper must be registered with the State. However, an air quality permit shall not be required to operate the unit. Based on the organic concentrations observed in the groundwater, emissions of total organics and individual constituents such as benzene, toluene, chlorobenzene, total xylenes, and 1,2-, 1,3- and 1,4-dichlorobenzene will not exceed de minimis emission rates established by the State.

6.3 Well Construction Permit

A recovery well shall be installed within the interceptor trench located along the southern side of the CSFF. Because water will be extracted from the well, a well construction permit shall be required by the State of North Carolina.

6.4 Certificate of Approval

Disposal of petroleum contaminated soils at an off-site treatment facility requires approval from the state of North Carolina. Approval of the certificate is automatic when the soils are stored on site less than 45 days and they are stored as shown on Figure 5-2. The off-site disposal facility must be permitted to dispose of petroleum contaminated soils.

7.0 REFERENCES

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Tables

TABLE 1-1

SUMMARY OF WELL CONSTRUCTION DETAILS - DECEMBER 1991
CAMPBELL STREET FUEL FARM
CONTRACT TASK ORDER 0265

Well No.	Date Installed	Top of Casing Elevation ⁽¹⁾ (feet, above MSL)	Ground Surface Elevation (feet, above MSL)	Boring Depth (feet, below ground surface)	Depth of Outer Casing (feet, below ground surface)	Well Depth (feet, below ground surface)	Screen Interval Depth (feet, below ground surface)	Depth to Sand Pack (feet, below ground surface)	Depth to Bentonite (feet, below ground surface)
MW-1	12/10/91	23.24	19.6	14.0	NA	14.0	4.0 - 13.8	2.0	1.0
MW-2	12/10/91	22.83	19.1	14.0	NA	14.0	4.0 - 13.8	2.0	1.0
MW-3	12/12/91	21.69	18.3	14.0	NA	14.0	4.0 - 13.8	2.0	1.0
MW-4	12/12/91	22.77	18.6	14.0	NA	14.0	4.0 - 13.8	2.0	1.0
MW-5	12/12/91	23.85	20.7	15.1	NA	15.1	5.3 - 14.7	2.0	1.0
MW-6	12/13/91	20.40	17.3	15.0	NA	15.0	5.0 - 14.8	2.0	1.0
MW-7	12/13/91	21.04	17.5	14.0	NA	14.0	4.0 - 13.8	2.0	1.0
DW-1 ⁽³⁾	12/17/91 12/18/91	20.79	18.3	30.0	20.0	30.0	25.0 - 29.8	23.0	19.0
DW-2	1/6/92 1/7/92	22.91	19.5	30.0	20.0	30.0	25.0 - 29.8	23.0	21.0
DW-3	1/6/92 1/7/92	22.98	19.6	30.0	20.0	28.0	25.0 - 27.8	21.0	19.0

(1) MSL - Mean Sea Level

(2) NA = Not Applicable

(3) Monitoring Wells DW-1, DW-2, and DW-3 were constructed as Type III monitoring wells.

Source: Baker Environmental, Inc., August 12, 1992. "Final Site Assessment Report, Campbell Street Fuel Farm and UST System AST-143" (Contract No. N62470-89-D-4814, Contract Task Order 0013).

TABLE 1-2

**SUMMARY OF WELL CONSTRUCTION DETAILS - NOVEMBER 1992
CAMPBELL STREET FUEL FARM
CONTRACT TASK ORDER 0265**

Well No.	Date Installed	Top of Casing Elevation ⁽¹⁾ (feet, above MSL)	Ground Surface Elevation (feet, above MSL)	Boring Depth (feet, below ground surface)	Depth of Outer Casing (feet, below ground surface)	Well Depth (feet, below ground surface)	Screen Interval Depth (feet, below ground surface)	Depth to Sand Pack (feet, below ground surface)	Depth to Bentonite (feet, below ground surface)
MW-8	11-19-92	20.45	17.8	13.5	NA ⁽²⁾	13.0	2.9 to 12.4	2.0	1.5
MW-9	11-19-92	20.45	18.0	14.5	NA	14.0	3.9 to 13.5	2.0	1.0
MW-10	11-19-92	21.17	18.4	15.5	NA	15.0	4.9 to 14.4	2.6	0.5
MW-11	11-18-92	22.03	19.3	16.5	NA	16.0	5.9 to 14.6	2.5	0.5
MW-12	11-19-92	21.41	18.9	14.5	NA	14.0	3.9 to 13.5	2.5	0.5
MW-13	11-20-92	22.80	20.0	15.5	NA	15.0	4.9 to 14.5	3.0	0.5
MW-14	11-20-92	20.07	17.3	13.5	NA	13.0	3.1 to 12.6	2.0	0.5
MW-15	11-21-92	21.08	18.4	16.5	NA	16.0	5.9 to 15.4	4.0	2.0
MW-16	11-20-92	21.45	18.8	15.5	NA	15.0	4.9 to 14.5	2.7	0.5
MW-17	11-20-92	22.51	19.8	13.5	NA	13.0	3.2 to 12.6	2.0	0.5
MW-18	11-22-92	18.69	18.9	13.5	NA	13.0	3.1 to 12.7	2.0	1.0

(1) MSL - Mean Sea Level

(2) NA = Not Applicable

MW-1 through MW-7 and DW-1 through DW-3 installed December 1992.

Source: Baker Environmental, Inc., February 15, 1993 Draft Site Assessment Report, Additional Assessment Activities, Campbell Street Fuel Farm and UST System 125-143 (Contract No. N62470-89-D-4814, Contract Task Order 0013).

TABLE 1-2

SUMMARY OF WELL CONSTRUCTION DETAILS - NOVEMBER 1992
CAMPBELL STREET FUEL FARM
CONTRACT TASK ORDER 0265

Well No.	Date Installed	Top of Casing Elevation ⁽¹⁾ (feet, above MSL)	Ground Surface Elevation (feet, above MSL)	Boring Depth (feet, below ground surface)	Depth of Outer Casing (feet, below ground surface)	Well Depth (feet, below ground surface)	Screen Interval Depth (feet, below ground surface)	Depth to Sand Pack (feet, below ground surface)	Depth to Bentonite (feet, below ground surface)
MW-19	11-23-92	19.10	19.2	14.0	NA ⁽²⁾	13.9	4.0 to 13.5	2.0	1.0
MW-20	11-23-92	19.40	19.7	15.0	NA	14.0	4.6 to 14.1	3.0	1.0
MW-21	11-21-92	21.76	19.1	14.5	NA	14.0	3.9 to 13.5	2.0	0.5
MW-22	11-23-92	21.69	18.9	13.0	NA	13.0	2.9 to 12.5	1.5	0.5
MW-23	11-21-92	21.35	18.9	13.5	NA	13.0	2.9 to 12.5	2.0	0.5
MW-24	11-22-92	21.56	19.0	11.5	NA	11.0	2.8 to 10.8	2.0	0.5
MW-25	11-23-92	21.17	18.6	14.5	NA	14.0	3.9 to 13.5	2.5	0.5
DW-4	11-22-92	21.07	18.5	52.0	41.0	51.0	45.6 to 50.4	39.5	37.0
DW-5	11-19-92	22.79	20.0	43.0	33.0	43.0	37.8 to 42.5	33.0	31.0
DW-6	12-02-92	21.83	19.1	42.5	32.0	42.5	37.3 to 42.0	35.0	29.0
RW-1	11-23-92	21.79	19.1	23.5	NA	23.0	3.0 to 22.4	1.5	0.5

(1) MSL - Mean Sea Level

(2) NA = Not Applicable

MW-1 through MW-7 and DW-1 through DW-3 installed December 1992.

Source: Baker Environmental, Inc., February 15, 1993 Draft Site Assessment Report, Additional Assessment Activities, Campbell Street Fuel Farm and UST System 125-143 (Contract No. N62470-89-D-4814, Contract Task Order 0013).

TABLE 1-3

SUMMARY OF FLUID LEVEL MEASUREMENTS
DECEMBER 7, 1992
CAMPBELL STREET FUEL FARM
CONTRACT TASK ORDER 0265

Well No.	Top of Casing Elevation ⁽¹⁾ (feet, above MSL)	Depth to Product (feet, below top of casing)	Depth to Groundwater (feet, below top of casing)	Product Thickness (feet)	Product Elevation (feet, above MSL)	Groundwater Elevation (feet, above MSL)
MW-1	23.24	NR ⁽²⁾	NR	NR	NR	NR
MW-2	22.83	NR	NR	NR	NR	NR
MW-3	21.69	-- ⁽³⁾	6.80	--	--	14.89
MW-4	22.77	--	8.58	--	--	14.19
MW-5	23.85	--	8.95	--	--	14.90
MW-6	20.40	NR	NR	NR	NR	NR
MW-7	21.04	--	4.96	--	--	16.08
MW-8	20.45	--	4.35	--	--	16.10
MW-9	20.45	--	6.08	--	--	14.37
MW-10	21.17	--	5.07	--	--	16.10
MW-11	22.03	--	7.72	--	--	14.31
MW-12	21.41	--	7.40	--	--	14.01
MW-13	22.80	--	12.33	--	--	10.47
MW-14	20.07	--	6.05	--	--	14.02
MW-15	21.08	--	7.59	--	--	13.49
MW-16	21.45	--	7.18	--	--	14.27

Notes: (1) MSL - Mean Sea Level

(2) NR = Not recorded on this date.

(3) -- = Not Detected

Source: Baker Environmental, Inc. February 15, 1993, Draft Site Assessment Report, Additional Assessment Activities, Campbell Street Fuel Farm and UST System AS-143 (Contract No. N62470-89-D-4814, Contract Task Order 0013).

SUMMARY OF FLUID LEVEL MEASUREMENTS
DECEMBER 7, 1992
CAMPBELL STREET FUEL FARM
CONTRACT TASK ORDER 0265

Well No.	Top of Casing Elevation ⁽¹⁾ (feet, above MSL)	Depth to Product (feet, below top of casing)	Depth to Groundwater (feet, below top of casing)	Product Thickness (feet)	Product Elevation (feet, above MSL)	Groundwater Elevation (feet, above MSL)
MW-17	22.51	-- ⁽²⁾	6.59	--	--	15.92
MW-18	18.69	--	4.34	--	--	14.35
MW-19	19.10	--	4.77	--	--	14.33
MW-20	19.40	--	4.07	--	--	15.33
MW-21	21.76	--	7.49	--	--	14.27
MW-22	21.69	--	7.38	--	--	14.31
MW-23	21.35	--	7.97	--	--	13.38
MW-24	21.56	--	7.88	--	--	13.68
MW-25	21.17	--	7.80	--	--	13.37
DW-1	20.79	--	6.92	--	--	13.87
DW-2	22.91	--	8.64	--	--	14.27
DW-3	22.98	NR ⁽³⁾	NR	NR	NR	NR
DW-4	21.07	--	6.63	--	--	14.44
DW-5	22.79	--	9.23	--	--	13.56
DW-6	22.83	--	8.15	--	--	14.68
RW-1	21.79	--	7.91	--	--	13.88

Notes: (1) MSL - Mean Sea Level

(2) NR = Not recorded on this date.

(3) -- = Not Detected

Source: Baker Environmental, Inc. February 15, 1993, Draft Site Assessment Report, Additional Assessment Activities, Campbell Street Fuel Farm and UST System AS-143 (Contract No. N62470-89-D-4814, Contract Task Order 0013).

TABLE 1-4

SUMMARY OF FLUID LEVEL MEASUREMENTS
DECEMBER 30, 1992
CAMPBELL STREET FUEL FARM
CONTRACT TASK ORDER 0265

Well No.	Top of Casing Elevation ⁽¹⁾ (feet, above MSL)	Depth to Product (feet, below top of casing)	Depth to Groundwater (feet, below top of casing)	Product Thickness (feet)	Product Elevation (feet, above MSL)	Groundwater Elevation (feet, above MSL)	Corrected Groundwater Elevation ⁽²⁾ (feet, above MSL)
MW-1	23.24	NR ⁽³⁾	NR	NR	NR	NR	NR
MW-2	22.83	NR	NR	NR	NR	NR	NR
MW-3	21.69	-- ⁽⁴⁾	5.83	--	--	15.86	--
MW-4	22.77	--	8.17	--	--	14.60	--
MW-5	23.85	--	8.97	--	--	14.88	--
MW-6	20.40	NR	NR	NR	NR	NR	NR
MW-7	21.04	NR	NR	NR	NR	NR	NR
MW-8	20.45	--	3.99	--	--	16.46	--
MW-9	20.45	--	5.61	--	--	14.84	--
MW-10	21.17	--	4.35	--	--	16.82	--
MW-11	22.03	--	6.86	--	--	15.17	--
MW-12	21.41	--	7.09	--	--	14.32	--
MW-13	22.80	8.33	8.35	0.02	14.47	14.45	14.46
MW-14	20.07	--	5.60	--	--	14.47	--
MW-15	21.08	--	7.10	--	--	13.98	--
MW-16	21.45	--	6.81	--	--	14.64	--

Notes: (1) MSL - Mean Sea Level

(2) Corrected groundwater elevations were determined by using the following equation:

CGE = Apparent Groundwater Elevation + (Product Thickness x 0.82) where 0.82 is the estimated specific gravity for JP-5 jet fuel.

(3) NR = Not recorded on this date.

(4) -- = Not Detected

Source: Baker Environmental, Inc. February 15, 1993, Draft Site Assessment Report, Additional Assessment Activities, Campbell Street Fuel Farm and UST System AS-143
 (Contract No. N62470-89-D-4814, Contract Task Order 0013).

SUMMARY OF FLUID LEVEL MEASUREMENTS
DECEMBER 30, 1992
CAMPBELL STREET FUEL FARM
CONTRACT TASK ORDER 0265

Well No.	Top of Casing Elevation ⁽¹⁾ (feet, above MSL)	Depth to Product (feet, below top of casing)	Depth to Groundwater (feet, below top of casing)	Product Thickness (feet)	Product Elevation (feet, above MSL)	Groundwater Elevation (feet, above MSL)	Corrected Groundwater Elevation ⁽²⁾ (feet, above MSL)
MW-17	22.51	-- ⁽³⁾	5.99	--	--	16.52	--
MW-18	18.69	--	3.84	--	--	14.85	--
MW-19	19.10	--	4.41	--	--	14.69	--
MW-20	19.40	--	3.78	--	--	15.62	--
MW-21	21.76	--	7.30	--	--	14.46	--
MW-22	21.69	--	7.05	--	--	14.64	--
MW-23	21.35	--	7.70	--	--	13.65	--
MW-24	21.56	--	7.62	--	--	13.94	--
MW-25	21.17	--	7.58	--	--	13.59	--
DW-1	20.79	--	6.48	--	--	14.31	--
DW-2	22.91	--	8.19	--	--	14.72	--
DW-3	22.98	NR ⁽⁴⁾	NR	NR	NR	NR	NR
DW-4	21.07	--	6.22	--	--	14.85	--
DW-5	22.79	--	8.25	--	--	14.54	--
DW-6	21.83	--	7.72	--	--	14.11	--
RW-1	21.79	--	7.51	--	--	14.28	--

Notes: (1) MSL - Mean Sea Level

(2) Corrected groundwater elevations were determined by using the following equation:

CGE = Apparent Groundwater Elevation + (Product Thickness x 0.82) where 0.82 is the estimated specific gravity for JP-5 jet fuel.

(3) -- = Not Detected

(4) NR = Not recorded on this date.

Source: Baker Environmental, Inc. February 15, 1993, Draft Site Assessment Report, Additional Assessment Activities, Campbell Street Fuel Farm and UST System AS-143 (Contract No. N62470-89-D-4814, Contract Task Order 0013).

TABLE 1-5

**SUMMARY OF SOIL ANALYSES, DECEMBER 1991
CAMPBELL STREET FUEL FARM
CONTRACT TASK ORDER 0265**

Boring No.	Field Sample No.	Parameter						Sample Depth (feet, below ground surface)
		Total Petroleum Hydrocarbons (mg/kg)		Petroleum Type(1)	TCLP Lead (mg/l)	pH	Flashpoint (°F)	
		Low-Med (5030)	Med-High (3550)					
MW-1	FF-S-1-01	0.75	1.71	weathered jet fuel	NA(2)	NA	NA	2.0 - 4.0
MW-1	FF-S-1-02	0.70	1.63	weathered jet fuel	--(3)	5.29	> 140	4.0 - 6.0
MW-2	FF-S-2-01	1.82	4.26	weathered jet fuel	NA	NA	NA	2.0 - 4.0
MW-2	FF-S-2-02	0.20	0.48	weathered jet fuel	--	4.84	> 140	4.0 - 6.0
MW-3	FF-S-3-01	0.59	1.53	weathered jet fuel	NA	NA	NA	2.0 - 4.0
MW-3	FF-S-3-02	0.86	1.92	weathered jet fuel	.0005	4.75	> 140	4.0 - 6.0
MW-4	FF-S-4-01	7.63	19.6	weathered jet fuel	NA	NA	NA	2.0 - 4.0
MW-4	FF-S-4-02	79.0	184	weathered jet fuel	--	5.28	> 140	4.0 - 6.0
MW-5	FF-S-5-01	0.16	0.37	weathered jet fuel	NA	NA	NA	4.0 - 6.0(4)
MW-5	FF-S-12-01(5)	--	0.27	weathered jet fuel	NA	NA	NA	4.0 - 6.0
MW-5	FF-S-5-02	--	--	Not Distinct	.0009	5.55	> 140	6.0 - 8.0
MW-5	FF-S-12-02(6)	--	0.57	weathered jet fuel	--	5.08	> 140	6.0 - 8.0

Notes:

- (1) EPA Method 5030/3550 estimated range of petroleum type
 - (2) NA = Not Analyzed
 - (3) -- = Not detected
 - (4) 2.0-4.0 not analyzed due to ability to recover sample closer to lower measured water table.
 - (5) Duplicate sample of FF-S-5-01.
 - (6) Duplicate sample of FF-S-5-02.
- Soil samples collected December 1991 through January 1992.
 TCLP Lead - Toxicity Characteristic Leaching Procedure analyzed using Method SW846-1311/7421.
 Total Petroleum Hydrocarbons analyzed using EPA Method 5030/3550, Modified 8015.

Source: Baker Environmental Inc., August 12, 1992. "Final Site Assessment Report, Campbell Street Fuel Farm and UST System AS-143 (Contract No. N62470-89-D-4814, Contract Task Order 0013).

TABLE 1-5

**SUMMARY OF SOIL ANALYSES, DECEMBER 1991
CAMPBELL STREET FUEL FARM
CONTRACT TASK ORDER 0265**

Boring No.	Field Sample No.	Parameter							Sample Depth (feet, below ground surface)
		Total Petroleum Hydrocarbons (mg/kg)			Petroleum Type ⁽¹⁾	TCLP Lead (mg/L)	pH	Flashpoint (°F)	
		Low-Med (5030)	Med-High (3550)						
MW-6	FF-S-6-01	1.05	2.24	weathered jet fuel	NA ⁽²⁾	NA	NA	2.0 - 4.0	
MW-6	FF-S-6-02	1.02	2.37	weathered jet fuel	0001	3.96	> 140	4.0 - 6.0	
MW-7	FF-S-7-01	0.29	0.57	weathered jet fuel	NA	NA	NA	2.0 - 4.0	
MW-7	FF-S-7-02	0.65	1.23	weathered jet fuel	--	4.20	> 140	4.0 - 6.0	
SB-1	FF-S-8-01	-- ⁽³⁾	0.30	weathered jet fuel	NA	NA	NA	2.0 - 4.0	
SB-1	FF-S-8-02	0.49	1.25	weathered jet fuel	.0005	4.53	> 140	4.0 - 6.0	
SB-2	FF-S-9-01	--	0.49	Not Distinct	NA	NA	NA	2.0 - 4.0	
SB-2	FF-S-9-02	2.29	6.86	weathered jet fuel	--	5.63	> 140	4.0 - 6.0	
SB-3	FF-S-10-01	0.68	1.37	weathered jet fuel	NA	NA	NA	2.0 - 4.0	
SB-3	FF-S-10-02	2.59	5.26	weathered jet fuel	.001	4.07	> 140	6.0 - 8.0	
SB-4	FF-S-11-01	--	0.53	weathered jet fuel	NA	NA	NA	2.0 - 4.0	
SB-4	FF-S-11-02	2.92	6.80	weathered jet fuel	--	4.73	> 140	4.0 - 6.0	

Notes:

(1) EPA Method 5030/3550 estimated range of petroleum type

(2) NA = Not Analyzed

(3) -- = Not detected

Soil samples collected December 1991 through January 1992.

TCLP Lead - Toxicity Characteristic Leaching Procedure analyzed using Method SW846-1311/7421.

Total Petroleum Hydrocarbons analyzed using EPA Method 5030/3550, Modified 8015.

Source: Baker Environmental Inc., August 12, 1992. "Final Site Assessment Report, Campbell Street Fuel Farm and UST System AS-143 (Contract No. N62470-89-D-4814, Contract Task Order 0013).

TABLE 1-5

**SUMMARY OF SOIL ANALYSES, DECEMBER 1991
CAMPBELL STREET FUEL FARM
CONTRACT TASK ORDER 0265**

Boring No.	Field Sample No.	Parameter						Sample Depth (feet, below ground surface)
		Total Petroleum Hydrocarbons (mg/kg)		Petroleum Type(1)	TCLP Lead (mg/L)	pH	Flashpoint (°F)	
		Low-Med (5030)	Med-High (3550)					
DW-1	FF-S-DW1-01	1.11	2.24	weathered jet fuel	NA(2)	NA	NA	2.0 - 4.0
DW-1	FF-S-DW1-02	0.66	1.47	weathered jet fuel	NA	NA	NA	4.0 - 6.0
DW-2	FF-S-DW2-01	0.88	2.27	weathered jet fuel	NA	NA	NA	2.0 - 4.0
DW-2	FF-S-DW2-02	7.76	18.1	weathered jet fuel	NA	NA	NA	4.0 - 6.0
DW-3	FF-S-DW3-01	3.10	6.97	weathered jet fuel	NA	NA	NA	2.0 - 4.0
DW-3	FF-S-DW3-02	0.32	0.71	weathered jet fuel	NA	NA	NA	4.0 - 6.0

Notes:

(1) EPA Method 5030/3550 estimated range of petroleum type

(2) NA = Not Analyzed

Soil samples collected December 1991 through January 1992.

TCLP Lead - Toxicity Characteristic Leaching Procedure analyzed using Method SW846-1311/7421.

Total Petroleum Hydrocarbons analyzed using EPA Method 5030/3550, Modified 8015.

Source: Baker Environmental Inc., August 12, 1992. "Final Site Assessment Report, Campbell Street Fuel Farm and UST System AS-143 (Contract No. N62470-89-D-4814, Contract Task Order 0013).

TABLE 1-6

**SUMMARY OF SOIL ANALYSES, DECEMBER 1992
CAMPBELL STREET FUEL FARM
CONTRACT TASK ORDER 0265**

Boring No.	Field Sample No.	Parameter				Sample Depth (feet, below ground surface)
		Total Petroleum Hydrocarbons (mg/kg)		Petroleum Type(1)		
		Low-Med Boiling Point (5030)	Med-High Boiling Point (3550)			
SB-5	FF-S-SB5-01	0.37	--(2)	Jet Fuel	2-4	
SB-5	FF-S-SB5-02	--	0.17	ND(3)	4-6	
SB-6	FF-S-SB6-01	0.07	0.22	ND	2-4	
SB-6	FF-S-SB6-02	0.05	--	ND	4-6	
SB-7	FF-S-SB7-01	1.56	--	Jet Fuel	4-6	
SB-7	FF-S-SB7-02	--	--	--	14-16	
SB-8	FF-S-SB8-01	--	--	--	2-4	
SB-8	FF-S-SB8-02	--	--	--	4-6	
SB-9	FF-S-SB9-01	24.0	50.4	Jet Fuel	4-5	
SB-9	FF-S-SB9-02	26.2	301	Jet Fuel	8-9	
SB-10	FF-S-SB10-01	0.10	--	ND	10-12	
SB-10	FF-S-SB10-02	--	--	--	14.5-15.5	
SB-11	FF-S-SB11-01	291	1900	Jet Fuel	3-4	
SB-11	FF-S-SB11-02	--	--	--	6.5-7.5	
SB-11	FF-S-SB11-03(4)	13.4	24.6	Jet Fuel	3-4	

Notes:

- (1) EPA Method 5030/3550 estimated range of petroleum type.
 (2) Below method detection limit.
 (3) ND = Not Determined
 (4) Duplicate sample of SB-11-01.
 Total Petroleum Hydrocarbons analyzed by EPA Method 5030/3550, Modified 8015.
 The calculated site sensitivity evaluation for TPH at this site is 35 mg/kg.

Source:

Baker Environmental, Inc. February 15, 1993, Draft Site Assessment Report, Additional Assessment Activities, Campbell Street Fuel Farm and UST System AS-143 (Contract No. N62470-89-D-4814, Contract Task Order 0013).

**SUMMARY OF SOIL ANALYSES, DECEMBER 1992
CAMPBELL STREET FUEL FARM
CONTRACT TASK ORDER 0265**

Boring No.	Field Sample No.	Parameter			Sample Depth (feet, below ground surface)
		Total Petroleum Hydrocarbons (mg/kg)		Petroleum Type(1)	
		Low-Med Boiling Point (5030)	Med-High Boiling Point (3550)		
SB-12	FF-S-SB12-01	35.6	870	Jet Fuel	3-4
SB-12	FF-S-SB12-02	2.64	19.0	Jet Fuel	7-8
MW-8	FF-S-MW8-01	-(2)	--	--	3-4
MW-8	FF-S-MW8-02	--	1.89	Jet Fuel	4.5-5.5
MW-9	FF-S-MW9-01	--	--	--	3-4
MW-9	FF-S-MW9-02	--	5.53	Jet Fuel	7-8
MW-10	FF-S-MW10-01	--	--	--	3-4
MW-10	FF-S-MW10-02	--	--	--	5-6
MW-11	FF-S-MW11-01	--	--	--	3-4
MW-11	FF-S-MW11-02	--	--	--	6-8
MW-12	FF-S-MW12-01	2.04	6.94	Jet Fuel	3-4
MW-12	FF-S-MW12-02	87.0	1.17	Jet Fuel	5-6
MW-12	FF-S-MW12-03(3)	151	34.0	Jet Fuel	3-4
MW-13	FF-S-MW13-01	283	14700	Jet Fuel	2-4
MW-13	FF-S-MW13-02	2.15	0.74	Jet Fuel	4-6

Notes:

- (1) EPA Method 5030/3550 estimated range of petroleum type.
 (2) Below method detection limit.
 (3) Duplicate sample of MW-12-01.
 Total Petroleum Hydrocarbons analyzed by EPA Method 5030/3550, Modified 8015.
 The calculated site sensitivity evaluation for TPH at this site is 35 mg/kg.

Source:

Baker Environmental, Inc. February 15, 1993, Draft Site Assessment Report, Additional Assessment Activities, Campbell Street Fuel Farm and UST System AS-143 (Contract No. N62470-89-D-4814, Contract Task Order 0013).

TABLE 1

**SUMMARY OF SOIL ANALYSES, DECEMBER 1992
CAMPBELL STREET FUEL FARM
CONTRACT TASK ORDER 0265**

Boring No.	Field Sample No.	Parameter			Sample Depth (feet, below ground surface)
		Total Petroleum Hydrocarbons (mg/kg)		Petroleum Type ⁽¹⁾	
		Low-Med Boiling Point (5030)	Med-High Boiling Point (3550)		
MW-14	FF-S-MW14-01	51.0	3.67	Jet Fuel	3-4
MW-14	FF-S-MW14-02	0.16	2.74	Jet Fuel	4-6
MW-14	FF-S-MW14-03 ⁽³⁾	15.0	19.5	Jet Fuel	3-4
MW-15	FF-S-MW15-01	-- ⁽²⁾	--	--	2-4
MW-15	FF-S-MW15-02	--	--	--	4-6
MW-16	FF-S-MW16-01	166	96.4	Jet Fuel	2-4
MW-16	FF-S-MW16-02	21.0	11.9	Jet Fuel	4-6
MW-17	FF-S-MW17-01	--	--	--	2-4
MW-17	FF-S-MW-17-02	--	--	--	4-6
MW-18	FF-S-MW18-01	0.14	5.26	Jet Fuel	2-4
MW-18	FF-S-MW18-02	--	23.6	Jet Fuel	4-6
MW-19	FF-S-MW19-01	--	--	--	2-4
MW-19	FF-S-MW19-02	--	--	--	4-6
MW-20	FF-S-MW20-01	--	--	--	2-4
MW-20	FF-S-MW20-02	--	--	--	4-6

Notes:

- (1) EPA Method 5030/3550 estimated range of petroleum type.
 - (2) Below method detection limit.
 - (3) Duplicate sample of MW-14-01.
- Total Petroleum Hydrocarbons analyzed by EPA Method 5030/3550, Modified 8015.
The calculated site sensitivity evaluation for TPH at this site is 35 mg/kg.

Source:

Baker Environmental, Inc. February 15, 1993, Draft Site Assessment Report, Additional Assessment Activities, Campbell Street Fuel Farm and UST System AS-143 (Contract No. N62470-89-D-4814, Contract Task Order 0013).

TABLE 1

**SUMMARY OF SOIL ANALYSES, DECEMBER 1992
CAMPBELL STREET FUEL FARM
CONTRACT TASK ORDER 0265**

Boring No.	Field Sample No.	Parameter			Sample Depth (feet, below ground surface)
		Total Petroleum Hydrocarbons (mg/kg)		Petroleum Type(1)	
		Low-Med Boiling Point (5030)	Med-High Boiling Point (3550)		
MW-21	FF-S-MW21-01	0.49	16.7	Jet Fuel	2-4
MW-21	FF-S-MW21-02	37.2	7.86	Jet Fuel	5-6
MW-21	FF-S-MW21-03(3)	82.8	--	Jet Fuel	5-6
MW-22	FF-S-MW22-01	--(2)	--	--	2-4
MW-22	FF-S-MW22-02	--	--	--	4-6
MW-23	FF-S-MW23-01	--	--	--	2-4
MW-23	FF-S-MW23-02	--	0.75	Jet Fuel	4-6
MW-24	FF-S-MW24-01	--	--	--	2-4
MW-24	FF-S-MW24-02	--	--	--	4-6
MW-25	FF-S-MW25-01	2.79	14.2	Gas	2-4
MW-25	FF-S-MW25-02	20.3	9.85	Gas	6-6.5
MW-25	FF-S-MW25-03(4)	--	4.45	Gas	6-6.5
DW-4	FF-S-DW4-01	--	--	--	2-4
DW-4	FF-S-DW4-02	--	--	--	48-50
DW-4	FF-S-DW4-03(5)	--	--	--	2-4

Notes:

⁽¹⁾ EPA Method 5030/3550 estimated range of petroleum type.

⁽²⁾ Below method detection limit.

⁽³⁾ Duplicate sample of MW-21-02.

⁽⁴⁾ Duplicate sample of MW-25-02.

⁽⁵⁾ Duplicate sample of DW-4-01.

Total Petroleum Hydrocarbons analyzed by EPA Method 5030/3550, Modified 8015.

The calculated site sensitivity evaluation for TPH at this site is 35 mg/kg.

Source:

Baker Environmental, Inc. February 15, 1993, Draft Site Assessment Report, Additional Assessment Activities, Campbell Street Fuel Farm and UST System AS-143 (Contract No. N62470-89-D-4814, Contract Task Order 0013).

**SUMMARY OF SOIL ANALYSES, DECEMBER 1992
CAMPBELL STREET FUEL FARM
CONTRACT TASK ORDER 0265**

Boring No.	Field Sample No.	Parameter			Sample Depth (feet, below ground surface)
		Total Petroleum Hydrocarbons (mg/kg)		Petroleum Type(1)	
		Low-Med Boiling Point (5030)	Med-High Boiling Point (3550)		
DW-5	FF-S-DW5-01	19.0	118	Jet Fuel	6-8
DW-5	FF-S-DW5-02	--(2)	5.80	M. Oil	40-42
DW-6	FF-S-DW6-01	5.10	204	Jet Fuel	2-4
DW-6	FF-S-DW6-02	--	--	--	40-42
RW-1	FF-S-RW1-01	--	0.99	ND(3)	2-4
RW-1	FF-S-RW1-02	--	--	--	4-6

Notes:

(1) EPA Method 5030/3550 estimated range of petroleum type.

(2) Below method detection limit.

(3) ND = Not Determined

Total Petroleum Hydrocarbons analyzed by EPA Method 5030/3550, Modified 8015.

The calculated site sensitivity evaluation for TPH at this site is 35 mg/kg.

Source:

Baker Environmental, Inc. February 15, 1993, Draft Site Assessment Report, Additional Assessment Activities, Campbell Street Fuel Farm and UST System AS-143 (Contract No. N62470-89-D-4814, Contract Task Order 0013).

SUMMARY OF CHEMICAL ANALYSES FOR GROUNDWATER SAMPLES COLLECTED BY HYDROPUNCH PROCEDURE IN DECEMBER 1991
CAMPBELL STREET FUEL FARM
CONTRACT TASK ORDER 0265

TABLE 7

Well No.	Field Sample No.	Parameter (µg/L)									Total VOCs(4)
		MTBE(1)	1,3 and 1,4-Dichloro-benzene	1,2-Dichloro-benzene	Benzene	Toluene/EDB(2)	Ethyl-benzene	Chloro-benzene and m- & p-Xylenes	o-Xylene	Total Xylene(3)	
HP-1	FF-W-H-1	--(5)	--	--	--	--	--	0.2	--	0.21	0.21
HP-2	FF-W-H-2	0.31	--	--	--	--	--	--	--	--	0.31
HP-3	FF-W-H-3	--	--	--	--	--	--	--	--	--	--
HP-4	FF-W-H-4	--	--	--	--	--	--	--	--	--	--
HP-5	FF-W-H-5	--	--	--	0.54	--	--	--	--	--	0.54
HP-6	FF-W-H-6	--	--	--	--	--	--	--	--	--	--
HP-7	FF-W-H-7	--	--	--	--	--	--	0.83	--	0.83	0.83
HP-8	FF-W-H-8	--	--	--	--	--	--	0.50	--	0.50	0.50
HP-9	FF-W-H-9	0.48	--	--	--	--	--	--	--	--	0.48
HP-10	FF-W-H-10	--	--	--	1.17	--	0.74	--	--	--	1.91
HP-11	FF-W-H-11	0.66	--	--	--	0.23	--	--	--	--	0.89
HP-12	FF-W-H-12	0.47	5.76	2.86	4.47	2.27	1.32	1.83	1.32	3.15	20.30
HP-13	FF-W-H-13	0.25	--	--	--	0.89	--	0.97	--	0.97	2.11
HP-13	FF-W-H-16(6)	0.52	--	--	--	--	--	--	--	--	0.52
HP-14	FF-W-H-14	0.27	--	--	1.05	0.72	--	0.89	--	0.89	2.93
HP-14	FF-W-H-17(6)	0.42	--	--	--	0.73	--	1.01	--	1.01	2.16
HP-15	FF-W-H-15	2.08	0.78	0.57	23.77	0.82	2.52	5.72	2.18	7.90	38.44
Federal MCLs(7)		NE(9)	NE/75	600	5.0	1,000/0.05	700	100/NE	NE	10,000	
State NC WQS(8)		50(10)	620/1.8	620	1.0	1,000/0.0005	29	300/NE	NE	400	

Notes:

- (1) MTBE = Methyl Tertiary Butyl Ether
 - (2) EDB = Ethylene Dibromide
 - (3) Include a combined value of chlorobenzene and m- & p-Xylenes
 - (4) Sum of total organic compounds detected using EPA Method 602
 - (5) -- = Not Detected
 - (6) Duplicate sample
 - (7) MCL = Maximum Contaminant Level
 - (8) NC WQS = North Carolina Water Quality Standard
 - (9) NE = Not Established
 - (10) MTBE NC WQS is an interim standard
- Samples analyzed using EPA Method 602. Method could not distinguish a difference between 1,3- and 1,4-dichlorobenzene; toluene and EDB; chlorobenzene and m- and p-Xylenes. Laboratory reported the concentration as a combined value.

Source: Baker Environmental, Inc. February 15, 1993, Draft Site Assessment Report, Additional Assessment Activities, Campbell Street Fuel Farm and UST System AS-143 (Contract No. N62470-89-D-4814, Contract Task Order 0013).

SUMMARY OF CHEMICAL ANALYSES FOR GROUNDWATER SAMPLES COLLECTED FROM MONITORING WELLS IN JANUARY 1992
CAMPBELL STREET FUEL FARM
CONTRACT TASK ORDER 0265

Parameter/Method	MW-1	MW-2	MW-3	MW-4	MW-5	MW-6	MW-7	MW-8 ⁽⁸⁾	DW-1	DW-2	DW-3	Trip Blank	Maximum Contaminant Level (µg/L)	NC Water Quality Standard (µg/L)
EPA Method 601 (µg/L)	-- ⁽⁶⁾	NA ⁽⁷⁾	NA	NA	NA	--	--	--	NA	--	NA	--		
EPA Method 602 ⁽²⁾ (µg/L)														
MTBE ⁽³⁾	--	0.21	--	--	--	--	--	--	--	--	--	--	NE ⁽⁹⁾	50 ⁽¹¹⁾
Benzene	--	0.20	2.79	2.47	--	--	--	--	--	2.05	--	--	5.0	1.0
Toluene/EDB ⁽⁴⁾	--	--	--	--	--	--	--	--	--	--	0.94	--	1,000/0.05	1,000/0.0005
Ethyl Benzene	--	--	--	0.42	--	--	--	--	--	0.36	--	--	700	29
m-, p- Xylene and Chlorobenzene	--	--	0.81	1.73	--	--	--	--	--	22.70	--	--	NE/100	NE/300
o-Xylene	--	--	0.76	--	0.79	--	--	--	--	--	--	--	NE	400
1,3 & 1,4-Dichlorobenzene	--	--	--	10.64	--	--	1.04	--	--	23.35	--	--	75	620/1.8
1,2-Dichlorobenzene	--	--	--	6.33	--	--	1.22	--	--	2.31	--	--	600	620
EPA Method 625 ⁽⁶⁾ (µg/L)	NA	NA	NA	NA	NA	--	NA	--	NA	--	NA	--		
Acenaphthene						--	--	--		46		--	NE	NE
Fluorene						--	--	--		36		--	NE	NE
Naphthalene						--	--	--		258		--	NE	NE
Phenanthrene						--	--	--		11		--	NE	NE
EPA Method 7421 (µg/L)														
Lead, total	--	3.4	--	2.6	2.0	0.9	0.5	1.0	0.8	4.3	0.7	NA	50 ⁽¹⁰⁾	50
Total Xylenes	--	--	1.57	1.73	0.79	--	--	--	--	22.70	--	--	10,000	400
Total VOCs	--	0.41	4.36	21.59	0.79	--	2.26	--	--	50.77	0.94	--	NE	NE

Notes:

- (1) Purgeable halocarbons analyzed using EPA Method 601. No purgeable halocarbons were detected.
- (2) Purgeable aromatics analyzed using EPA Method 602. Method could not distinguish a difference between toluene and EDB; m-, p-Xylene and chlorobenzene; 1,3- and 1,4-dichlorobenzene. Laboratory reported the concentrations as a combined value.
- (3) MTBE = Methyl Tertiary Butyl Ether
- (4) EDB = Ethylene Dibromide
- (5) Base Neutral/Acid Extractables (BNAs) analyzed using EPA Method 625. Only four contaminants were detected.
- (6) -- = Not Detected
- (7) NA = Not Analyzed
- (8) MW-8 was the number assigned to the duplicate sample for monitoring well MW-6 at time of sampling. Actual monitoring well MW-8 was installed during the second phase of work.
- (9) NE = Not Established
- (10) Standard based on dissolved lead concentrations.
- (11) MTBE NC WQS is an interim standard.

Table reflects only those parameters which were detected.

Source: Baker Environmental, Inc. February 15, 1993, Draft Site Assessment Report, Additional Assessment Activities, Campbell Street Fuel Farm and UST System AS-143 (Contract No. N62470-89-D-4814, Contract Task Order 0013).

TABLE 1-9

**SUMMARY OF CHEMICAL ANALYSES FOR GROUNDWATER SAMPLES COLLECTED FROM MONITORING WELLS IN DECEMBER 1992
CAMPBELL STREET FUEL FARM
CONTRACT TASK ORDER 0265**

Parameter/Method	MW-8	MW-9	MW-10	MW-11	MW-12	MW-13	MW-14	MW-15	MW-16	MW-17	MW-18	Federal Maximum Contaminant Level (µg/L)	NC Water Quality Standard (µg/L)
EPA Method 602 ⁽¹⁾ (µg/L)													
Purgeable Aromatic Hydrocarbons													
MTBE ⁽²⁾	-- ⁽⁶⁾	--	--	--	2.4	--	--	--	416	--	--	NE ⁽⁶⁾	50 ⁽⁸⁾
Benzene	7.85	--	--	--	--	--	--	--	69.5	--	--	5.0	1.0
Toluene/EDB ⁽³⁾	--	--	--	--	--	--	--	--	40.6	--	5.8	1,000/0.05	1,000/0.0005
Chlorobenzene	--	--	--	--	--	--	--	--	--	--	--	100	300
Ethylbenzene	12.9	--	--	--	--	11.8	--	--	--	--	--	700	29
m-, p-Xylene	52.8	--	--	--	4.34	8.09	--	--	125	--	13.2	NE	NE
o-Xylene	--	--	--	--	--	--	--	--	--	--	--	NE	NE
1,3-Dichlorobenzene	--	--	--	--	--	--	--	--	--	--	9.27	NE	620
1,4-Dichlorobenzene	--	--	--	--	--	30.8	--	--	113	--	--	75	1.8
1,2-Dichlorobenzene	--	--	--	--	--	--	--	--	28.8	--	13.0	600	620
Total Xylenes	52.8	--	--	--	4.34	8.09	--	--	125	--	13.2	10,000 ⁽⁷⁾	400 ⁽⁸⁾
Total VOCs ⁽⁴⁾	73.55	--	--	--	6.74	50.69	--	--	792.9	--	41.27	NE	NE

Notes:

(1) Purgeable aromatics analyzed by EPA Method 602. Method could not resolve toluene and EDB. Laboratory reported the concentrations as a combined value.

(2) MTBE = Methyl Tertiary Butyl Ether

(3) EDB = Ethylene Dibromide. Method could not resolve toluene and EDB. Concentrations reported as a combined value.

(4) Sum of total volatile organic compounds detected by EPA Method 602.

(5) -- = Less than method detection limit.

(6) NE = Not Established

(7) The MCL and NCWQS for xylene (total) includes meta, para, and ortho xylenes.

(8) MTBE WQS is an interim standard.

Source: Baker Environmental, Inc. February 15, 1993, Draft Site Assessment Report, Additional Assessment Activities, Campbell Street Fuel Farm and UST System AS-143 (Contract No. N62470-89-D-4814, Contract Task Order 0013).

TABLE 1-9

**SUMMARY OF CHEMICAL ANALYSES FOR GROUNDWATER SAMPLES COLLECTED FROM MONITORING WELLS IN DECEMBER 1992
CAMPBELL STREET FUEL FARM
CONTRACT TASK ORDER 0265**

Parameter/Method	MW-19	MW-20	MW-21	MW-22	MW-23	MW-24	MW-25	MW-26 ⁽⁹⁾	MW-27 ⁽¹⁰⁾	DW-4	DW-5	DW-6	RW-1	Federal Maximum Contaminant Level (µg/L)	NC Water Quality Standard (µg/L)
EPA Method 602 ⁽¹⁾ (µg/L)															
Purgeable Aromatic Hydrocarbons	160	-- ⁽⁶⁾	21.9	--	--	400	1490	--	29.4	--	--	--	147	NE ⁽⁶⁾	50 ⁽⁸⁾
MTBE ⁽²⁾	--	--	--	--	--	73	58.1	--	--	--	--	--	26.7	5.0	1.0
Benzene	--	--	514	--	--	762	241	--	64.3	--	--	--	--	1,000/0.05	1,000/0.0005
Toluene/EDB ⁽³⁾	--	--	--	--	--	--	--	--	--	--	--	--	--	100	300
Chlorobenzene	--	--	--	--	--	--	63.9	--	30	--	--	--	--	700	29
Ethylbenzene	--	--	661	--	--	199	1130	5.89	755	--	--	3.93	62.9	NE	NE
m-, p-Xylene	--	--	4700	--	5.46	--	--	--	818	--	--	--	--	NE	NE
o-Xylene	--	--	383	--	--	--	400	--	--	--	--	--	--	NE	620
1,3-Dichlorobenzene	--	--	--	--	--	207	550	--	3045	--	--	8.46	30.1	75	1.8
1,4-Dichlorobenzene	--	--	3060	--	--	148	101	--	97	--	--	--	25.7	600	620
1,2-Dichlorobenzene	--	--	486	--	--	--	--	--	--	--	--	--	--	--	--
Total Xylenes	--	--	5083	--	5.46	199	1530	5.89	1573	--	--	3.93	62.9	10,000 ⁽⁷⁾	400 ⁽⁸⁾
Total VOCs ⁽⁴⁾	160	--	9825.9	--	5.46	1789	4034	5.89	4838.7	--	--	12.39	292.4	NE	NE

Notes:

(1) Purgeable aromatics analyzed by EPA Method 602. Method could not resolve toluene and EDB. Laboratory reported the concentrations as a combined value.

(2) MTBE = Methyl Tertiary Butyl Ether

(3) EDB = Ethylene Dibromide. Method could not resolve toluene and EDB. Concentrations reported as a combined value.

(4) Sum of total volatile organic compounds detected by EPA Method 602.

(5) -- = Less than method detection limit.

(6) NE = Not Established

(7) The MCL and NCWQS for xylene (total) includes meta, para, and ortho xylenes.

(8) MTBE WQS is an interim standard.

(9) MW-26 is a duplicate for MW-23.

(10) MW-27 is a duplicate for MW-25.

Source: Baker Environmental, Inc. February 15, 1993, Draft Site Assessment Report, Additional Assessment Activities, Campbell Street Fuel Farm and UST System AS-143 (Contract No. N62470-89-D-4814, Contract Task Order 0013).

TABLE 2-1

**GROUNDWATER REMEDIATION ENDPOINTS
CAMPBELL STREET FUEL FARM
CONTRACT TASK ORDER 0265**

Parameter	NC Water quality Standard (µg/L)	Maximum Concentration Detected (µg/L)	Sampling Point with Highest Concentration	Number of Sampling Points above WQS (µg/L)
MTBE	50.0	1490	MW-24	5
Benzene	1.0	73.0	MW-24	12
Toluene	1,000	762	MW-24	0
Ethylbenzene	29	661	MW-21	3
Xylenes	400	5,083	MW-21	3
EDB	0.0005	762	MW-24	12
Chlorobenzene	300	22.7	DW-2	0
1,2-Dichlorobenzene	620	486	MW-21	0
1,3-Dichlorobenzene	620	23.65	MW-21	0
1,4-Dichlorobenzene	1.8	3,060	MW-21	11
Naphthalene	NE	258	DW-2	NA
Acenaphthene	NE	46	DW-2	NA

Notes: NE = Not established

MTBE = Methyl Tertiary Butyl Ether

EDB = Ethylene Dibromide

NA = Not Applicable

NC Water Quality Standard shall be used as the initial groundwater remediation endpoints

TABLE 3-1

MAJOR COMPONENTS OF JP-5 JET FUEL
CAMPBELL STREET FUEL FARM
CONTRACT TASK ORDER 0265

Benzene	Naphthalene
Toluene	2-Methylundecane
Ethylbenzene	n-Dodecane
n-Octane	2,6-Dimethylundecane
1,3,5-Trimethylcyclohexane	1,2,4-Triethylbenzene
1,1,3-Tremethylcyclohexane	2-Methylnaphthalene
3-Methyloctane	1-Methylnaphthalene
2,4,6-Trimethylheptane	1-Tridecene
o-Xylene	Phenylcyclohexane
p-Xylene	n-Tridecane
m-Xylene	1-t-Butyl-3,4,5-trimethylbenzene
n-Nonane	n-Heptylcyclohexane
1,2,4-Trimethylbenzene	n-Heptylbenzene
n-Decane	Biphenyl
n-Butylcyclohexane	1-Ethyl-naphthalene
1,3-Diethylbenzene	2,6-Dimethylnaphthalene
1,4-Diethylbenzene	n-Tetradecane
4-Methyldecane	2,3-Dimethylnaphthalene
2-Methyldecane	n-Octylbenzene
1-Ethylpropylbenzene	n-Pentadecane
n-Undecane	n-Hexadecane
2,6-Dimethyldecane	n-Heptadecane
1,2,3,4-Tetramethylbenzene	

Source: "Analysis and Environmental Fate of Air Force Distillate and High Density Fuels."
SRI International. October 1981.

TABLE 3-2

**CONCENTRATIONS OF SELECT WATER SOLUBLE
COMPONENTS OF JP-5
CAMPBELL STREET FUEL FARM
CONTRACT TASK ORDER 0265**

Constituent	Concentration (mg/L) ⁽¹⁾
Toluene	0.6
Ethylbenzene	0.3
m,p-xylenes	0.16
o-xylene	0.09
Naphthalene	0.46
2-Methylnaphthalene	0.23

Notes: (1) Concentration of the constituent detected in a mixture of 1 part JP-5 to 1,000 parts water

Benzene was not detected as a water soluble component.

Source: "Analysis and Environmental Fate of Air Force Distillate and High Density Fuels." SRI International. October 1981.

TABLE 3-3

**PHYSICAL-CHEMICAL PROPERTIES AND RELATIVE MOBILITY INDICES FOR JP-5 CONSTITUENTS
CAMPBELL STREET FUEL FARM
CONTRACT TASK ORDER 0265**

Constituent	Molecular Weight (g/mol.)	Specific Gravity (g/cm ³ @ 20/4°C)	Water Solubility (ppm @ 20°C)	Vapor Pressure (mm Hg @ 25°C)	Henry's Law Coefficient (atm m ³ /mol-l)	log K _{ow}	log K _{oc}	Relative Mobility Index
Benzene	78.1	0.879	1,780	76	5.5 x 10 ⁻³	2.13	1.92	3.0
Toluene	92.13	0.867	534.8 (25°C)	28.7 (25°C)	6.6 x 10 ⁻³	2.48	2.79	1.5
Ethylbenzene	106.16	0.873	152	7	6.6 x 10 ⁻³	3.34	3.04	-0.01
Xylene, Total	106.16	0.870	180	6	4.64 x 10 ⁻³	2.84	3.02	0.19
Naphthalene	128.2	1.162	31.7 (25°C)	8.7 x 10 ⁻²	4.6 x 10 ⁻⁴	3.29	2.97	-2.5
Acenaphthylene	152.2	1.18	3.93 (25°C)	2.9 x 10 ⁻² (20°C)	1.45 x 10 ⁻³	3.72	3.40	-4.3
Acenaphthene	154.2	1.189	3.42 (25°C)	1.55 x 10 ⁻³	9.1 x 10 ⁻⁵	3.98	3.66	-5.9

Notes: NC = Not calculated

References:

USEPA, 1982. Aquatic Fate Process Data for Organic Priority Pollutants.
Verscheueren, 1983. Handbook of Environmental Data on Organic Chemicals. 2nd Edition.
Lyman, et al., 1982. Handbook of Chemical Property Estimation Methods.
Ford and Gurba, 1984. Methods of Determining Relative Contaminant Mobilities and Migration Pathways Using Physical-Chemical Data.

TABLE 3-4

**PRELIMINARY EXPOSURE ASSESSMENT SUMMARY
CAMPBELL STREET FUEL FARM
CONTRACT TASK ORDER 0265**

Exposure Pathways	Maximum Detected Levels (1)	Potential for Migration of Contaminants	Potential for Human Exposure
Soil	TPH: 14700 mg/kg TCLP Lead: 0.001 pH: 5.63 FP: > 140°F Only 8 of 96 samples had TPH values above 180 mg/kg (samples collected during both phases of work)	Soils are generally a mixture of silt and clay, underlain by a fine-grained sand. Because of the lesser permeability of the silt and clay soils, minimal migration through the soil is considered possible. In general, the highest concentrations were detected at depths of 2 to 6 feet.	Covered by grass top soil and concrete, the site poses no immediate exposure. If the site is disturbed due to construction or remediation activities, exposure to workers does exist by both direct contact and the inhalation of dust generated from the site.
Groundwater	Benzene: 73 µg/L Toluene: 762 µg/L Ethylbenzene: 661 µg/L Xylene: 5083 µg/L EPA Method 601: (2) Total Lead: 4.3 µg/L	Groundwater, on the average, was 6 to 8 feet below ground surface. It is believed that groundwater migration through this type of soil would be limited. However, a flow velocity of 70 feet/year would indicate that this medium would allow for greatest contamination migration.	Because the base drinking water is supplied by the deeper Castle Hayne Aquifer and there are no water supply wells within a 1/4-mile radius of the site in the surficial aquifer, no groundwater exposure pathways are believed to exist.
Vapor	No detection by use of Dräger tubes. Maximum vapor detected using PID is 600 ppm (Boring MW-12)	The type of soils present (silt/clay) may reduce the rate of vapor migration. However, subsurface utilities in the area may increase the rate of migration in portions of the site.	The ground surface conditions at the site will promote the dispersion of vapors. Subsurface utility trenches may create areas for vapors to accumulate. In the event that the site is disturbed due to construction or remediation activities, inhalation from the volatilization of the TPH could occur.

(1) Analytical Results listed are based on both phases of work.

(2) Concentrations were below detection limits.

TABLE 4-1

**SCREENING OF POTENTIAL SOIL REMEDIATION OPTIONS
CAMPBELL STREET FUEL FARM
CONTRACT TASK ORDER 0265**

Option	Process	Estimated Costs ⁽¹⁾	Practical Constraints	Remarks	Applicable to Site (Y/N)
Excavation and disposal as hazardous waste	Excavate and haul to Class I landfill; emplace and compact clean fill	\$300/yd ³	Cradle-to-grave liability as waste generator	High cost	N
Excavation and disposal as solid waste (nonhazardous)	Excavate and haul to Class III landfill; backfill with clean fill	\$60/yd ³	Location of a suitable landfill	Economical on small projects	Y
Excavation, aeration and disposal off site (off-site bioremediation)	Excavate and spread on site; turn repeatedly to aerate, haul to clean fill disposal site; emplace and compact new clean fill	\$30/ton Plus transportation and backfill costs	Emission considerations	Technically feasible; permitted facilities located near activity; may require numerous analytical tests	Y
Excavation, landfarming and replacement	Excavate and spread on site; aerate and add nutrients and water; re-emplac and compact	\$50/yd ³	Emission considerations; leaves excavation open during treatment	Technically feasible, permitting may be difficult; requires numerous analytical tests	N
Mechanically enhanced volatilization	Excavate, pass through crusher, aerator, and re-emplac	\$250/yd ³	Requires dust control and vapor treatment	High cost, but suitable for specific locations	N
<i>In-situ</i> venting (vacuum extraction)	Investigate extent of contamination and soil conditions; design and install venting system; permit system; operate system; reinvestigate to monitor effectiveness	\$20-50/yd ³	Fine-grained soils and low volatility of hydrocarbon in soils limit the effectiveness of this method	Not a technically viable option for sites with clayey soils; requires disposal of air filtration medium	Y
Excavation and low temperature thermal reduction (L ₁ TR)	Contamination in soil reduced through volatilization by the application of heat	\$50/ton + transportation	Emissions considerations	Effective method of reducing contaminant concentrations	Y

(1) Estimated costs reflect 1990 dollars.

Source: Testa, Stephen M. and Duane L. Winegardner. Restoration of Petroleum-Contaminated Aquifers. Lewis Publishers, Inc., Chelsea, Michigan. 1991.

TABLE 4-1
(Continued)

SCREENING OF POTENTIAL SOIL REMEDIATION OPTIONS
CAMPBELL STREET FUEL FARM
CONTRACT TASK ORDER 0265

Option	Process	Estimated Costs ⁽¹⁾	Practical Constraints	Remarks	Applicable to Site (Y/N)
<i>In-situ</i> biodegradation or chemical degradation	Investigate extent of contamination and soil and groundwater conditions; conduct feasibility study; design and install pumping and injection system; permit system; operate system; reinvestigate to monitor effectiveness	\$75/yd ³	Fine-grained soils limit ability to inject and pump fluids through soils. System could be engineered to be installed and operated around existing facilities; requires ongoing operation and maintenance (O&M) and monitoring. Requires periodic soil sampling and final investigation	Overall effectiveness cannot be assured; pending results of pilot study; requires on site monitoring	Y
Steam injection and stripping	Investigate extent of contamination and soil and groundwater conditions; conduct feasibility study; design and install steam injection and recovery system; permit system; operate system; monitor effectiveness on an ongoing basis	\$100-200/yd ³	Fine-grained soils limit ability to inject steam and recover fluids from soils	Overall effectiveness cannot be assured, pending pilot study results; O&M cost	N
Asphalt incorporation	Excavate and transport	\$125/ton	Soil must pass flash-test before acceptance	Very good option for low-volatile hydrocarbon affected soils	N
Passive remediation	Passive remediation		No risk to public health, safety and welfare. No risk to surface water or groundwater; considered of beneficial use	Site-specific. High concentrations present at the site may require a significant period of time to degrade to acceptable levels	N

1) Estimated costs reflect 1990 dollars.

Source: Testa, Stephen M. and Duane L. Winegardner. Restoration of Petroleum-Contaminated Aquifers. Lewis Publishers, Inc., Chelsea, Michigan. 1991.

TAB 4-1
(Continued)

SCREENING OF POTENTIAL SOIL REMEDIATION OPTIONS
CAMPBELL STREET FUEL FARM
CONTRACT TASK ORDER 0265

Option	Process	Estimated Costs ⁽¹⁾	Practical Constraints	Remarks	Applicable to Site (Y/N)
Soil washing/extraction	Excavate, crush, mix with wash fluid, separate, replace, treat wash water		Limited to granular soils, wash fluid treatment may be difficult	Technically feasible, high cost, limited applications	N
In-situ leaching	Construct infiltration and recovery systems, irrigate washing fluid, retrieve fluid, treat fluid	\$150 to \$200/yd ³	Limited to permeable soils, and higher solubility hydrocarbons	Often used in conjunction with biotreatment practices; permit approval may be difficult	Y
Aboveground leaching/replacement	Excavate, crush, place over collector bed, flush with wash fluid, replace, treat fluid		Total washing fluid collection, temperature and odor control; requires fairly large open area	May be used in association with biotreatment, often effective; permitting not as difficult	N

(1) Estimated costs reflect 1990 dollars.

Source: Testa, Stephen M. and Duane L. Winegardner. Restoration of Petroleum-Contaminated Aquifers. Lewis Publishers, Inc., Chelsea, Michigan. 1991.

**SCREENING OF POTENTIAL GROUNDWATER RECOVERY ALTERNATIVES
CAMPBELL STREET FUEL FARM
CONTRACT TASK ORDER 0265**

Alternative	Description	Capability	Limitation	Evaluation	Applicable to Site (Y/N)
1. Passive Remediation	Take no action - continue groundwater monitoring to determine if product plume is migrating off site.	Simplest, least costly option	Does not facilitate containment, control or recovery of product.	The option does not actively improve site groundwater quality.	N
2. Subsurface Flow Controls (barriers)	Install slurry, membrane or structural walls around plume to isolate it and preclude further migration.	A conventional, demonstrated technology	This option is usually very expensive. Many slurry wall mixtures or membranes may not provide long-term durability.	This option does not improve site groundwater quality. It may not provide long-term benefits.	N
3. Well Points	Install several closely-spaced small diameter wells around the plume.	A conventional, demonstrated technology	Requires a large number of well points to be effective. Large quantities of water would be generated. Requires frequent maintenance.	Effective for sites with high permeability and shallow water table.	Y
4. Recovery wells	Install groundwater/free product recovery wells at selected locations.	A conventional, demonstrated technology	Several wells required to renovate the aquifer. Usually suited for use in sandy aquifers.	Effective for sites with groundwater levels over 25 feet deep.	Y
5. Large-Diameter Sumps	Install a few large diameter sumps at selected locations.	A conventional, demonstrated technology	Only effective in shallow aquifers with low permeabilities.	May be effective in shallow conditions where low permeabilities exist.	N
6. Interceptor Trenches	Construct trenches with sumps at right angles to existing groundwater flow patterns.	A conventional, demonstrated technology	Only effective in shallow aquifers with low permeabilities. Construction may disrupt facility operations. Installation may not be possible in many areas.	May be effective in shallow conditions where low permeabilities exist. Construction is limited to open areas.	Y
7. In-Situ Biotreatment	Utilize recovery and injection wells along with a fixed film biotreatment unit to biodegrade contaminants.	A conventional, demonstrated technology	Requires large capital costs. Usually maintenance is extensive. Biotreatment is slow as compared to other remediation methods.	Presence of lead makes this option less effective.	N

Note: Estimated costs for remediation alternatives are not possible due to variables such as volume of groundwater to be removed, number of pumps required, etc.

TABLE 5-1
MONITORING PLAN SUMMARY
CAMPBELL STREET FUEL FARM
CONTRACT TASK ORDER 0265

PHASE OF CONTAMINATION	PROPOSED CLEANUP ENDPOINTS	PROPOSED MONITORING TO ACHIEVE ENDPOINTS						PROPOSED POST OPERATION MONITORING	
		SAMPLING LOCATION	SAMPLING FREQUENCY AND TYPE	METHOD OF ANALYSIS	SCHEDULE TO ACHIEVE ENDPOINTS	SCHEDULE TO MAINTAIN ENDPOINTS	S Y S T E M	SAMPLING FREQUENCY AND TYPE	POST OPERATION MONITORING SCHEDULE
Free Product- JP-5	< 0.01 Feet	Monitoring wells MW-3, MW-9, MW-10, MW-11 MW-12, MW-14 MW-15, MW-16 MW-21, MW-22 MW-23, MW-24 MW-25, DW-2 DW-6, RW-1 and RW-2	Monthly Free product measurement	Electronic probe or tape, chalk, and water indicating paste method	Free product is to be removed by excavation activities	12 months		Monthly Free product measurement	Monitoring will continue for 12 consecutive months no free product detection
Dissolved Petroleum Contamination in Groundwater	State WQS or asymptotic conditions	Monitoring wells MW-3, MW-11, MW-12, MW-14, MW-16, MW-21, MW-23, MW-24, MW-25, DW-2 and DW-6	Quarterly Grab	All Monitoring wells EPA Method 602 Monitoring wells DW-2 and DW-6 EPA Method 625	1 - 2 years	Endpoints must be maintained for 12 months before post-operational monitoring is initiated	S H U T D O W N	Quarterly sampling of monitoring wells MW-3, MW-11, MW-12, MW-14, MW-16, MW-21, MW-23, MW-24, MW-25, DW-2 and DW-6	Endpoints must be maintained for 12 months before post-operational monitoring is terminated
Treated Effluent	As specified on NPDES Permit	Effluent discharge point	Monthly	EPA Method 602	1 - 2 years	12 months		System will not be in operation during post monitoring period	N/A
Residual Product in Soils	TPH 180 (mg/kg)	One for every 50 ft. along excavation wall	At time of excavation Grab	EPA Method 8015 (5030/3550)	Less than 30 days	Endpoints are to be attained by the completion of excavation activities		Sampling will not be performed during post monitoring period	N/A

TABLE 6-1

**NPDES PERMIT MONITORING REQUIREMENTS
CAMPBELL STREET FUEL FARM
CONTRACT TASK ORDER 0265**

Effluent Characteristics	Discharge Limitation		Monitoring Requirements		
	Monthly Average	Daily Maximum	Measurement Frequency	Sample Type	Sample Location
Flow			Weekly	Pump or Meter Log	Effluent
Toluene	11 µg/L	22 µg/L	Monthly	Grab	Effluent
Benzene	71.4 µg/L	142.8 µg/L	Monthly	Grab	Effluent
Methyl Tertiary Butyl Ether			Monthly	Grab	Effluent

There shall be no discharge of floating solids or visible foam in other than trace amounts.

Additional Chemical constituents analyzed by EPA Methods 602 and EPA Method 625 shall also be reported. No discharge limitations are specified for these constituents.

Source: State of North Carolina Department of Environment, Health, and Natural Resources, Division of Environmental Management.

Figures

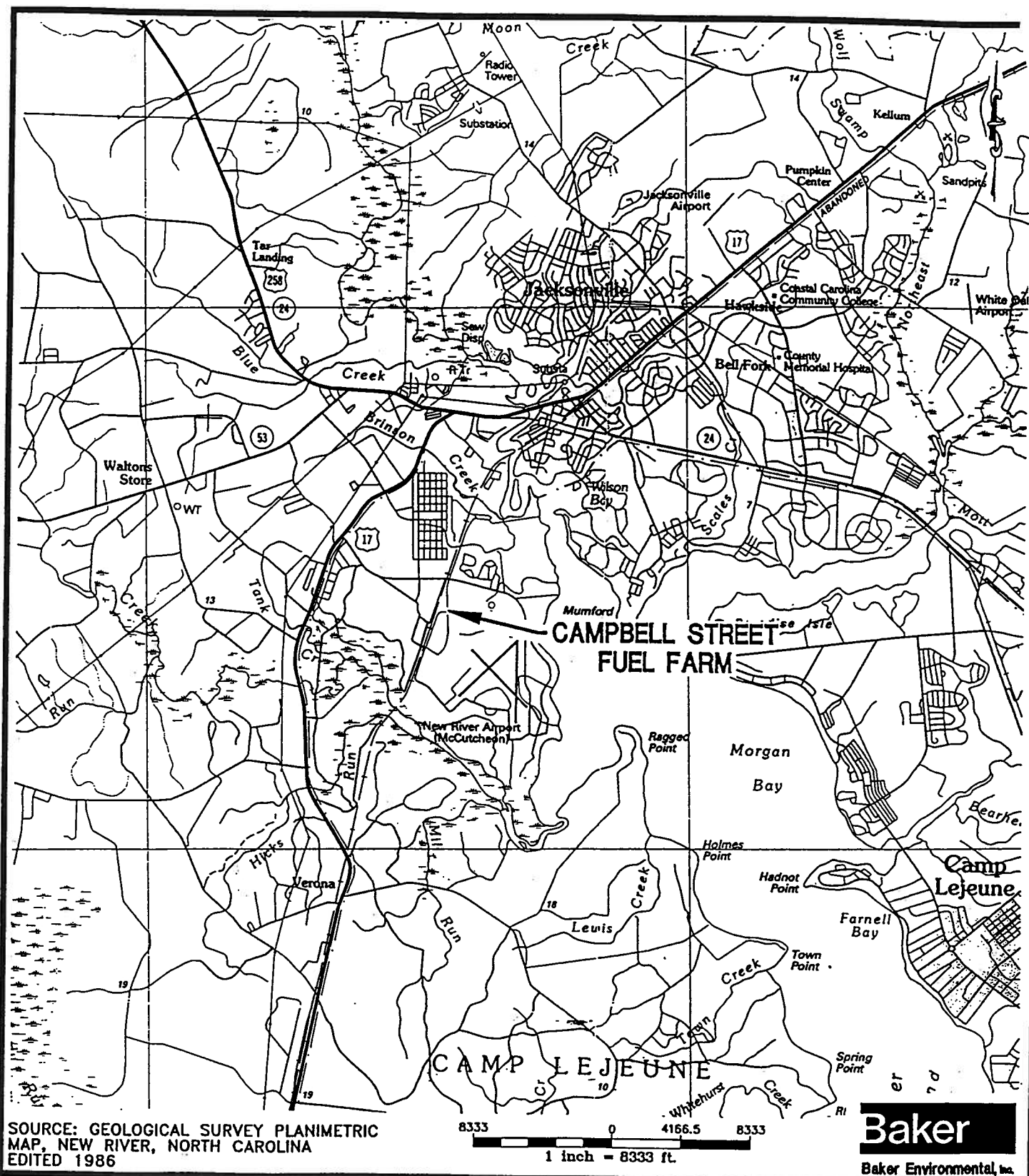
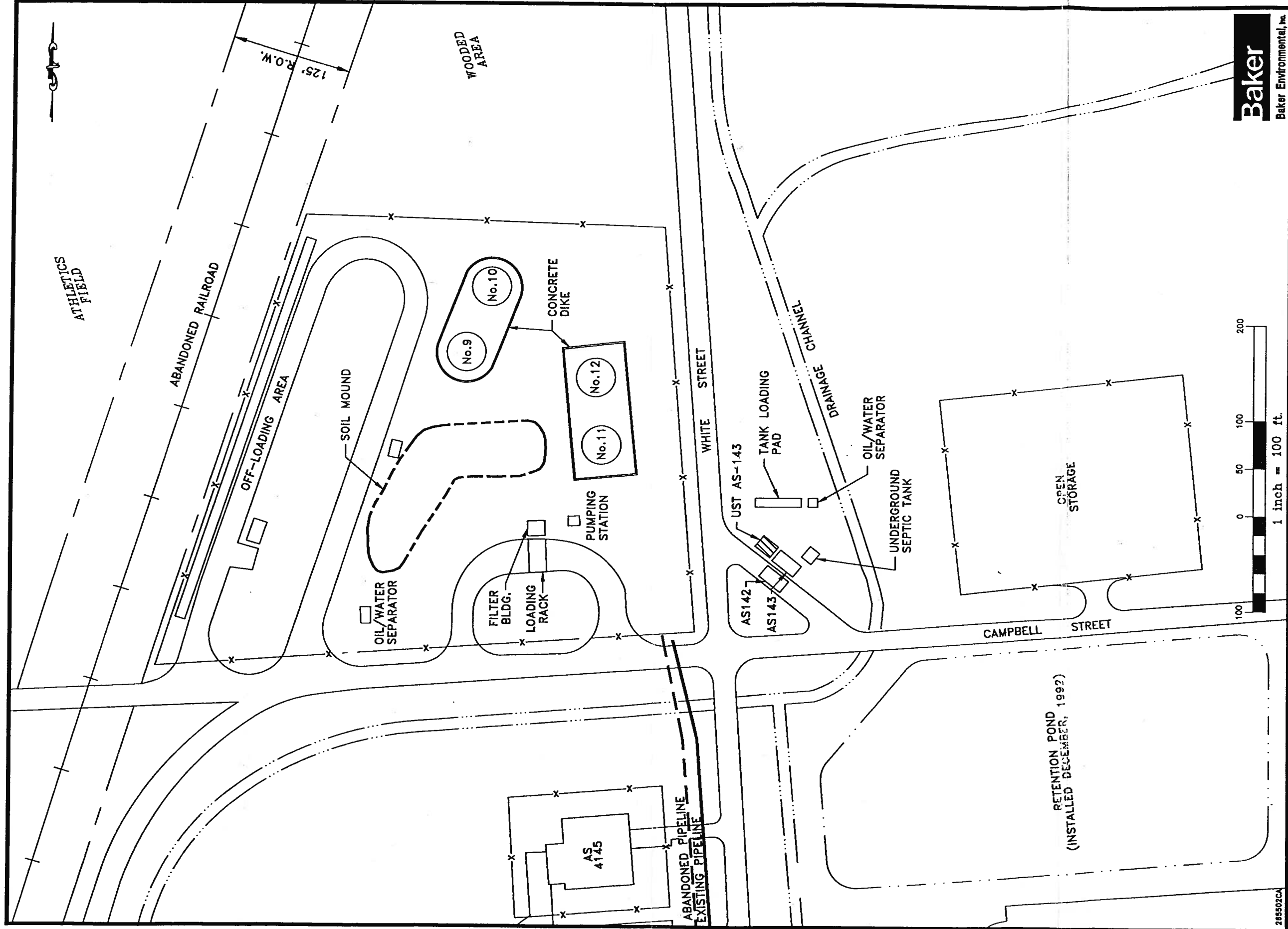


FIGURE 1-1
SITE LOCATION MAP
CAMPBELL STREET FUEL FARM
AND UST AS-143

MARINE CORPS AIR STATION, NEW RIVER
JACKSONVILLE, NORTH CAROLINA



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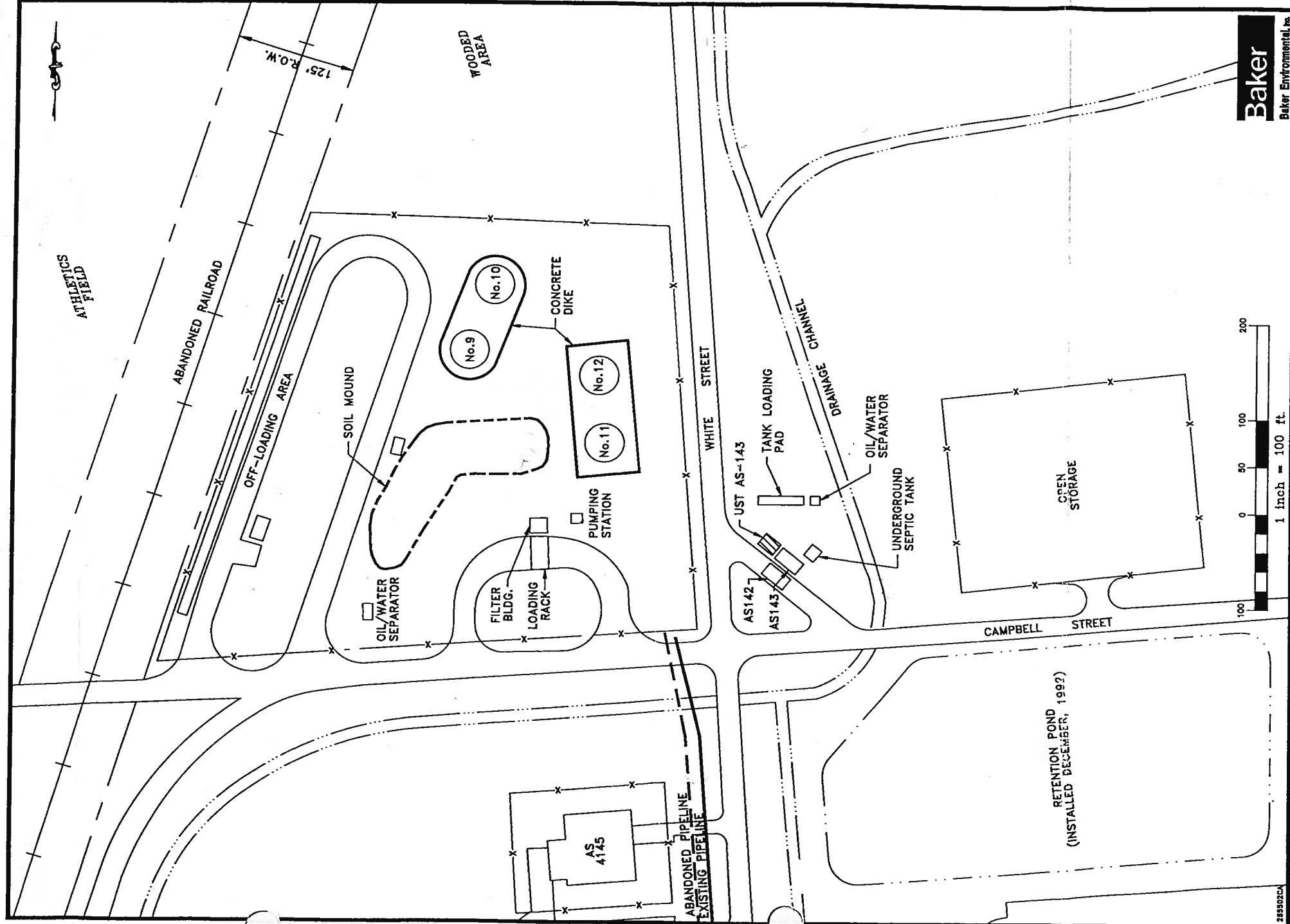
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FIGURE 1-2
SITE PLAN
CAMPBELL STREET FUEL FARM
AND UST AS-143
MARINE CORPS AIR STATION, NEW RIVER
JACKSONVILLE, NORTH CAROLINA

No. 9
ABOVE GROUND
STORAGE TANK

—X— FENCE

LEGEND



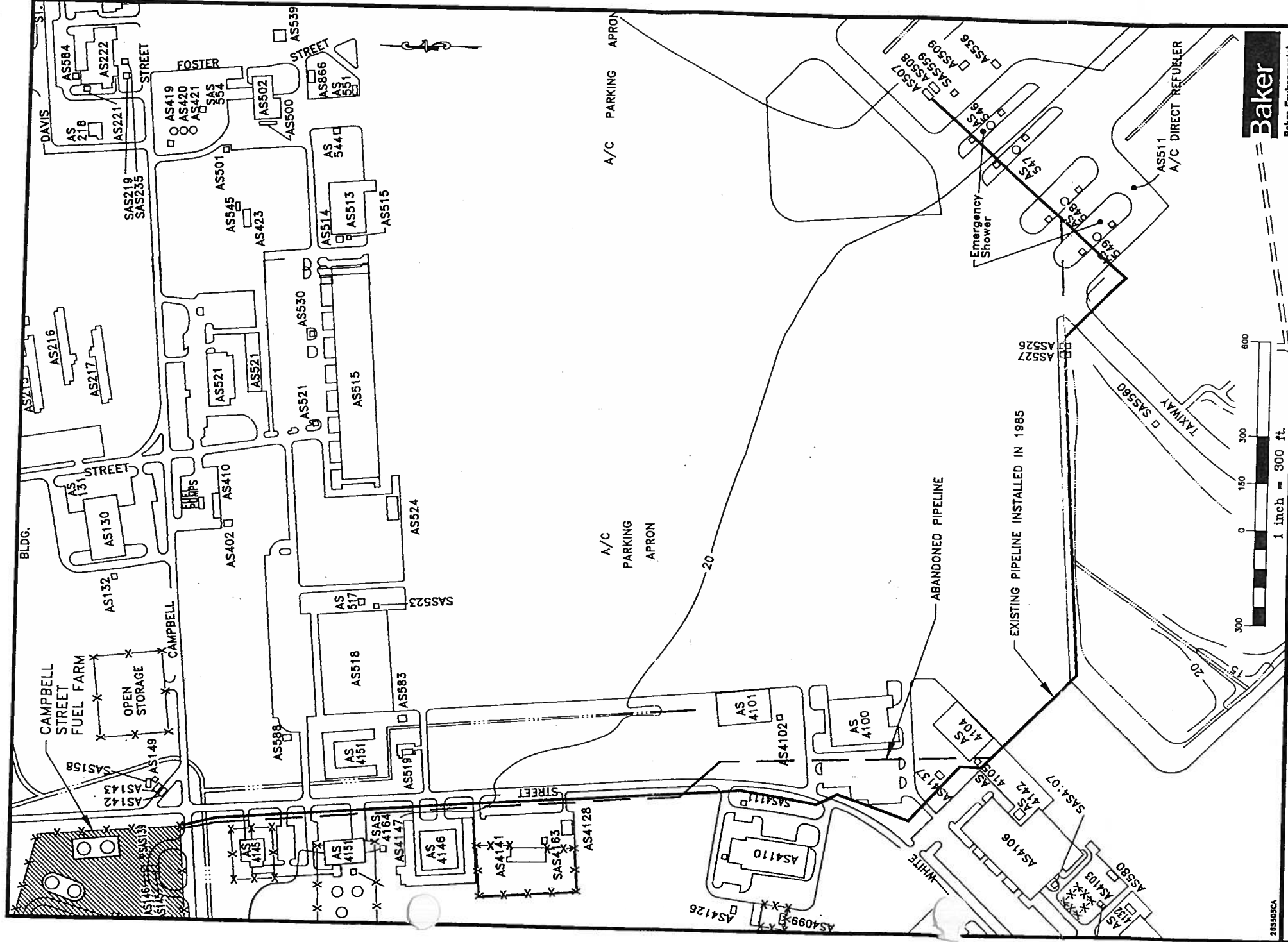
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FIGURE 1-2
SITE PLAN
CAMPBELL STREET FUEL FARM
AND UST AS-143
MARINE CORPS AIR STATION, NEW RIVER
JACKSONVILLE, NORTH CAROLINA

LEGEND

—X— ABOVE GROUND STORAGE TANK

—X— FENCE



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FIGURE 1-3
CAMPBELL STREET FUEL FARM PIPELINE
CAMPBELL STREET FUEL FARM
AND UST AS-143

SOURCE: LANTRIV, OCT. 1991; O'BRIEN & GERE, "CORRECTIVE ACTION PLAN, JP-5 LINE AREA", JUNE 1991.

- LEGEND**
- CAMPBELL STREET FUEL FARM
 - ABANDONED PIPELINE
 - EXISTING PIPELINE INSTALLED IN 1985

MARINE CORPS AIR STATION, NEW RIVER
JACKSONVILLE, NORTH CAROLINA

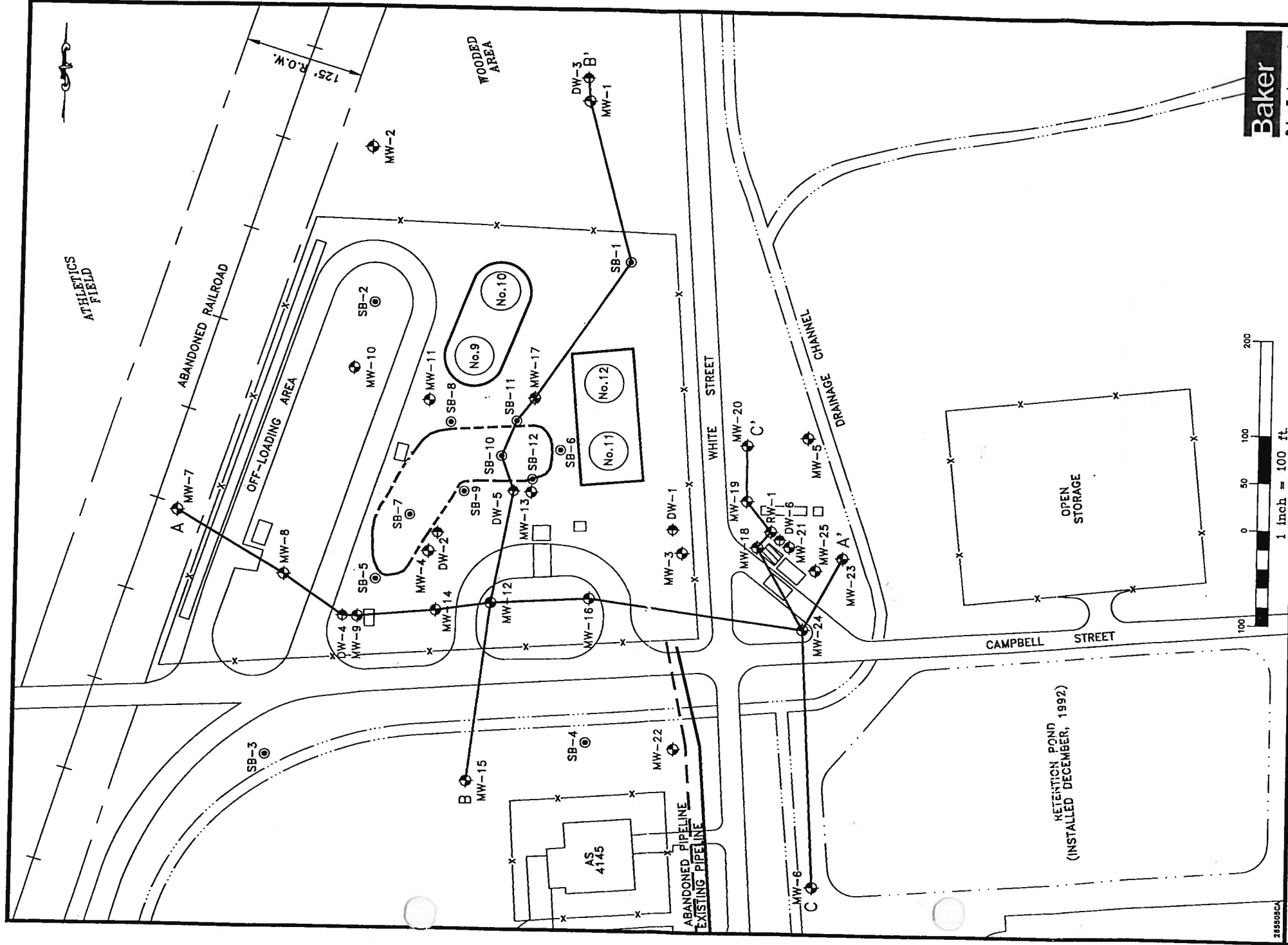
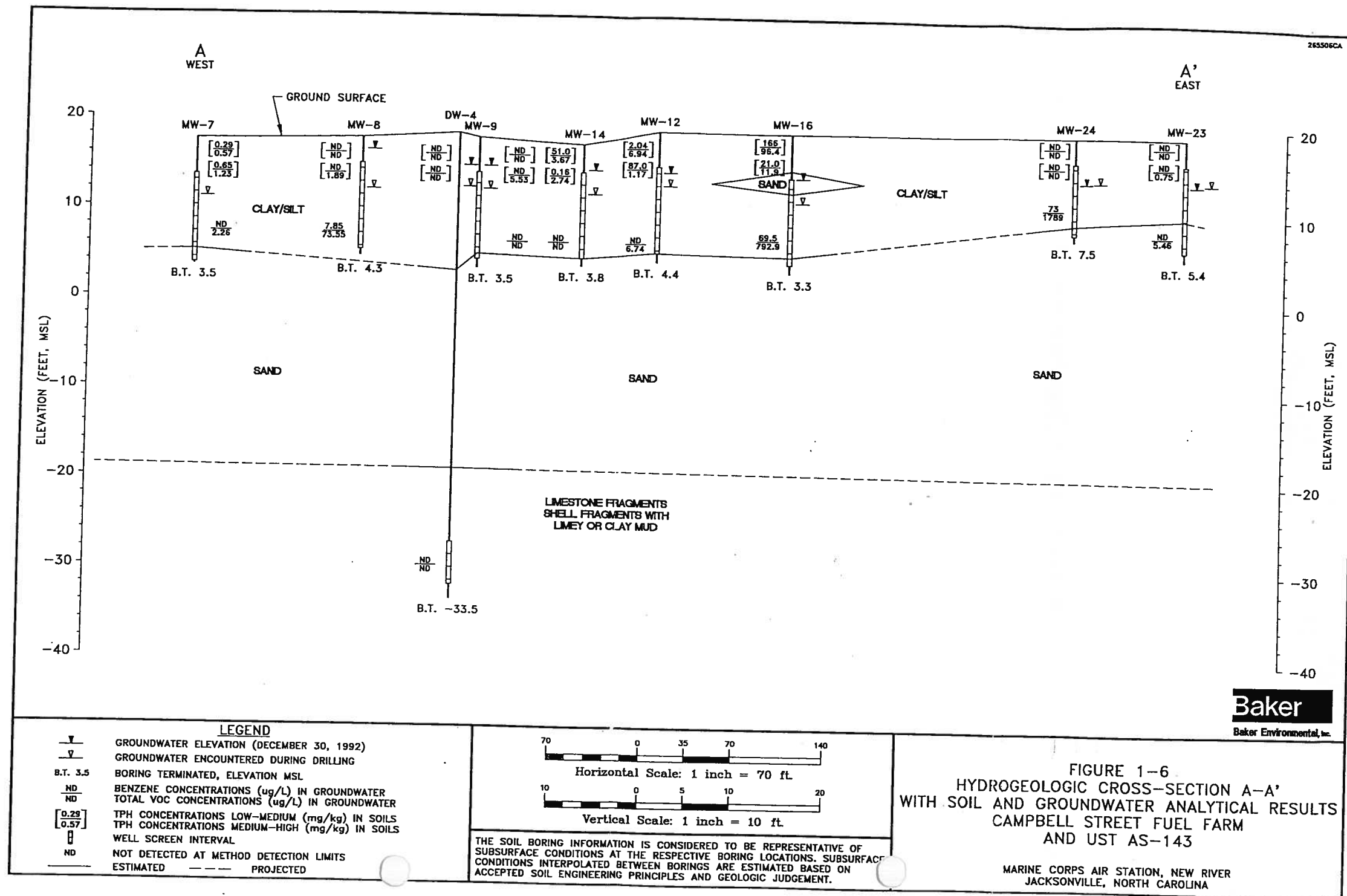
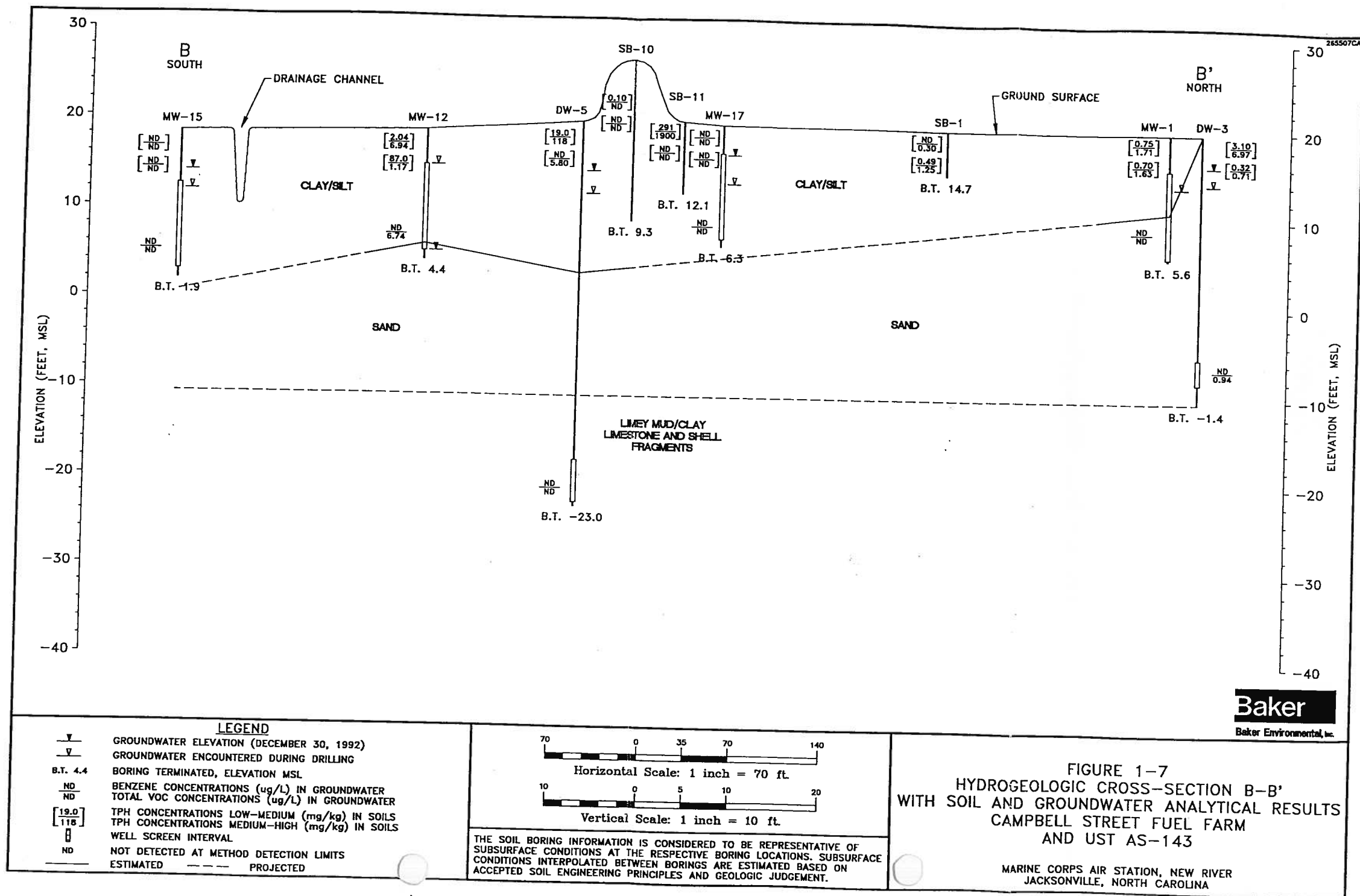
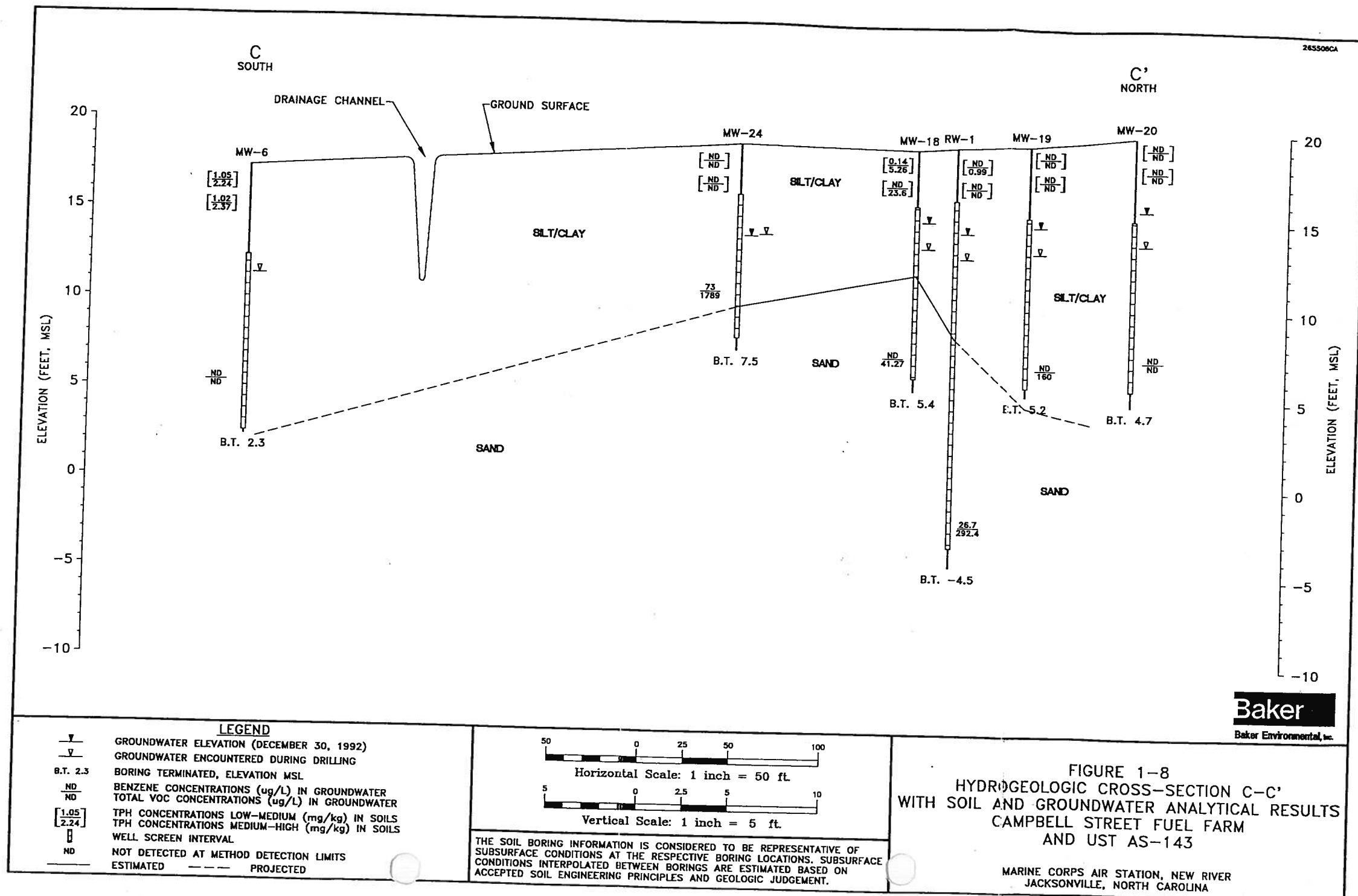


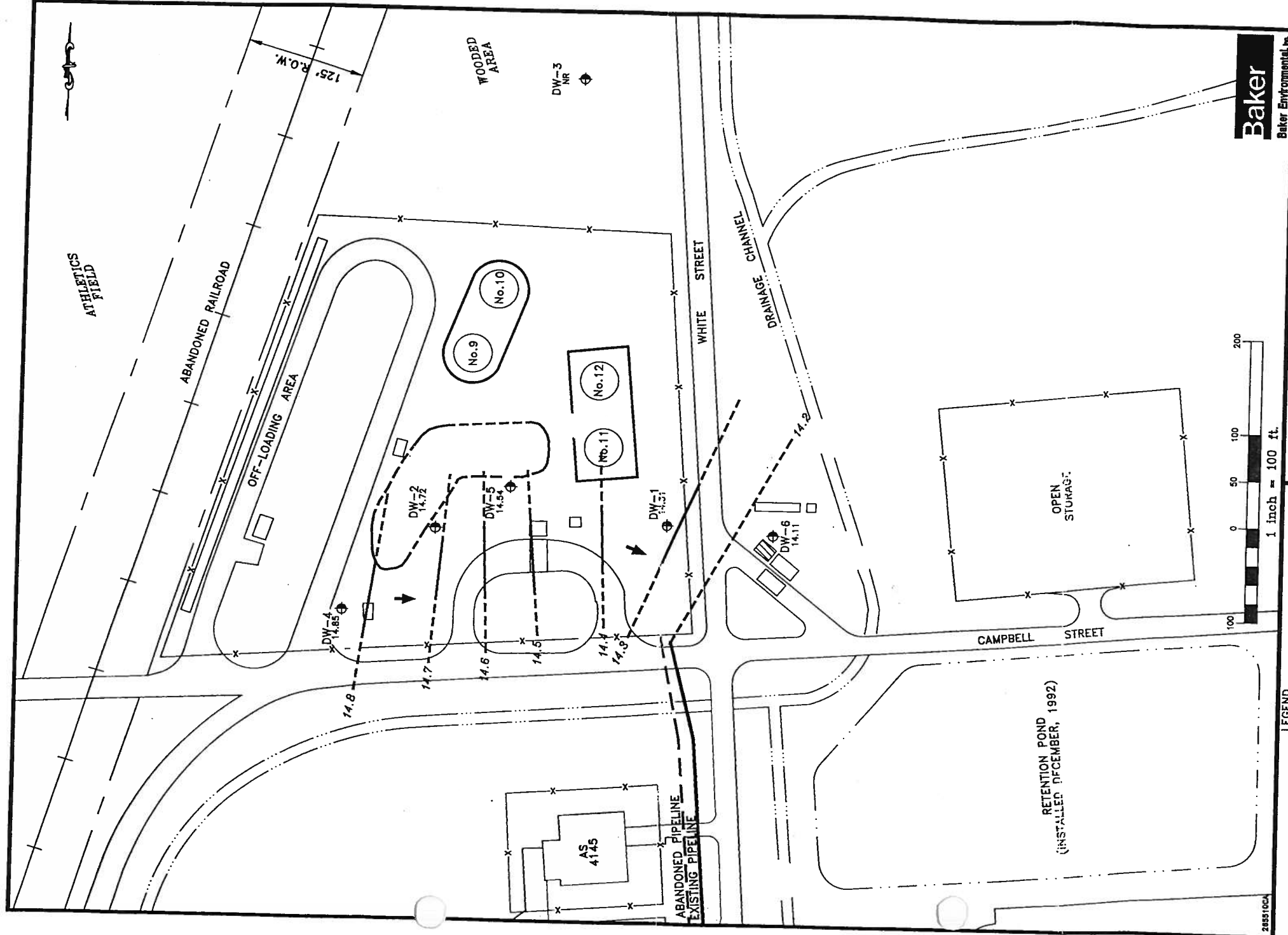
FIGURE 1-5
HYDROGEOLOGIC CROSS-SECTION LOCATION MAP
CAMPBELL STREET FUEL FARM
AND UST AS-143

MARINE CORPS AIR STATION, NEW RIVER
JACKSONVILLE, NORTH CAROLINA





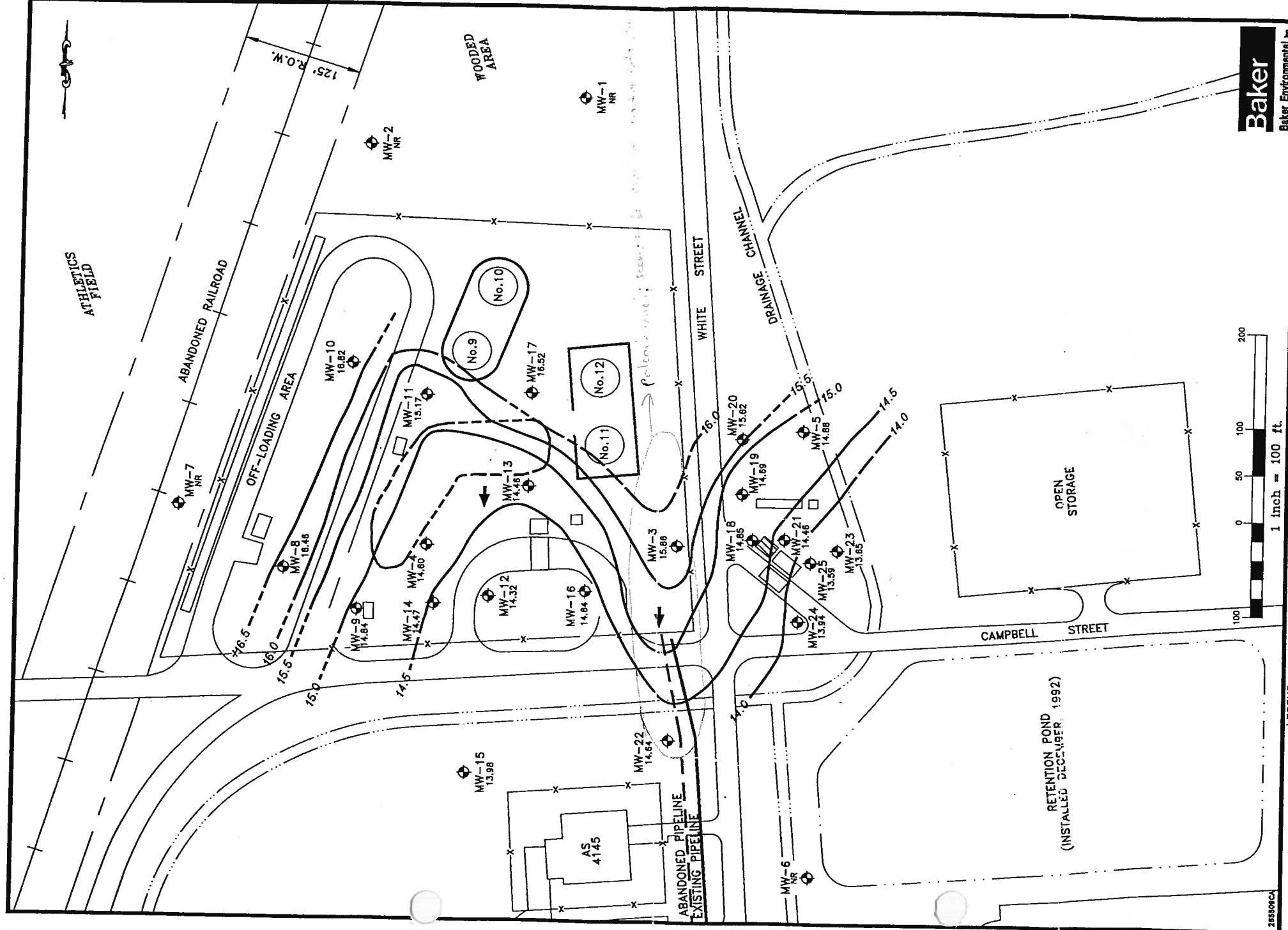




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FIGURE 1-10
POTENTIOMETRIC SURFACE MAP
DEEP AQUIFER - DECEMBER 30, 1992
CAMPBELL STREET FUEL FARM AND UST AS-143
 MARINE CORPS AIR STATION, NEW RIVER
 JACKSONVILLE, NORTH CAROLINA

LEGEND
 DW-1 TYPE III DEEP MONITORING WELL WITH WATER LEVEL
 14.31 ELEVATION (WELL SPECIFIC, MSL)
 — GROUNDWATER CONTOUR ELEVATION (MSL)
 — ESTIMATED GROUNDWATER FLOW DIRECTION
 NR NOT MEASURED ON THIS DATE

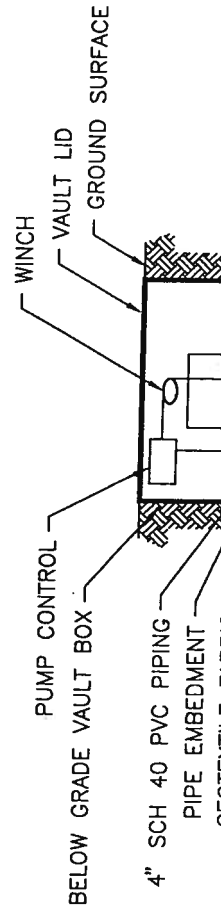


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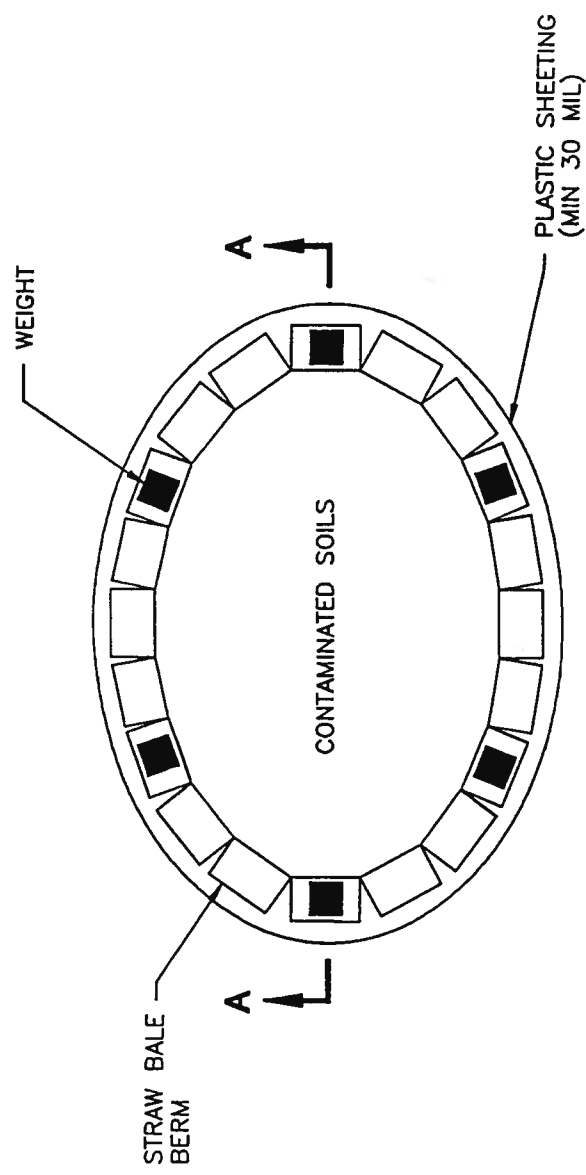
FIGURE 1-9
POTENTIOMETRIC SURFACE MAP
SHALLOW AQUIFER - DECEMBER 30, 1992
CAMPBELL STREET FUEL FARM AND UST AS-143
MARINE CORPS AIR STATION, NEW RIVER
JACKSONVILLE, NORTH CAROLINA

LEGEND

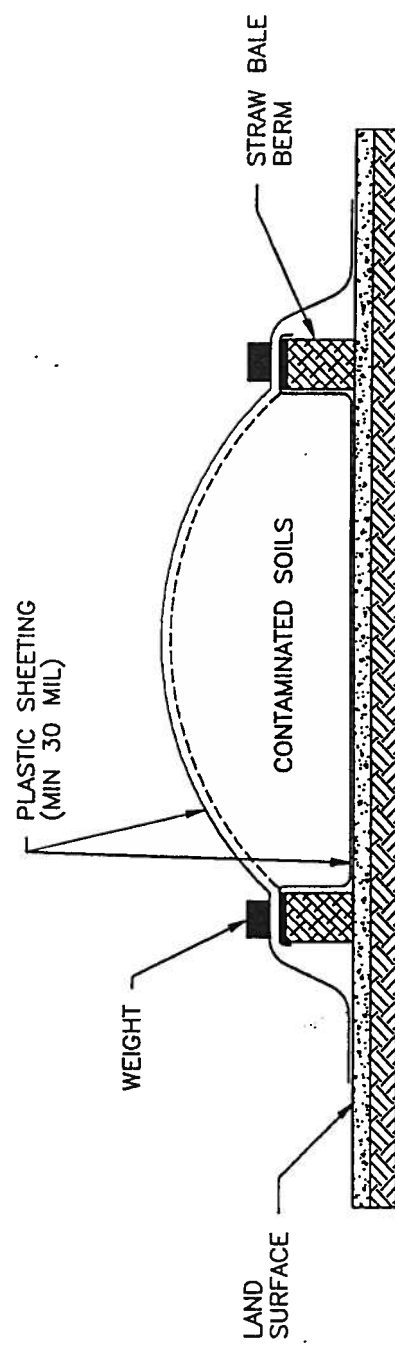
- MW-3 15.86 TYPE II SHALLOW MONITORING WELL WITH WATER LEVEL ELEVATION (WELL SPECIFIC, MSL)
- GROUNDWATER CONTOUR ELEVATION (MSL)
- ➔ ESTIMATED GROUNDWATER FLOW DIRECTION
- NR NOT MEASURED ON THIS DATE



24551 PCA



PLAN VIEW

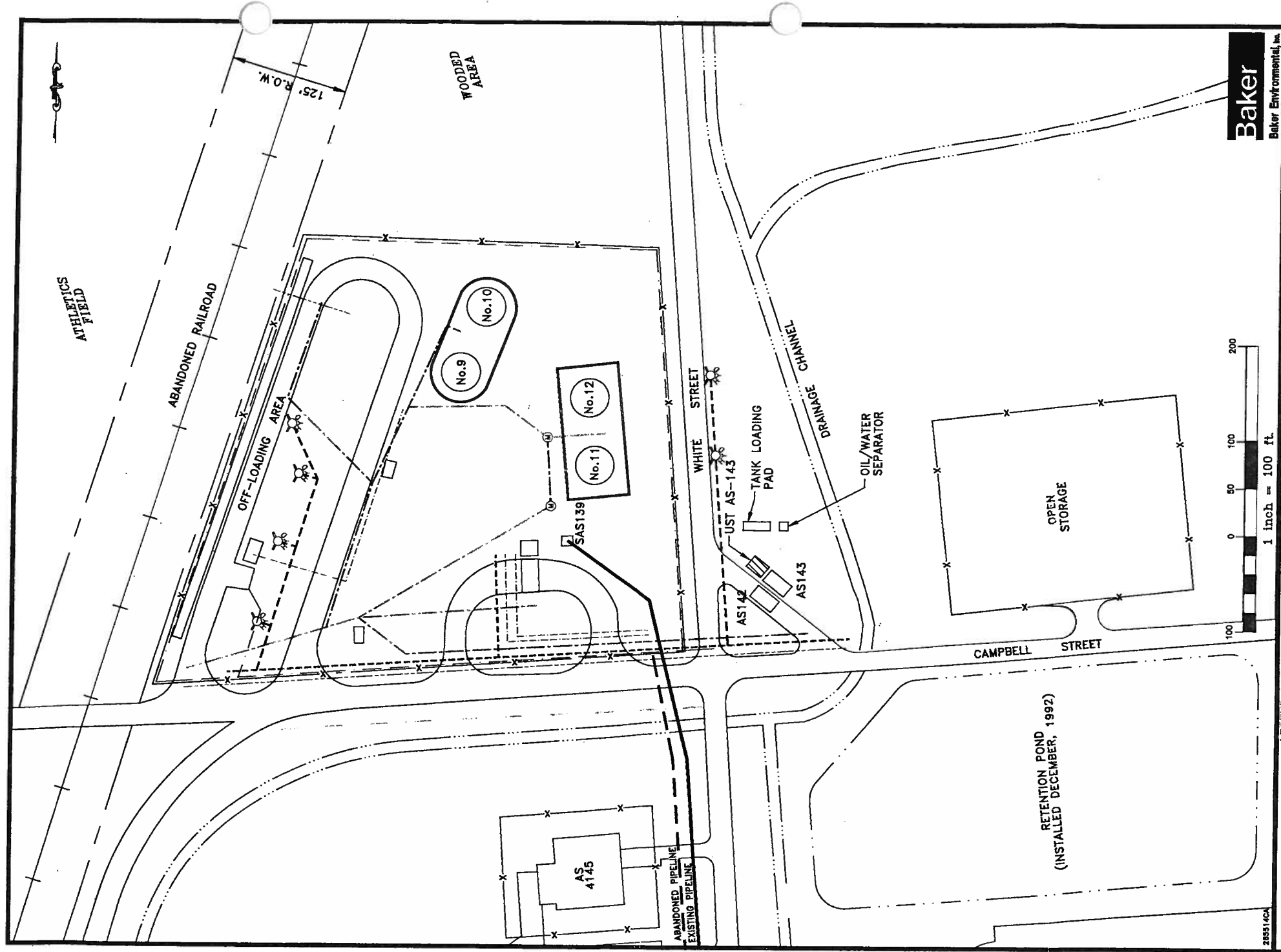


SECTION A-A

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FIGURE 5-2
DIAGRAM FOR TEMPORARY CONTAINMENT
OF PETROLIUM CONTAMINATED SOIL



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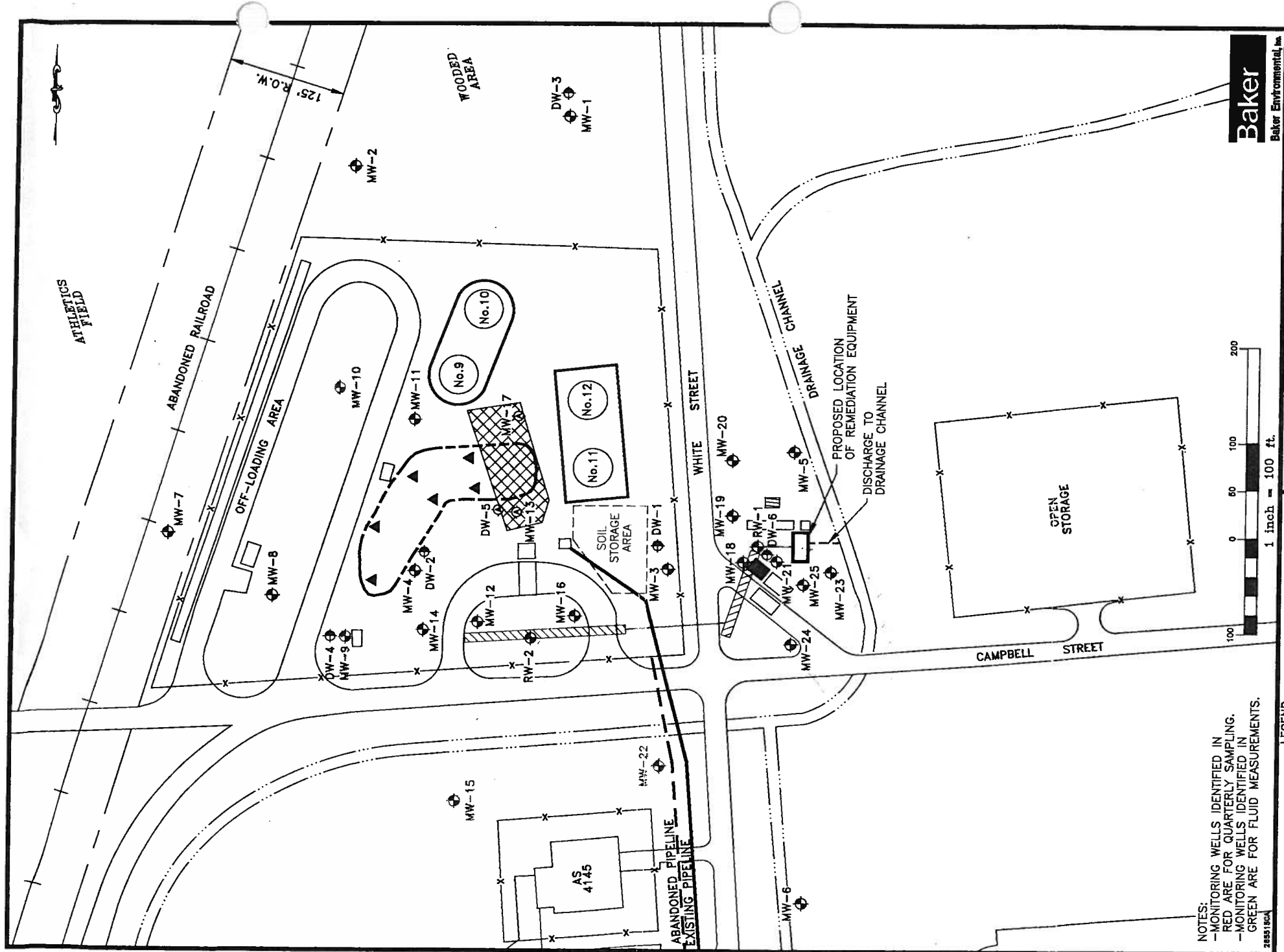
FIGURE 4-1
LOCATION OF UNDERGROUND UTILITIES
CAMPBELL STREET FUEL FARM AND UST AS-143
MARINE CORPS AIR STATION, NEW RIVER
JACKSONVILLE, NORTH CAROLINA

LEGEND

- OILY WATER DRAINAGE
- ELECTRIC LINE
- STORM DRAIN
- WATER LINE
- ⊗ MANHOLE
- ABANDONED PIPELINE
- EXISTING PIPELINE
- FIBER OPTIC CABLE
- ⊗ FIRE HYDRANT

SOURCE: LANTDIV, OCT. 1991; NAVFAC DRAWING NO. 4164666,
"REPLACE FUEL STORAGE TANKS", JULY 17, 1987

255514CA



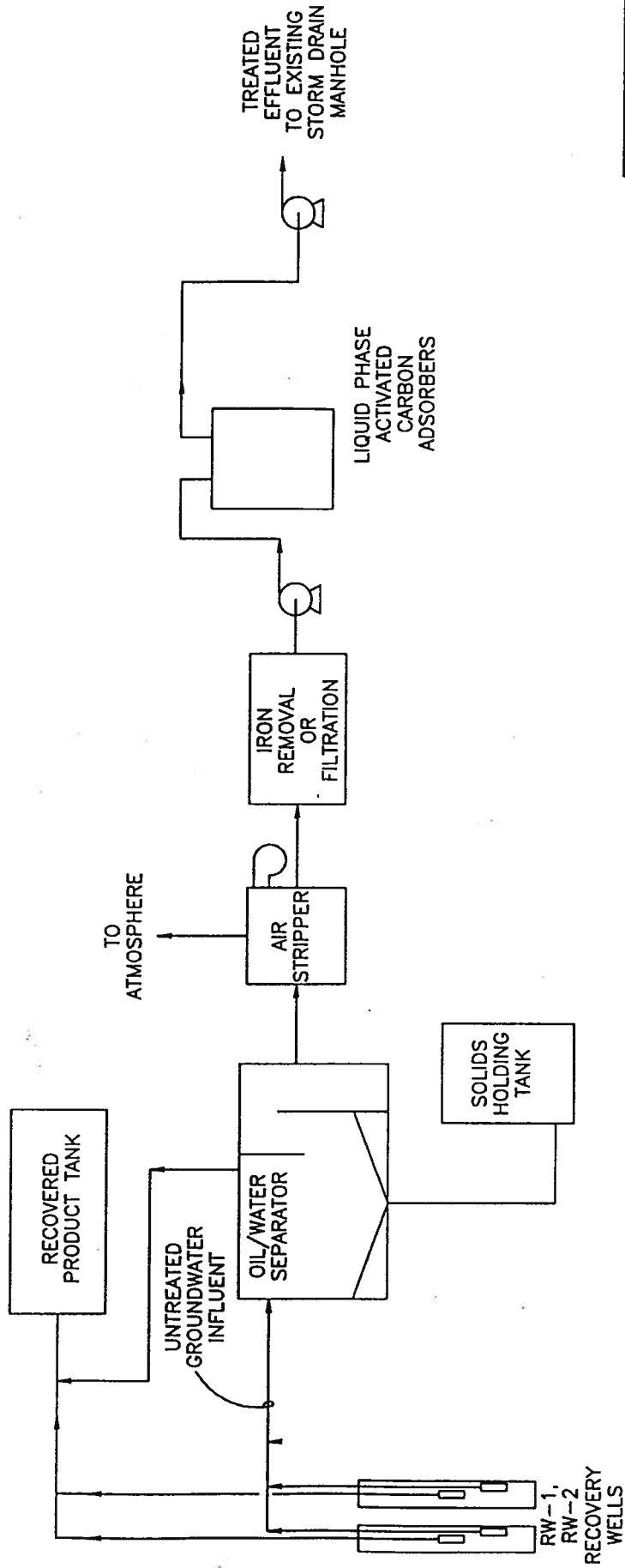
NOTES:
 - MONITORING WELLS IDENTIFIED IN RED ARE FOR QUARTERLY SAMPLING.
 - MONITORING WELLS IDENTIFIED IN GREEN ARE FOR FLUID MEASUREMENTS.

LEGEND
 MW-1 SHALLOW MONITORING WELL
 MW-3 MONITORING WELL TO BE ABANDONED
 MW-6 SHALLOW SUBSURFACE EQUIPMENT TRENCH
 MW-15 PROPOSED LOCATION OF INTERCEPTOR TRENCH
 MW-19 PROPOSED EXTENT OF SOILS TO BE EXCAVATED
 MW-20 DEEP MONITORING WELL
 MW-21 RECOVERY WELL
 MW-22 PROPOSED HAND AUGER LOCATION
 MW-23 UST TO BE REMOVED
 MW-24 PROPOSED LOCATION OF NEW UST

FIGURE 5-1
 RECOMMENDED SITE REMEDIATION PLAN
 CAMPBELL STREET FUEL FARM
 AND UST AS-143

SOURCE: LANTDIV, OCT. 1991

MARINE CORPS AIR STATION, NEW RIVER
 JACKSONVILLE, NORTH CAROLINA



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FIGURE 5-4
RECOMMENDED GROUNDWATER
TREATMENT SYSTEM PROCESS
SCHEMATIC

MARINE CORPS AIR STATION, NEW RIVER
JACKSONVILLE, NORTH CAROLINA

Appendix A

Site Sensitivity Evaluation

Site Sensitivity Evaluation (SSE)

Site Characteristics Evaluation (Step 1)

Characteristic	Condition	Rating	
Grain Size*	Gravel	150	50
	Sand	100	
	Silt	50	
	Clay	0	
Are relict structures, sedimentary structures, and/or textures present in the zone of contamination and underlying "soils"?	Present and intersecting the water table.	10	0
	Present but <u>not</u> intersecting the water table.	5	
	None present.	0	
Distance from location of deepest contaminated soil** to water table.	0 - 5 feet	20	20
	(C, D & E sites only)	20	
	5 - 10 feet	10	
	>10 - 40 feet	0	
	> 40 feet		
Is the top of bedrock or transmissive indurated sediments located above the water table?	Yes	20	0
	No	0	
Artificial conduits present within the zone of contamination.	Present and intersecting the water table.	10	5
	Present but <u>not</u> intersecting the water table.	5	
	Not present.	0	

Total Site Characteristics Score: 75

* Predominant grain size based on Unified Soil Classification System or U.S. Dept. of Agriculture's Soil Classification Method.

** (>10 ppm TPFH by Method 5030; >40 ppm TPFH by Method 3550; >250 ppm O&G by Method 9071)

Site Sensitivity Evaluation (SSE)

Initial Cleanup Level
(Step 2)

Final Cleanup Level
(Step 3)

EPA Method 5030 for Low Boiling Point Hydrocarbons such as Gasoline, Aviation Fuels, Gasohol

Low Boiling Point Hydrocarbons such as Gasoline, Aviation Fuels, Gasohol					Final Cleanup Level
Total Site Characteristics Score	Initial Cleanup Level TPFH (ppm)	Select Site Category* →	Category A & B (Multiply initial cleanup level by 1)	1 x _____ = _____ ppm	
>150	≤10		Category C & D (Multiply initial cleanup level by 2)	2 x _____ = _____ ppm	
121-150	20				
91-120	40				
61-90	60				
31-60	80				
0-30	100		Category E (Multiply initial cleanup level by 3)	3 x <u>60</u> = <u>180</u> ppm	

EPA Method 8550 for High Boiling Point Hydrocarbons such as Kerosene, Diesel, Varsol, Mineral Spirits, Naphtha

High Boiling Oil by distillates such as Kerosene, Diesel, Varsol, Mineral Spirits, Naphtha				
Total Site Characteristics Score	Initial Cleanup Level TPFH (ppm)	Select Site Category* →	Category A & B (Multiply initial cleanup level by 1)	Final Cleanup Level
>150	≤40		1 x _____ = _____ ppm	
121-150	80		Category C & D (Multiply initial cleanup level by 2)	2 x _____ = _____ ppm
91-120	160			
61-90	240			
31-60	320		Category E (Multiply initial cleanup level by 3)	3 x _____ = _____ ppm
0-30	400			

EPA Method 9071 for Heavy Fuels - Oil & Grease (O&G) such as Fuel Oil #4, #5, #6, Motor Oil, Hydraulic Fluid

Heavy Fuels - Oil & Grease (O&G) such as Fuel Oil #4, #5, #6, Motor Oil, Hydraulic Fluid				
Total Site Characteristics Score	Initial Cleanup Level O&G (ppm)	Select Site Category* →	Category A & B (Multiply initial cleanup level by 1)	Final Cleanup Level
>150	≤250		1 x _____ = _____ ppm	
121-150	400		Category C & D (Multiply initial cleanup level by 2)	2 x _____ = _____ ppm
91-120	550			
61-90	700			
31-60	850		Category E (Multiply initial cleanup level by 3)	3 x _____ = _____ ppm
0-30	1000			

* See Site Category Descriptions, Table 3

3/10/93

TABLE 3

SSE SITE CATEGORY DESCRIPTIONS

CATEGORY A (*Site meets any one of the criteria*)

1. Water supply well(s) contaminated and not served by accessible public water supply.
2. Vapors present in confined areas at explosive or health concern levels.
3. Treated surface water supply in violation of the safe drinking water standards.

CATEGORY B (*Site meets any one of the criteria*)

1. Water supply well(s) contaminated, but served by accessible public water supply.
2. Water supply well(s) within 1500 feet of site, but not contaminated and not served by accessible public water supply.
3. Vapors present in confined areas but not at explosive or health concern levels.

CATEGORY C (*Site meets both of the criteria*)

1. No known water supply well(s) contaminated.
2. Water supply well(s) greater than 1500 feet from site but not served by accessible public water supply.

CATEGORY D (*Site meets both of the criteria*)

1. No known water supply well(s) contaminated.
2. Water supply well(s) within 1500 feet of site but served by accessible public water supply.

CATEGORY E (*Site meets both of the criteria*)

1. No known water supply well(s) contaminated or within 1500 feet of site.
2. Area served by accessible public water supply.

Appendix B
Field Testing of Contaminated Soils



EnSys RIS[®] Test System

PETRO in Soil

A FIELD ANALYTICAL TEST FOR PETROLEUM HYDROCARBONS IN SOIL

EPA TEST METHOD 4030

The PETRO RIS[®] Soil Test is the only testing product accepted for the performance of petroleum hydrocarbon testing by USEPA SW-846 draft Method 4030.

TEST CHARACTERISTICS

The PETRO RIS[®] Soil Test is a field-compatible immunoassay-based test for petroleum fuels in soil. It can be used to measure petroleum fuels down to 10 ppm. For ease of use on-site, PETRO RIS[®] Soil Test provides an accurate semi-quantitative (absence/presence) result at a set concentration level. The user can test at any petroleum hydrocarbon concentration to suit the actual site action level(s). The minimum detection levels for the most common sources of petroleum product contamination are listed in the table below.

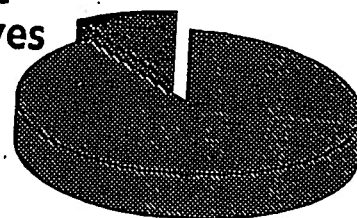
The PETRO RIS[®] Test is specific primarily to petroleum fuels and petroleum solvents with no sensitivity to relevant potential interferents such as chlorinated solvents and MTBE.

SENSITIVITY

Product	Minimum Detection Level (ppm)
gasoline	10
diesel fuel, #2	15
jet A fuel	15
jet fuel, JP-4	15
kerosene	15
fuel oil, #2	15
fuel oil, #6	25
mineral spirits	40
crude oil	60-130*

* variable depending on source

< 11%
False
Positives



> 89%
Correlation
to Lab Methods

ACCURACY

The PETRO RIS[®] Test has been rigorously tested against the standard laboratory method, SW-846 modified Method 8015, using actual contaminated samples. It has been shown to correlate extremely well with the laboratory-based GC test. In particular, a very low occurrence rate (<1%) of false negative results has been observed.

ADVANTAGES OF USING THE PETRO RIS[®] TEST SYSTEM

The application of the PETRO RIS[®] Test System can result in substantial project savings from:

- ☐ Reduced equipment and personnel costs
- ☐ Reduced analytical costs

Other field methods for testing petroleum hydrocarbons in soil are either considerably more complicated (portable GC) or less accurate (Organic Vapor Meters and other colorimetric tests) than the PETRO RIS[®] Soil Test.



EnSys RIS[®] Test System

APPLICATIONS

PETROCHEMICAL INDUSTRY	Delineation of soil contamination at plant sites.
	Monitoring of land farm/land treatment units.
	Delineation of soil contamination at off-site waste impounds
	Monitoring the progress of on-site remediation
UST REMOVAL AND REMEDIATION	Testing for petroleum hydrocarbon contamination in soil
	Delineation of petroleum hydrocarbon contamination in soil
	Monitoring the progress of soil remediation
	Guiding collection of samples for closure permitting

OPERATIONAL CHARACTERISTICS

Detection Levels	One semi-quantitative level (Single Level Test) Two semi-quantitative levels (Multiple Level Test).
Sample Testing Throughput	Ten samples completed in less than 50 minutes.
Quality Control	Duplicate standards are provided with each set of samples to ensure accuracy under field conditions.
Temperature	Stored at room temperature, no refrigeration necessary.
Shelf Life	3 months (Extended with additional real time data).

PO Box 14063, Research Triangle Park, NC 27709
Royal Center, 4222 Emperor Blvd., Morrisville, NC 27560
(919) 941-5509 (919) 941-5519 FAX



SECTION 200 ON-SITE PLATFORM

200.1 DESCRIPTION

200.11 Scope

Equipment to be furnished under this section shall include an Ejector Systems On-Site Platform, prefabricated ground water and soil remediation system with equipment as described elsewhere in this specification, securely mounted, piped, wired, ducted and tested at the factory. Provisions of Section 100, General Conditions shall apply.

200.12 Functional Description

A. Platform

The dimensions of the platform are 8, 12 or 16 feet long x 8.5 feet wide x 9 feet high. The platform shall consist of a structural steel base on which major process equipment is mounted at the factory. The base structure shall be of 4 inch I-beam floor joists which are carried by 10 inch I-beams. It shall be capable of being shipped and off-loaded at the job site by fork lift or crane without damaging the equipment, inter-connecting pipe or electrical conduit. It shall be capable of functioning as a complete operating equipment package with or without the enclosure. Flooring shall be one inch thick plywood securely fastened to the platform.

B. Enclosure

In order to provide security and/or protection from the weather, the platform shall be provided with an enclosure. The enclosure shall be made up of 4 foot wide by 8 foot high insulated panels. Panels shall be faced inside and out with aluminum sheeting and be constructed such that they can be reversed and/or interchanged with any other panel. Insulation shall consist of 1-1/2 inches of urethane foam board with an R value of 10. In order to facilitate accessibility to all equipment on the platform, each and every panel shall be easily removable by one individual. Weight of an individual panel shall not exceed 55 lbs.

The roof shall be constructed of 1" aluminum extruded I-beams on 1 foot centers and covered with an aluminum skin. One and a half inches of urethane foam board with a R value of 10 shall insulate the roof. The roof shall be capable of carrying a 40 pound per square foot live load.

The integral roof shall be constructed with a structural steel frame mounted securely to the platform supporting the roof and its dead load and specified live load. The enclosure panels will be fastened to the roof. The frame shall be capable of withstanding a 20 pound per square foot wind load transferred by the enclosure panels.



200.2 PERFORMANCE AND DESIGN REQUIREMENTS

200.21 Platform and Enclosure

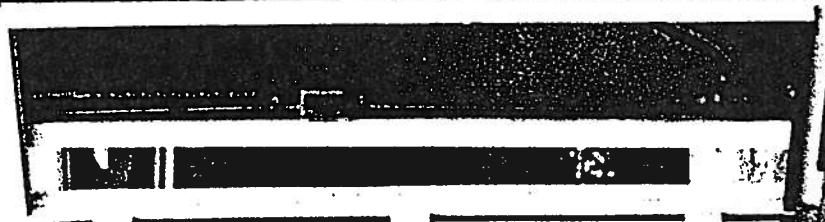
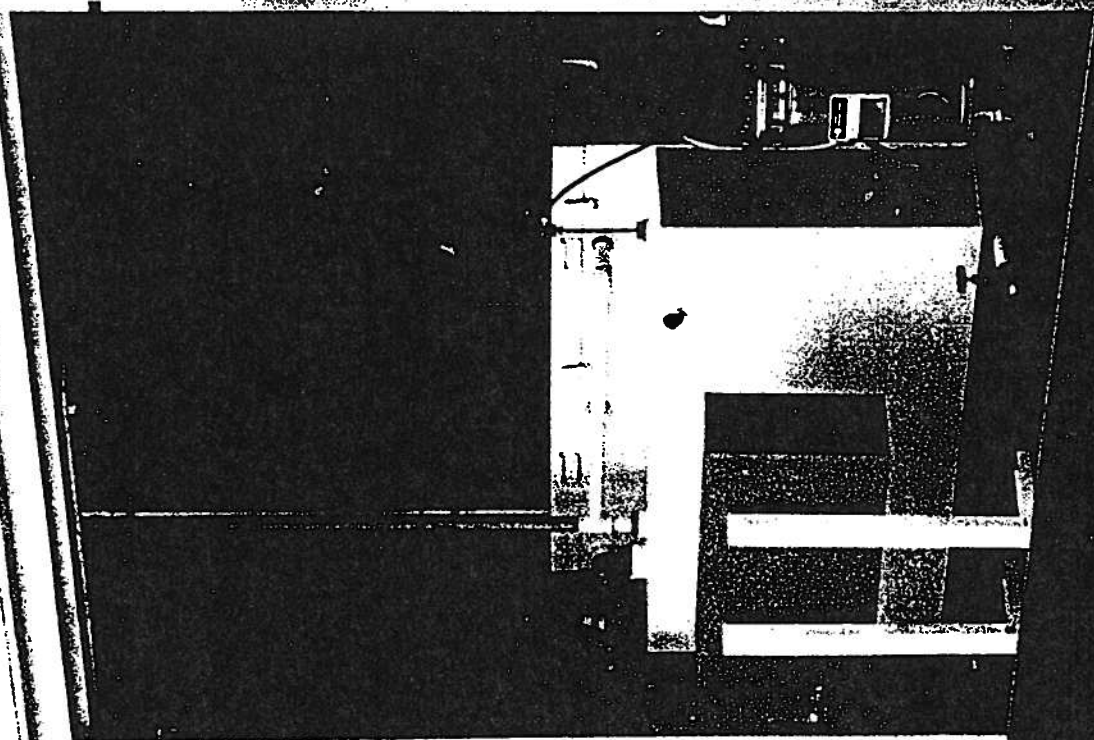
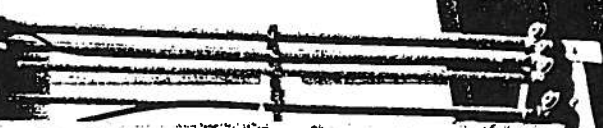
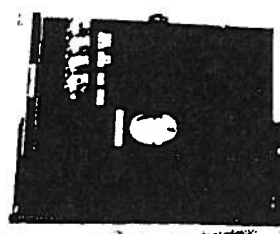
- A. Maximum width to any part shall not exceed 8 feet 6 inches and be of sufficient length to provide access for visual inspection of the operation and routine maintenance.
- B. Access shall be by way of a 2 foot 8 inch wide door hinged to swing outward. It shall not be necessary to remove a 4 foot x 8 inch wide panel to enter the enclosure.
- C. An explosion-proof electric heater with thermostat capable of a 12,000 btu output will be mounted and wired at the factory within the enclosure.
- D. An explosion-proof 100 watt light will be mounted on the ceiling.

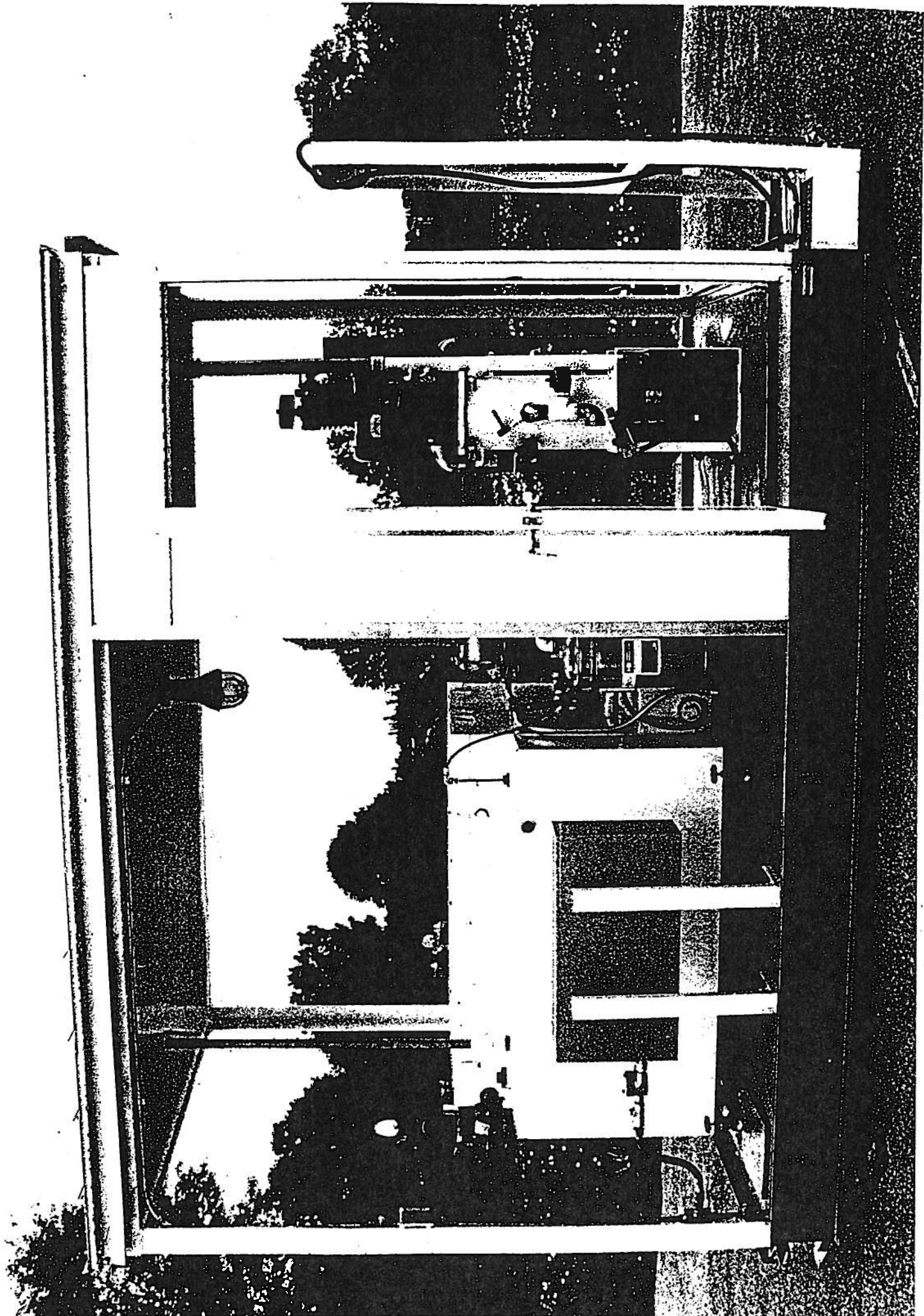
200.22 System Electrical

- A. All electrical components in the classified area including fittings, wiring, lights, thermostats, motors, etc. shall conform to the National Electrical Codes to meet the requirements for Class I, Division I, Group D.
- B. A motor control center housing starters and other control components shall be mounted in a NEMA 3R enclosure external to the platform enclosure. Circuit breakers shall be located in their own, separate 3R enclosure. These enclosures shall be mounted at the factory on a structural steel bracket attached to the platform in a fashion which will not inhibit removal of any platform enclosure panel. All interconnecting wiring from the panel to platform components shall be done at the factory. Tops of the electrical enclosures shall be at least 6 feet above the ground. Entry to the enclosures shall be possible either top or bottom.
- C. Service shall consist of one service drop or lateral. Main disconnect is to be rated suitable for service equipment where ground rod shall be installed per NEC 250-23. Other conditions may apply. Electrical conditions are ___phase 60 cycle ___volts ___ wire.

200.23 Monitoring and Safety Devices

- A. Devices described elsewhere in the specifications used to detect abnormal operation and take shut down or notification functions shall be mounted, wired and integrated into the motor control center.
- B. These devices shall be "wet tested" at the factory prior to shipment.



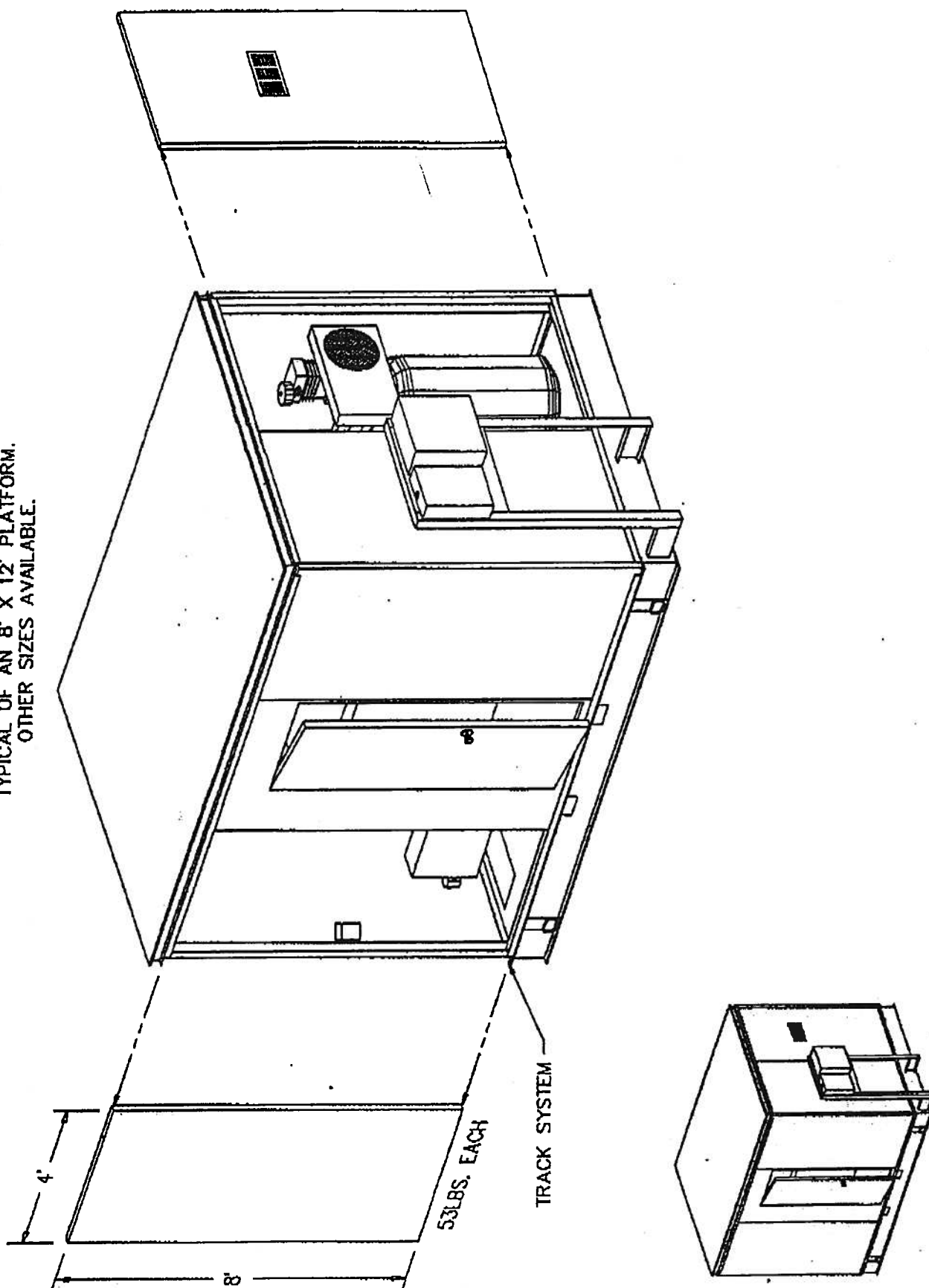


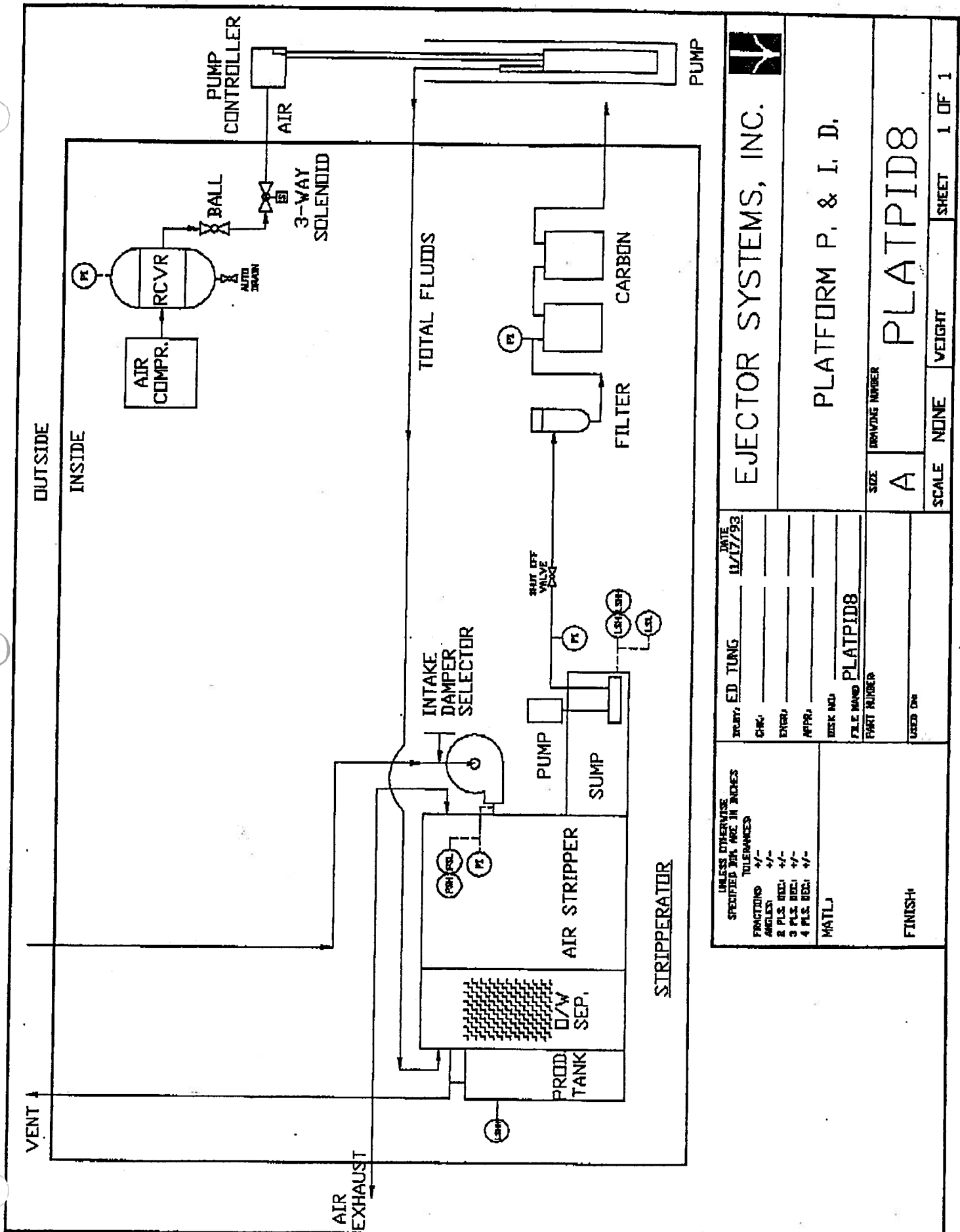
EJECTOR SYSTEMS ON-SITE PLATFORM

INSULATED, REMOVABLE WALL PANELS

TYPICAL OF AN 8' X 12' PLATFORM.

OTHER SIZES AVAILABLE.





EJECTOR SYSTEMS, INC.

PLATFORM P. & I. D.

PLATPID8

UNLESS OTHERWISE SPECIFIED DIM. ARE IN INCHES		DATE
FRACTIONS		11/17/93
TOLERANCES		
1. FRACTIONS	+/-	
2. P.L.S. DEC.	+/-	
3. P.L.S. DEC.	+/-	
4. P.L.S. DEC.	+/-	
MATERIAL		
FINISH		
DESIGN	ED TUNG	
CHECK		
ENTER		
APPROV.		
DISK NO.		
FILE NAME	PLATPID8	
PART NUMBER		
USED ON		

SHEET 1 OF 1

WEIGHT

SCALE NONE

SCALE

SCALE

SCALE

SCALE

SCALE

SCALE

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SCALE

SCALE

SCALE

SCALE

SCALE

SCALE

SCALE

SCALE

SCALE

EJECTOR SYSTEMS ON-SITE PLATFORM

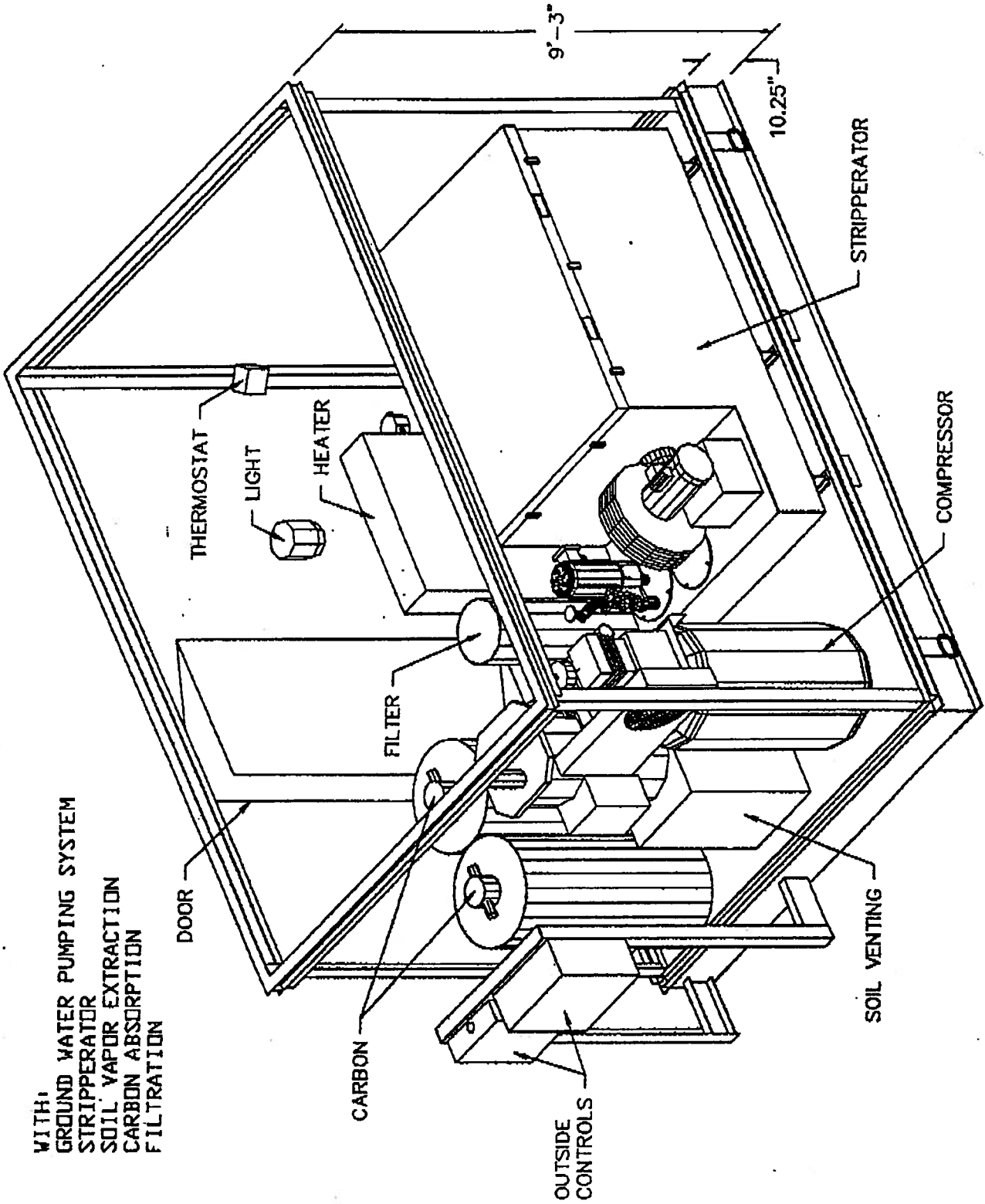
0-10 OR 0-20 GPM PACKAGED GROUND WATER REMEDIATION

WITH:
GROUND WATER PUMPING SYSTEM
STRIPPERATOR
SOIL VAPOR EXTRACTION
CARBON ABSORPTION
FILTRATION

PAGE.007

06-11-93 D.B.
PLAT3.DWG

APR 22 '94 12:05

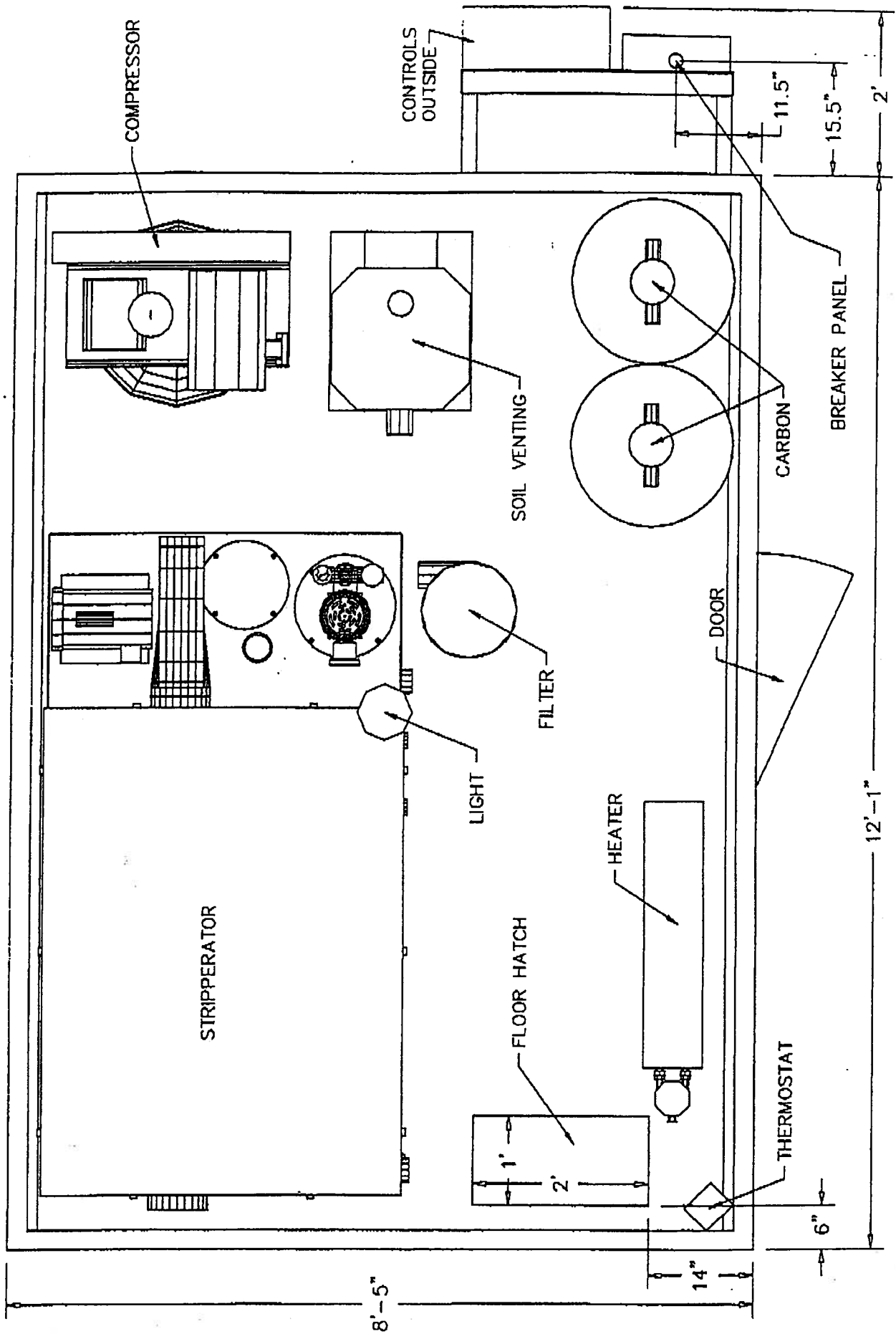


WITH:
GROUND WATER PUMPING SYSTEM
STRIPPERATOR
SOIL VAPOR EXTRACTION
CARBON ABSORPTION
FILTRATION

EJECTOR SYSTEMS ON-SITE PLATFORM

0-10 OR 0-20 GPM PACKAGED GROUND WATER REMEDIATION

PLAN VIEW





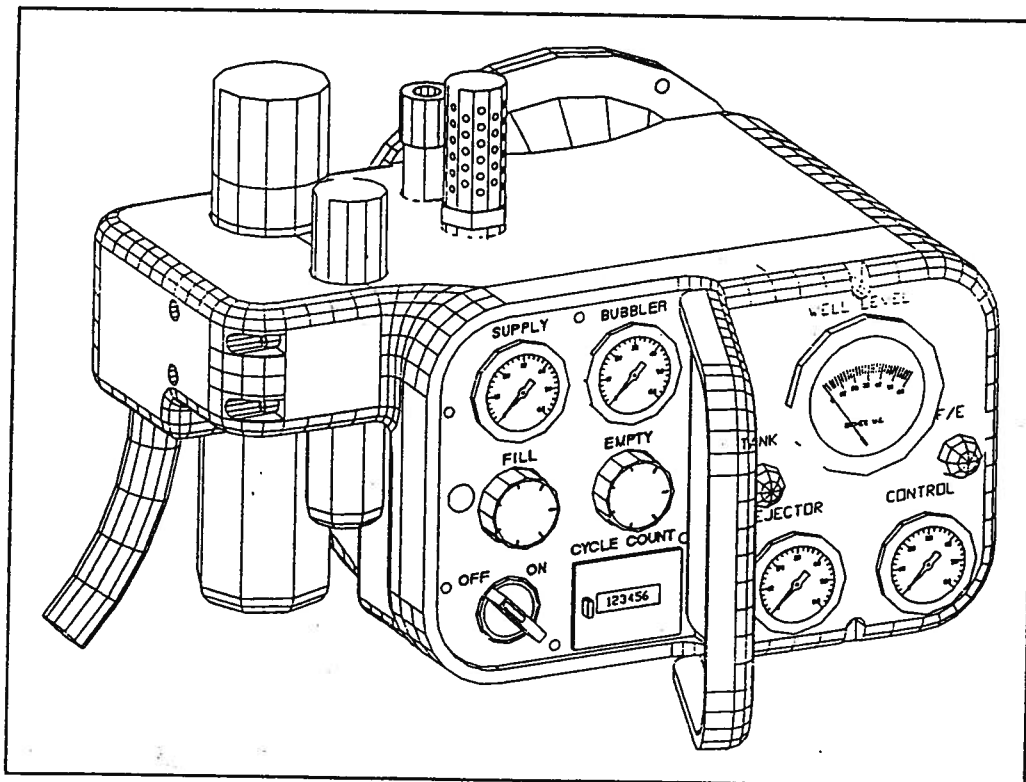
EJECTOR SYSTEMS, INC.

S2 SINGLE-WELL PUMPING SYSTEM

**EJECTOR SYSTEMS, INC.
910 NATIONAL AVENUE
ADDISON, IL
60101
(708) 543-2214
1-800-OIL-LEAK
1/92**



Ejector Systems, Inc. presents the most advanced solution yet for groundwater remediation and leachate pumping. The same ingenuity that made ESI the first to use pneumatics for groundwater pumping is now combined with the new S2 single well controller to offer a vast number of options, yet remain amazingly economical.



S2 SINGLE WELL CONTROLLER

Product Only and Total Fluids pumps are both compatible with the new S2 controller. Ejector Systems, Inc.'s pumps are entirely pneumatic and have only two moving parts thereby reducing maintenance. In addition to leachate pumping, they can be used to pump lighter-than-water, phase-separated hydrocarbons, such as gasoline and fuel oils; heavier-than-water hydrocarbons, such as creosote or chlorinated solvents; or dissolved hydrocarbons only. Refer to the chart on page four for flow rate and air consumption.



Some standard features on the new S2 single-well controller are:

- The S2 system is totally submersible.
 - An extremely rugged 11" high x 14.5" wide x 10" deep casing encloses the S2 so it fits easily into a below grade box.
 - Water problems are virtually eliminated with the S2's Pulsed Auto-Drain which eliminates condensate in the compressed air system.
 - The Manual Discharge feature allows the pump to fire with the simple push of a button.
-

Dependent upon the specific site requirements, optional features are available:

- To ensure accurate level control in sealed well applications with a vacuum, the Differential Pressure option is available.
- The High Tank Shut-Off option will shut down the pumping system in the event of a high level condition.
- A Vacuum Fill Unit which will apply a vacuum to the vent line during the fill cycle is available.
- Product recovery is maximized with the Level Tracking option which ensures that the inlet of the Product Only pump is always at the liquid surface of the well.

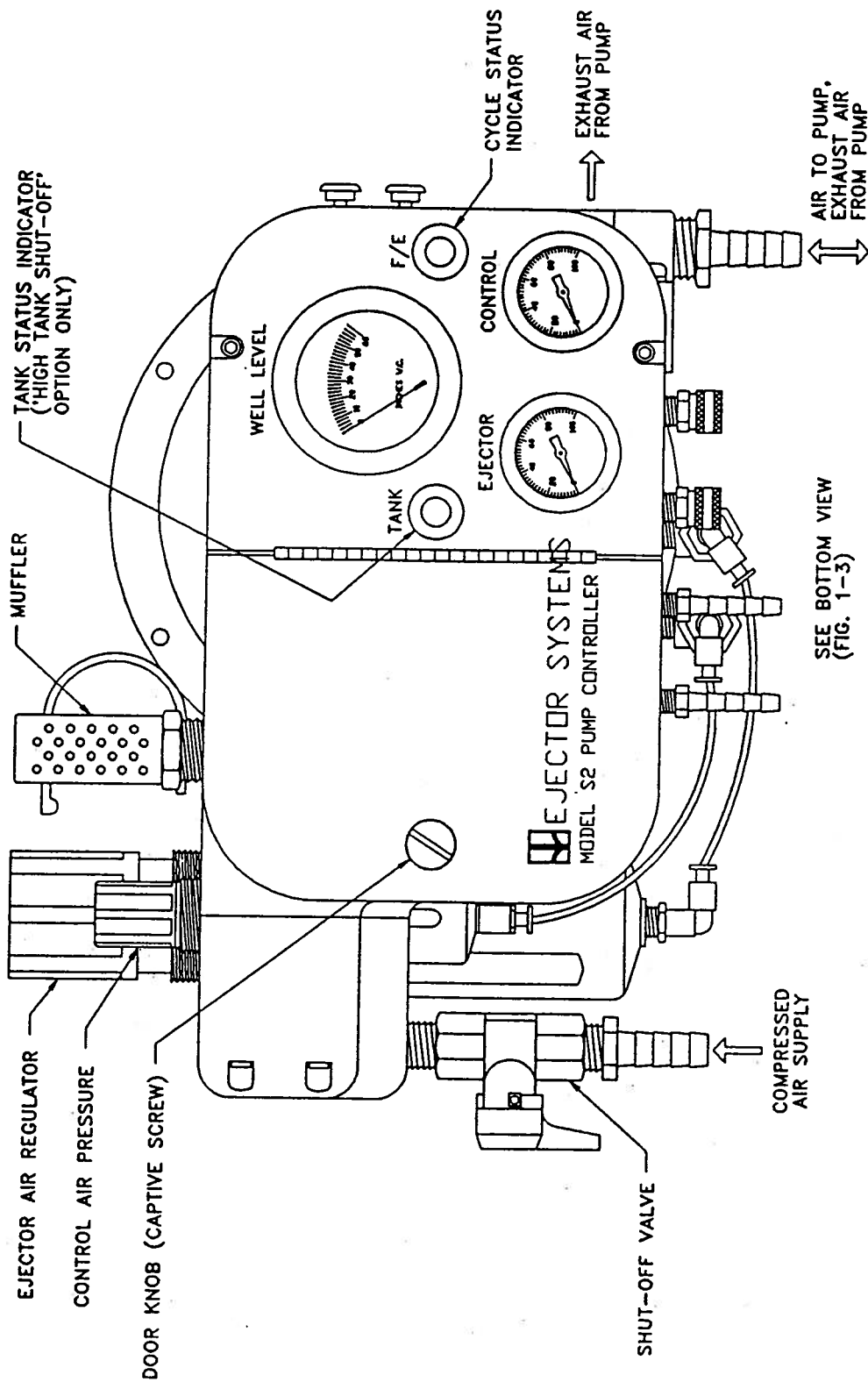


MAXIMUM FLOW RATE AND APPROXIMATE AIR CONSUMPTION VS. EJECTOR DIAMETER AND LENGTH

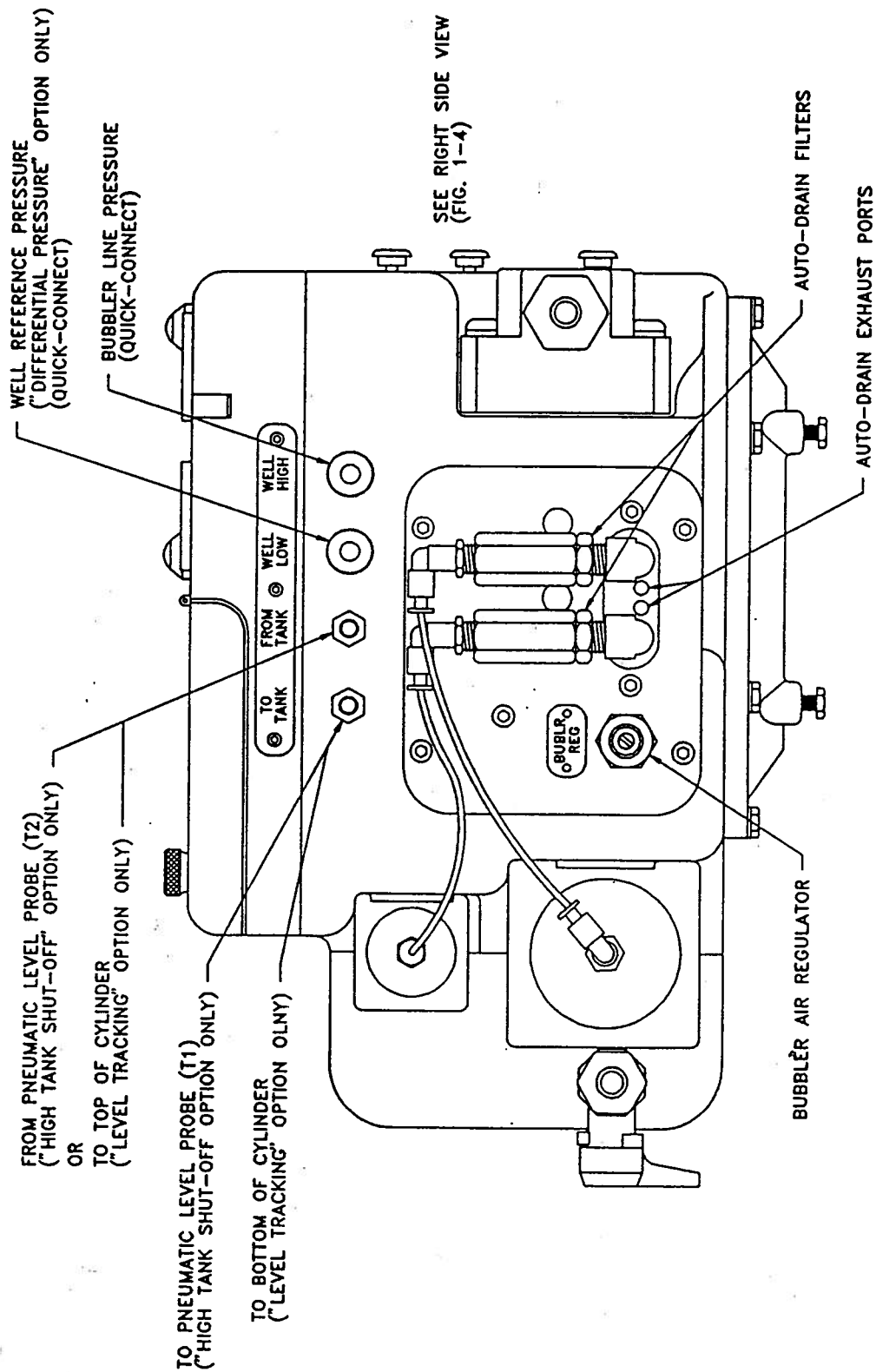
	Diameter of Ejector					
	1.5 inches	3 inches	4 inches	5 inches	6 inches	8 inches
1.5 feet	0.5 1.0	2.0 1.8	3.8 6.5	6.5 4.2	9.3 5.7	17.3 10.9
3 feet	1.0 1.2	4.1 2.9	7.5 4.8	12.9 8.6	18.6 11.7	34.5 21.5
4 feet	1.3 1.4	5.4 3.6	10.0 7.0	17.2 10.5	24.8 13.0	46.0 27.7
5 feet	** Special	6.8 4.4	12.5 8.3	21.5 13.2	31.0 19.6	57.5 34.0
6 feet	** Special	8.1 5.1	15.0 9.7	25.8 15.6	** Special	** Special

Length of Ejector

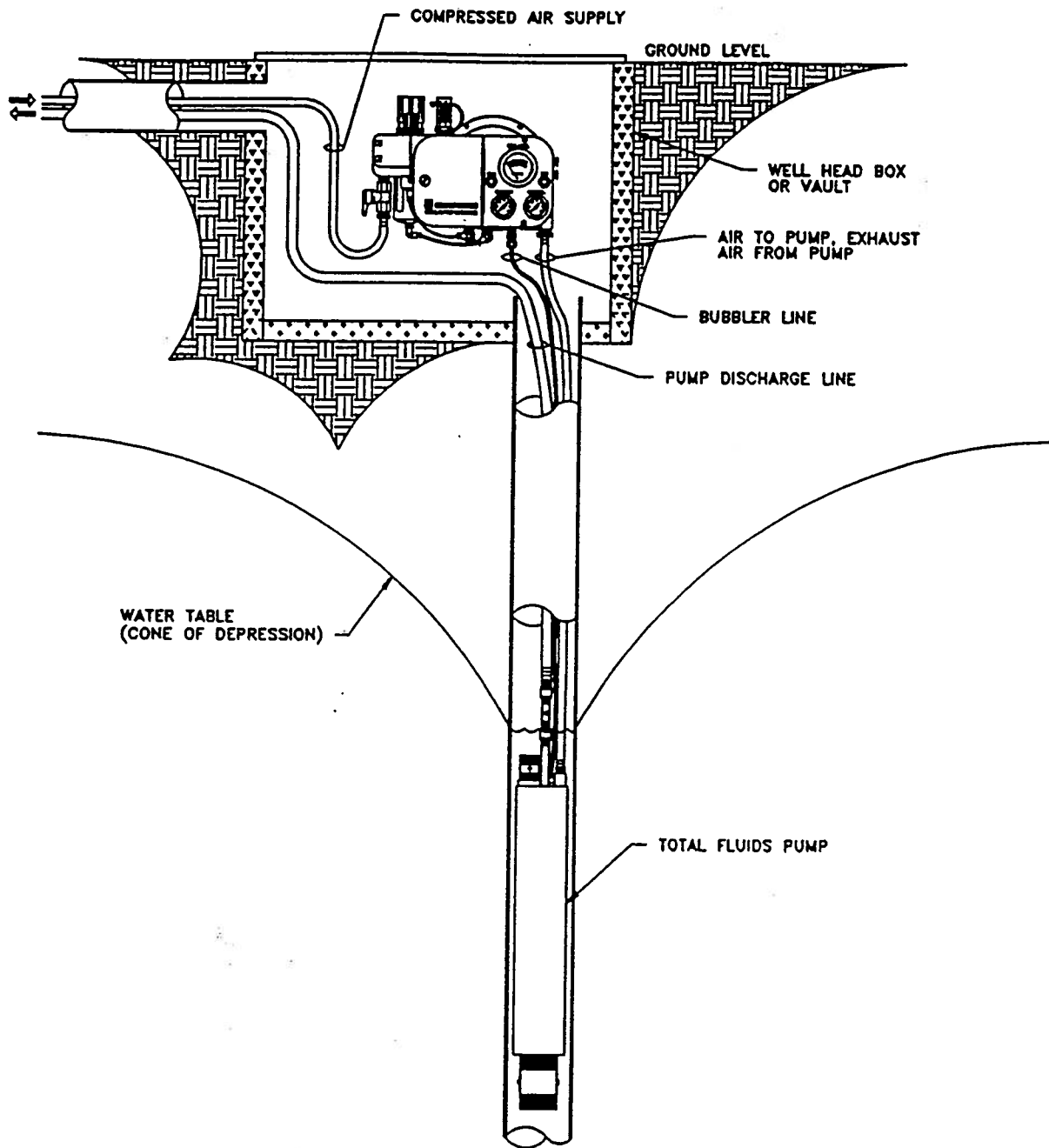
- Top number in each cell represents maximum flow rate at 5 cpm.
- Bottom number represents approximate air consumption assuming 25 feet of 1/2 inch ID air line and 1 inch diameter discharge line.
- **Special - These pumps must be special ordered.



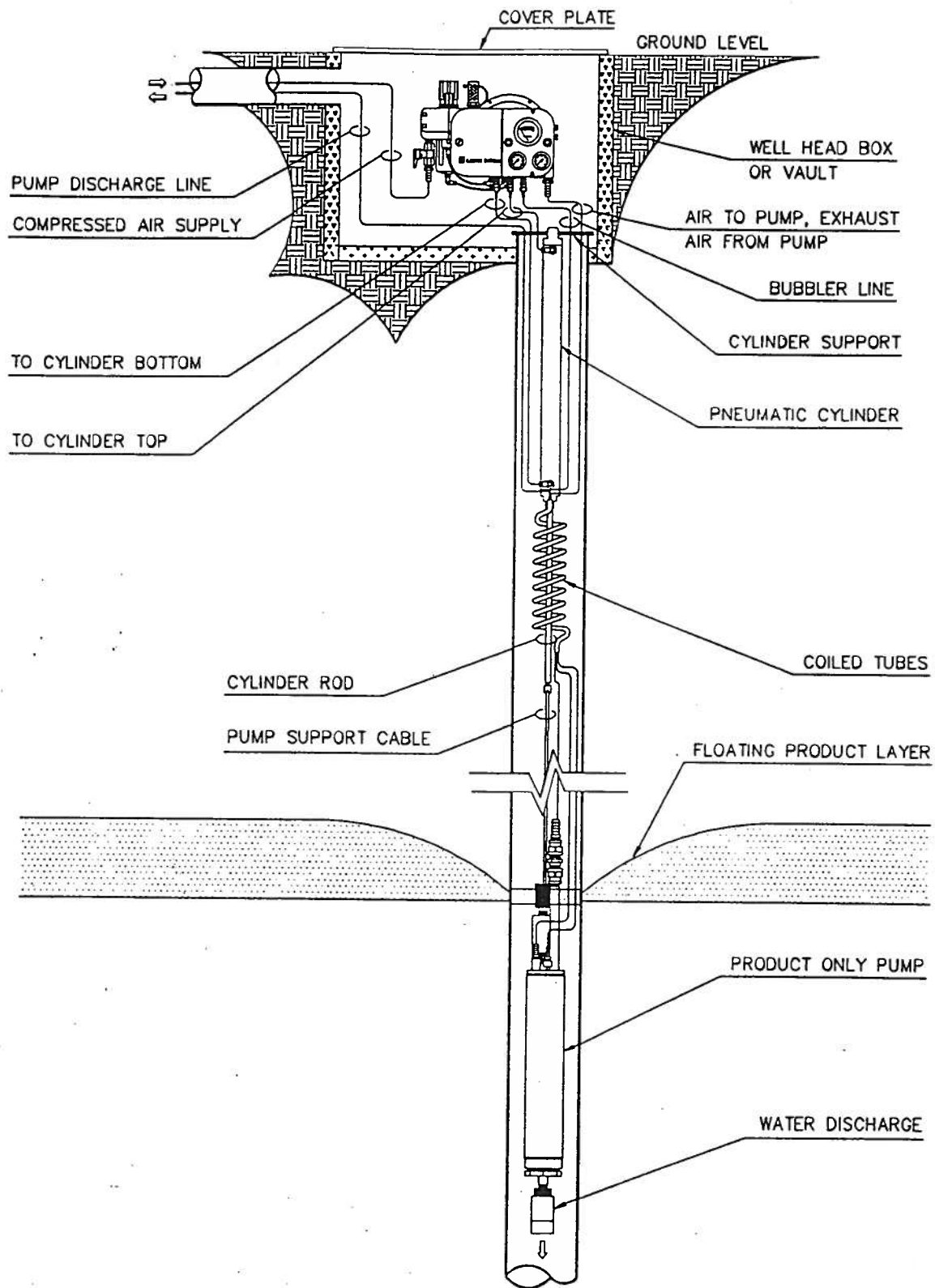
FRONT VIEW



BOTTOM VIEW



BELOW GRADE WELL HEAD ELEVATION



S2 WITH OPTIONAL LEVEL TRACKING

RECIPROCATING AIR COMPRESSORS

- MOST COMMONLY USED WITH ESI SYSTEMS
- PRODUCES HIGH PRESSURES (175 PSIG max), BUT LIMITED VOLUMES (100 SCFM max)
- CAN BE MADE EXPLOSION PROOF
- USUALLY OPERATED AT 50%-70% UTILIZATION
- ALWAYS USE COMPRESSORS WITH CAST IRON HEADS (NO ALUM.)
- DESIGNED FOR NON-CONTINUOUS OPERATION
- OVER SIZING THE COMPRESSOR HEADS WILL REDUCE THE RPM'S WHICH WILL DECREASE NOISE LEVEL AND INCREASE COMPRESSOR LIFE.

SCFM	* ACTUAL	PSIG(max)	H.P.	** APPROX. MAX FLOW
1-7	11	125	3.0	7 GPM
8-15	18	125	5.0	13 GPM
15-25	27	125	7.5	19 GPM
25-35	35	125	10.0	25 GPM
35-50	55	125	15.0	39 GPM
50-70	70	125	20.0	49 GPM
70-85	88	125	25.0	62 GPM
85-100	105	125	30.0	74 GPM

RECOMMENDED OPTIONS:

- AUTO START/STOP WITH OIL LEVEL SWITCH
- BELT GUARD
- MAGNETIC STARTER
- SINGLE PHASE IS ONLY AVAILABLE ON 3 AND 5 H.P.

* REFERS TO AIR VOLUME OUTPUT THAT COMPRESSOR IS CAPABLE OF PRODUCING. HOWEVER, ALWAYS SIZE COMPRESSORS WITH A 50%-70% UTILIZATION FACTOR.

** REFERS TO FLOW FOR A TOTAL FLUIDS SYSTEM WITH A MAXIMUM HEAD OF 50 FEET.

ROTARY SCREW COMPRESSORS

- PRODUCES HIGH VOLUMES (2500 SCFM max), BUT LIMITED PRESSURE (125 PSIG max)
- CANNOT BE MADE EXPLOSION PROOF
- CAN BE OPERATED AT 100% UTILIZATION
- USUALLY 20%-30% MORE EXPENSIVE THAN RECIPROCATING COMPRESSORS
- PRODUCES LESS NOISE WHEN OPERATING THAN RECIPROCATING COMPS.
- POORLY SUITED FOR LOW DUTY CYCLES
- DESIGNED FOR CONTINUOUS USE DUTY

SCFM	* ACTUAL	PSIG (max)	H.P.	** APPROX. MAX FLOW
20-34	34	125	10.0	34 GPM
34-56	56	125	15.0	56 GPM
57-78	78	125	20.0	78 GPM
78-92	92	125	25.0	92 GPM
92-120	120	125	25.0	120 GPM
120-125	125	125	30.0	125 GPM
125-162	162	125	40.0	162 GPM

RECOMMENDED OPTIONS:

- MOTOR STARTER
- 10.0 H.P. AND GREATER ONLY AVAILABLE IN 3-PHASE

* REFERS TO AIR VOLUME OUTPUT THAT COMPRESSOR IS CAPABLE OF PRODUCING. HOWEVER, ALWAYS SIZE COMPRESSORS WITH A 85%-95% UTILIZATION FACTOR.

** REFERS TO FLOW FOR A TOTAL FLUIDS SYSTEM WITH A MAXIMUM HEAD OF 50 FEET.

COOLERS AND DRYERS

AIR COOLED AFTER COOLERS

- USE WITH BOTH RECIPROCATING AND ROTARY SCREW TYPE COMPRESSORS
- COOLS THE AIR FROM THE COMPRESSOR
- REQUIRED IF A DRYER IS BEING IMPLEMENTED
- VERY USEFUL IN HIGH HUMIDITY, HIGH TEMPERATURE CLIMATES
- INCREASES LIFE OF COMPRESSOR AND REDUCES MAINTENANCE REQUIREMENTS

DRYERS

- USED TO ELIMINATE HUMIDITY IN COMPRESSOR AIR
- TWO TYPES (RECOMMEND USE OF REGENERATIVE)
 - 1.] REFRIGERATIVE
 - LOWERS D.P. TO 32 DEGREE F
 - FOR USE IN WARM AND HUMID CLIMATES
 - 2.] REGENERATIVE (USES DESICCANT)
 - LOWERS D.P. TO -40 DEGREES F
 - FOR USE IN EXTREMELY COLD CLIMATES
 - USES APPROXIMATELY 15% OF COMPRESSOR AIR VOLUME



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1-800-OIL-LEAK

EJECTOR SYSTEMS, INC. CORRUGATED PLATE INTERCEPTOR OIL/WATER SEPARATOR

EJECTOR SYSTEMS, INC. has designed an oil/water separator specifically for groundwater remediation. The system is available in two configurations, 10 gpm and 25 gpm. Both systems have been designed to effectively remove 36 micron and larger oil droplets.

The units come standard with gasketed aluminum lids to allow easy removal of the coalescing pack, if required. The coalescing pack is constructed of hydrocarbon resistant polypropylene with plates spaced 1-1/2 inches apart at a 60 degree angle for maximum separation and minimum maintenance.

The 10 gpm and 25 gpm units are very similar in design. The only functional difference is the amount of corrugated plate interceptor pack utilized.

System parameters, 10 and 25 gpm:

Dimensions:	80-3/8 inches L x 46-3/8 inches W x 40-3/8 inches H
Total volume:	507 gallons
Working volume:	412 gallons
Product reservoir:	136 gallons
Material of construction:	3/16 inch hot rolled Carbon steel plate
Influent and effluent:	3 inches FNPT
Product effluent:	1-1/4 inch FNPT
Type of separator:	Baffles with coalescing pack

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1-800-OIL-LEAK



SECTION _____
OIL/WATER SEPARATION SPECIFICATIONS

PART 1 - GENERAL

1.01 DESCRIPTION

A. Scope

1. The following oil/water separator shall be furnished and installed as shown on the contract drawings and described hereinafter. The oil/water separator system shall be manufactured by EJECTOR SYSTEMS, INC. and consist of:
 - a. Oil/water separator equipment, which includes, but is not limited to, base unit, lid, and coalescing packing. In order to assure a congruent oil/water separating system, the equipment as listed above shall be furnished by a single responsible supplier, that is established in the design and manufacture of oil/water separators for groundwater.
 - b. The oil/water separation system furnished under this section of the specifications shall be placed in a ventilated area that will not affect the performance of the system. All appurtenant components of the system not furnished by the system supplier, such as piping and fittings for influent and outlet water streams, piping and fittings for effluent product, concrete pads or foundations for system placement, and electrical controls and supplies not mentioned herein are the responsibilities of others.
2. The oil/water separator supplier shall provide the contractor adequate information on all aspects of the project as specified in these contract specifications and/or as shown on the contract drawings.



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B. Functional Description

1. The requirements of the _____ groundwater remediation project are such that they mandate the use of a high performance, extremely flexible oil/water separating system. Therefore, in order to meet the performance requirements for the project, as specified hereinafter, it has been determined that the oil/water separating system shall incorporate, at a minimum, the following standard features:
 - a. Separation of lighter than water hydro-carbons shall be done through the use of a combination of baffles and a clog-resistant coalescing pack incorporated within the separation system.
 - b. Integral to the Oil/Water Separation System, an intermittent product overflow basin with a minimum volume of 136 gallons shall be included.
 - c. In conjunction with the baffle/packing network, the coalescing packing must be easily accessible so as to permit removal for cleaning.

C. System Description

1. Flow into the separator will be through a 3 inch NPT fitting. Flow through the separating unit will be via gravity. Effluent from the separator will be through a 3 inch NPT fitting.
2. Within each unit, baffles set perpendicular to the flow shall be supplied for the following reasons:
 - 1] To dissipate inlet turbulence
 - 2] To congeal solids for easier removal
 - 3] To assist in oil/water separation
3. The unit shall incorporate a hydrocarbon resistant polypropylene corrugated plate interceptor for the means of separation.
4. Hydrocarbon that has been separated will exit the separating stage



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via an 1-1/4 inch FNPT fitting near the top of the separator and flow into the intermittent product overflow reservoir.

5. A site window shall be provided for viewing oil/water interface.

1.02 SUBMITTAL

A. General

Submit all material pertaining to oil/water separating equipment furnished hereunder in the name of the separator supplier.

B. Shop Drawings and Product Data

1. Complete layout drawings
2. Details and specifications for separator appurtenances

C. Operation and Maintenance Manual

Submit a comprehensive and coordinated operation and maintenance manual which includes products furnished by the separator supplier.

D. Submittal with Bid

Each bidder shall submit with his proposal or, the separator supplier shall submit to the Engineer at the time of opening bids the following:

1. Name, address, and telephone number of manufacturer.
2. Number of years experience in manufacturing oil/water separator systems of the type specified herein.
3. Number of oil/water separators of this type sold to date.
4. Name, address, and telephone number of at least three customers.
5. Evidence that the separating system will meet each of the performance and functional requirements.

F. Submittal Pre-Bid

Each oil/water separator system supplier shall submit shop drawings and sufficient details to clearly define the equipment to be furnished and the total installation effort, including workmanship and materials that will be



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required to install the separating equipment as specified in this section. If the manufacturer's shop drawings require work, equipment, or materials beyond that called for in the Contract Documents, the Contractor shall bear the total costs (including redesign engineering) of such work, equipment or materials.

PART 2

2.01 PERFORMANCE AND DESIGN REQUIREMENTS

A. Flow Rate and Influent Conditions to Oil/Water Separator

1. Total flow
2. Influent water temperature
3. Performance specification

The oil/water separating system specification is a performance type specification. In order to meet the intent of the specification and be suitable for the proposed application, the system shall be capable of meeting the following performance requirements:

- a. The oil/water separating system shall be capable of removing all lighter than water free-phase hydrocarbon. The system shall be designed to remove down to 36 micron droplets.
- b. Depending on the type of groundwater being separated, the following factors should not inhibit system operation nor quality of effluent stream.
 - i. High levels of suspended solids
 - ii. High levels of iron
 - iii. Build up of calcium deposits
 - iv. High levels of water hardness
 - v. High levels of dissolved solids

The acceptance of the oil/water separating system shall be based on the proven ability of the system to meet each of the performance criteria listed above. The Engineer will be the sole authority in reviewing the performance data, as submitted by the separator supplier in his bid

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submittal, and determining the acceptability of the proposed system to meet the performance requirements, as stated hereinfore, for the project. Refer to Substitution Clause in the INSTRUCTION TO THE BIDDERS for pre-bid requirements.

B. Methods of Influent Feed

Gravity flow or pumping are both acceptable methods of feeding the separating system. (Pumping equipment to be by others, unless specified.)

C. Method of Effluent Draw-Off

Gravity flow.

D. Oil/water separating System Characteristics

1. Type: Coalescing with clog-resistant corrugated plate interceptors and baffles
2. Working dimensions: 6.33' x 3.03' x 3.53'
3. Working volume: 507 gallons
4. Product reservoir volume: 136 gallons
5. System shall incorporate an integral, intermittent product overflow basin.
6. Provisions shall be available to allow for easy removal of coalescing pack for cleaning.

2.02 MATERIALS OF CONSTRUCTION

A. Main Body of Separator

Unit and baffles shall be constructed of 3/16 inch hot rolled Carbon steel plate. The entire unit shall be leak tested prior to shipment.

B. Lid

The separator lid shall implement a completely removable lid. Lid shall be constructed of 0.190 inch thick, anodized 5052 aluminum.

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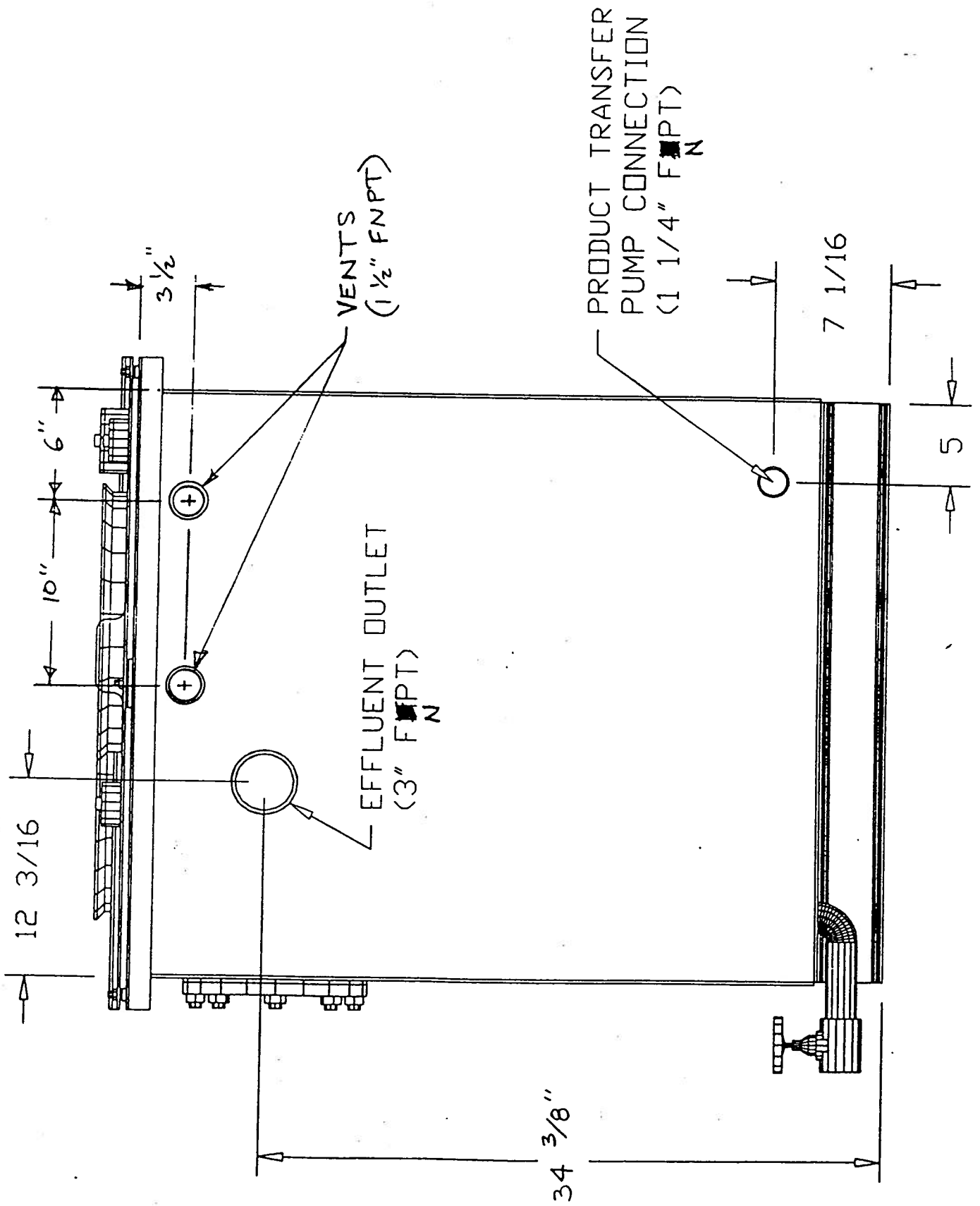
C. Coatings

All internal separator components shall be coated with a modified, hydrocarbon resistant, epoxy coating and all external components shall be covered with an epoxy and polyurethane coating.

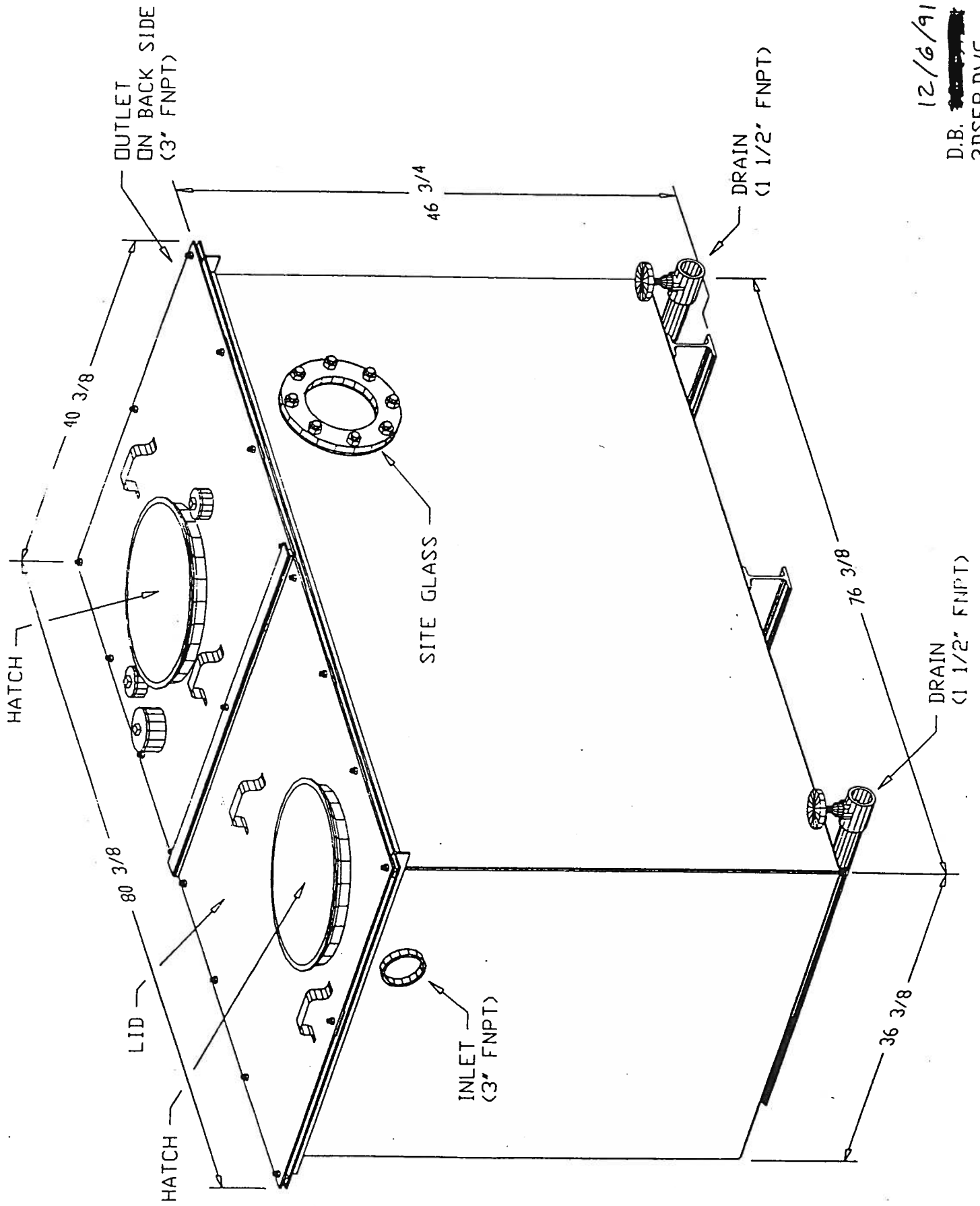
D. Packing

The oil/water separator corrugated plate interceptors shall be constructed of polypropylene. Spacing between plates shall be 1-1/2" which will allow for easy cleaning and less chance of clogging. Plates shall be at a 60 degree angle in reference to the bottom. A stainless steel cable shall be attached to the packing to assist in removal.

REAR VIEW

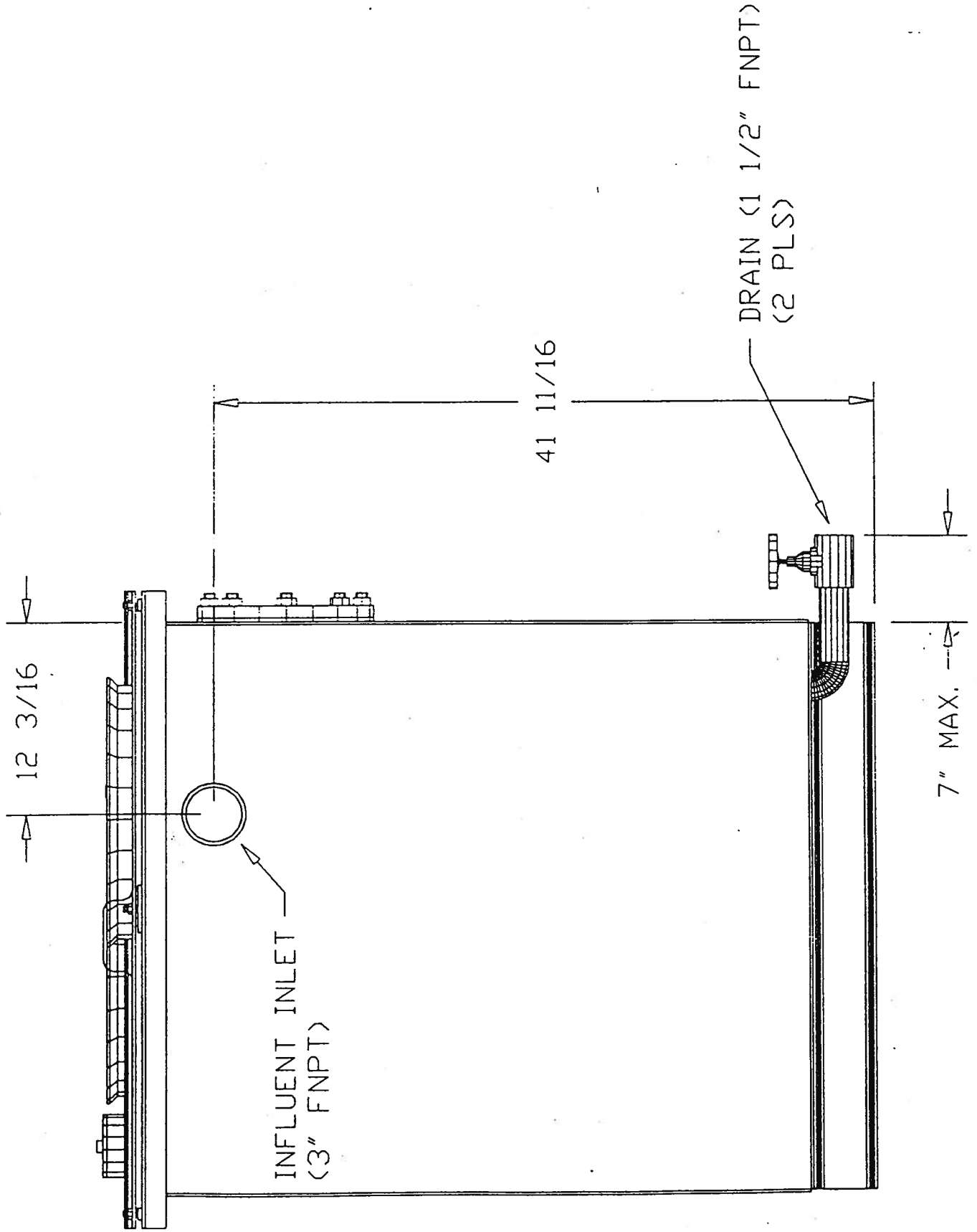


COALESIN PARATUR

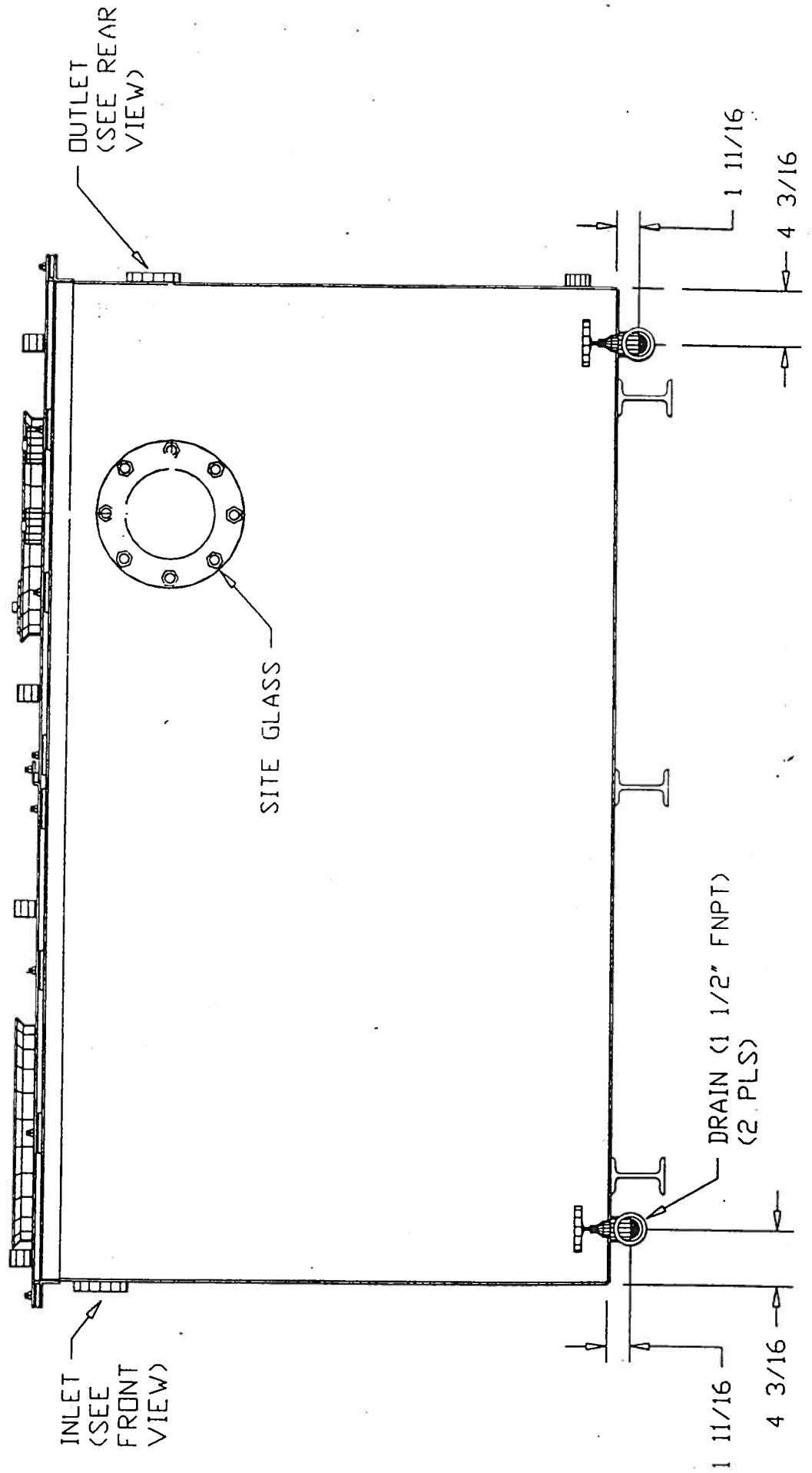


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D.B. ~~XXXXXX~~
3DSEP.DWG

FRONT VIEW



RIGHT SIDE VIEW



Ejector Systems Incorporated
910 National Avenue, Addison, IL 60101-9812



STRIPPERATOR

process treatment unit for hydrocarbon contaminated water

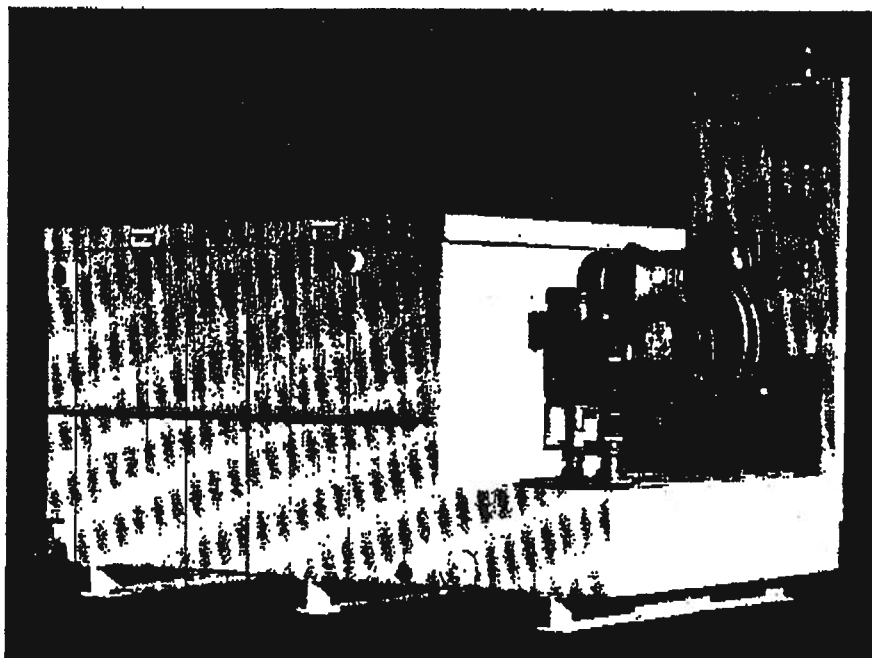
Standard Specifications:

- 82" long x 50" wide x 65" high
- 11 gauge epoxy-coated carbon steel exterior
- Approximate Weight: 1,400 lbs.
- 185 gallon separator working capacity
- 60 micron droplet removal
- cast aluminum AMCA Type B spark-resistant blower
- influent 2 1/2" FNTF
- separated product 1 1/2" FNTF
- 3" FNTF effluent port
- effluent sump included
- 3 - 1 1/2" FNTF drain valves included
- 400 scfm blower

Options:

- Blower motor starter
- TEFC 3/4 hp transfer pump
- TEFC 3/4 hp transfer pump controls
- Explosion-proof blower motor
- Explosion-proof blower motor starter
- Explosion-proof 3/4 hp transfer pump
- Explosion-proof 3/4 hp transfer pump controls
- High/low air switch
- High effluent switch

(Continued on back)



Principle of Operation

The Stripperator is a complete process treatment unit for hydrocarbon-contaminated water. It integrates both a coalescing oil/water separator and Cascade low profile Air Stripper into one component. The unit will separate free product, coalesce suspended or colloidal hydrocarbons, settle solids and remove 99.99% of dissolved volatile organic compounds. The ESI STRIPPERATOR is available in 5 GPM (Model SA5), 10 GPM (Model SA10) and 20 GPM (Model SA20) configurations.

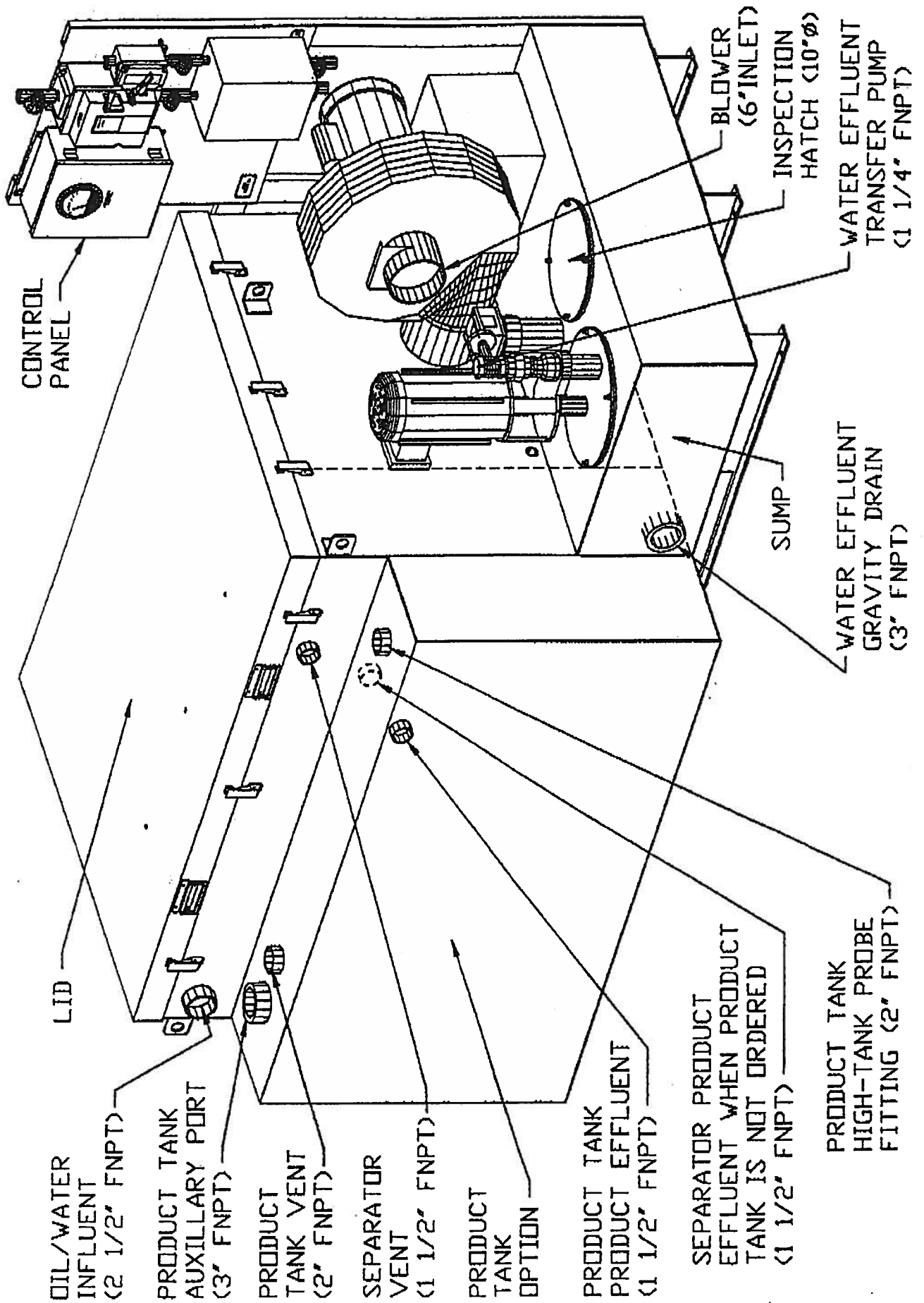
Removal Data:

Flow	Benzene	TCA	MTBE
5 GPM	.99995	.99995	.97
10 GPM	.9994	.99995	.90
20 GPM	.9994	.99995	.81

Feature

Benefit

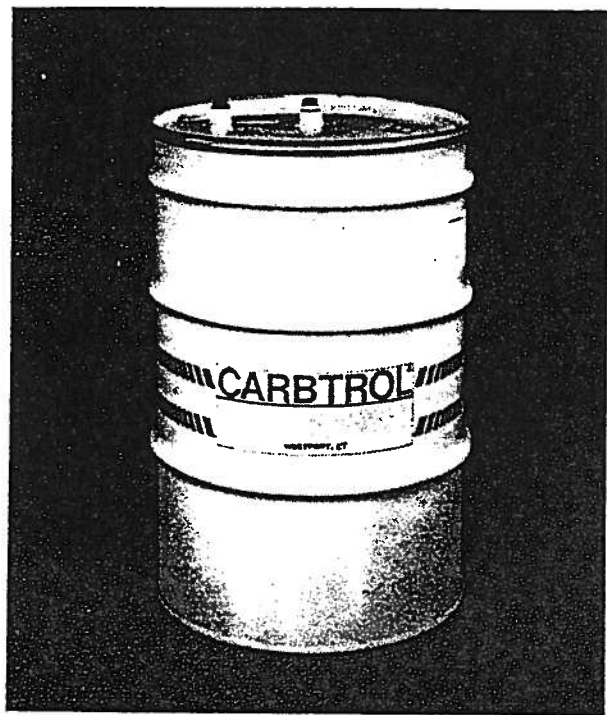
Low profile	- Unobtrusive and "out-of sight"
Small	- Will fit through a standard double door, minimal space required
Integrated processes	- One unit process does not require extra tanks, pumps, piping, etc.
One piece lid with quick release adjustable latches	- Easy access to separator and air stripper as well as being simple to maintain
Side mounted exhaust	- Allows for quick inspection and viewing of operation in progress without disturbing piping
Gravity flow	- Eliminates re-pumping, sumps and controls
Fully gasketed	- Leak-free indoor installation
Rubber isolated dynamically balanced blower	- Minimal vibration

E.S.I. SA15 STRIPPER

CARBOTROL®

WATER PURIFICATION CANISTER 200 POUND ACTIVATED CARBON

L-1



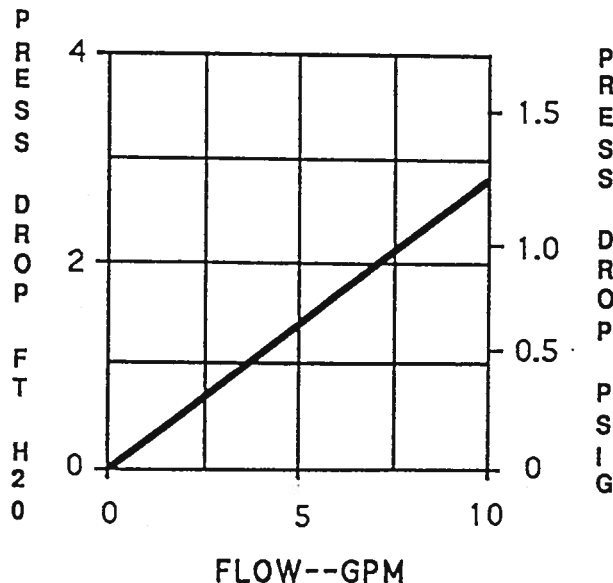
The CARBOTROL L-1 (liquid)
Canister handles up to 10 gpm.

FEATURES

- 200 pounds of high activity carbon.
- Large 1 1/4" internal piping. Low pressure drop allows operation of three canisters in series.
- Standard FPT couplings for easy installation - saves time and money.
- Special "no leak" lid gasket.
- Heavy duty steel drums, DOT 17C, suitable for shipment of spent hazardous carbon.
- Piping design eliminates channeling.

SPECIFICATIONS

DRUM	24" Ø x 34" high, mild steel, epoxy phenolic internal coating, with polyethylene liner.
CARBON	200 lbs.
SHIPPING WEIGHT	250 lbs.
INLET	1 1/4" FPT, steel
OUTLET	1 1/4" FPT, steel
INTERNAL PIPING	1 1/4" PVC
DRAIN	3/4" bung
PRESSURE DROP	1.25 psi @ 10 gpm
MAX. OPERATING PRESSURE	10 psi



CARBOTROL®
CORPORATION

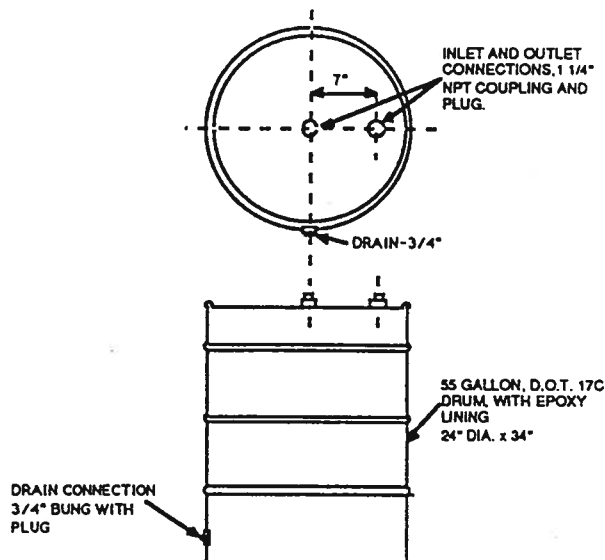
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AT-100/#2

WATER PURIFICATION CANISTER 200 POUND ACTIVATED CARBON

L-1



OPTIONS

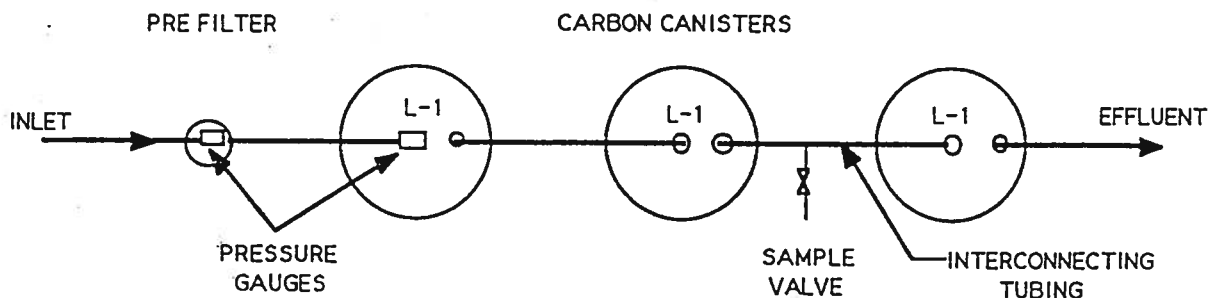
Interconnecting Piping Kit

Flexible 1 1/4" diameter PVC tubing with hose clamps. Includes inlet pressure gauge and intermediate sample valve.

Pre-filter For Suspended Solids Removal

Pre-filter consisting of a basket filter piped and mounted on support frame. Filter is of carbon steel construction.

ARRANGEMENT (3) L-1 Canisters in series for 10 gpm flow (contact time @ 10 gpm - 15 minutes)



TYPICAL INSTALLATION



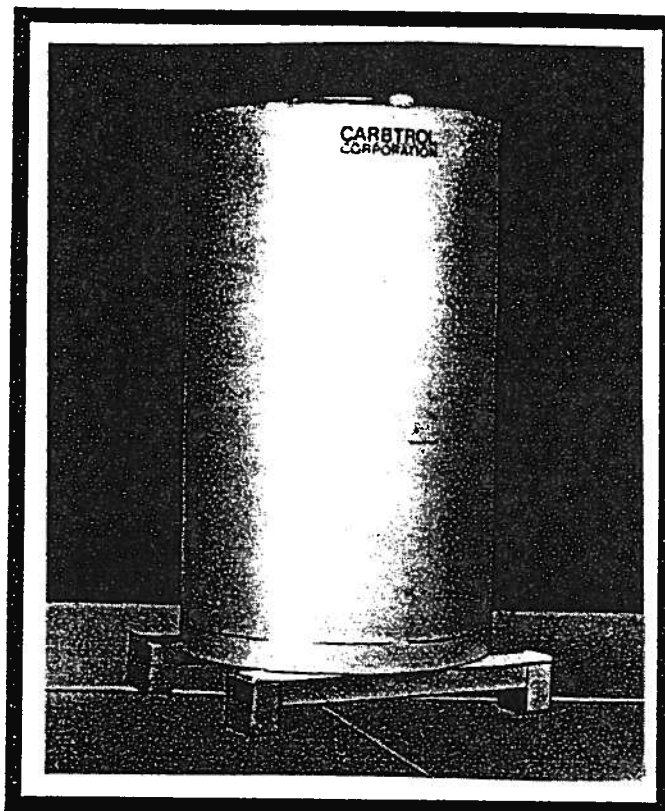
WATER PURIFICATION ADSORBERS

1,000 LB. ACTIVATED CARBON

L-4

1,800 LB. ACTIVATED CARBON

L-5



FEATURES

- Low pressure drop
 - L-4 0.25psi @ 25 gpm
 - L-5 1 psi @ 50 gpm
- Epoxy lined, mild steel construction.
- 2 1/2" dia. multiple pipe underdrain system.
- Fork lift fittings for easy handling.
- DOT rated. Acceptable for shipment of hazardous spent carbon.
- 9 psi max. operating pressure.
- High activity carbon.

OPTIONS

- Plastisol, PVC lining.
- Interconnecting piping and fittings.
- Non transportable units.
- Air release valve.

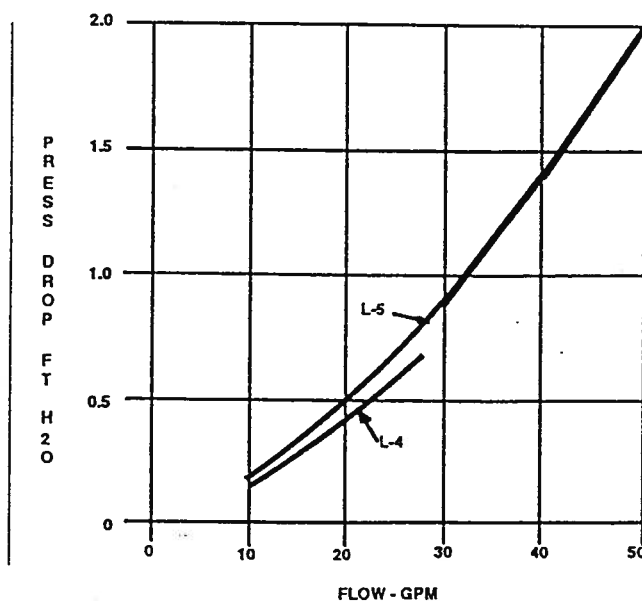
SPECIFICATIONS

L-4

CARBON: 1,000 lbs
DIMENSIONS: 45-1/2" Ø x 66-1/2" overall height
SHIPPING WT: 1500 lbs. (Dry Carbon)
2300 lbs. (Drained Carbon)

L-5

CARBON: 1,800 lbs.
DIMENSIONS: 45-1/2" Ø x 90" overall height
SHIPPING WT: 2400 lbs. (Dry Carbon)
4200 lbs. (Drained Carbon)



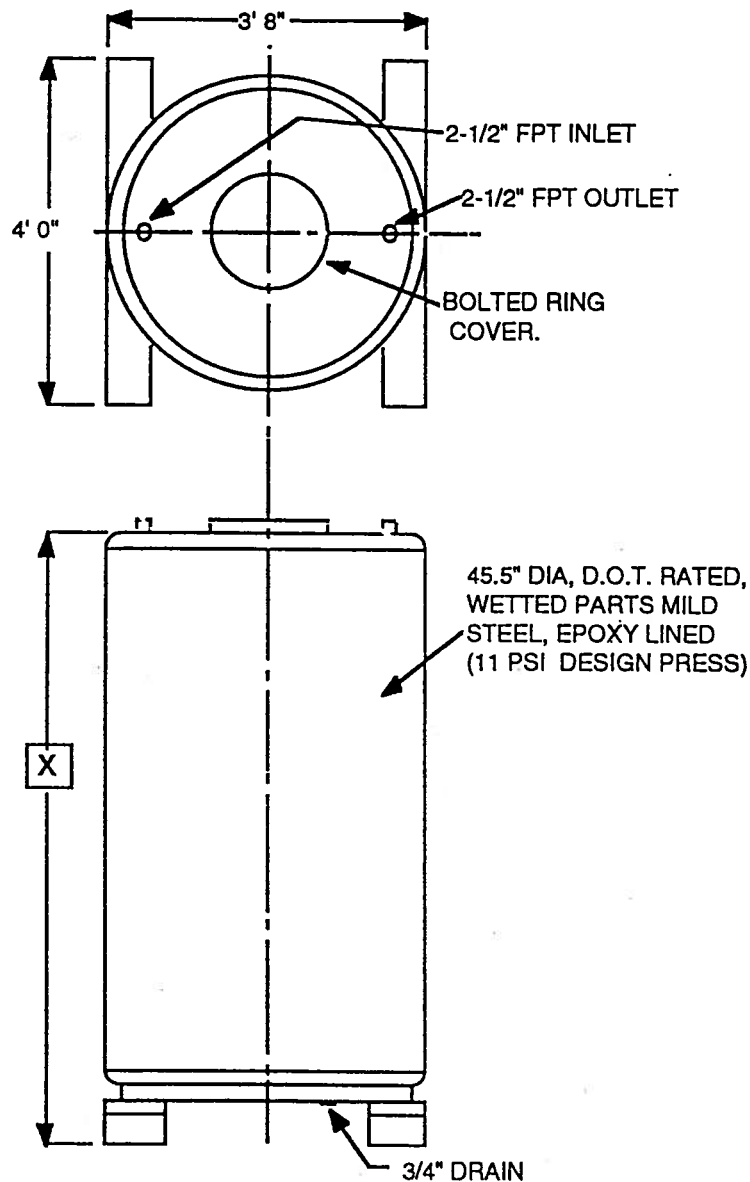
WATER PURIFICATION ADSORBERS

1,000 LB. ACTIVATED CARBON

L-4

1,800 LB. ACTIVATED CARBON

L-5



UNIT	DIM	X
L-4	5'-2"	
L-5	7'-2"	

DIMENSIONS AND DETAILS SHOWN
ARE FOR TRANSPORTABLE MODELS

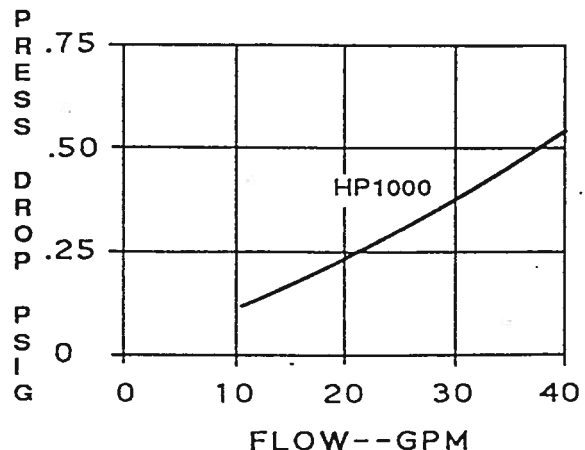
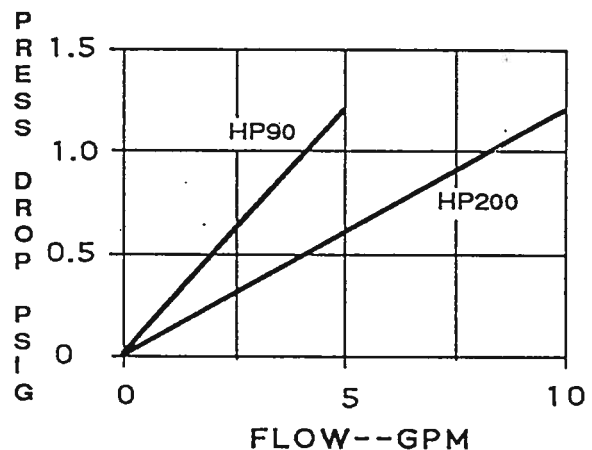
CARBTROL®

HIGH PRESSURE ACTIVATED CARBON WATER PURIFICATION SYSTEMS



SIZES

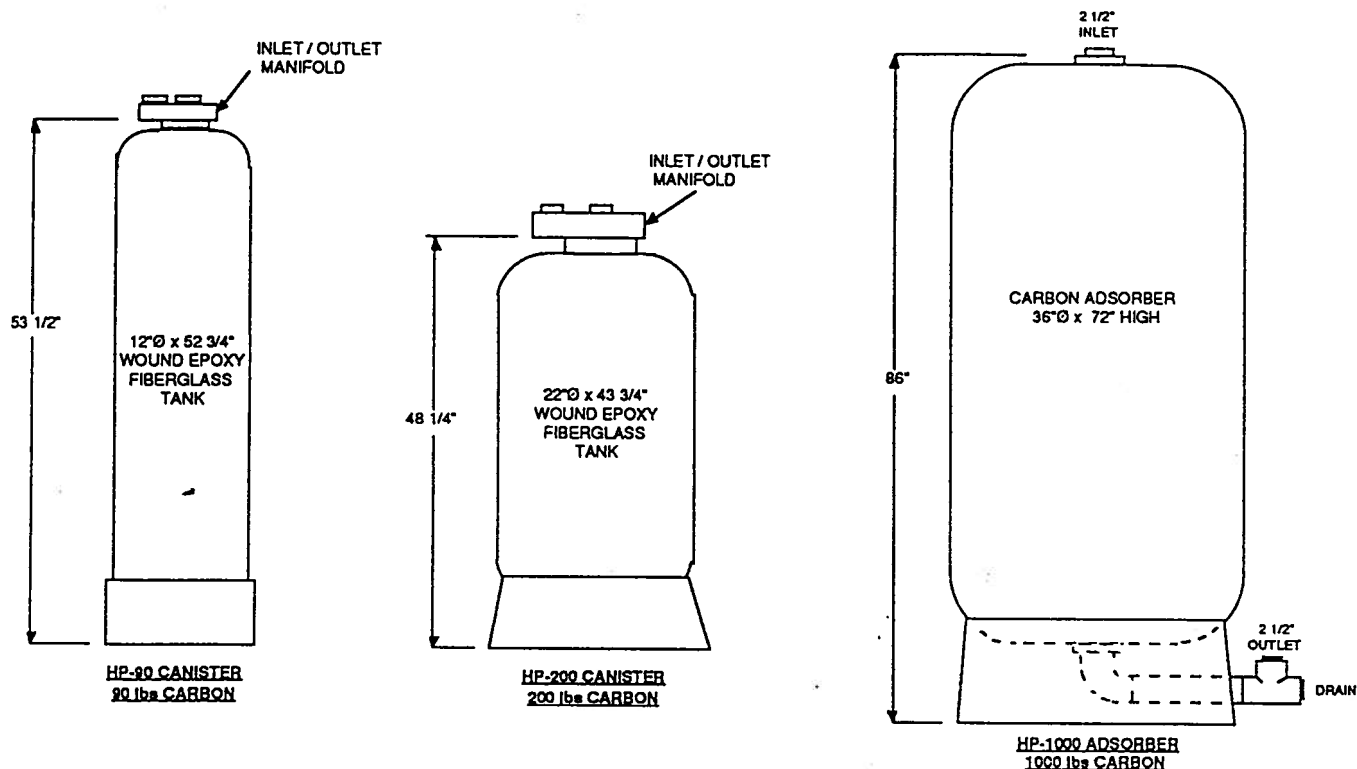
<u>MODEL</u>	<u>CARBON QUANTITY</u>	<u>FLOW CAPACITY</u>
HP-90	90 lbs.	10 gpm
HP-200	200 lbs.	10 gpm
HP-1000	1000 lbs.	30 gpm



FEATURES

- High activity liquid phase carbon.
- Operating pressure from 50-75 psi.
- Corrosion resistant wound/fiber glass/epoxy construction.
- ABS fittings, PVC internal piping.
- Standard FPT couplings for easy installation.
- Complete with support stand.

HIGH PRESSURE ACTIVATED CARBON WATER PURIFICATION SYSTEMS



SPECIFICATIONS

<u>MODEL</u>	<u>DIAMETER/ HEIGHT</u>	<u>CARBON WEIGHT</u>	<u>INLET/ OUTLET</u>	<u>SHIPPING WEIGHT</u>
HP-90	12"/54"	90 lbs.	1" FPT	125 lbs.
HP-200	22"/48"	200 lbs.	1" FPT	250 lbs.
HP-1000	36"/72"	1000 lbs.	2 1/2" FPT	1750 lbs.

Appendix D
Standard Operating Procedures

SOP F102
Soil and Rock Sample Acquisition

SOIL AND ROCK SAMPLE ACQUISITION TABLE OF CONTENTS

- 1.0 PURPOSE**
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SOIL AND ROCK SAMPLE ACQUISITION

1.0 PURPOSE

The purpose of this procedure is to describe the handling of rock cores and subsurface soil samples collected during drilling operations. Surface soil sampling also is described.

2.0 SCOPE

The methods described in this SOP are applicable for the recovery of subsurface soil and rock samples acquired by coring operations or soil sampling techniques such as split-barrel sampling and thin-walled tube sampling. Procedures for the collection of surface soil samples also are discussed. This SOP does not discuss drilling techniques or well installation procedures. ASTM procedures for "Penetration Test and Split-Barrel Sampling of Soils," "Thin-Walled Tube Sampling of Soils," and "Diamond Core Drilling for Site Investigation" have been included as Attachments A through C, respectively.

3.0 DEFINITIONS

Thin-Walled Tube Sampler - A thin-walled metal tube (also called Shelby tube) used to recover relatively undisturbed soil samples. These tubes are available in various sizes, ranging from 2 to 5 inches outer diameter (O.D.) and 18 to 54 inches length. A stationary piston device is included in the sampler to reduce sample disturbance and increase recovery.

Split-Barrel Sampler - A steel tube, split in half lengthwise, with the halves held together by threaded collars at either end of the tube. Also called a split-spoon sampler, this device can be driven into unconsolidated materials using a drive weight mounted on the drilling string. A standard split-spoon sampler (used for performing Standard Penetration Tests) is two inches O.D. and 1-3/8-inches inner diameter (I.D.). This standard spoon is available in two common lengths providing either 20-inch or 26-inch internal longitudinal clearance for obtaining 18-inch or 24-inch long samples, respectively.

Grab Sample - An individual sample collected from a single location at a specific time or period of time generally not exceeding 15 minutes. Grab samples are associated with surface water,

groundwater, wastewater, waste, contaminated surfaces, soil, and sediment sampling. Grab samples are typically used to characterize the media at a particular instant in time.

Composite Samples - A sample collected over time that typically consists of a series of discrete samples which are combined or "composited". Two types of composite samples are listed below:

- Areal Composite: A sample collected from individual grab samples collected on an areal or cross-sectional basis. Areal composites shall be made up of equal volumes of grab samples. Each grab sample shall be collected in an identical manner. Examples include sediment composites from quarter-point sampling of streams and soil samples from grid points.
- Vertical Composite: A sample collected from individual grab samples collected from a vertical cross section. Vertical composites shall be made up of equal volumes of grab samples. Each grab sample shall be collected in an identical manner. Examples include vertical profiles of soil/sediment columns, lakes and estuaries.

4.0 RESPONSIBILITIES

Project Manager - The Project Manager is responsible for ensuring that, where applicable, project-specific plans are in accordance with these procedures, or that other approved procedures are developed. Furthermore, the Project Manager is responsible for development of documentation of procedures which deviate from those presented herein.

Field Team Leader - The Field Team Leader is responsible for selecting and detailing the specific sampling techniques and equipment to be used, and documenting these in the Sampling and Analysis Plan. It is the responsibility of the Field Team Leader to ensure that these procedures are implemented in the field and to ensure that personnel performing sampling activities have been briefed and trained to execute these procedures.

Drilling Inspector - It is the responsibility of the drilling inspector to follow these procedures, or to follow documented, project-specific procedures as directed by the Field Team Leader and/or the Project Manager. The Drilling Inspector is responsible for the proper acquisition of rock cores and subsurface soil samples.

Sampling Personnel - It is the responsibility of the field sampling personnel to follow these procedures, or to follow documented, project-specific procedures as directed by the Field Team Leader and/or the Project Manager. The sampling personnel are responsible for the proper acquisition of samples.

5.0 PROCEDURES

Subsurface soil and rock samples are used to characterize the three-dimensional subsurface stratigraphy. This characterization can indicate the potential for migration of contaminants from various sites. In addition, definition of the actual migration of contaminants can be obtained through chemical analysis of subsurface soil samples. Where the remedial activities may include in-situ treatment, or the excavation and removal of the contaminated soil, the depth and areal extent of contamination must be known as accurately as possible.

Surface soil samples serve to characterize the extent of surface contamination at various sites. These samples may be collected during initial site screening to determine gross contamination levels and levels of personal protection required as part of more intensive field sampling activities, to gather more detailed site data during design, or to determine the need for, or success of, cleanup actions.

Site construction activities may require that the engineering and physical properties of soil and rock be determined. Soil types, bearing strength, compressibility, permeability, plasticity, and moisture content are some of the geotechnical characteristics that may be determined by laboratory tests of soil samples. Rock quality, strength, stratigraphy, structure, etc. often are needed to design and construct deep foundations or remedial components.

5.1 Rock Cores

Once rock coring has been completed and the core recovered, the rock core must be carefully removed from the barrel, placed in a core tray (previously labeled "top" and "bottom" to avoid confusion), classified, and measured for percentage of recovery, as well as the rock quality designation (RQD) (see SOP F101). If split-barrels are used, the core may be measured and classified in the split barrel after opening and then transferred to a core box.

Each core shall be described and classified on a Field Test Boring Record using a uniform system as presented in SOP F101. If moisture content will be determined or if it is desirable to prevent drying (e.g., to prevent shrinkage of hydrated formations) or oxidation of the core, the core must be wrapped in plastic sleeves immediately after logging. Each plastic sleeve shall be labeled with indelible ink. The boring number, run number and the footage represented in each sleeve shall be included, as well as the top and bottom of the core run.

After sampling, rock cores must be placed in the sequence of recovery in wooden or plastic core boxes provided by the drilling contractor. Rock cores from two different borings shall not be placed in the same core box. The core boxes should be constructed to accommodate at least 20 linear feet of core in rows of approximately five feet each and should be constructed with hinged tops secured with screws, and a latch (usually a hook and eye) to keep the top securely fastened. Wood partitions shall be placed at the end of each core run and between rows. The depth from the surface of the boring to the top and bottom of the drill run and the run number shall be marked on the wooden partitions with indelible ink. The order of placing cores shall be the same in all core boxes. The top of each core obtained should be clearly and permanently marked on each box. The width of each row must be compatible with the core diameter to prevent lateral movement of the core in the box. Similarly, any empty space in a row shall be filled with an appropriate filler material or spacers to prevent longitudinal movement of the core in the box.

The inside and outside of the core-box lid shall be marked by indelible ink to show all pertinent data pertaining to the box's contents. At a minimum, the following information must be included:

- Project name
- Date
- CTO number
- Boring number
- Footage (depths)
- Run number(s)
- Recovery
- Rock Quality Designation (RQD)
- Box number (x of x)

It is also useful to draw a large diagram of the core in the box, on the inside of the box top. This

provides more room for elevations, run numbers, recoveries, comments, etc., than could be entered on the upper edges of partitions or spaces in the core box.

For easy retrieval when core boxes are stacked, the sides and ends of the box should also be labeled and include CTO number, boring number, top and bottom depths of core and box number.

Due to the weight of the core, a filled core box should always be handled by two people. Core boxes stored on site should be protected from the weather. The core boxes should be removed from the site in a careful manner as soon as possible. Exposure to extreme heat or cold should be avoided whenever possible.

5.2 Subsurface Soil Samples

This section discusses three methods for collecting subsurface soil samples: (1) split-spoon sampling; (2) shelly tube sampling; and, (3) bucket auger sampling. All three methods yield samples suitable for laboratory analysis. Copies of the ASTM procedures for split-spoon sampling and shelly-tube sampling are provided in Attachments A and B, respectively.

5.2.1 Split-Barrel (Split-Spoon) Sampling

The following procedures are to be used for split-spoon, geotechnical soil sampling:

1. Clean out the borehole to the desired sampling depth using equipment that will ensure that the material to be sampled is not disturbed by the operation.
2. Side-discharge bits are permissible. A bottom-discharge bit should not be used. The process of jetting through the sampler and then sampling when the desired depth is reached shall not be permitted. Where casing is used, it may not be driven below the sampling elevation.
3. The two-inch O.D. split-barrel sampler should be driven with blows from a 140-pound hammer falling 30 inches in accordance with ASTM D1586-84, Standard Penetration Test.
4. Repeat this operation at intervals not longer than 5 feet in homogeneous strata, or as specified in the Sampling and Analysis Plan.
5. Record on the Field Test Boring Record or field logbook the number of blows required to effect each six inches of penetration or fraction thereof. The first six inches is considered to be a seating drive. The sum of the number of blows required for the

second and third six inches of penetration is termed the penetration resistance, N. If the sampler is driven less than 18 inches, the penetration resistance is that for the last one foot of penetration. (If less than one foot is penetrated, the logs shall state the number of blows and the fraction of one foot penetrated.) In cases where samples are driven 24 inches, the sum of second and third six-inch increments will be used to calculate the penetration resistance. (Refusal of the SPT will be noted as 50 blows over an interval equal to or less than 6 inches; the interval driven will be noted with the blow count.)

6. Bring the sampler to the surface and remove both ends and one half of the split-spoon such that the soil recovered rests in the remaining half of the barrel. Describe carefully the recovery (length), composition, structure, consistency, color, condition, etc. of the recovered soil according to SOP F101; then put into jars without ramming. Jars with samples not taken for chemical analysis should be sealed with wax, or hermetically sealed (using a teflon cap liner) to prevent evaporation of the soil moisture. Affix labels to the jar and complete Chain-of-Custody and other required sample data forms (see SOP F302). Protect samples against extreme temperature changes and breakage by placing them in appropriate cartons stored in a protected area.
7. Split-spoon samplers shall be decontaminated after each use and prior to the initial use at a site according to SOP F501.

In addition to collecting soils for geotechnical purposes, split-spoon sampling can be employed to obtain samples for environmental analytical analysis. The following procedures are to be used for split-spoon, environmental soil sampling:

1. Follow sample collection procedures 1 through 6 as outlined in Section 5.2.1.
2. After sample collection, remove the soil from the split-spoon sampler. Prior to filling laboratory containers, the soil sample should be mixed thoroughly as possible to ensure that the sample is as representative as possible of the sample interval. Soil samples for volatile organic compounds should not be mixed. Further, sample containers for volatile organic compounds analyses should be filled completely without head space remaining in the container to minimize volatilization.
3. Record all pertinent sampling information such as soil description, sample depth, sample number, sample location, and time of sample collection in the Field Test Boring Record or field logbook. In addition, label, tag, and number the sample bottle(s).
4. Pack the samples for shipping (see SOP F300). Attach seal to the shipping package. Make sure that Chain-of-Custody Forms and Sample Request Forms are properly filled out and enclosed or attached (see SOP F301).
5. Decontaminate the split-spoon sample as described in SOP F501. Replace disposable latex gloves between sample stations to prevent cross-contaminating samples.

For obtaining composite soil samples (see Definitions), a slightly modified approach is employed. Each individual discrete soil sample from the desired sample interval will be placed into a stainless-steel, decontaminated bowl prior to filling the laboratory sample containers. Special care should be taken to cover the bowl between samples with aluminum foil to minimize volatilization. Immediately after obtaining soils from the desired sampling interval, the sample to be analyzed for Volatile Organic Compounds (VOCs) should be collected. Care should be taken to obtain a representative sampling of each sample interval. The remaining soils should be thoroughly mixed. Adequate mixing can be achieved by stirring in a circular fashion and occasionally turning the soils over. Once the remaining soils have been thoroughly combined, samples for analyses other than VOCs should be placed into the appropriate sampling containers.

5.2.2 Thin-Wall (Shelby Tube) Sampling

When it is desired to take undisturbed samples of soil for physical laboratory testing, thin-walled seamless tube samplers (Shelby tubes) will be used. The following method applies:

1. Clean out the hole to the sampling elevation, being careful to minimize the chance for disturbance or contamination of the material to be sampled.
2. The use of bottom discharge bits or jetting through an open-tube sampler to clean out the hole shall not be allowed. Any side discharge bits are permitted.
3. The sampler must be of a stationary piston-type, to limit sample disturbance and aid in retaining the sample. Either the hydraulically operated or control rod activated-type of stationary piston sampler may be used. Prior to inserting the tube sampler in the hole, check to ensure that the sampler head contains a check valve. The check valve is necessary to keep water in the rods from pushing the sample out of the tube sampler during sample withdrawal and to maintain a suction within the tube to help retain the sample.
4. With the sampling tube resting on the bottom of the hole and the water level in the boring at the natural groundwater level or above, push the tube into the soil by a continuous and rapid motion, without impacting or twisting. In no case shall the tube be pushed further than the length provided for the soil sample. Allow a free space in the tube for cuttings and sludge.
5. After pushing the tube, the sample should sit 5 to 15 minutes prior to removal. Immediately before removal, the sample must be sheared by rotating the rods with a pipe wrench a minimum of two revolutions.
6. Upon removal of the sampler tube from the hole, measure the length of sample in the tube and also the length penetrated. Remove disturbed material in the upper end of the tube and measure the length of sample again. After removing at least an inch of

soil, from the lower end and after inserting an impervious disk, seal both ends of the tube with at least a 1/2-inch thickness of wax applied in a way that will prevent the wax from entering the sample. Newspaper or other types of filler must be placed in voids at either end of the sampler prior to sealing with wax. Place plastic caps on the ends of the sampler, tape them into place and then dip the ends in wax to seal them.

7. Affix labels to the tubes and record sample number, depth, penetration, and recovery length on the label. Mark the same information and "up" direction on the tube with indelible ink, and mark the end of the sample. Complete chain-of-custody and other required forms (see SOP F302). Do not allow tubes to freeze, and store the samples vertically (with the same orientation they had in the ground, i.e., top of sample is up) in a cool place out of the sun at all times. Ship samples protected with suitable resilient packing material to reduce shock, vibration, and disturbance.
8. From soil removed from the ends of the tube, make a careful description using the methods presented in SOP F101.
9. When thin-wall tube samplers are used to collect soil for certain chemical analyses, it may be necessary to avoid using wax, newspaper, or other fillers. The SAP for each site should address specific materials allowed dependent on analytes being tested.

Thin-walled undisturbed tube samplers are restricted in their usage by the consistency of the soil to be sampled. Often very loose and/or wet samples cannot be retrieved by the samplers, and soils with a consistency in excess of very stiff cannot be penetrated by the sampler. Devices such as Dension or Pitcher cores can be used in conjunction with the tube samplers to obtain undisturbed samples of stiff soils. Using these devices normally increases sampling costs and, therefore, their use should be weighed against the increased cost and the need for an undisturbed sample. In any case, if a sample cannot be obtained with a tube sampler, an attempt should be made with a split-spoon sampler at the same depth so that at least one sample can be obtained for classification purposes.

5.2.3 Bucket (Hand) Auger Sampling

Hand augering is the most common manual method used to collect subsurface samples. Typically, 4-inch auger buckets with cutting heads are pushed and twisted into the ground and removed as the buckets are filled. The auger holes are advanced one bucket at a time. The practical depth of investigation using a hand auger is related to the material being sampled. In sands, augering is usually easily accomplished, but the depth of investigation is controlled by the depth at which sands begin to cave. At this point, auger holes usually begin to collapse and cannot practically be advanced to lower depths, and further samples, if required, must be collected using some type of pushed or driven device. Hand augering may

also become difficult in tight clays or cemented sands. At depths approaching 20 feet, torquing of hand auger extensions becomes so severe that in resistant materials, powered methods must be used if deeper samples are required.

When a vertical sampling interval has been established, one auger bucket is used to advance the auger hole to the first desired sampling depth. If the sample at this location is to be a vertical composite of all intervals, the same bucket may be used to advance the hole, as well collect subsequent samples in the same hole. However, if discrete grab samples are to be collected to characterize each depth, a new bucket must be placed on the end of the auger extension immediately prior to collecting the next sample. The top several inches of soil should be removed from the bucket to minimize the chances of cross-contamination of the sample from fall-in of material from the upper portions of the hole. The bucket auger should be decontaminated between samples as outlined in SOP F502.

In addition to hand augering, powered augers can be used to advance a boring for subsurface soil collection. However, this type of equipment is technically a sampling aid and not a sampling device, and 20 to 25 feet is the typical lower depth range for this equipment. It is used to advance a hole to the required sample depth, at which point a hand auger is usually used to collect the sample.

5.3 Surface Soil Samples

Surface soils are generally classified as soils between the ground surface and 6 to 12 inches below ground surface. For loosely packed surface soils, stainless steel (organic analyses) or plastic (inorganic analyses) scoops or trowels, can be used to collect representative samples. For densely packed soils or deeper soil samples, a hand or power soil auger may be used.

The following methods are to be used:

1. Use a soil auger for deep samples (greater than 12 inches) or a scoop or trowel for surface samples. Remove debris, rocks, twigs, and vegetation before collecting the sample.
2. Immediately transfer the sample to the appropriate sample container. Attach a label and identification tag. Record all required information in the field logbook and on the sample log sheet, chain-of-custody record, and other required forms.

3. Classify and record a description of the sample, as discussed in SOP F101. Descriptions for surface soil samples should be recorded in the field logbook; descriptions for soil samples collected with power or hand augers shall be recorded on a Field Test Boring Record.
4. Store the sampling utensil in a plastic bag until decontamination or disposal. Use a new or freshly-decontaminated sampling utensil for each sample taken.
5. Pack and ship as described in SOP F304.
6. Mark the location with a numbered stake if possible and locate sample points on a sketch of the site or on a sketch in the field logbook.
7. When a representative composited sample is to be prepared (e.g., samples taken from a gridded area or from several different depths), it is best to composite individual samples in the laboratory where they can be more precisely composited on a weight or volume basis. If this is not possible, the individual samples (all of equal volume, i.e., the sample bottles should be full) should be placed in a stainless steel bucket, mixed thoroughly using a stainless steel spatula or trowel, and a composite sample collected. In some cases, as delineated in project-specific sampling and analysis plans, laboratory compositing of the samples may be more appropriate than field compositing. Samples to be analyzed for parameters sensitive to volatilization should be composited and placed into the appropriate sample bottles immediately upon collection.

6.0 QUALITY ASSURANCE RECORDS

Where applicable, Field Test Boring Records and Test Boring Records will serve as the quality assurance records for subsurface soil samples, rock cores and near surface soil samples collected with a hand or power auger. Observations shall be recorded in the Field Logbook as described in SOP F303. Chain-of-Custody records shall be completed for samples collected for laboratory analysis as described in SOP F302.

7.0 REFERENCES

1. American Society for Testing and Materials, 1987. Standard Method for Penetration Test and Split-Barrel Sampling of Soils. ASTM Method D1586-84, Annual Book of Standards, ASTM, Philadelphia, Pennsylvania.
2. American Society for Testing and Materials, 1987. Standard Practice for Thin-Walled Tube Sampling of Soils. Method D1587-83, Annual Book of Standards, ASTM, Philadelphia, Pennsylvania.

3. American Society for Testing and Materials, 1987. Standard Practice for Diamond Core Drilling for Site Investigation. Method D2113-83 (1987), Annual Book of Standards ASTM, Philadelphia, Pennsylvania.
4. U. S. EPA, 1991. Standard Operating Procedures and Quality Assurance Manual. Environmental Compliance Branch, U. S. EPA, Environmental Services Division, Athens, Georgia.

ATTACHMENT A

ASTM D1586-84

**STANDARD METHOD FOR PENETRATION TEST AND
SPLIT-BARREL SAMPLING OF SOILS**



Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils¹

This standard is issued under the fixed designation D 1586; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense. Consult the DOD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

^{ε1}NOTE—Editorial changes were made throughout October 1992.

1. Scope

1.1 This test method describes the procedure, generally known as the Standard Penetration Test (SPT), for driving a split-barrel sampler to obtain a representative soil sample and a measure of the resistance of the soil to penetration of the sampler.

1.2 *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For a specific precautionary statement, see 5.4.1.

1.3 The values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents

2.1 ASTM Standards:

- D 2487 Test Method for Classification of Soils for Engineering Purposes²
- D 2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)²
- D 4220 Practices for Preserving and Transporting Soil Samples²
- D 4633 Test Method for Stress Wave Energy Measurement for Dynamic Penetrometer Testing Systems²

3. Terminology

3.1 Descriptions of Terms Specific to This Standard

3.1.1 *anvil*—that portion of the drive-weight assembly which the hammer strikes and through which the hammer energy passes into the drill rods.

3.1.2 *cathead*—the rotating drum or windlass in the rope-cathead lift system around which the operator wraps a rope to lift and drop the hammer by successively tightening and loosening the rope turns around the drum.

3.1.3 *drill rods*—rods used to transmit downward force and torque to the drill bit while drilling a borehole.

3.1.4 *drive-weight assembly*—a device consisting of the

hammer, hammer fall guide, the anvil, and any hammer drop system.

3.1.5 *hammer*—that portion of the drive-weight assembly consisting of the 140 ± 2 lb (63.5 ± 1 kg) impact weight which is successively lifted and dropped to provide the energy that accomplishes the sampling and penetration.

3.1.6 *hammer drop system*—that portion of the drive-weight assembly by which the operator accomplishes the lifting and dropping of the hammer to produce the blow.

3.1.7 *hammer fall guide*—that part of the drive-weight assembly used to guide the fall of the hammer.

3.1.8 *N-value*—the blowcount representation of the penetration resistance of the soil. The *N-value*, reported in blows per foot, equals the sum of the number of blows required to drive the sampler over the depth interval of 6 to 18 in. (150 to 450 mm) (see 7.3).

3.1.9 ΔN —the number of blows obtained from each of the 6-in. (150-mm) intervals of sampler penetration (see 7.3).

3.1.10 *number of rope turns*—the total contact angle between the rope and the cathead at the beginning of the operator's rope slackening to drop the hammer, divided by 360° (see Fig. 1).

3.1.11 *sampling rods*—rods that connect the drive-weight assembly to the sampler. Drill rods are often used for this purpose.

3.1.12 *SPT*—abbreviation for Standard Penetration Test, a term by which engineers commonly refer to this method.

4. Significance and Use

4.1 This test method provides a soil sample for identification purposes and for laboratory tests appropriate for soil obtained from a sampler that may produce large shear strain disturbance in the sample.

4.2 This test method is used extensively in a great variety of geotechnical exploration projects. Many local correlations and widely published correlations which relate SPT blowcount, or *N-value*, and the engineering behavior of earthworks and foundations are available.

5. Apparatus

5.1 *Drilling Equipment*—Any drilling equipment that provides at the time of sampling a suitably clean open hole before insertion of the sampler and ensures that the penetration test is performed on undisturbed soil shall be acceptable. The following pieces of equipment have proven to be

¹ This method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.02 on Sampling and Related Field Testing for Soil Investigations.

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² *Annual Book of ASTM Standards*, Vol 04.08.

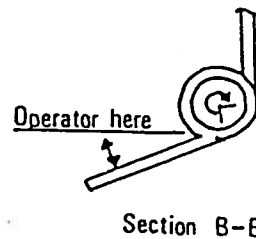
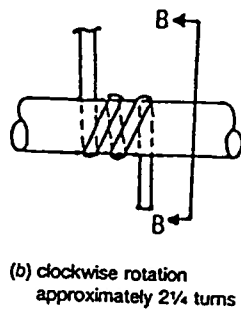
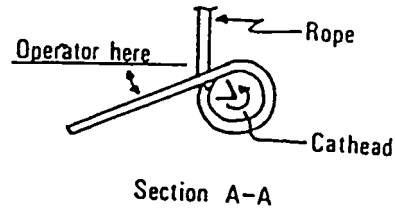
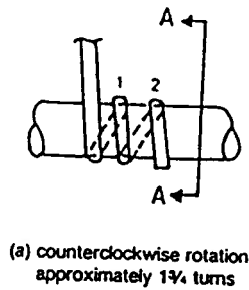


FIG. 1 Definitions of the Number of Rope Turns and the Angle for (a) Counterclockwise Rotation and (b) Clockwise Rotation of the Cathead

suitable for advancing a borehole in some subsurface conditions.

5.1.1 *Drag, Chopping, and Fishtail Bits*, less than 6.5 in. (162 mm) and greater than 2.2 in. (56 mm) in diameter may be used in conjunction with open-hole rotary drilling or casing-advancement drilling methods. To avoid disturbance of the underlying soil, bottom discharge bits are not permitted; only side discharge bits are permitted.

5.1.2 *Roller-Cone Bits*, less than 6.5 in. (162 mm) and greater than 2.2 in. (56 mm) in diameter may be used in conjunction with open-hole rotary drilling or casing-advancement drilling methods if the drilling fluid discharge is deflected.

5.1.3 *Hollow-Stem Continuous Flight Augers*, with or without a center bit assembly, may be used to drill the boring. The inside diameter of the hollow-stem augers shall be less than 6.5 in. (162 mm) and greater than 2.2 in. (56 mm).

5.1.4 *Solid, Continuous Flight, Bucket and Hand Augers*, less than 6.5 in. (162 mm) and greater than 2.2 in. (56 mm) in diameter may be used if the soil on the side of the boring does not cave onto the sampler or sampling rods during sampling.

5.2 *Sampling Rods*—Flush-joint steel drill rods shall be used to connect the split-barrel sampler to the drive-weight assembly. The sampling rod shall have a stiffness (moment of inertia) equal to or greater than that of parallel wall "A" rod (a steel rod which has an outside diameter of 1 3/8 in. (41.2 mm) and an inside diameter of 1 1/8 in. (28.5 mm)).

NOTE 1—Recent research and comparative testing indicates the type rod used, with stiffness ranging from "A" size rod to "N" size rod, will usually have a negligible effect on the N -values to depths of at least 100 ft (30 m).

5.3 *Split-Barrel Sampler*—The sampler shall be constructed with the dimensions indicated in Fig. 2. The driving shoe shall be of hardened steel and shall be replaced or repaired when it becomes dented or distorted. The use of liners to produce a constant inside diameter of 1 3/8 in. (35 mm) is permitted, but shall be noted on the penetration record if used. The use of a sample retainer basket is permitted, and should also be noted on the penetration record if used.

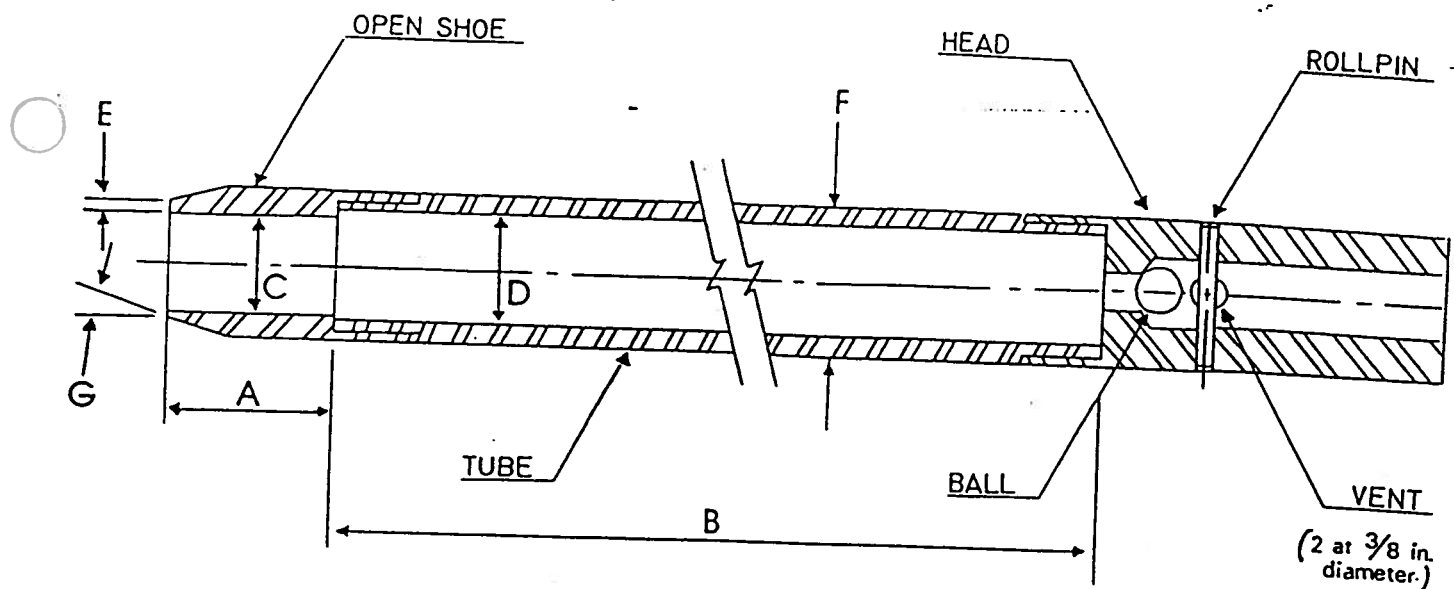
NOTE 2—Both theory and available test data suggest that N -values may increase between 10 to 30 % when liners are used.

5.4 *Drive-Weight Assembly*:

5.4.1 *Hammer and Anvil*—The hammer shall weigh 140 ± 2 lb (63.5 ± 1 kg) and shall be a solid rigid metallic mass. The hammer shall strike the anvil and make steel on steel contact when it is dropped. A hammer fall guide permitting a free fall shall be used. Hammers used with the cathead and rope method shall have an unimpeded overlift capacity of at least 4 in. (100 mm). For safety reasons, the use of a hammer assembly with an internal anvil is encouraged.

NOTE 3—It is suggested that the hammer fall guide be permanently marked to enable the operator or inspector to judge the hammer drop height.

5.4.2 *Hammer Drop System*—Rope-cathead, trip, semi-automatic, or automatic hammer drop systems may be used, providing the lifting apparatus will not cause penetration of



- A = 1.0 to 2.0 in. (25 to 50 mm)
 B = 18.0 to 30.0 in. (0.457 to 0.762 m)
 C = 1.375 ± 0.005 in. (34.93 ± 0.13 mm)
 D = $1.50 \pm 0.05 - 0.00$ in. ($38.1 \pm 1.3 - 0.0$ mm)
 E = 0.10 ± 0.02 in. (2.54 ± 0.25 mm)
 F = $2.00 \pm 0.05 - 0.00$ in. ($50.8 \pm 1.3 - 0.0$ mm)
 G = 16.0° to 23.0°

The $1\frac{1}{2}$ in. (38 mm) inside diameter split barrel may be used with a 16-gage wall thickness split liner. The penetrating end of the drive shoe may be slightly rounded. Metal or plastic retainers may be used to retain soil samples.

FIG. 2 Split-Barrel Sampler

the sampler while re-engaging and lifting the hammer.

5.5 Accessory Equipment—Accessories such as labels, sample containers, data sheets, and groundwater level measuring devices shall be provided in accordance with the requirements of the project and other ASTM standards.

6. Drilling Procedure

6.1 The boring shall be advanced incrementally to permit intermittent or continuous sampling. Test intervals and locations are normally stipulated by the project engineer or geologist. Typically, the intervals selected are 5 ft (1.5 m) or less in homogeneous strata with test and sampling locations at every change of strata.

6.2 Any drilling procedure that provides a suitably clean and stable hole before insertion of the sampler and assures that the penetration test is performed on essentially undisturbed soil shall be acceptable. Each of the following procedures have proven to be acceptable for some subsurface conditions. The subsurface conditions anticipated should be considered when selecting the drilling method to be used.

6.2.1 Open-hole rotary drilling method.

6.2.2 Continuous flight hollow-stem auger method.

6.2.3 Wash boring method.

6.2.4 Continuous flight solid auger method.

6.3 Several drilling methods produce unacceptable borings. The process of jetting through an open tube sampler and then sampling when the desired depth is reached shall not be permitted. The continuous flight solid auger method shall not be used for advancing the boring below a water table or below the upper confining bed of a confined non-cohesive stratum that is under artesian pressure. Casing

may not be advanced below the sampling elevation prior to sampling. Advancing a boring with bottom discharge bits is not permissible. It is not permissible to advance the boring for subsequent insertion of the sampler solely by means of previous sampling with the SPT sampler.

6.4 The drilling fluid level within the boring or hollow-stem augers shall be maintained at or above the in situ groundwater level at all times during drilling, removal of drill rods, and sampling.

7. Sampling and Testing Procedure

7.1 After the boring has been advanced to the desired sampling elevation and excessive cuttings have been removed, prepare for the test with the following sequence of operations.

7.1.1 Attach the split-barrel sampler to the sampling rods and lower into the borehole. Do not allow the sampler to drop onto the soil to be sampled.

7.1.2 Position the hammer above and attach the anvil to the top of the sampling rods. This may be done before the sampling rods and sampler are lowered into the borehole.

7.1.3 Rest the dead weight of the sampler, rods, anvil, and drive weight on the bottom of the boring and apply a seating blow. If excessive cuttings are encountered at the bottom of the boring, remove the sampler and sampling rods from the boring and remove the cuttings.

7.1.4 Mark the drill rods in three successive 6-in. (0.15-m) increments so that the advance of the sampler under the impact of the hammer can be easily observed for each 6-in. (0.15-m) increment.

7.2 Drive the sampler with blows from the 140-lb (63.5-

kg) hammer and count the number of blows applied in each 6-in. (0.15-m) increment until one of the following occurs:

7.2.1 A total of 50 blows have been applied during any one of the three 6-in. (0.15-m) increments described in 7.1.4.

7.2.2 A total of 100 blows have been applied.

7.2.3 There is no observed advance of the sampler during the application of 10 successive blows of the hammer.

7.2.4 The sampler is advanced the complete 18 in. (0.45 m) without the limiting blow counts occurring as described in 7.2.1, 7.2.2, or 7.2.3.

7.3 Record the number of blows required to effect each 6 in. (0.15 m) of penetration or fraction thereof. The first 6 in. is considered to be a seating drive. The sum of the number of blows required for the second and third 6 in. of penetration is termed the "standard penetration resistance," or the "*N*-value." If the sampler is driven less than 18 in. (0.45 m), as permitted in 7.2.1, 7.2.2, or 7.2.3, the number of blows per each complete 6-in. (0.15-m) increment and per each partial increment shall be recorded on the boring log. For partial increments, the depth of penetration shall be reported to the nearest 1 in. (25 mm), in addition to the number of blows. If the sampler advances below the bottom of the boring under the static weight of the drill rods or the weight of the drill rods plus the static weight of the hammer, this information should be noted on the boring log.

7.4 The raising and dropping of the 140-lb (63.5-kg) hammer shall be accomplished using either of the following two methods:

7.4.1 By using a trip, automatic, or semi-automatic hammer drop system which lifts the 140-lb (63.5-kg) hammer and allows it to drop 30 ± 1.0 in. ($0.76 \text{ m} \pm 25 \text{ mm}$) unimpeded.

7.4.2 By using a cathead to pull a rope attached to the hammer. When the cathead and rope method is used the system and operation shall conform to the following:

7.4.2.1 The cathead shall be essentially free of rust, oil, or grease and have a diameter in the range of 6 to 10 in. (150 to 250 mm).

7.4.2.2 The cathead should be operated at a minimum speed of rotation of 100 RPM, or the approximate speed of rotation shall be reported on the boring log.

7.4.2.3 No more than $2\frac{1}{4}$ rope turns on the cathead may be used during the performance of the penetration test, as shown in Fig. 1.

NOTE 4—The operator should generally use either $1\frac{1}{4}$ or $2\frac{1}{4}$ rope turns, depending upon whether or not the rope comes off the top ($1\frac{1}{4}$ turns) or the bottom ($2\frac{1}{4}$ turns) of the cathead. It is generally known and accepted that $2\frac{1}{4}$ or more rope turns considerably impedes the fall of the hammer and should not be used to perform the test. The cathead rope should be maintained in a relatively dry, clean, and unfrayed condition.

7.4.2.4 For each hammer blow, a 30-in. (0.76-m) lift and drop shall be employed by the operator. The operation of pulling and throwing the rope shall be performed rhythmically without holding the rope at the top of the stroke.

7.5 Bring the sampler to the surface and open. Record the percent recovery or the length of sample recovered. Describe the soil samples recovered as to composition, color, stratification, and condition, then place one or more representative portions of the sample into sealable moisture-proof containers (jars) without ramming or distorting any apparent

stratification. Seal each container to prevent evaporation of soil moisture. Affix labels to the containers bearing job designation, boring number, sample depth, and the blow count per 6-in. (0.15-m) increment. Protect the samples against extreme temperature changes. If there is a soil change within the sampler, make a jar for each stratum and note its location in the sampler barrel.

8. Report

8.1 Drilling information shall be recorded in the field and shall include the following:

8.1.1 Name and location of job,

8.1.2 Names of crew,

8.1.3 Type and make of drilling machine,

8.1.4 Weather conditions,

8.1.5 Date and time of start and finish of boring,

8.1.6 Boring number and location (station and coordinates, if available and applicable),

8.1.7 Surface elevation, if available,

8.1.8 Method of advancing and cleaning the boring,

8.1.9 Method of keeping boring open,

8.1.10 Depth of water surface and drilling depth at the time of a noted loss of drilling fluid, and time and date when reading or notation was made,

8.1.11 Location of strata changes,

8.1.12 Size of casing, depth of cased portion of boring,

8.1.13 Equipment and method of driving sampler,

8.1.14 Type sampler and length and inside diameter of barrel (note use of liners),

8.1.15 Size, type, and section length of the sampling rods, and

8.1.16 Remarks.

8.2 Data obtained for each sample shall be recorded in the field and shall include the following:

8.2.1 Sample depth and, if utilized, the sample number,

8.2.2 Description of soil,

8.2.3 Strata changes within sample,

8.2.4 Sampler penetration and recovery lengths, and

8.2.5 Number of blows per 6-in. (0.15-m) or partial increment.

9. Precision and Bias

9.1 *Precision*—A valid estimate of test precision has not been determined because it is too costly to conduct the necessary inter-laboratory (field) tests. Subcommittee D18.02 welcomes proposals to allow development of a valid precision statement.

9.2 *Bias*—Because there is no reference material for this test method, there can be no bias statement.

9.3 Variations in *N*-values of 100 % or more have been observed when using different standard penetration test apparatus and drillers for adjacent borings in the same soil formation. Current opinion, based on field experience, indicates that when using the same apparatus and driller, *N*-values in the same soil can be reproduced with a coefficient of variation of about 10 %.

9.4 The use of faulty equipment, such as an extremely massive or damaged anvil, a rusty cathead, a low speed cathead, an old, oily rope, or massive or poorly lubricated rope sheaves can significantly contribute to differences in *N*-values obtained between operator-drill rig systems.

9.5 The variability in N -values produced by different drill rigs and operators may be reduced by measuring that part of the hammer energy delivered into the drill rods from the sampler and adjusting N on the basis of comparative energies. A method for energy measurement and N -value

adjustment is given in Test Method D 4633.

10. Keywords

10.1 blow count; in-situ test; penetration resistance; split-barrel sampling; standard penetration test

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This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, PA 19103.

ATTACHMENT B

ASTM D1587-83

STANDARD PRACTICE FOR THIN-WALLED TUBE SAMPLING OF SOILS



Standard Practice for Thin-Walled Tube Sampling of Soils¹

This standard is issued under the fixed designation D 1587; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

This practice has been approved for use by agencies of the Department of Defense and for listing in the DOD Index of Specifications and Standards.

1. Scope

1.1 This practice covers a procedure for using a thin-walled metal tube to recover relatively undisturbed soil samples suitable for laboratory tests of structural properties. Thin-walled tubes used in piston, plug, or rotary-type samplers, such as the Denison or Pitcher, must comply with the portions of this practice which describe the thin-walled tubes (5.3).

NOTE 1—This practice does not apply to liners used within the above samplers.

2. Referenced Documents

2.1 ASTM Standards:

D 2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)²

D 3550 Practice for Ring-Lined Barrel Sampling of Soils²

D 4220 Practices for Preserving and Transporting Soil Samples²

3. Summary of Practice

3.1 A relatively undisturbed sample is obtained by pressing a thin-walled metal tube into the in-situ soil, removing the soil-filled tube, and sealing the ends to prevent the soil from being disturbed or losing moisture.

4. Significance and Use

4.1 This practice, or Practice D 3550, is used when it is necessary to obtain a relatively undisturbed specimen suitable for laboratory tests of structural properties or other tests that might be influenced by soil disturbance.

5. Apparatus

5.1 *Drilling Equipment*—Any drilling equipment may be used that provides a reasonably clean hole; that does not disturb the soil to be sampled; and that does not hinder the penetration of the thin-walled sampler. Open borehole diameter and the inside diameter of driven casing or hollow stem auger shall not exceed 3.5 times the outside diameter of the thin-walled tube.

5.2 *Sampler Insertion Equipment*, shall be adequate to provide a relatively rapid continuous penetration force. For

hard formations it may be necessary, although not recommended, to drive the thin-walled tube sampler.

5.3 *Thin-Walled Tubes*, should be manufactured as shown in Fig. 1. They should have an outside diameter of 2 to 5 in. and be made of metal having adequate strength for use in the soil and formation intended. Tubes shall be clean and free of all surface irregularities including projecting weld seams.

5.3.1 *Length of Tubes*—See Table 1 and 6.4.

5.3.2 *Tolerances*, shall be within the limits shown in Table 2.

5.3.3 *Inside Clearance Ratio*, should be 1 % or as specified by the engineer or geologist for the soil and formation to be sampled. Generally, the inside clearance ratio used should increase with the increase in plasticity of the soil being sampled. See Fig. 1 for definition of inside clearance ratio.

5.3.4 *Corrosion Protection*—Corrosion, whether from galvanic or chemical reaction, can damage or destroy both the thin-walled tube and the sample. Severity of damage is a function of time as well as interaction between the sample and the tube. Thin-walled tubes should have some form of protective coating. Tubes which will contain samples for more than 72 h shall be coated. The type of coating to be used may vary depending upon the material to be sampled. Coatings may include a light coat of lubricating oil, lacquer, epoxy, Teflon, and others. Type of coating must be specified by the engineer or geologist if storage will exceed 72 h. Plating of the tubes or alternate base metals may be specified by the engineer or geologist.

5.4 *Sampler Head*, serves to couple the thin-walled tube to the insertion equipment and, together with the thin-walled tube, comprises the thin-walled tube sampler. The sampler head shall contain a suitable check valve and a venting area to the outside equal to or greater than the area through the check valve. Attachment of the head to the tube shall be concentric and coaxial to assure uniform application of force to the tube by the sampler insertion equipment.

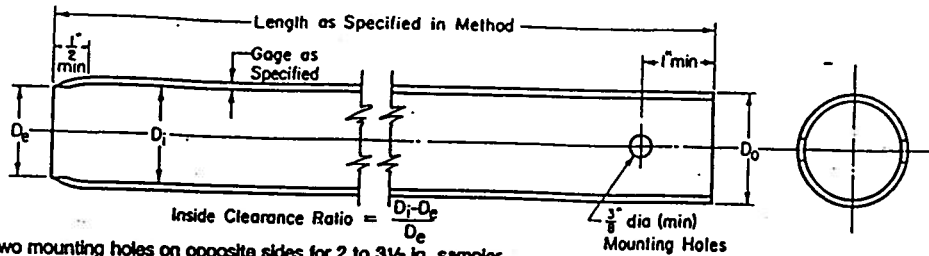
6. Procedure

6.1 Clean out the borehole to sampling elevation using whatever method is preferred that will ensure the material to be sampled is not disturbed. If groundwater is encountered, maintain the liquid level in the borehole at or above ground water level during the sampling operation.

6.2 Bottom discharge bits are not permitted. Side discharge bits may be used, with caution. Jetting through an open-tube sampler to clean out the borehole to sampling elevation is not permitted. Remove loose material from the center of a casing or hollow stem auger as carefully as

¹ This practice is under the jurisdiction of ASTM Committee D-18 on Soil and Rocks and is the direct responsibility of Subcommittee D18.02 on Sampling and Field Testing for Soil Investigations.
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² *Annual Book of ASTM Standards*, Vol 04.08.



- NOTE 1—Minimum of two mounting holes on opposite sides for 2 to 3½ in. sampler.
 NOTE 2—Minimum of four mounting holes spaced at 90° for samplers 4 in. and larger.
 NOTE 3—Tube held with hardened screws.
 NOTE 4—Two-inch outside-diameter tubes are specified with an 18-gage wall thickness to comply with area ratio criteria accepted for “undisturbed samples.” Users are advised that such tubing is difficult to locate and can be extremely expensive in small quantities. Sixteen-gage tubes are generally readily available.

Metric Equivalents	
in.	mm
¾	6.77
½	12.7
1	25.4
2	50.8
3½	88.9
4	101.6

FIG. 1 Thin-Walled Tube for Sampling

TABLE 1 Suitable Thin-Walled Steel Sample Tubes^A

Outside diameter:			
in.	2	3	5
mm	50.8	76.2	127
Wall thickness:			
Bwg	18	16	11
in.	0.049	0.065	0.120
mm	1.24	1.65	3.05
Tube length:			
	36	36	54
	0.91	0.91	1.45
Clearance ratio, %	1	1	1

^A The three diameters recommended in Table 1 are indicated for purposes of standardization, and are not intended to indicate that sampling tubes of intermediate or larger diameters are not acceptable. Lengths of tubes shown are illustrative. Proper lengths to be determined as suited to field conditions.

TABLE 2 Dimensional Tolerances for Thin-Walled Tubes

Nominal Tube Diameters from Table 1^A Tolerances, in.

Size Outside Diameter	2	3	5
Outside diameter	+0.007 -0.000	+0.010 -0.000	+0.015 -0.000
Inside diameter	+0.000 -0.007	+0.000 -0.010	+0.000 -0.015
Wall thickness	±0.007	±0.010	±0.015
Ovality	0.015	0.020	0.030
Straightness	0.030/ft	0.030/ft	0.030/ft

^A Intermediate or larger diameters should be proportional. Tolerances shown are essentially standard commercial manufacturing tolerances for seamless steel mechanical tubing. Specify only two of the first three tolerances; that is, O.D. and I.D., or O.D. and Wall, or I.D. and Wall.

possible to avoid disturbance of the material to be sampled.

NOTE 2—Roller bits are available in downward-jetting and diffused-jet configurations. Downward-jetting configuration rock bits are not acceptable. Diffuse-jet configurations are generally acceptable.

6.3 Place the sample tube so that its bottom rests on the bottom of the hole. Advance the sampler without rotation by a continuous relatively rapid motion.

6.4 Determine the length of advance by the resistance and condition of the formation, but the length shall never exceed

5 to 10 diameters of the tube in sands and 10 to 15 diameters of the tube in clays.

NOTE 3—Weight of sample, laboratory handling capabilities, transportation problems, and commercial availability of tubes will generally limit maximum practical lengths to those shown in Table 1.

6.5 When the formation is too hard for push-type insertion, the tube may be driven or Practice D 3550 may be used. Other methods, as directed by the engineer or geologist, may be used. If driving methods are used, the data regarding weight and fall of the hammer and penetration achieved must be shown in the report. Additionally, that tube must be prominently labeled a “driven sample.”

6.6 In no case shall a length of advance be greater than the sample-tube length minus an allowance for the sampler head and a minimum of 3 in. for sludge-end cuttings.

NOTE 4—The tube may be rotated to shear bottom of the sample after pressing is complete.

6.7 Withdraw the sampler from the formation as carefully as possible in order to minimize disturbance of the sample.

7. Preparation for Shipment

7.1 Upon removal of the tube, measure the length of sample in the tube. Remove the disturbed material in the upper end of the tube and measure the length again. Seal the upper end of the tube. Remove at least 1 in. of material from the lower end of the tube. Use this material for soil description in accordance with Practice D 2488. Measure the overall sample length. Seal the lower end of the tube. Alternatively, after measurement, the tube may be sealed without removal of soil from the ends of the tube if so directed by the engineer or geologist.

NOTE 5—Field extrusion and packaging of extruded samples under the specific direction of a geotechnical engineer or geologist is permitted.

NOTE 6—Tubes sealed over the ends as opposed to those sealed with expanding packers should contain end padding in end voids in order to prevent drainage or movement of the sample within the tube.

7.2 Prepare and immediately affix labels or apply markings as necessary to identify the sample. Assure that the

markings or labels are adequate to survive transportation and storage.

Report

- 8.1 The appropriate information is required as follows:
 - 8.1.1 Name and location of the project,
 - 8.1.2 Boring number and precise location on project,
 - 8.1.3 Surface elevation or reference to a datum,
 - 8.1.4 Date and time of boring—start and finish,
 - 8.1.5 Depth to top of sample and number of sample,
 - 8.1.6 Description of sampler: size, type of metal, type of coating,
 - 8.1.7 Method of sampler insertion: push or drive,

- 8.1.8 Method of drilling, size of hole, casing, and drilling fluid used,
- 8.1.9 Depth to groundwater level: date and time measured,
- 8.1.10 Any possible current or tidal effect on water level,
- 8.1.11 Soil description in accordance with Practice D 2488,
- 8.1.12 Length of sampler advance, and
- 8.1.13 Recovery: length of sample obtained.

9. Precision and Bias

- 9.1 This practice does not produce numerical data; therefore, a precision and bias statement is not applicable.

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ATTACHMENT C

**ASTM D2113-83 (1987)
STANDARD PRACTICE FOR DIAMOND CORE DRILLING FOR
SITE INVESTIGATION**



Standard Practice for Diamond Core Drilling for Site Investigation¹

This standard is issued under the fixed designation D 2113; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice describes equipment and procedures for diamond core drilling to secure core samples of rock and some soils that are too hard to sample by soil-sampling methods. This method is described in the context of obtaining data for foundation design and geotechnical engineering purposes rather than for mineral and mining exploration.

2. Referenced Documents

2.1 ASTM Standards:

D 1586 Method for Penetration Test and Split-Barrel Sampling of Soils²

D 1587 Practice for Thin-Walled Tube Sampling of Soils²

D 3550 Practice for Ring-Lined Barrel Sampling of Soils²

3. Significance and Use

3.1 This practice is used to obtain core specimens of superior quality that reflect the in-situ conditions of the material and structure and which are suitable for standard physical-properties tests and structural-integrity determination.

4. Apparatus

4.1 *Drilling Machine*, capable of providing rotation, feed, and retraction by hydraulic or mechanical means to the drill rods.

4.2 *Fluid Pump or Air Compressor*, capable of delivering sufficient volume and pressure for the diameter and depth of hole to be drilled.

4.3 Core barrels, as required:

4.3.1 *Single Tube Type, WG Design*, consisting of a hollow steel tube, with a head at one end threaded for drill rod, and a threaded connection for a reaming shell and core bit at the other end. A core lifter, or retainer located within the core bit is normal, but may be omitted at the discretion of the geologist or engineer.

4.3.2 *Double Tube, Swivel-Type, WG Design*—An assembly of two concentric steel tubes joined and supported at the upper end by means of a ball or roller-bearing swivel arranged to permit rotation of the outer tube without causing rotation of the inner tube. The upper end of the outer tube, or removable head, is threaded for drill rod. A threaded connection is provided on the lower end of the outer tube for

a reaming shell and core bit. A core lifter located within the core bit is normal but may be omitted at the discretion of the geologist or engineer.

4.3.3 *Double-Tube, Swivel-Type, WT Design*, is essentially the same as the double tube, swivel-type, WG design, except that the WT design has thinner tube walls, a reduced annular area between the tubes, and takes a larger core from the same diameter bore hole. The core lifter is located within the core bit.

4.3.4 *Double Tube, Swivel Type, WM Design*, is similar to the double tube, swivel-type, WG design, except that the inner tube is threaded at its lower end to receive a core lifter case that effectively extends the inner tube well into the core bit, thus minimizing exposure of the core to the drilling fluid. A core lifter is contained within the core lifter case on the inner tube.

4.3.5 *Double Tube Swivel-Type, Large-Diameter Design*, is similar to the double tube, swivel-type, WM design, with the addition of a ball valve, to control fluid flow, in all three available sizes and the addition of a sludge barrel, to catch heavy cuttings, on the two larger sizes. The large-diameter design double tube, swivel-type, core barrels are available in three core per hole sizes as follows: 2½ in. (69.85 mm) by 3½ in. (98.43 mm), 4 in. (101.6 mm) by 5½ in. (139.7 mm), and 6 in. (152.4 mm) by 7½ in. (196.85 mm). Their use is generally reserved for very detailed investigative work or where other methods do not yield adequate recovery.

4.3.6 *Double Tube, Swivel-Type, Retrievable Inner-Tube Method*, in which the core-laden inner-tube assembly is retrieved to the surface and an empty inner-tube assembly returned to the face of the borehole through the matching large-bore drill rods without need for withdrawal and replacement of the drill rods in the borehole. The inner-tube assembly consists of an inner tube with removable core lifter case and core lifter at one end and a removable inner-tube head, swivel bearing, suspension adjustment, and latching device with release mechanism on the opposite end. The inner-tube latching device locks into a complementary recess in the wall of the outer tube such that the outer tube may be rotated without causing rotation of the inner tube and such that the latch may be actuated and the inner-tube assembly transported by appropriate surface control. The outer tube is threaded for the matching, large-bore drill rod and internally configured to receive the inner-tube latching device at one end and threaded for a reaming shell and bit, or bit only, at the other end.

4.4 *Longitudinally Split Inner Tubes*—As opposed to conventional cylindrical inner tubes, allow inspection of, and access to, the core by simply removing one of the two halves. They are not standardized but are available for most core barrels including many of the retrievable inner-tube types.

¹ This practice is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.02 on Sampling and Related Field Testing for Soil Investigations.

Current edition approved June 24, 1983. Published August 1983. Originally published as D 2113 - 62 T. Last previous edition D 2113 - 70 (1976).

² Annual Book of ASTM Standards, Vol 04.08.

4.5 Core Bits—Core bits shall be surface set with diamonds, impregnated with small diamond particles, inserted with tungsten carbide slugs, or strips, hard-faced with various hard surfacing materials or furnished in saw-tooth form, all as appropriate to the formation being cored and with concurrence of the geologist or engineer. Bit matrix material, crown shape, water-way type, location and number of water ways, diamond size and carat weight, and bit facing materials shall be for general purpose use unless otherwise approved by the geologist or engineer. Nominal size of some bits is shown in Table 1.

NOTE 1—Size designation (letter symbols) used throughout the text and in Tables 1, 2, and 3 are those standardized by the Diamond Core Drill Manufacturers' Assoc. (DCDMA). Inch dimensions in the tables have been rounded to the nearest hundredth of an inch.

4.6 Reaming Shells, shall be surface set with diamonds, impregnated with small diamond particles, inserted with tungsten carbide strips or slugs, hard faced with various types of hard surfacing materials, or furnished blank, all as appropriate to the formation being cored.

4.7 Core Lifters—Core lifters of the split-ring type, either plain or hard-faced, shall be furnished and maintained, along with core-lifter cases or inner-tube extensions or inner-tube shoes, in good condition. Basket or finger-type lifters, together with any necessary adapters, shall be on the job and available for use with each core barrel if so directed by the geologist or engineer.

4.8 Casings:

4.8.1 Drive Pipe or Drive Casing, shall be standard weight (schedule 40), extra-heavy (schedule 80), double extra-heavy (schedule 160) pipe or W-design flush-joint casing as re-

quired by the nature of the overburden or the placement method. Drive pipe or W-design casing shall be of sufficient diameter to pass the largest core barrel to be used, and it shall be driven to bed rock or to firm seating at an elevation below water-sensitive formation. A hardened drive shoe is to be used as a cutting edge and thread protection device on the bottom of the drive pipe or casing. The drive shoe inside diameter shall be large enough to pass the tools intended for use, and the shoe and pipe or casing shall be free from burrs or obstructions.

4.8.2 Casing—When necessary to case through formations already penetrated by the borehole or when no drive casing has been set, auxiliary casing shall be provided to fit inside the borehole to allow use of the next smaller core barrel. Standard sizes of telescoping casing are shown in Table 2. Casing bits have an obstruction in their interior and will not pass the next smaller casing size. Use a casing shoe if additional telescoping is anticipated.

4.8.3 Casing Liner—Plastic pipe or sheet-metal pipe may be used to line an existing large-diameter casing. Liners, so used, should not be driven, and care should be taken to maintain true alignment throughout the length of the liner.

4.8.4 Hollow Stem Auger—Hollow stem auger may be used as casing for coring.

4.9 Drill Rods:

4.9.1 Drill Rods of Tubular Steel Construction are normally used to transmit feed, rotation, and retraction forces from the drilling machine to the core barrel. Drill-rod sizes that are presently standardized are shown in Table 3.

4.9.2 Large bore drill rods used with retrievable inner-tube core barrels are not standardized. Drill rods used with retrievable inner-tube core barrels should be those manufactured by the core-barrel manufacturer specifically for the core barrel.

4.9.3 Composite Drill Rods are specifically constructed from two or more materials intended to provide specific properties such as light weight or electrical nonconductivity.

4.9.4 Nonmagnetic Drill Rods are manufactured of nonferrous materials such as aluminum or brass and are used primarily for hole survey work. Some nonmagnetic rods have left-hand threads in order to further their value in survey work. No standard exists for nonmagnetic rods.

4.10 Auxiliary Equipment, shall be furnished as required by the work and shall include: roller rock bits, drag bits, chopping bits, boulder busters, fishtail bits, pipe wrenches, core barrel wrenches, lubrication equipment, core boxes, and marking devices. Other recommended equipment includes:

TABLE 1 Core Bit Sizes

Size Designation	Outside Diameter		Inside Diameter	
	in.	mm	in.	mm
RWT	1.18	29.5	0.375	18.7
EWT	1.47	37.3	0.905	22.9
EWG, EWM	1.47	37.3	0.845	21.4
AWT	1.88	47.8	1.281	32.5
AWG, AWM	1.88	47.8	1.185	30.0
BWT	2.35	59.5	1.750	44.5
BWG, BWM	2.35	59.5	1.655	42.0
NWT	2.97	75.3	2.313	58.7
NWG, NWM	2.97	75.3	2.155	54.7
2 1/4 x 3/4	3.84	97.5	2.69	68.3
HWT	3.89	98.8	3.187	80.9
HWG, ...	3.89	98.8	3.000	76.2
4 x 5/8	5.44	138.0	3.97	100.8
6 x 7/8	7.66	194.4	5.97	151.6

TABLE 2 Casing Sizes

Size Designation	Outside Diameter		Inside Diameter		Threads per in.	Will Fit Hole Drilled with Core Bit Size
	in.	mm	in.	mm		
RW	1.144	36.5	1.19	30.1	5	EWG, EWM
EW	1.81	46.0	1.50	38.1	4	AWT, AWG, AWM
AW	2.25	57.1	1.91	48.4	4	BWT, BWG, BWM
BW	2.88	73.0	2.38	60.3	4	NWT, NWG, NWM
NW	3.50	88.9	3.00	76.2	4	HWT, HWG
HW	4.50	114.3	4.00	101.6	4	4 x 5/8
PW	5.50	139.7	5.00	127.0	3	6 x 7/8
SW	6.63	168.2	6.00	152.4	3	6 x 7/8
UW	7.63	193.6	7.00	177.8	2	...
ZW	8.63	219.0	8.00	203.2	2	...

TABLE 3 Drill Rods

Size Designation	Rod and Coupling Outside Diameter		Rod Inside Diameter		Coupling Bore, Threads		
	in.	mm	in.	mm	in.	mm	per in.
RW	1.09	27.7	0.72	18.2	0.41	10.3	4
EW	1.38	34.9	1.00	25.4	0.44	11.1	3
AW	1.72	43.6	1.34	34.1	0.63	15.8	3
BW	2.13	53.9	1.75	44.4	0.75	19.0	3
NW	2.63	66.6	2.25	57.1	1.28	34.9	3
HW	3.50	88.9	3.06	77.7	2.38	60.3	3

core splitter, rod wicking, pump-out tools or extruders, and hand sieve or strainer.

5. Transportation and Storage of Core Containers

5.1 *Core Boxes*, shall be constructed of wood or other durable material for the protection and storage of cores while enroute from the drill site to the laboratory or other processing point. All core boxes shall be provided with longitudinal separators and recovered cores shall be laid out as a book would read, from left to right and top to bottom, within the longitudinal separators. Spacer blocks or plugs shall be marked and inserted into the core column within the separators to indicate the beginning of each coring run. The beginning point of storage in each core box is the upper left-hand corner. The upper left-hand corner of a hinged core box is the left corner when the hinge is on the far side of the box and the box is right-side up. All hinged core boxes must be permanently marked on the outside to indicate the top and the bottom. All other core boxes must be permanently marked on the outside to indicate the top and the bottom and additionally, must be permanently marked internally to indicate the upper-left corner of the bottom with the letters UL or a splotch of red paint not less than 1 in.² Lid or cover fitting(s) for core boxes must be of such quality as to ensure against mix up of the core in the event of impact or upsetting of the core box during transportation.

5.2 Transportation of cores from the drill site to the laboratory or other processing point shall be in durable core boxes so padded or suspended as to be isolated from shock or impact transmitted to the transporter by rough terrain or careless operation.

5.3 Storage of cores, after initial testing or inspection at the laboratory or other processing point, may be in cardboard or similar less costly boxes provided all layout and marking requirements as specified in 5.1 are followed. Additional spacer blocks or plugs shall be added if necessary at time of storage to explain missing core. Cores shall be stored for a period of time specified by the engineer but should not normally be discarded prior to completion of the project for which they were taken.

6. Procedure

6.1 Use core-drilling procedures when formations are encountered that are too hard to be sampled by soil-sampling methods. A 1-in. (25.4-mm) or less penetration for 50 blows in accordance with Method D 1586 or other criteria established by the geologist or engineer, shall indicate that soil-sampling methods are not applicable.

6.1.1 Seat the casing on bedrock or in a firm formation to prevent raveling of the borehole and to prevent loss of

drilling fluid. Level the surface of the rock or hard formation at the bottom of the casing when necessary, using the appropriate bits. Casing may be omitted if the borehole will stand open without the casing.

6.1.2 Begin the core drilling using an N-size double-tube swivel-type core barrel or other size or type approved by the engineer. Continue core drilling until core blockage occurs or until the net length of the core barrel has been drilled in. Remove the core barrel from the hole and disassemble it as necessary to remove the core. Reassemble the core barrel and return it to the hole. Resume coring.

6.1.3 Place the recovered core in the core box with the upper (surface) end of the core at the upper-left corner of the core box as described in 5.1. Continue boxing core with appropriate markings, spacers, and blocks as described in 5.1. Wrap soft or friable cores or those which change materially upon drying in plastic film or seal in wax, or both, when such treatment is required by the engineer. Use spacer blocks or slugs properly marked to indicate any noticeable gap in recovered core which might indicate a change or void in the formation. Fit fracture, bedded, or jointed pieces of core together as they naturally occurred.

6.1.4 Stop the core drilling when soft materials are encountered that produce less than 50 % recovery. If necessary, secure samples of soft materials in accordance with the procedures described in Method D 1586, Practice D 1587, or Practice D 3550, or by any other method acceptable to the geologist or engineer. Resume diamond core drilling when refusal materials as described in 6.1 are again encountered.

6.2 Subsurface structure, including the dip of strata, the occurrence of seams, fissures, cavities, and broken areas are among the most important items to be detected and described. Take special care to obtain and record information about these features. If conditions prevent the continued advance of the core drilling, the hole should be cemented and redrilled, or reamed and cased, or cased and advanced with the next smaller-size core barrel, as required by the geologist or engineer.

6.3 Drilling mud or grouting techniques must be approved by the geologist or engineer prior to their use in the borehole.

6.4 Compatibility of Equipment:

6.4.1 Whenever possible, core barrels and drill rods should be selected from the same letter-size designation to ensure maximum efficiency. See Tables 1 and 3.

6.4.2 Never use a combination of pump, drill rod, and core barrel that yields a clear-water up-hole velocity of less than 120 ft/min.

6.4.3 Never use a combination of air compressor, drill rod, and core barrel that yields a clear-air up-hole velocity of less than 3000 ft/min.

1. Boring Log

7.1 The boring log shall include the following:

- 7.1.1 Project identification, boring number, location, date boring began, date boring completed, and driller's name.
- 7.1.2 Elevation of the ground surface.
- 7.1.3 Elevation of or depth to ground water and raising or lowering of level including the dates and the times measured.
- 7.1.4 Elevations or depths at which drilling fluid return was lost.
- 7.1.5 Size, type, and design of core barrel used. Size, type, and set of core bit and reaming shell used. Size, type, and length of all casing used. Description of any movements of the casing.
- 7.1.6 Length of each core run and the length or percentage, or both, of the core recovered.
- 7.1.7 Geologist's or engineer's description of the formation recovered in each run.
- 7.1.8 Driller's description, if no engineer or geologist is present, of the formation recovered in each run.
- 7.1.9 Subsurface structure description, including dip of strata and jointing, cavities, fissures, and any other observations made by the geologist or engineer that could yield information regarding the formation.

7.1.10 Depth, thickness, and apparent nature of the filling of each cavity or soft seam encountered, including opinions gained from the feel or appearance of the inside of the inner tube when core is lost. Record opinions as such.

7.1.11 Any change in the character of the drilling fluid or drilling fluid return.

7.1.12 Tidal and current information when the borehole is sufficiently close to a body of water to be affected.

7.1.13 Drilling time in minutes per foot and bit pressure in pound-force per square inch gage when applicable.

7.1.14 Notations of character of drilling, that is, soft, slow, easy, smooth, etc.

8. Precision and Bias

8.1 This practice does not produce numerical data; therefore, a precision and bias statement is not applicable.

NOTE 2—Inclusion of the following tables and use of letter symbols in the foregoing text is not intended to limit the practice to use of DCDMA tools. The table and text references are included as a convenience to the user since the vast majority of tools in use do meet DCDMA dimensional standards. Similar equipment of approximately equal size on the metric standard system is acceptable unless otherwise stipulated by the engineer or geologist.

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SOP F104
Groundwater Sample Acquisition

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GROUNDWATER SAMPLE ACQUISITION

1.0 PURPOSE

The purpose of this guideline is to provide general reference information on the sampling of groundwater wells. The methods and equipment described are for the collection of water samples from the saturated zone of the subsurface.

2.0 SCOPE

This guideline provides information on proper sampling equipment and techniques for groundwater sampling. Review of the information contained herein will facilitate planning of the field sampling effort by describing standard sampling techniques. The techniques described should be followed whenever applicable, noting that site-specific conditions or project-specific plans may require adjustments in methods.

3.0 DEFINITIONS

None.

4.0 RESPONSIBILITIES

Project Manager - The Project Manager is responsible for ensuring that project-specific plans are in accordance with these procedures, where applicable, or that other, approved procedures are developed. The Project Manager is responsible for development of documentation of procedures which deviate from those presented herein.

Field Team Leader - The Field Team Leader is responsible for selecting and detailing the specific groundwater sampling techniques and equipment to be used, and documenting these in the Sampling and Analysis Plan. It is the responsibility of the Field Team Leader to ensure that these procedures are implemented in the field and that personnel performing sampling activities have been briefed and trained to execute these procedures.

Sampling Personnel - It is the responsibility of the field sampling personnel to follow these procedures, or to follow documented, project-specific procedures as directed by the Field Team

Leader and the Project Manager. The sampling personnel are responsible for the proper acquisition of groundwater samples.

5.0 PROCEDURES

To be useful and accurate, a groundwater sample must be representative of the particular zone being sampled. The physical, chemical, and bacteriological integrity of the sample must be maintained from the time of sampling to the time of testing in order to minimize any changes in water quality parameters.

The groundwater sampling program should be developed with reference to ASTM D4448-85A, Standard Guide for Sampling Groundwater Monitoring Wells (Attachment A). This reference is not intended as a monitoring plan or procedure for a specific application, but rather is a review of methods. Specific methods shall be stated in the Sampling and Analysis Plan (SAP).

Methods for withdrawing samples from completed wells include the use of pumps, compressed air, bailers, and various types of samplers. The primary considerations in obtaining a representative sample of the groundwater are to avoid collection of stagnant (standing) water in the well and to avoid physical or chemical alteration of the water due to sampling techniques. In a non-pumping well, there will be little or no vertical mixing of water in the well pipe or casing, and stratification will occur. The well water in the screened section will mix with the groundwater due to normal flow patterns, but the well water above the screened section will remain largely isolated and become stagnant. To safeguard against collecting non-representative stagnant water in a sample, the following approach should be followed during sample withdrawal:

1. All monitoring wells shall be pumped or bailed prior to withdrawing a sample. Evacuation of three to five volumes is recommended for a representative sample.
2. Wells that can be pumped or bailed to dryness with the sampling equipment being used, shall be evacuated and allowed to recover prior to sample withdrawal. If the recovery rate is fairly rapid and time allows, evacuation of at least three well volumes of water is preferred; otherwise, a sample will be taken when enough water is available to fill the sample containers.

Stratification of contaminants may exist in the aquifer formation. This is from concentration gradients due to dispersion and diffusion processes in a homogeneous layer, and from

separation of flow streams by physical division (for example, around clay leases) or by contrasts in permeability (for example, between a layer of silty, fine sand and a layer of medium sand).

Pumping rates and volumes for non-production wells during sampling development should be moderate; pumping rates for production wells should be maintained at the rate normal for that well. Excessive pumping can dilute or increase the contaminant concentrations in the recovered sample compared to what is representative of the integrated water column at that point, thus result in the collection of a non-representative sample. Water produced during purging shall be collected, stored or treated and discharged as allowed. Disposition of purge water is usually site specific and must be addressed in the Sampling and Analysis Plan.

5.1 Sampling, Monitoring, and Evacuation Equipment

Sample containers shall conform with EPA regulations for the appropriate contaminants and to the specific Quality Assurance Project Plan.

The following list is an example of the type of equipment that generally must be on hand when sampling groundwater wells:

1. Sample packaging and shipping equipment - Coolers for sample shipping and cooling, chemical preservatives, and appropriate packing cartons and filler, labels and chain-of-custody documents.
2. Field tools and instrumentation - Thermometer; pH meter; specific conductivity meter; appropriate keys (for locked wells) or bolt-cutter; tape measure; water-level indicator; and, where applicable, flow meter.
3. Pumps
 - a. Shallow-well pumps - Centrifugal, pitcher, suction, or peristaltic pumps with droplines, air-lift apparatus (compressor and tubing), as applicable.
 - b. Deep-well pumps - Submersible pump and electrical power generating unit, bladder pump with compressed air source, or air-lift apparatus, as applicable.
4. Tubing - Sample tubing such as teflon, polyethylene, polypropylene, or PVC. Tubing type shall be selected based on specific site requirements and must be chemically inert to the groundwater being sampled.
5. Other Sampling Equipment - Bailers, teflon-coated wire, stainless steel single strand wire, and polypropylene monofilament line (not acceptable in EPA Region I) with

tripod-pulley assembly (if necessary). Bailers shall be used to obtain samples for volatile organics from shallow and deep groundwater wells.

6. Pails - Plastic, graduated.
7. Decontamination solutions - Decontamination materials are discussed in SOP F501 and F502.

Ideally, sample withdrawal equipment should be completely inert, economical, easily cleaned, sterilized, and reusable, able to operate at remote sites in the absence of power sources, and capable of delivering variable rates for well flushing and sample collection.

5.2 Calculations of Well Volume

Calculation of gallons/linear feet from a well

$$V = \pi r^2 h$$

Where: V = volume of standing water in well
r = well radius
h = feet of standing water in well

Table 5-1 lists gallons and cubic feet of water per standing foot of water for a variety of well diameter.

TABLE 5-1
WELL VOLUMES

Diameter of Casing or Hole (in.)	Gallons per Foot of Depth	Cubic Feet per Foot of Depth
1	0.041	0.0055
2	0.163	0.0218
4	0.653	0.0873
6	1.469	0.1963
8	2.611	0.3491
10	4.080	0.5454

Notes:

1. Gallons per foot of depth will be multiplied by amount of standing water to obtain well volume quantity.
2. 1 gallon = 3.785 liters
1 meter = 3.281 feet
1 gallon water weighs 8.33 pounds = 3.785 kilograms
1 liter water weighs 1 kilogram = 2.205 pounds
1 gallon per foot of depth = 12.419 liters per foot of depth
1 gallon per meter of depth = 12.419 x 10⁻³ cubic meters per meter of depth

To insure that the proper volume of water has been removed from the well prior to sampling, it is first necessary to determine the volume of standing water in the well pipe or casing. The volume can be easily calculated by the following method. Calculations shall be entered in the field logbook:

1. Obtain all available information on well construction (location, casing, screens, etc.).
2. Determine well or casing diameter.
3. Measure and record static water level (depth below ground level or top of casing reference point), using one of the methods described in Section 5.1 of SOP F202.
4. Determine the depth of the well (if not known from past records) to the nearest 0.01-foot by sounding using a clean, decontaminated weighted tape measure.
5. Calculate number of linear feet of static water (total depth or length of well pipe or casing minus the depth to static water level).
6. Calculate the volume of water in the casing:

$$VW = \pi D^2 (TD - DW)$$

$$V_{gal} = VW \times 7.48 \text{ gallons/ft}^3$$

$$V_{purge} = V_{gal} (\# \text{ Well Vol})$$

Where:

VW = Volume of water in well in cubic feet (i.e., one well volume)
 π = pi, 3.14
 D = Well diameter in feet (use $(D/12)$ if D is in inches)
 TD = Total depth of well in feet (below ground surface or top of casing)
 DW = Depth to water in feet (below ground surface or top of casing)
 V_{gal} = Volume of water in well in gallons
 V_{purge} = Volume of water to be purged from well in gallons
 $\# \text{ Well Vol.}$ = Number of well volumes of water to be purged from the well (typically three to five)

7. Determine the minimum number of gallons to be evacuated before sampling. (Note: V_{purge} should be rounded to the next highest whole gallon. For example, 7.2 gallons should be rounded to 8 gallons.)

5.3 Evacuation of Static Water (Purging)

The amount of flushing a well should receive prior to sample collection will depend on the intent of the monitoring program and the hydrogeologic conditions. Programs to determine overall quality of water resources may require long pumping periods to obtain a sample that is representative of a large volume of that aquifer. The pumped volume may be specified prior to sampling so that the sample can be a composite of a known volume of the aquifer.

For defining a contaminant plume, a representative sample of only a small volume of the aquifer is required. These circumstances require that the well be pumped enough to remove the stagnant water but not enough to induce significant groundwater flow from a wide area. Generally, three to five well volumes are considered effective for purging a well.

An alternative method of purging a well, and one accepted in EPA Regions I and IV, is to purge a well continuously (usually using a low volume, low flow pump) while monitoring specific conductance, pH, and water temperature until the values stabilize. The well is considered properly purged when the values have stabilized.

The Project Manager shall define the objectives of the groundwater sampling program in the Sampling and Analysis Plan, and provide appropriate criteria and guidance to the sampling personnel on the proper methods and volumes of well purging.

5.3.1 Evacuation Devices

The following discussion is limited to those devices which are commonly used at hazardous waste sites. Note that all of these techniques involve equipment which is portable and readily available.

Bailers - Bailers are the simplest evacuation devices used and have many advantages. They generally consist of a length of pipe with a sealed bottom (bucket-type bailer) or, as is more useful and favored, with a ball check-valve at the bottom. An inert line (e.g., Teflon-coated) is used to lower the bailer and retrieve the sample.

Advantages of bailers include:

- Few limitations on size and materials used for bailers.
- No external power source needed.
- Inexpensive.
- Minimal outgassing of volatile organics while the sample is in the bailer.
- Relatively easy to decontaminate.

Limitations on the use of bailers include the following:

- Potentially excessively time consuming to remove stagnant water using a bailer.
- Transfer of sample may cause aeration.
- Use of bailers is physically demanding, especially in warm temperatures at protection levels above Level D.

Suction Pumps - There are many different types of inexpensive suction pumps including centrifugal, diaphragm, peristaltic, and pitcher pumps. Centrifugal and diaphragm pumps can be used for well evacuation at a fast pumping rate and for sampling at a low pumping rate. The peristaltic pump is a low volume pump (generally not suitable for well purging) that uses rollers to squeeze a flexible tubing, thereby creating suction. This tubing can be dedicated to a well to prevent cross contamination. The pitcher pump is a common farm hand-pump.

These pumps are all portable, inexpensive and readily available. However, because they are based on suction, their use is restricted to areas with water levels within 10 to 25 feet of the ground surface. A significant limitation is that the vacuum created by these pumps will cause significant loss of dissolved gases, including volatile organics. In addition, the complex internal components of these pumps may be difficult to decontaminate.

Gas-Lift Samples - This group of samplers uses gas pressure either in the annulus of the well or in a venturi to force the water up a sampling tube. These pumps are also relatively inexpensive. Gas lift pumps are more suitable for well development than for sampling because the samples may be aerated, leading to pH changes and subsequent trace metal precipitation or loss of volatile organics. An inert gas such as nitrogen is generally used as a gas source.

Submersible Pumps - Submersible pumps take in water and push the sample up a sample tube to the surface. The power sources for these samplers may be compressed air or

electricity. The operation principles vary and the displacement of the sample can be by an inflatable bladder, sliding piston, gas bubble, or impeller. Pumps are available for two-inch diameter wells and larger. These pumps can lift water from considerable depths (several hundred feet).

Limitations of this class of pumps include:

- Potentially low delivery rates.
- Many models of these pumps are expensive.
- Compressed gas or electric power is needed.
- Sediment in water may cause clogging of the valves or eroding the impellers with some of these pumps.
- Decontamination of internal components is difficult and time-consuming.

5.4 Sampling

The sampling approach consisting of the following, should be developed as part of the Sampling and Analysis Plan prior to the field work:

1. Background and objectives of sampling.
2. Brief description of area and waste characterization.
3. Identification of sampling locations, with map or sketch, and applicable well construction data (well size, depth, screened interval, reference elevation).
4. Sampling equipment to be used.
5. Intended number, sequence volumes, and types of samples. If the relative degrees of contamination between wells is unknown or insignificant, a sampling sequence which facilitates sampling logistics may be followed. Where some wells are known or strongly suspected of being highly contaminated, these should be sampled last to reduce the risk of cross-contamination between wells as a result of the sampling procedures.
6. Sample preservation requirements.
7. Schedule.
8. List of team members.
9. Other information, such as the necessity for a warrant or permission of entry, requirement for split samples, access problems, location of keys, etc.

5.4.1 Sampling Methods

The collection of a groundwater sample includes the following steps:

1. First open the well cap and use volatile organic detection equipment (HNU or OVA) on the escaping gases at the well head to determine the need for respiratory protection. This task is usually performed by the Field Team Leader, Health and Safety Officer, or other designee.
2. When proper respiratory protection has been donned, sound the well for total depth and water level (decontaminated equipment) and record these data in the field logbook. Calculate the fluid volume in the well according to Section 5.2 of this SOP.
3. Lower purging equipment or intake into the well to a short distance below the water level and begin water removal. Collect the purged water and dispose of it in an acceptable manner (e.g., DOT-approved 55-gallon drum).
4. Measure the rate of discharge frequently. A bucket and stopwatch are most commonly used; other techniques include using pipe trajectory methods, weir boxes or flow meters.
5. Observe peristaltic pump intake for degassing "bubbles" and all pump discharge lines. If bubbles are abundant and the intake is fully submerged, this pump is not suitable for collecting samples for volatile organics. The preferred method for collecting volatile organic samples and the accepted method by EPA Regions I through IV is with a bailer.
6. Purge a minimum of three to five well volumes before sampling. In low permeability strata (i.e., if the well is pumped to dryness), one volume will suffice. Allow the well to recharge as necessary, but preferably to 70 percent of the static water level, and then sample.
7. Record measurements of specific conductance, temperature, and pH during purging to ensure the groundwater stabilizes. Generally, these measurements are made after three, four, and five well volumes.
8. If sampling using a pump, lower the pump intake to midscreen or the middle of the open section in uncased wells and collect the sample. If sampling with a bailer, lower the bailer to the sampling level before filling (this requires use of other than a "bucket-type" bailer). Purged water should be collected in a designated container and disposed of in an acceptable manner.
9. (For pump and packer assembly only). Lower assembly into well so that packer is positioned just above the screen or open section and inflate. Purge a volume equal to at least twice the screened interval or unscreened open section volume below the packer before sampling. Packers should always be tested in a casing section above ground to determine proper inflation pressures for good sealing.
10. In the event that recovery time of the well is very slow (e.g., 24 hours), sample collection can be delayed until the following day. If the well has been bailed early in

the morning, sufficient water may be standing in the well by the day's end to permit sample collection. If the well is incapable of producing a sufficient volume of sample at any time, take the largest quantity available and record in the logbook.

11. Add preservative if required (see SOP F301). Label, tag, and number the sample bottle(s).
12. Purgeable organics vials (40 ml) should be completely filled to prevent volatilization and extreme caution should be exercised when filling a vial to avoid turbulence which could also produce volatilization. The sample should be carefully poured down the side of the vial to minimize turbulence. As a rule, it is best to gently pour the last few drops into the vial so that surface tension holds the water in a "convex meniscus." The cap is then applied and some overflow is lost, but air space in the bottle is eliminated. After capping, turn the bottle over and tap it to check for bubbles; if any are present, repeat the procedure.
13. Replace the well cap. Make sure the well is readily identifiable as the source of the samples.
14. Pack the samples for shipping (see SOP F301). Attach custody seals to the shipping container. Make sure that Chain-of-Custody forms and Sample Analysis Request forms are properly filled out and enclosed or attached (see SOP F302).
15. Decontaminate all equipment.

5.4.2 Sample Containers

For most samples and analytical parameters, either glass or plastic containers are satisfactory. SOP F301 describes the required sampling containers for various analytes at various concentrations. Container requirements shall follow those given in NEESA 20.2-047B.

5.4.3 Preservation of Samples and Sample Volume Requirements

Sample preservation techniques and volume requirements depend on the type and concentration of the contaminant and on the type of analysis to be performed. SOP F301 describes the sample preservation and volume requirements for most of the chemicals that will be encountered during hazardous waste site investigations. Sample volume and preservation requirements shall follow those given in NEESA 20.2-047B.

5.4.4 Field Filtration

In general, preparation and preservation of water samples involve some form of filtration. All filtration must occur in the field immediately upon collection. The recommended method is through the use of a disposable in-line filtration module (0.45 micron filter) utilizing the pressure provided by the upstream pumping device for its operation.

In Region I, all inorganics are to be collected and preserved in the filtered form, including metals. In Region II, metals samples are to be collected and preserved unfiltered. In Regions III and IV, samples collected for metals analysis are also to be unfiltered. However, if metals analysis of monitoring wells is required, then both an unfiltered and filtered sample are to be collected, regardless of regulatory requirements. Filtration and preservation are to occur immediately in the field with the sample aliquot passing through a 0.45 micron filter. Samples for organic analyses shall never be filtered. Filters must be prerinsed with organic-free, deionized water.

5.4.5 Handling and Transporting Samples

After collection, samples should be handled as little as possible. It is preferable to use self-contained "chemical" ice (e.g., "blue ice") to reduce the risk of contamination. If water ice is used, it should be double-bagged and steps taken to ensure that the melted ice does not cause sample containers to be submerged, and thus possibly become cross-contaminated. All sample containers should be enclosed in plastic bags or cans to prevent cross-contamination. Samples should be secured in the ice chest to prevent movement of sample containers and possible breakage. Sample packing and transportation requirements are described in SOP F301.

5.4.6 Sample Holding Times

Holding times (i.e., allowed time between sample collection and analysis) for routine samples are given in NEESA 20.2-047B.

6.0 QUALITY ASSURANCE RECORDS

Quality assurance records will be maintained for each sample that is collected. The following information will be recorded in the Field Logbook:

- Sample identification (site name, location, project no.; sample name/number and location; sample type and matrix; time and date; sampler's identity).
- Sample source and source description.
- Field observations and measurements (appearance; volatile screening; field chemistry; sampling method; volume of water purged prior to sampling; number of well volumes purged).
- Sample disposition (preservatives added; lab sent to; date and time).
- Additional remarks, as appropriate.

Proper chain-of-custody procedures play a crucial role in data gathering. SOP F302 describes the requirements for correctly completing a chain-of-custody form. Chain-of-custody forms (and sample analysis request forms) are considered quality assurance records.

7.0 REFERENCES

American Society of Testing and Materials. 1987. Standard Guide for Sampling Groundwater Monitoring Wells. Method D4448-85A, Annual Book of Standards, ASTM, Philadelphia, Pennsylvania.

U. S. EPA, 1991. Standard Operating Procedures and Quality Assurance Manual. Environmental Compliance Branch, U. S. EPA, Environmental Services Division, Athens, Georgia.

ATTACHMENT A

ASTM D4448-85A

STANDARD GUIDE FOR SAMPLING GROUNDWATER MONITORING WELLS



Standard Guide for Sampling Groundwater Monitoring Wells¹

This standard is issued under the fixed designation D 4448; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide covers procedures for obtaining valid, representative samples from groundwater monitoring wells. The scope is limited to sampling and "in the field" preservation and does not include well location, depth, well development, design and construction, screening, or analytical procedures.

1.2 This guide is only intended to provide a review of many of the most commonly used methods for sampling groundwater quality monitoring wells and is not intended to serve as a groundwater monitoring plan for any specific application. Because of the large and ever increasing number of options available, no single guide can be viewed as comprehensive. The practitioner must make every effort to ensure that the methods used, whether or not they are addressed in this guide, are adequate to satisfy the monitoring objectives at each site.

1.3 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of whoever uses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Summary of Guide

2.1 The equipment and procedures used for sampling a monitoring well depend on many factors. These include, but are not limited to, the design and construction of the well, rate of groundwater flow, and the chemical species of interest. Sampling procedures will be different if analyzing for trace organics, volatiles, oxidizable species, or trace metals is needed. This guide considers all of these factors by discussing equipment and procedure options at each stage of the sampling sequence. For ease of organization, the sampling process can be divided into three steps: well flushing, sample withdrawal, and field preparation of samples.

2.2 Monitoring wells must be flushed prior to sampling so that the groundwater is sampled, not the stagnant water in the well casing. If the well casing can be emptied, this may be done although it may be necessary to avoid oxygen contact with the groundwater. If the well cannot be emptied, procedures must be established to demonstrate that the sample represents groundwater. Monitoring an indicative parameter such as pH during flushing is desirable if such a parameter can be identified.

2.3 The types of species that are to be monitored as well as the concentration levels are prime factors for selecting sampling devices (1, 2).² The sampling device and all materials and devices the water contacts must be constructed of materials that will not introduce contaminants or alter the analyte chemically in any way.

2.4 The method of sample withdrawal can vary with the parameters of interest. The ideal sampling scheme would employ a completely inert material, would not subject the sample to negative pressure and only moderate positive pressure, would not expose the sample to the atmosphere, or preferably, any other gaseous atmosphere before conveying it to the sample container or flow cell for on-site analysis.

2.5 The degree and type of effort and care that goes into a sampling program is always dependent on the chemical species of interest and the concentration levels of interest. As the concentration level of the chemical species of analytical interest decreases, the work and precautions necessary for sampling are increased. Therefore, the sampling objective must clearly be defined ahead of time. For example, to prepare equipment for sampling for mg/L (ppm) levels of Total Organic Carbon (TOC) in water is about an order of magnitude easier than preparing to sample for $\mu\text{g/L}$ (ppb) levels of a trace organic like benzene. The specific precautions to be taken in preparing to sample for trace organics are different from those to be taken in sampling for trace metals. No final Environmental Protection Agency (EPA) protocol is available for sampling of trace organics. A short guidance manual, (3) and an EPA document (4) concerning monitoring well sampling, including considerations for trace organics are available.

2.6 Care must be taken not to cross contaminate samples or monitoring wells with sampling or pumping devices or materials. All samples, sampling devices, and containers must be protected from the environment when not in use. Water level measurements should be made before the well is flushed. Oxidation-reduction potential, pH, dissolved oxygen, and temperature measurements and filtration should all be performed on the sample in the field, if possible. All but temperature measurement must be done prior to any significant atmospheric exposure, if possible.

2.7 The sampling procedures must be well planned and all sample containers must be prepared and labeled prior to going to the field.

3. Significance and Use

3.1 The quality of groundwater has become an issue of national concern. Groundwater monitoring wells are one of

¹ This guide is under the jurisdiction of ASTM Committee D-34 on Waste Disposal and is the direct responsibility of Subcommittee D34.01 on Sampling and Monitoring.

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² The boldface numbers in parentheses refer to a list of references at the end of this guide.

TABLE 1 Typical Container and Preservation Requirements for a Ground-Water Monitoring Program

Sample and Measurement	Volume Required (mL)	Container P—Polyethylene G—Glass	Preservative	Maximum Holding Time
Metals As/Ba/Cd/Cr/Fe Pb/Sc/ Ag/Mn/Na	1000–2000	P/G (special acid cleaning)	high purity nitric acid to pH <2	6 months
Mercury	200–300	P/G (special acid cleaning)	high purity nitric acid to pH <2 +0.05 % K ₂ Cr ₂ O ₇	28 days
Radioactivity alpha/beta/radium	4000	P/G (special acid cleaning)	high purity nitric acid to pH <2	6 months
Phenolics	500–1000	G	cool, 4°C H ₂ SO ₄ to pH <2	28 days
Miscellaneous	1000–2000	P	cool, 4°C	28 days
Fluoride	300–500	P		28 days
Chloride	50–200	P/G		28 days
Sulfate	100–500	P/G		48 hours
Nitrate	100–250	P/G		6 h
Coliform	100	P/G		on site/24 h
Conductivity	100	P/G		on site/6 h
pH	100	P/G		48 h
Turbidity	100	P/G		
Total organic carbon (TOC)	25–100	P/G	cool, 4°C or cool, 4°C HCl or H ₂ SO ₄ to pH <2	24 h
Pesticides, herbicides and total organic halogen (TOX)	1000–4000	G/TFE-fluorocarbon lined cap solvent rinsed	cool, 4°C	28 days
Extractable organics	1000–2000	G/TFE-fluorocarbon-lined cap solvent rinsed	cool, 4°C	7 days/extraction +30 days/analysis
Organic purgeables acrolein/acrylonitrile	25–120	G/vial TFE-fluorocarbon-lined septum	cool, 4°C	14 days 3 days

the more important tools for evaluating the quality of groundwater, delineating contamination plumes, and establishing the integrity of hazardous material management facilities.

3.2 The goal in sampling groundwater monitoring wells is to obtain samples that are truly representative of the aquifer or groundwater in question. This guide discusses the advantages and disadvantages of various well flushing, sample withdrawal, and sample preservation techniques. It reviews the parameters that need to be considered in developing a valid sampling plan.

4. Well Flushing (Purging)

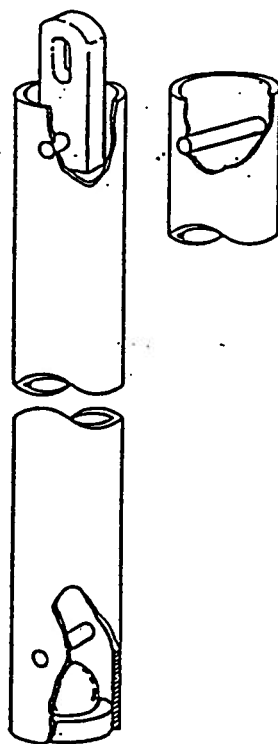
4.1 Water that stands within a monitoring well for a long period of time may become unrepresentative of formation water because chemical or biochemical change may cause water quality alterations and even if it is unchanged from the time it entered the well, the stored water may not be representative of formation water at the time of sampling, or both. Because the representativeness of stored water is questionable, it should be excluded from samples collected from a monitoring well.

4.2 The surest way of accomplishing this objective is to remove all stored water from the casing prior to sampling. Research with a tracer in a full scale model 2 in. PVC well (5) indicates that pumping 5 to 10 times the volume of the well via an inlet near the free water surface is sufficient to remove all the stored water in the casing. The volume of the well may

be calculated to include the well screen and any gravel pack if natural flow through these is deemed insufficient to keep them flushed out.

4.3 In deep or large diameter wells having a volume of water so large as to make removal of all the water impractical, it may be feasible to lower a pump or pump inlet to some point well below the water surface, purge only the volume below that point then withdraw the sample from a deeper level. Research indicates this approach should avoid most contamination associated with stored water (5, 6, 7). Sealing the casing above the purge point with a packer may make this approach more dependable by preventing migration of stored water from above. But the packer must be above the top of the screened zone, or stagnant water from above the packer will flow into the purged zone through the well's gravel/sand pack.

4.4 In low yielding wells, the only practical way to remove all standing water may be to empty the casing. Since it is not always possible to remove all water, it may be advisable to let the well recover (refill) and empty it again at least once. If introduction of oxygen into the aquifer may be of concern, it would be best not to uncover the screen when performing the above procedures. The main disadvantage of methods designed to remove all the stored water is that large volumes may need to be pumped in certain instances. The main advantage is that the potential for contamination of samples with stored water is minimized.



NOTE—Taken from Ref (15).

FIG. 1 Single Check Valve Baller

4.5 Another approach to well flushing is to monitor one or more indicator parameters such as pH, temperature, or conductivity and consider the well to be flushed when the indicator(s) no longer change. The advantage of this method is that pumping can be done from any location within the casing and the volume of stored water present has no direct bearing on the volume of water that must be pumped. Obviously, in a low yielding well, the well may be emptied before the parameters stabilize. A disadvantage of this approach is that there is no assurance in all situations that the stabilized parameters represent formation water. If significant drawdown has occurred, water from some distance away may be pulled into the screen causing a steady parameter reading but not a representative reading. Also, a suitable indicator parameter and means of continuously measuring it in the field must be available.

4.6 Gibb (4, 8) has described a time-drawdown approach using a knowledge of the well hydraulics to predict the percentage of stored water entering a pump inlet near the top of the screen at any time after flushing begins. Samples are taken when the percentage is acceptably low. As before, the advantage is that well volume has no direct effect in the duration of pumping. A current knowledge of the well's hydraulic characteristics is necessary to employ this approach. Downward migration of stored water due to effects other than drawdown (for example density differences) is not accounted for in this approach.

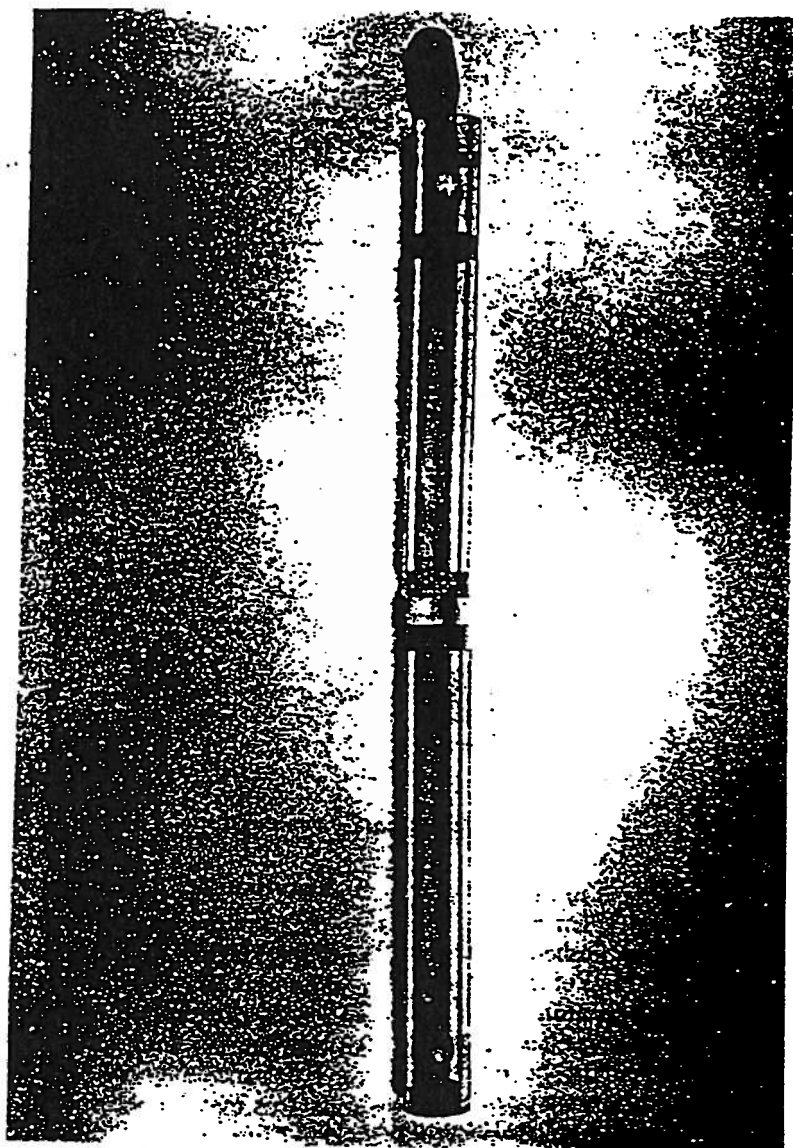
4.7 In any flushing approach, a withdrawal rate that minimizes drawdown while satisfying time constraints should be used. Excessive drawdown distorts the natural flow patterns around a well and can cause contaminants that were not present originally to be drawn into the well.

5. Materials and Manufacture

5.1 The choice of materials used in the construction of sampling devices should be based upon a knowledge of what compounds may be present in the sampling environment and how the sample materials may interact via leaching, adsorption, or catalysis. In some situations, PVC or some other plastic may be sufficient. In others, an all glass apparatus may be necessary.

5.2 Most analytical protocols suggest that the devices used in sampling and storing samples for trace organics analysis ($\mu\text{g/L}$ levels) must be constructed of glass or TFE-fluorocarbon resin, or both. One suggestion advanced by the EPA is that the monitoring well be constructed so that only TFE-fluorocarbon tubing be used in that portion of the sampling well that extends from a few feet above the water table to the bottom of the borehole. (3, 5) Although this type of well casing is now commercially available, PVC well casings are currently the most popular. If adhesives are avoided, PVC well casings are acceptable in many cases although their use may still lead to some problems if trace organics are of concern. At present, the type of background presented by PVC and interactions occurring between PVC and groundwater are not well understood. Tin, in the form of an organotin stabilizer added to PVC, may enter samples taken from PVC casing. (9)

5.3 Since the most significant problem encountered in trace organics sampling, results from the use of PVC adhesives in monitoring well construction, threaded joints might avoid the problem (3, 5). Milligram per litre (parts per million) levels of compounds such as tetrahydrofuran, methyl-ethyl-ketone, and toluene are found to leach into



NOTE—Taken from Ref (17).

FIG. 2 Acrylic Point Source Baller

groundwater samples from monitoring well casings sealed with PVC solvent cement. Pollutant phthalate esters (8, 10) are often found in water samples at ppb levels; the EPA has found them on occasion at ppm levels in their samples. The ubiquitous presence of these phthalate esters is unexplained, except to say that they may be leached from plastic pipes, sampling devices, and containers.

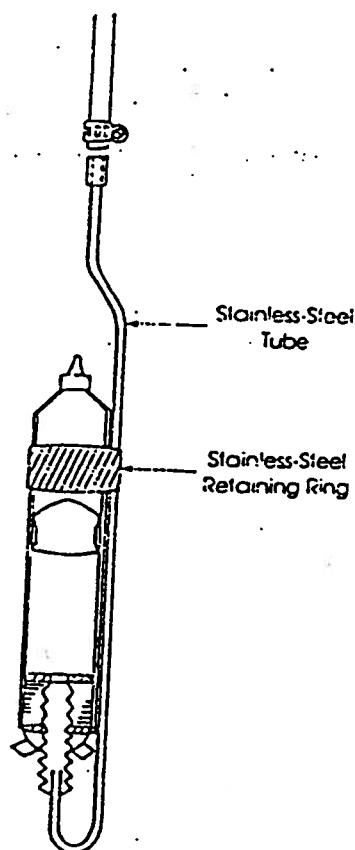
5.4 TFE-fluorocarbon resins are highly inert and have sufficient mechanical strength to permit fabrication of sampling devices and well casings. Molded parts are exposed to high temperature during fabrication which destroys any organic contaminants. The evolution of fluorinated compounds can occur during fabrication, will cease rapidly, and does not occur afterwards unless the resin is heated to its melting point.

5.5 Extruded tubing of TFE-fluorocarbon for sampling may contain surface traces of an organic solvent extrusion aid. This can be removed easily by the fabricator and, once

removed by flushing, should not affect the sample. TFE-fluorocarbon FEP and TFE-fluorocarbon PFA resins do not require this extrusion aid and may be suitable for sample tubing as well. Unsintered thread-sealant tape of TFE-fluorocarbon is available in an "oxygen service" grade and contains no extrusion aid and lubricant.

5.6 Louneman, et al. (11) alludes to problems caused by a lubricating oil used during TFE-fluorocarbon tubing extrusion. This reference also presents evidence that a fluorinated ethylene-propylene copolymer adsorbed acetone to a degree that later caused contamination of a gas sample.

5.7 Glass and stainless steel are two other materials generally considered inert in aqueous environments. Glass is probably among the best choices though it is not inconceivable it could adsorb some constituents as well as release other contaminants (for example, Na, silicate, and Fe). Of course, glass sampling equipment must be handled carefully in the field. Stainless steel is strongly and easily machined to



NOTE—Taken from Ref (21).

FIG. 3 Schematic of the Inverted Syringe Sampler

fabricate equipment. Unfortunately, it is not totally immune to corrosion that could release metallic contaminants. Stainless steel contains various alloying metals, some of these (for example Ni) are commonly used as catalysts for various reactions. The alloyed constituents of some stainless steels can be solubilized by the pitting action of nonoxidizing anions such as chloride, fluoride, and in some instances sulfate, over a range of pH conditions. Aluminum, titanium, polyethylene, and other corrosion resistant materials have been proposed by some as acceptable materials, depending on groundwater quality and the constituents of interest.

5.8 Where temporarily installed sampling equipment is used, the sampling device that is chosen should be non-plastic (unless TFE-fluorocarbon), cleanable of trace organics, and must be cleaned between each monitoring well use in order to avoid cross-contamination of wells and samples. The only way to ensure that the device is indeed "clean" and acceptable is to analyze laboratory water blanks and field water blanks that have been soaked in and passed through the sampling device to check for the background levels that may result from the sampling materials or from field conditions. Thus, all samplings for trace materials should be accompanied by samples which represent the field background (if possible), the sampling equipment background, and the laboratory background.

5.9 Additional samples are often taken in the field and spiked (spiked-field samples) in order to verify that the sample handling procedures are valid. The American Chem-

ical Society's committee on environmental improvement has published guidelines for data acquisition and data evaluation which should be useful in such environmental evaluation (10, 12).

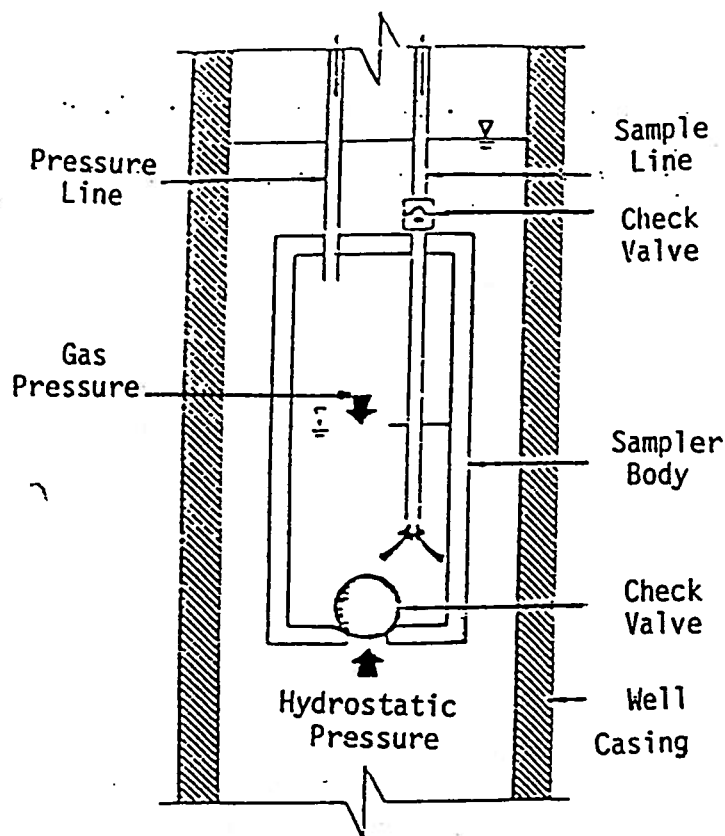
6. Sampling Equipment

6.1 There is a fairly large choice of equipment presently available for groundwater sampling from single screened wells and well clusters. The sampling devices can be categorized into the following eight basic types.

6.1.1 Down-Hole Collection Devices:

6.1.1.1 Bailers, messenger bailers, or thief samplers (10, 14) are examples of down-hole devices that probably provide valid samples once the well has been flushed. They are not practical for removal of large volumes of water. These devices can be constructed in various shapes and sizes from a variety of materials. They do not subject the sample to pressure extremes.

6.1.1.2 Bailers do expose part of the sample to the atmosphere during withdrawal. Bailers used for sampling of volatile organic compounds should have a sample cock or draft valve in or near the bottom of the sampler allowing withdrawal of a sample from the well below the exposed surface of the water or the first few inches of the sample should be discarded. Suspension lines for bailers and other samplers should be kept off the ground and free of other contaminating materials that could be carried into the well. Down-hole devices are not very practical for use in deep



NOTE—Taken from Ref (5).

FIG. 4 The Principal of Gas Displacement Pumping

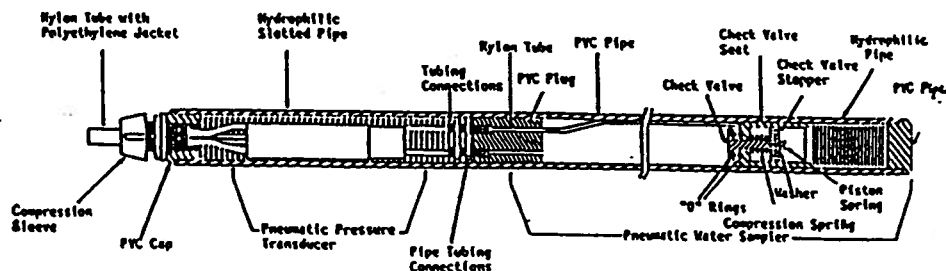
wells. However, potential sample oxidation during transfer of the sample into a collection vessel and time constraints for lowering and retrieval for deep sampling are the primary disadvantages.

6.1.1.3 Three down-hole devices are the single and double check valve bailers and thief samplers. A schematic of a single check valve unit is illustrated in Fig. 1. The bailer may be threaded in the middle so that additional lengths of blank casing may be added to increase the sampling volume. TFE-fluorocarbon or PVC are the most common materials used for construction (15).

6.1.1.4 In operation, the single check valve bailer is lowered into the well, water enters the chamber through the bottom, and the weight of the water column closes the check

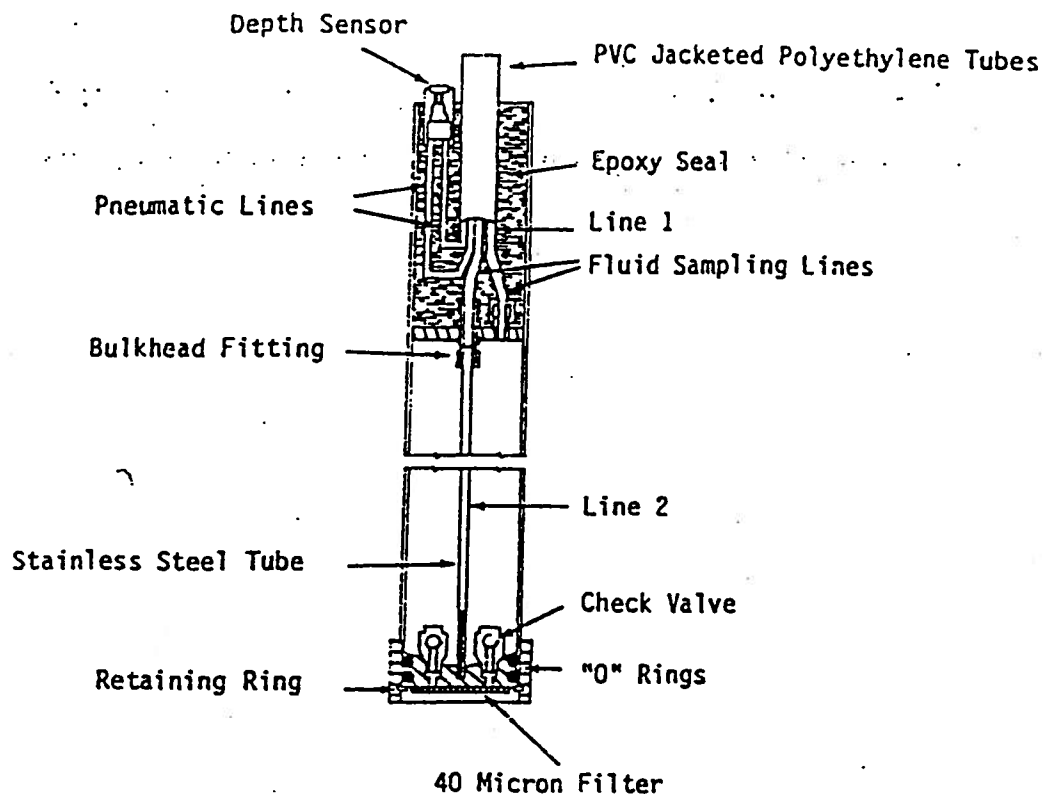
valve upon bailer retrieval. The specific gravity of the ball should be about 1.4 to 2.0 so that the ball almost sits on the check valve seat during chamber filling. Upon bailer withdrawal, the ball will immediately seat without any samples loss through the check valve. A similar technique involves lowering a sealed sample container within a weighted bottle into the well. The stopper is then pulled from the bottle via a line and the entire assembly is retrieved upon filling of the container (14, 16).

6.1.1.5 A double check valve bailer allows point source sampling at a specific depth (15, 17). An example is shown in Fig. 2. In this double check valve design, water flows through the sample chamber as the unit is lowered. A venturi tapered inlet and outlet ensures that water passes freely through the



NOTE—Taken from Ref (41).

FIG. 5 Pneumatic Water Sampler With Internal Transducer



NOTE—Taken from Ref (42).

FIG. 6 Pneumatic Sampler With Externally Mounted Transducer

unit. When a depth where the sample is to be collected is reached, the unit is retrieved. Because the difference between each ball and check valve seat is maintained by a pin that blocks vertical movement of the check ball, both check valves close simultaneously upon retrieval. A drainage pin is placed into the bottom of the bailer to drain the sample directly into a collection vessel to reduce the possibility of air oxidation. The acrylic model in Fig. 2 is threaded at the midsection allowing the addition of threaded casing to increase the sampling volume.

6.1.1.6 Another approach for obtaining point source samples employs a weighted messenger or pneumatic change to "trip" plugs at either end of an open tube (for example, tube water sampler or thief sampler) to close the chamber (18). Foerst, Kemmerer, and Bacon samplers are of this variety (14, 17, 19). A simple and inexpensive pneumatic sampler was recently described by Gillham (20). The device (Fig. 3) consists of a disposable 50 mL plastic syringe modified by sawing off the plunger and the finger grips. The syringe is then attached to a gas-line by means of a rubber stopper assembly. The gas-line extends to the surface, and is used to drive the stem-less plunger, and to raise and lower the syringe into the hole. When the gas-line is pressurized, the rubber plunger is held at the tip of the syringe. The sampler is then lowered into the installation, and when the desired depth is reached, the pressure in the gas-line is reduced to atmospheric (or slightly less) and water enters the syringe. The sampler is then retrieved from the installation and the syringe detached from the gas-line. After the tip is sealed, the syringe is used as a short-term storage container. A number

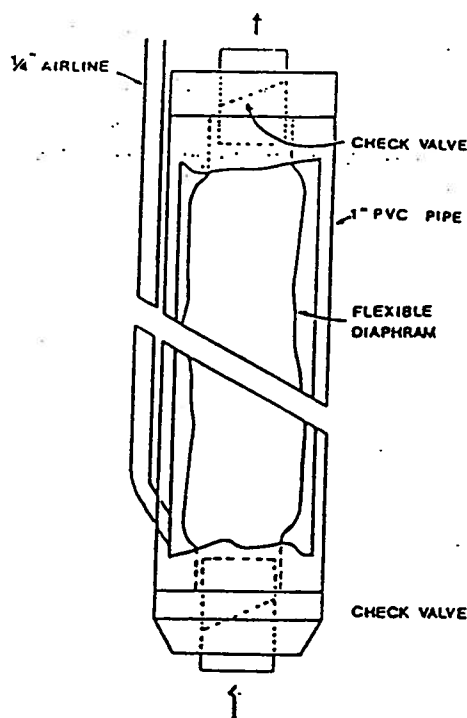
of thief or messenger devices are available in various materials and shapes.

6.1.2 Suction Lift Pumps:

6.1.2.1 Three types of suction lift pumps are the direct line, centrifugal, and peristaltic. A major disadvantage of any suction pump is that it is limited in its ability to raise water by the head available from atmospheric pressure. Thus, if the surface of the water is more than about 25 ft below the pump, water may not be withdrawn. The theoretical suction limit is about 34 ft, but most suction pumps are capable of maintaining a water lift of only 25 ft or less.

6.1.2.2 Many suction pumps draw the water through some sort of volute in which impellers, pistons, or other devices operate to induce a vacuum. Such pumps are probably unacceptable for most sampling purposes because they are usually constructed of common materials such as brass or mild steel and may expose samples to lubricants. They often induce very low pressures around rotating vanes or other such parts such that degassing or even cavitation may occur. They can mix air with the sample via small leaks in the casing, and they are difficult to adequately clean between uses. Such pumps are acceptable for purging of wells, but should not generally be used for sampling.

6.1.2.3 One exception to the above statements is a peristaltic pump. A peristaltic pump is a self-priming, low volume suction pump which consists of a rotor with ball bearing rollers (21). Flexible tubing is inserted around the pump rotor and squeezed by heads as they revolve in a circular pattern around the rotor. One end of the tubing is placed into the well while the other end can be connected



NOTE—Taken from Ref (4).

FIG. 7 Bladder Pump

directly to a receiving vessel. As the rotor moves, a reduced pressure is created in the well tubing and an increased pressure (<40 psi) on the tube leaving the rotor head. A drive shaft connected to the rotor head can be extended so that multiple rotor heads can be attached to a single drive shaft.

6.1.2.4 The peristaltic pump moves the liquid totally within the sample tube. No part of the pump contacts the liquid. The sample may still be degassed (cavitation is unlikely) but the problems due to contact with the pump mechanism are eliminated. Peristaltic pumps do require a fairly flexible section of tubing within the pumphead itself. A section of silicone tubing is commonly used within the peristaltic pumphead, but other types of tubing can be used particularly for the sections extending into the well or from the pump to the receiving container. The National Council of the Paper Industry for Air and Stream Improvement (22) recommends using medical grade silicone tubing for organic sampling purposes as the standard grade uses an organic vulcanizing agent which has been shown to leach into samples. Medical grade silicone tube is, however, limited to use over a restricted range of ambient temperatures. Various manufacturers offer tubing lined with TFE-fluorocarbon or Viton³ for use with their pumps. Gibb (1, 8) found little difference between samples withdrawn by a peristaltic pump and those taken by a bailer.

6.1.2.5 A direct method of collecting a sample by suction consists of lowering one end of a length of plastic tubing into the well or piezometer. The opposite end of the tubing is connected to a two way stopper bottle and a hand held or

mechanical vacuum pump is attached to a second tubing leaving the bottle. A check valve is attached between the two lines to maintain a constant vacuum control. A sample can then be drawn directly into the collection vessel without contacting the pump mechanism (5, 23, 24).

6.1.2.6 A centrifugal pump can be attached to a length of plastic tubing that is lowered into the well. A foot valve is usually attached to the end of the well tubing to assist in priming the tube. The maximum lift is about 4.6 m (15 ft) for such an arrangement (23, 25, 26).

6.1.2.7 Suction pump approaches offer a simple sample retrieval method for shallow monitoring. The direct line method is extremely portable though considerable oxidation and mixing may occur during collection. A centrifugal pump will agitate the sample to an even greater degree although pumping rates of 19 to 151 Lpm (5 to 40 gpm) can be attained. A peristaltic pump provides a lower sampling rate with less agitation than the other two pumps. The withdrawal rate of peristaltic pumps can be carefully regulated by adjustment of the rotor head revolution.

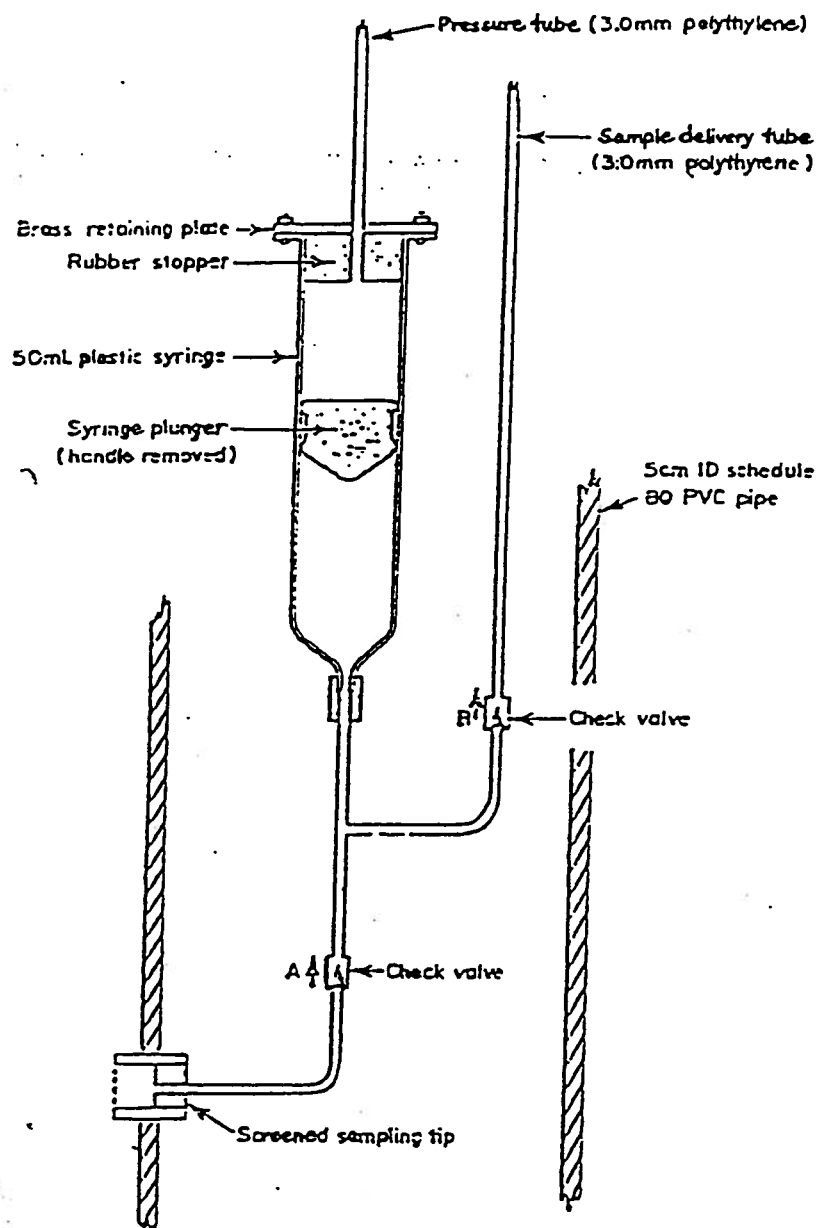
6.1.2.8 All three systems can be specially designed so that the water sample contacts only the TFE fluorocarbon or silicone tubing prior to sample bottle entry. Separate tubing is recommended for each well or piezometer sampled.

6.1.3 Electric Submersible Pumps:

6.1.3.1 A submersible pump consists of a sealed electric motor that powers a piston or helical single thread worm at a high rpm. Water is brought to the surface through an access tube. Such pumps have been used in the water well industry for years and many designs exist (5, 26).

6.1.3.2 Submersible pumps provide relatively high discharge rates for water withdrawal at depths beyond suction

³ Viton is a trademark of E. I. du Pont de Nemours & Co., Wilmington, DE 19898 and has been found suitable for this purpose.



NOTE—Taken from Ref (48).

FIG. 8 Positive Displacement Syringe Pump

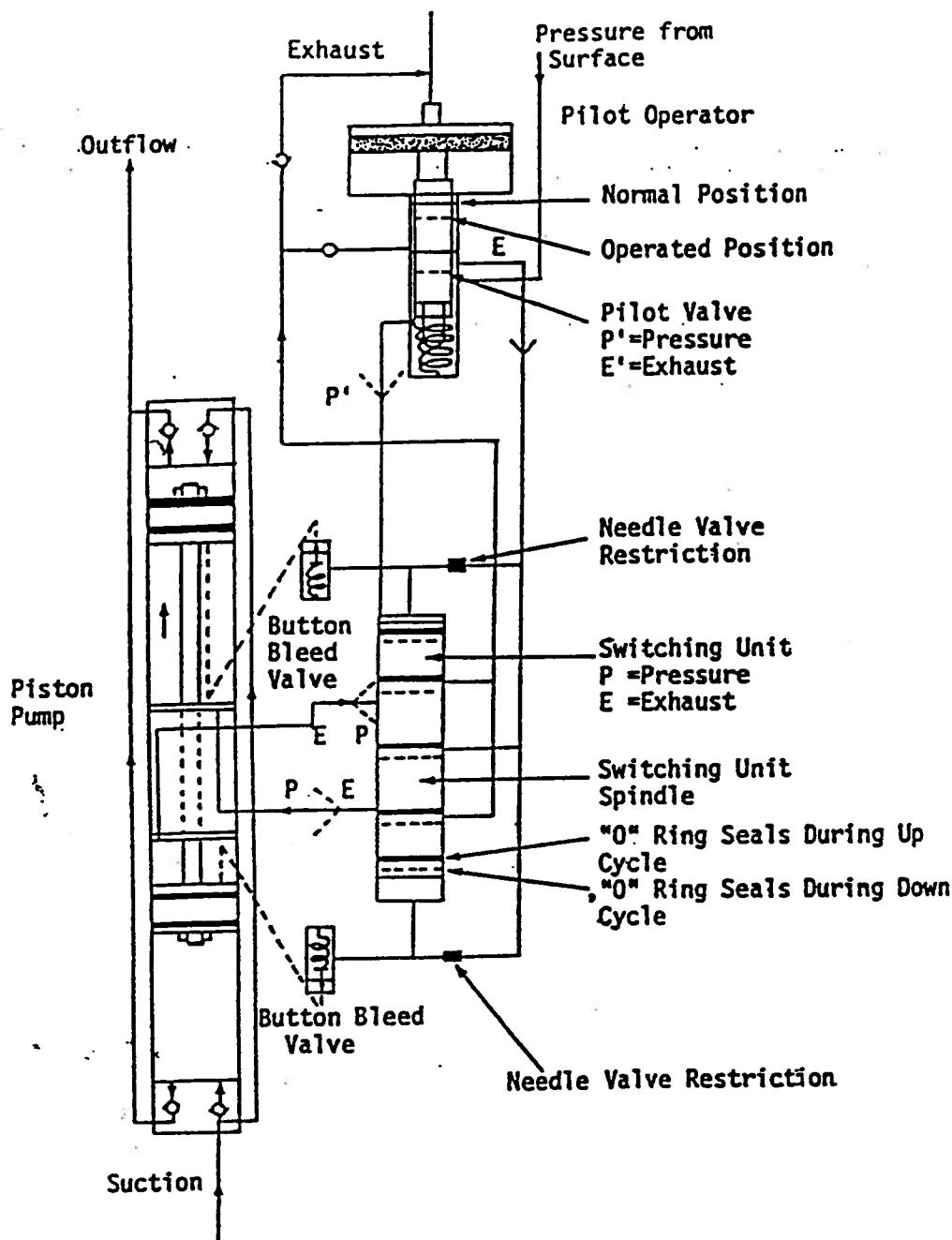
lift capabilities. A battery operated unit 3.6 cm (1.4 in.) in diameter and with a 4.5 Lpm (1.2 gpm) flow rate at 33.5 m (110 ft) has been developed (27). Another submersible pump has an outer diameter of 11.4 cm (4.5 in.) and can pump water from 91 m (300 ft). Pumping rates vary up to 53.0 Lpm (14 gpm) depending upon the depth of the pump (28).

6.1.3.3 A submersible pump provides higher extraction rates than many other methods. Considerable sample agitation results, however, in the well and in the collection tube during transport. The possibility of introducing trace metals into the sample from pump materials also exists. Steam cleaning of the unit followed by rinsing with unchlorinated, deionized water is suggested between sampling when analysis for organics in the parts per million (ppm) or parts per billion (ppb) range is required (29).

6.1.4 Gas-Lift Pumps:

6.1.4.1 Gas-lift pumps use compressed air to bring a water sample to the surface. Water is forced up an eductor pipe that may be the outer casing or a smaller diameter pipe inserted into the well annulus below the water level (30, 31).

6.1.4.2 A similar principle is used for a unit that consists of a small diameter plastic tube perforated in the lower end. This tube is placed within another tube of slightly larger diameter. Compressed air is injected into the inner tube; the air bubbles through the perforations, thereby lifting the water sample via the annulus between the outer and inner tubing (32). In practice, the eductor line should be submerged to a depth equal to 60 % of the total submerged eductor length during pumping (26). A 60 % ratio is considered optimal although a 30 % submergence ratio is adequate.



NOTE—Taken from Ref (49).

FIG. 9 Gas Driven Piston Pump

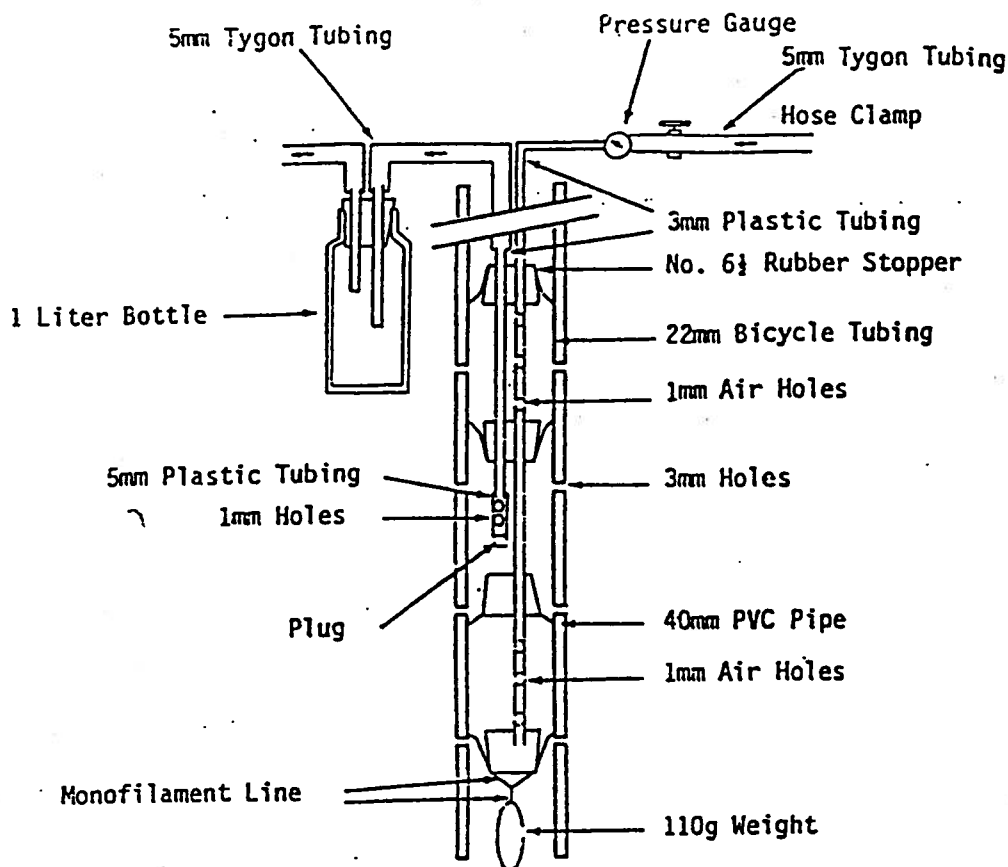
6.1.4.3 The source of compressed gas may be a hand pump for depths generally less than 7.6 m (25 ft). For greater depths, air compressors, pressurized air bottles, and air compressed from an automobile engine have been used.

6.1.4.4 As already mentioned, gas-lift methods result in considerable sample agitation and mixing within the well, and cannot be used for samples which will be tested for volatile organics. The eductor pipe or weighted plastic tubing is a potential source of sample contamination. In addition, Gibb (8) uncovered difficulties in sampling for inorganics. These difficulties were attributed to changes in redox, pH,

and species transformation due to solubility constant changes resulting from stripping, oxidation, and pressure changes.

6.1.5 Gas Displacement Pumps:

6.1.5.1 Gas displacement or gas drive pumps are distinguished from gas-lift pumps by the method of sample transport. Gas displacement pumps force a discrete column of water to the surface via mechanical lift without extensive mixing of the pressurized gas and water as occurs with air-lift equipment. The principle is shown schematically in Fig. 4. Water fills the chamber. A positive pressure is applied to the



NOTE—Taken from Ref (53).

FIG. 10 Packer Pump Arrangement

gas line closing the sampler check valve and forcing water up the sample line. By removing the pressure the cycle can be repeated. Vacuum can also be used in conjunction with the gas (30). The device can be permanently installed in the well (33, 34, 35) or lowered into the well (36, 37).

6.1.5.2 A more complicated two stage design constructed of glass with check valves made of TFE-fluorocarbon has been constructed (38, 39). The unit was designed specifically for sample testing for trace level organics. Continuous flow rates up to 2.3 Lpm (0.6 gpm) are possible with a 5.1 cm (2 in.) diameter unit.

6.1.5.3 Gas displacement pumps have also been developed with multiple functions. The water sample in Fig. 5 provides piezometric data measurements with an internally mounted transducer (40). A sample with its transducer exposed externally for piezometric measurements is illustrated in Fig. 6 (41). The sensor can activate the gas source at the surface to cause sample chamber pressurization at the predetermined depth. Another design can be used as a water sampler or as a tool for injecting brine or other tracers into a well (42).

6.1.5.4 Gas displacement pumps offer reasonable potential for preserving sample integrity because little of the driving gas comes in contact with the sample as the sample is conveyed to the surface by a positive pressure. There is, however, a potential loss of dissolved gasses or contamination from the driving gas and the housing materials.

6.1.6 Bladder Pumps:

6.1.6.1 Bladder pumps, also referred to as gas-operated squeeze pumps, consist of a flexible membrane enclosed by a rigid housing. Water enters the membrane through a check valve in the vessel bottom; compressed gas injected into the cavity between the housing and bladder forces the sample through a check valve at the top of the membrane and into a discharge line (Fig. 7). Water is prevented from re-entering the bladder by the top check valve. The process is repeated to cycle the water to the surface. Samples taken from depths of 30.5 m (100 ft) have been reported.

6.1.6.2 A variety of design modifications and materials are available (43, 44). Bladder materials include neoprene, rubber, ethylene propylene terpolymer (E.P.T.), nitrile, and the fluorocarbon Viton.³ A bladder made of TFE-fluorocarbon is also under development (45). Automated sampling systems have been developed to control the time between pressurization cycles (46).

6.1.6.3 Bladder pumps provide an adaptable sampling tool due primarily to the number of bladder shapes that are feasible. These devices have a distinct advantage over gas displacement pumps in that there is no contact with the driving gas. Disadvantages include the large gas volumes required, low pumping rates, and potential contamination from many of the bladder materials, the rigid housing, or both.

6.1.7 Gas Driven Piston Pumps:

6.1.7.1 A simple and inexpensive example of a gas driven piston pump is a syringe pump (47). The pump (Fig. 8) is constructed from a 50 mL plastic syringe with plunger stem removed. The device is connected to a gas line to the surface and the sample passes through a check valve arrangement to a sampling container at the surface. By successively applying positive and negative pressure to the gas-line, the plunger is activated driving water to the surface.

6.1.7.2 A double piston pump powered by compressed air is illustrated in Fig. 9. Pressurized gas enters the chamber between the pistons; the alternating chamber pressurization activates the piston which allows water entry during the suction stroke of the piston and forces the sample to the surface during the pressure stroke (48). Pumping rates between 9.5 and 30.3 L/hr (2.5 to 8 gal/hr) have been reported from 30.5 m (100 ft). Depths in excess of 457 m (1500 ft) are possible.

6.1.7.3 The gas piston pump provides continuous sample withdrawal at depths greater than is possible with most other approaches. Nevertheless, contribution of trace elements from the stainless steel and brass is a potential problem and the quantity of gas used is significant.

6.1.8 Packer Pump Arrangement:

6.1.8.1 A packer pump arrangement provides a means by which two expandable "packers" isolate a sampling unit between two packers within a well. Since the hydraulic or pneumatic activated packers are wedged against the casing wall or screen, the sampling unit will obtain water samples only from the isolated well portion. The packers are deflated for vertical movement within the well and inflated when the desired depth is attained. Submersible, gas lift, and suction pumps can be used for sampling. The packers are usually constructed from some type of rubber or rubber compound (48, 49, 50, 51). A packer pump unit consisting of a vacuum sampler positioned between two packers is illustrated in Fig. 10 (52).

6.1.8.2 A packer assembly allows the isolation of discrete sampling points within a well. A number of different samplers can be situated between the packers depending upon the analytical specifications for sample testing. Vertical movement of water outside the well casing during sampling is possible with packer pumps but depends upon the pumping rate and subsequent disturbance. Deterioration of the expandable materials will occur with time with the increased possibility of undesirable organic contaminants contributing to the water sample.

7. Sample Containers and Preservation

7.1 Complete and unequivocal preservation of samples, whether domestic wastewater, industrial wastes, or natural waters, is practically impossible. At best, preservation techniques only retard the chemical and biological changes that inevitably continue after the sample is removed from the source. Therefore, insuring the timely analysis of a sample should be one of the foremost considerations in the sampling plan schedule. Methods of preservation are somewhat limited and are intended to retard biological action, retard hydrolysis of chemical compounds and complexes, and reduce the volatility of constituents. Preservation methods are generally limited to pH control, chemical addition, refrigeration and freezing. For water samples, immediate

refrigeration just above freezing (4°C in wet ice) is often the best preservation technique available, but it is not the only measure nor is it applicable in all cases. There may be special cases where it might be prudent to include a recording thermometer in the sample shipment to verify the maximum and minimum temperature to which the samples were exposed. Inexpensive devices for this purpose are available.

7.2 All bottles and containers must be specially pre-cleaned, pre-labelled, and organized in ice-chests (isolating samples and sampling equipment from the environment) before one goes into the field. Otherwise, in any comprehensive program utter chaos usually develops in the field or laboratory. The time in the field is very valuable and should be spent on taking field notes, measurements, and in documenting samples, not on labelling and organizing samples. Therefore, the sampling plan should include clear instructions to the sampling personnel concerning the information required in the field data record logbook (notebook), the information needed on container labels for identification, the chain-of-custody protocols, and the methods for preparing field blanks and spiked samples. Example of detailed plans and documentation procedures have been published (14, 53).

7.3 The exact requirements for the volumes of sample needed and the number of containers to use may vary from laboratory to laboratory. This will depend on the specific analyses to be performed, the concentration levels of interest, and the individual laboratory protocols. The manager of the sampling program should make no assumptions about the laboratory analyses. He should discuss the analytical requirements of the sampling program in detail with the laboratory coordinator beforehand. This is especially the case since some analyses and preservation measures must be performed at the laboratory as soon as possible after the samples arrive. Thus, appropriate arrangements must be made.

7.4 There are a number of excellent references available which list the containers and preservation techniques appropriate for water and soils (13, 14, 50, 54, 55, 56). The "Handbook for Sampling and Sample Preservation of Water and Wastewater" is an excellent reference and perhaps the most comprehensive one (14). Some of this information is summarized in Table 1.

7.5 Sample containers for trace organic samples require special cleaning and handling considerations (57). The sample container for purgeable organics consist of a screw-cap vial (25 to 125 mL) fitted with a TFE-fluorocarbon faced silicone septum. The vial is sealed in the laboratory immediately after cleaning and is only opened in the field just prior to pouring sample into it. The water sample then must be sealed into the vial headspace free (no air bubbles) and immediately cooled (4°C) for shipment. Multiple samples (usually about four taken from one large sample container) are taken because leakage of containers may cause losses, may allow air to enter the containers, and may cause erroneous analysis of some constituents. Also, some analyses are best conducted on independent protected samples.

7.6 The purgeable samples must be analyzed by the laboratory within 14 days after collection, unless they are to be analyzed for acrolein or acrylonitrile (in which case they are to be analyzed within 3 days). For samples for solvent extractions (extractable organics-base neutrals, acids and

pesticides), the sample bottles are narrow mouth, screw cap quart bottles or half-gallon bottles that have been precleaned, rinsed with the extracting organic solvent and oven dried at 105°C for at least 1 h. These bottles must be sealed with TFE-fluorocarbon lined caps (Note). Samples for organic extraction must be extracted within 7 days and analyzed within 30 days after extraction. Special pre-cleaned, solvent rinsed and oven-dried stainless steel beakers (one for each monitoring well) may be used for transferring samples from the sampling device to the sample containers.

NOTE—When collecting samples, the bottles should not be overfilled or prerinsed with sample before filling because oil and other materials may remain in the bottle. This can cause erroneously high results.

7.7 For a number of groundwater parameters, the most meaningful measurements are those made in the field at the time of sample collection or at least at an on-site laboratory. These include the water level in the well and parameters that sometimes can change rapidly with storage. A discussion of the various techniques for measuring the water level in the well is contained in a NCASI publication (5) and detailed procedures are outlined in a U.S. Geological Survey publication (58). Although a discussion of these techniques is beyond the scope of this guide, it is important to point out that accurate measurements must be made before a well is flushed or only after it has had sufficient time to recover. Parameters that can change rapidly with storage include specific conductance, pH, turbidity, redox potential, dissolved oxygen, and temperature. For some of the other

parameters, the emphasis in groundwater monitoring is on the concentration of each specific dissolved component, not the total concentration of each. Samples for these types of measurements should be filtered through 0.45 µm membrane filters ideally in the field or possibly at an on-site laboratory as soon as possible. Analyses often requiring filtered samples include all metals, radioactivity parameters, total organic carbon, dissolved orthophosphate (if needed), and total dissolved phosphorous (if needed) (13, 14). If metals are to be analyzed, filter the sample prior to acid preservation. For TOC organics, the filter material should be tested to assure that it does not contribute to the TOC. The type or size of the filter to be used is not well understood. However, if results of metal, TOC or other parameters that could be effected by solids are to be compared, the same filtering procedure must be used in each case. Repeated analytical results should state whether the samples were filtered and how they were filtered.

7.8 Shipment and receipt of samples must be coordinated with the laboratory to minimize time in transit. All samples for organic analysis (and many other parameters), should arrive at the laboratory within one day after it is shipped and be maintained at about 4°C with wet ice. The best way to get them to the laboratory in good condition is to send them in sturdy insulated ice chests (coolers) equipped with bottle dividers. 24-h courier service is recommended, if personal delivery service is not practical.

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SOP F201
On-Site Water Quality Testing

**ON-SITE WATER QUALITY TESTING
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ON-SITE WATER QUALITY TESTING (FIELD PARAMETERS)

1.0 PURPOSE

This SOP describes the procedures and equipment required to measure the following parameters of an aqueous sample in the field:

- pH
- Specific Conductance (Sc)/Salinity
- Temperature (T)
- Dissolved Oxygen Concentration (DO)
- Turbidity (Secchi Disc)

The first three are the usual field parameters; dissolved oxygen may be used in particular applications according to project requirements.

2.0 SCOPE

These procedures are applicable for use in an on-site water quality monitoring program to be conducted during a Remedial Investigation or Site Investigation at a hazardous or nonhazardous site. The procedures and equipment described are applicable to nearly all aqueous samples, including potable well water, monitoring well water, surface water, leachate and drummed water, etc.

This procedure provides generic information for measuring the parameters listed above with instruments and techniques in common use. Since instruments from different manufacturers may vary, review of the manufacturer's literature pertaining to the use of a specific instrument is required before use.

3.0 DEFINITIONS

Conductance - A measurement of water's capacity for conveying electrical current and is directly related to the concentrations of ionized substances in the water. The units of measurement for conductance are the inverse of ohms, the unit commonly used to express resistance. Conductivity and specific conductance are used synonymously.

Electrolytic Cell - An electrochemical cell in which electrical energy is supplied from an external source. This cell functions in much the same way as a galvanic cell, only in the opposite direction due to the external source of applied voltage.

Galvanic Cell - An electrochemical cell in which chemical energy is spontaneously converted to electrical energy. The electrical energy produced is supplied to an external circuit.

Ohm - Standard unit of electrical resistance (R). A siemen or ohm is the standard unit of electrical conductance, the inverse of the ohm.

Oxidation - The process in which an atom or group of atoms loses electrons to achieve an increasing positive charge.

pH - The negative logarithm (base 10) of the hydrogen ion activity. The hydrogen ion activity is related to the hydrogen ion concentration, and, in a relatively weak solution, the two are nearly equal. Thus, for all practical purposes, pH is a measure of the hydrogen ion concentration.

Resistance - A measure of the solution's ability to oppose the passage of electrical current. For metals and solutions, resistance is defined by Ohm's Law, $E = IR$, where E is the potential difference, I is the current, and R is the resistance.

Secchi disc - A metal disc having four quadrants, two opposing ones painted black and the other two either white or unpainted. The Secchi disc is used to measure turbidity based on the depth of light penetration.

Turbidity - An optical property of water that causes light to be scattered or absorbed in the water, resulting in decrease in water transparency. It is a function of at least three variables: 1) dissolved chemicals, such as tannins, acids, or salts; 2) suspended particles, such as silt, clay, and organic matter; and, 3) density of microbial and planktonic life.

Salinity refers to the total amount of soluble salts in water, either naturally or added to the environment as pollutants.

4.0 RESPONSIBILITIES

Project Manager - The Project Manager is responsible for ensuring that project-specific plans are in accordance with these procedures, where applicable, or that other, approved procedures are developed. The Project Manager is responsible for determining which on-site water quality measurements shall be made, the data quality objectives (DQOs) for these measurements, and for ensuring that these measurements are made in accordance with project-specific plans.

Field Team Leader - The Field Team Leader is responsible for determining that these water quality measurement procedures are implemented in the field in accordance with this SOP, or in accordance with project-specific plans, and to ensure that personnel performing sampling activities have been briefed and trained to execute these procedures.

Sampling Personnel - It is the responsibility of the field sampling personnel to follow these procedures for collecting on-site water quality measurements including instrument calibration, quality control and recording of results, as well as care and maintenance of the instruments in the field.

5.0 PROCEDURES

The following sections provide general procedures for collecting pH, specific conductance/salinity, temperature, dissolved oxygen concentration and turbidity measurements.

5.1 Measurement of pH

Measurement of pH is one of the most important and frequently used tests in water chemistry. Practically every phase of water supply and wastewater treatment, such as acid-base neutralization, water softening, and corrosion control, is pH dependent. Likewise, the pH of leachate can be correlated with other chemical analyses to determine the probable source of contamination. It is therefore important that reasonably accurate pH measurements be taken.

Measurements of pH also can be used to check the quality and corrosivity of soil and solid waste samples. However, these samples must be immersed in water prior to analysis; specific measurement techniques are not described here.

Two methods are given for pH measurement: the pH meter and pH indicator paper. The indicator paper is used when only a rough estimate of the pH is required; the pH meter is used when a more accurate measurement is needed. The response of a pH meter can be effected to a slight degree by high levels of colloidal or suspended solids, but the effect is usually small and generally of little significance. Consequently, specific methods to overcome this interference are not described. The response of pH paper is unaffected by solution interferences from color, turbidity, colloidal or suspended materials unless extremely high levels capable of coating or masking the paper are encountered. In most cases, use of a pH meter will be required.

5.1.1 Principles of Equipment Operation

Use of pH papers for pH measurement relies on a chemical reaction caused by the acidity or alkalinity of the solution with the indicator compound on the paper. Depending on the indicator and the pH range of interest, a variety of different colors can be used. Typical indicators are weak acids or bases, or both. Process chemistry and molecular transformations leading to the color change are variable and complex.

Use of a pH meter relies on the same principle as other ion-specific electrodes. Measurement relies on the establishment of a potential difference across a glass or other type of membrane. The membrane is conductive to ionic species and, in combination with a standard or reference electrode, a potential difference proportional to hydrogen ion concentration can be generated and measured.

5.1.2 Equipment

The following equipment and reagents are needed for taking pH measurements:

- Portable pH meter, or pH indicator paper, such as Mydrion or Alkacid, to cover the pH range 2 through 12.

- Laboratory-prepared buffer solutions of pH 4, 7 and 10, or other buffers which bracket the expected pH range.

5.1.3 Measurement Techniques for Field Determination of pH

1. pH Meter

Standardization, calibration, and operation and maintenance shall be performed according to the manufacturers instructions. The following procedure is used for measuring pH with a pH meter:

- a. The batteries and instrument shall be checked and calibrated prior to initiation of the field effort.
- b. The accuracy of the buffer solutions used for field and laboratory calibration shall be checked. Buffer solutions need to be changed often due to degradation upon exposure to the atmosphere.
- c. Immerse the tip of the electrodes in water overnight. If this is not possible due to field conditions, immerse the electrode tip in water for at least an hour before use. The electrode tip may be immersed in a rubber or plastic sack containing buffer solution for field transport or storage. This is not applicable for all electrodes as some must be stored dry.
- d. Make sure all electrolyte solutions within the electrode(s) are at their proper levels and that no air bubbles are present within the electrode(s).
- e. Immerse the electrode(s) in a pH-7 buffer solution.
- f. Adjust the temperature compensator to the proper temperature (on models with automatic temperature adjustment, immerse the temperature probe into the buffer solution). It is best to maintain the buffer solution at or near expected sample temperature before calibration, if possible.
- g. Adjust the pH meter to read 7.0.

- h. Remove the electrode(s) from the buffer and rinse well with distilled-deionized water. Immerse the electrode(s) in pH-4 or 10 buffer solution (depending on the expected pH of the sample) and adjust the slope control to read the appropriate pH. For best results, the standardization and slope adjustments shall be repeated at least once.
- i. Immerse the electrode(s) in the unknown solution, slowly stirring the probe until the pH stabilizes. Stabilization may take several seconds to minutes. If the pH continues to drift, the sample temperature may not be stable, a chemical reaction (e.g., degassing) may be taking place in the sample, or the meter or electrode may be malfunctioning. This must be clearly noted in the logbook.
- j. After adjusting the temperature compensator to the sample temperature, read and record the pH of the solution. The pH value shall be recorded to the nearest 0.1 pH unit. Also record the sample temperature. All measurements shall be recorded in the Field Logbook.
- k. Upon completion of measurement and removal of the electrode from the sample, the electrode shall be thoroughly rinsed with deionized water.
- l. The electrode(s) shall remain immersed in deionized water when not in use.

The sample used for pH measurement shall never be saved for subsequent conductivity or chemical analysis. All pH electrodes leak small quantities of electrolytes (e.g., sodium or potassium chloride) into the solution. Precipitation of saturated electrolyte solution, especially at colder temperatures, or in cold water, may result in slow electrode response. Any visual observation of conditions which may interfere with pH measurement, such as oily materials, or turbidity, shall be noted in the Field Logbook.

2. pH Paper

Use of pH paper is very simple and requires no sample preparation, standardization, etc. pH paper is available in several ranges, including wide-range (indicating approximately pH 1 to 12), mid-range (approximately pH 0 to 6, 6 to 9, or 8 to 14) and narrow-range (many available, with ranges as narrow as 1.5 pH units). The appropriate range of pH paper shall be selected. If the pH is unknown the investigation shall start with wide-range paper.

5.2 Measurement of Specific Conductance/Salinity

Conductance provides a measure of dissolved ionic species in water and can be used to suggest the direction and extent of migration of contaminants in groundwater or surface water. Salinity refers to the total amount of soluble salts in water, either naturally or added to the environment as pollutants. One basic measure of salinity is the ability of water to conduct electric current, and, therefore, a measurement of specific conductance provides a measurement of salinity and the same instrument can be used. Salinity measurements are important in ecological field investigations because flora and fauna can be limited in their distribution based on the salinity of the sampled waters.

Conductivity is a numerical expression of the ability of a water sample to carry an electric current. This value depends on the total concentration of the ionized substances dissolved in the water and the temperature at which the measurement is made. The mobility of each of the various dissolved ions, their valences, and their actual and relative concentrations affect conductivity.

It is important to obtain a specific conductance and salinity measurement soon after taking a sample, since temperature changes, precipitation reactions, and absorption of carbon dioxide from the air all affect the specific conductance.

5.2.1 Principles of Equipment Operation

An aqueous system containing ions will conduct an electric current. In a direct-current field, the positive ions migrate toward the negative electrode, while the negatively charged ions migrate toward the positive electrode. Most inorganic acids, bases and salts (such as

hydrochloric acid, sodium carbonate, or sodium chloride, respectively) are relatively good conductors. Conversely, organic compounds such as sucrose or benzene, which do not disassociate in aqueous solution, conduct a current very poorly, if at all.

A conductance cell and a Wheatstone Bridge (for the measurement of potential difference) may be used for measurement of electrical resistance. The ratio of current applied to voltage across the cell also may be used as a measure of conductance. The core element of the apparatus is the conductivity cell containing the solution of interest. Depending on ionic strength of the aqueous solution to be tested, a potential difference is developed across the cell which can be converted directly or indirectly (depending on instrument type) to a measurement of specific conductance.

5.2.2 Equipment

A portable conductivity meter, probe and thermometer are needed for taking specific conductance and salinity measurements.

A variety of conductivity meters are available which also may be used to monitor salinity and temperatures. Probe types and cable lengths vary, so equipment may be obtained to meet the specific requirements of the sampling program.

5.2.3 Measurement Techniques for Specific Conductance/Salinity

Standardization, calibration, and operation and maintenance shall be performed according to manufacturers instructions. The steps involved in taking specific conductance and salinity measurements are listed below.

- Check batteries and calibrate instrument before going into the field.
- Calibrate the instrument daily when used. Potassium chloride solutions with a specific conductance closest to the values expected in the field shall be used.
- Rinse the cell with one or more portions of the sample to be tested or with deionized water.

