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**Site Characterization and Analysis
Penetrometer System (SCAPS)
Field Investigation at the
Sierra Army Depot, California**

*by Landris T. Lee, Jr., William M. Davis,
Ricky A. Goodson, Jeff F. Powell,
Bryan A. Register*

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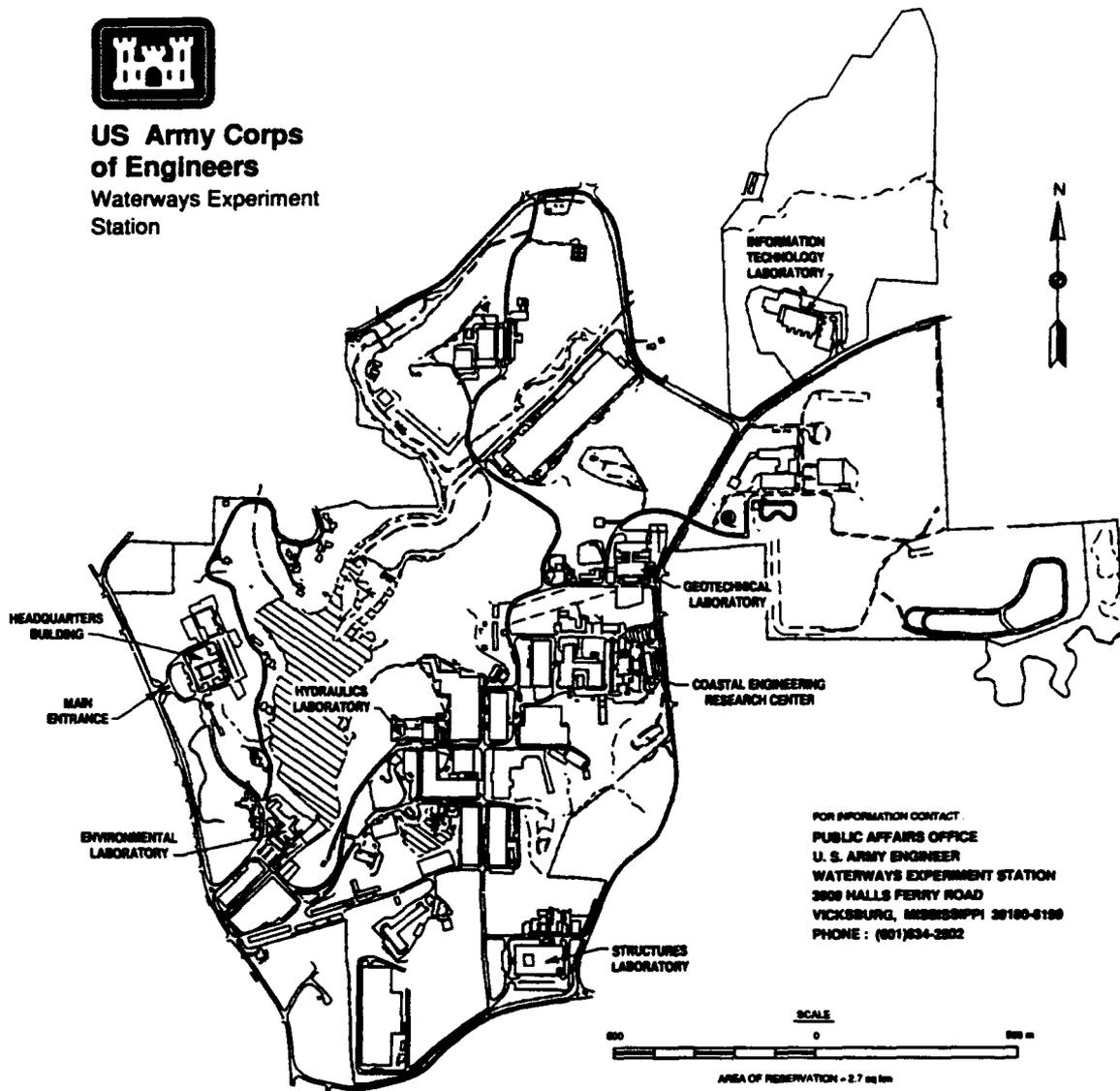
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Preface

The United States Army Engineer Waterways Experiment Station (WES) was tasked by the United States Army Environmental Center (AEC) to perform Site Characterization and Analysis Penetrometer System (SCAPS) site investigations at a designated location within the United States Army Sierra Army Depot (SIAD) near Herlong, California.

The AEC requested the WES to conduct SCAPS field investigations using cone penetrometer-based sensors and samplers as screening-level tools in evaluating the presence and location of suspected underground diesel fuel contamination at the designated Diesel Spill Area near Building 403 within the Magazine Storage Area. The field investigation was conducted in coordination with the Department of Defense/AEC Installation Restoration Program SIAD contractor Montgomery Watson, Inc. The SCAPS field investigation was conducted within the period of 28 September through 15 October 1993.

The AEC SCAPS Program Manager was Mr. George Robitaille, and the AEC SIAD Project Officer was Mr. Harry Kleiser. The SIAD Directorate of Engineering and Housing Environmental Management Division Director was Mr. James Ryan, and coordination and helpful assistance was also provided by that office's Mr. Bob Weis, Ms. Susan Holliday, and Mr. John Colberg.

The Montgomery Watson, Inc. Project Manager was Mr. Jerry Wickham. Site coordination and helpful assistance was provided by Mr. John Byrnes, Project Hydrogeologist, and Ms. Coleen Morf, Project Geologist.

The SCAPS field investigation was conducted by Messrs. Landris T. Lee, Jr., Karl F. Konecny, Geotechnical Laboratory (GL); Jeff F. Powell and Bryan A. Register, Instrumentation Services Division (ISD); and Donald S. Harris, (Engineering and Construction Services Division). Field sample verification analysis was conducted by Dr. William Davis, Mr. Roy Wade, and Mr. Javier Cortes, Environmental Laboratory (EL).

Report preparation was done by Mr. Landris T. Lee, Jr., GL, Dr. William Davis, Mr. Ricky Goodson, EL, Mr. Jeff Powell, and Mr. Bryan Register, ISD. Mr. J. D. Overton (Hilton Systems, Inc.) assisted with data postprocessing, 3-D visualizations, and mapping. Sample analyses were performed by the Environmental Chemistry Branch, WES. Ms. Ann Strong supervised the analytical effort. The analysts included

Mr. Richard Karn and Ms. Allyson Lynch (American Science International Corporation). Mineral x-ray diffraction analysis was accomplished by Mr. Jerry P. Burkes (Structures Laboratory). Soil index test analyses were accomplished in the GL's Soil Testing Facility, supervised by Mr. Jessie Oldham.

The project was supervised by Mr. Joseph R. Curro, Jr., Chief, Engineering Geophysics Branch, Mr. Mark Vispi, Chief, In Situ Evaluation Branch, Dr. A. G. Franklin, Chief, Engineering and Geosciences Division, and Dr. W. F. Marcuson III, Director, GL. The project was under the management of Mr. John H. Ballard, Assistant Program Manager EL, Dr. John Harrison, Director, EL, and Dr. Jerome L. Mahloch, Program Manager, Executive Office.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander was COL Bruce K. Howard, EN.

Conversion Factors, Non-SI to SI Units of Measurement

Non-SI units of measurement used in this document can be converted to SI units as follows:

Multiply	By	To Obtain
acres	4,046.573	square meters
feet	0.3048	meters
gallons	3.785412	cubic decimeters
inches	2.54	centimeters
miles (U.S. statue)	1.609347	kilometers
pounds (mass)	0.4535924	kilograms
tons (2,000 pounds mass)	907.1847	kilograms

1 Introduction

Overview

The United States Army Environmental Center (AEC) tasked the United States Army Engineer Waterways Experiment Station (WES) to perform site characterization activities at a designated site within the United States Army Sierra Army Depot (SIAD). The SIAD is located in northern California, near the town of Herlong (Figure 1).

The Site Characterization and Analysis Penetrometer System (SCAPS) was deployed at SIAD from 28 September through 15 October 1993 (18 days). The deployment site was the Diesel Spill Area located adjacent to Building 403 within the Magazine Storage Area. Data from a total of 41 subsurface penetration events (22 for sensing and 19 for sampling) were collected during this time period. The maximum depth achieved for data collection purposes was 70 ft below ground surface.

Objectives

There were five basic objectives for this site investigation. The first objective was to collect sensing data from both the soil classification sensor and the fiber optic fluorometer (also referred to as the Laser-Induced Fluorometer, or LIF) sensor housed within the cone penetrometer probe. The soil classification sensor's purpose was to delineate the locations of subsurface stratigraphic changes to enable a better understanding of the site geology. The fiber optic fluorometer sensor's purpose was to detect the presence of suspected subsurface diesel fuel contamination adjacent to Building 403. The contaminant source was a previous underground fuel line leak (Montgomery Watson, Inc. 1993). A spatial extent determination of both the soil classification and contamination detection data was possible by arranging the probe locations in strategic patterns around the extent of the site.

A second objective was to collect samples of subsurface soil and water for subsequent laboratory analysis to determine contaminant concentrations. A limited set of soil and groundwater samples was obtained by pushing samplers

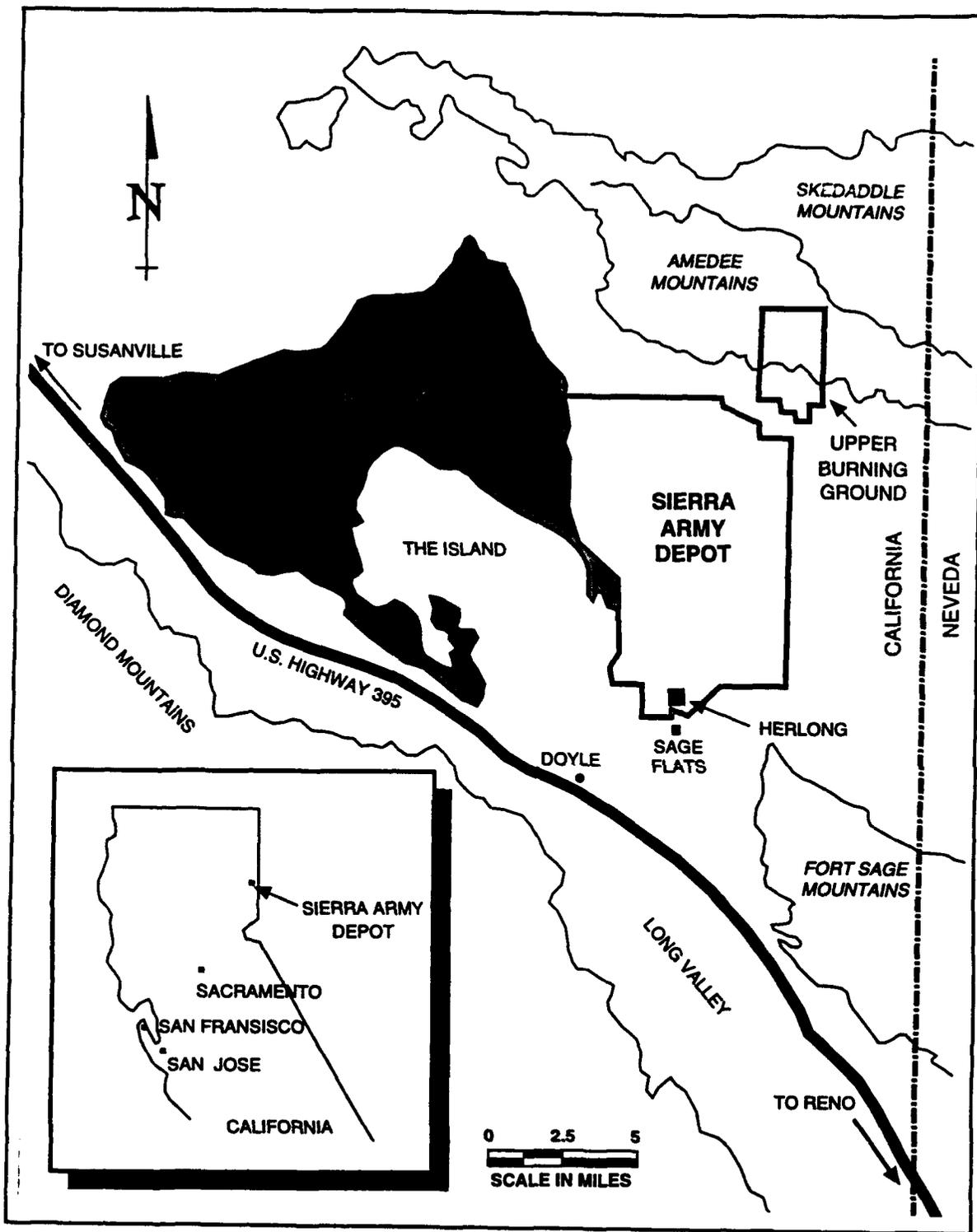


Figure 1. Site map showing location of the Sierra Army Depot (Source: Montgomery Watson, Inc. 1993)

housed within the cone penetrometer to various depths at selected locations on the site.

The third objective was to conduct a robust verification of contaminant sensing capability as part of the ongoing SCAPS research and development. An onsite field-portable laboratory system was utilized to analyze retrieved soil samples for contaminant concentration, and for direct comparison with the fiber optic fluorometer and soil classification sensor data.

The fourth objective was to continue the evaluation of the SCAPS demonstration phase regarding the system capabilities. Identification of needed refinements to the existing SCAPS system was an objective goal, and the daily operations provided additional experience in observing system performance.

The fifth objective was closely related to the fourth objective. Specifically, the field performance of the larger diameter (1.75 in.) pushpipe was evaluated at this site.

2 Site Description

Physiography and Climate

The SIAD is located in the broad Honey Lake Valley in the Basin and Range physiographic province. The Honey Lake Valley area has an extent of 529 square miles within southeastern Lassen County, California. The Honey Lake Valley is bordered by northwest-trending mountains that rise 2,000 to 3,000 ft above the valley floor. To the southeast are the Fort Sage mountains, to the northeast are the Skedaddle and Amedee mountains, and to the southwest are the Diamond mountains. The SIAD topography varies in elevation from 3,986 ft at Honey Lake level to approximately 4,134 ft above sea level at Herlong. The surface relief does not vary appreciably within the SIAD main depot area (Montgomery Watson, Inc. 1993).

The surface environment consists mainly of sagebrush and low-lying desert vegetation. The climate is arid, and the average precipitation is only 5.6 in./year U.S. Army Toxic and Hazardous Materials Agency (USATHAMA) (1979). During the period of this site investigation, rainfall in amounts up to approximately 1 in. were observed at the site. The rainfall occurred during approximately 6 days out of 18. Daytime temperatures averaged approximately 70 °F, and nighttime temperatures often dipped to approximately 30 °F during the period.

Geology and Hydrogeology

Volcanoes, sedimentation, and erosion processes have formed the topography of the SIAD region. The Honey Lake Valley lies over unconsolidated to semiconsolidated sediments and volcanic rocks which themselves overlie granitic bedrock. These rocks range in age from approximately 12 million years (Miocene era) to one million years (Pleistocene era). Pliocene and Holocene basin-fill deposits are intermixed with consolidated volcanic rocks along the north and northeast margins of the basin. These semiconsolidated deposits consist of thick layers of volcanic tuff and ash that typically were deposited in shallow lakes in conjunction with lacustrine and fluvial deposits of clay, silt, and sand. This unit (lake deposit and a volcanic tuff) comprises the majority of the basin fill. Quaternary age sediments were deposited by an ancient lake

of which Honey Lake is a remnant. Sands and gravels predominate in these sediments (Handman, Londquist, and Maurer 1990). Figures 2, 3, and 4 depict the site geology. The surface soil in the general vicinity of the Diesel Spill Area consists of the Amedee loamy sand series (Benioff, Filley, and Tsai 1988). Between ground surface and 40 ft, the soil type is generally light brown, fine- to medium-grained, and well-sorted sand. Silts and clays interbedded with sands are typical from approximately 40 to 120 ft below surface.

The surface soil in the Diesel Spill Area has been modified during recent building construction, but originally consisted of the Preston sands. The Preston sands are loose sands which are generally uniform to a depth of 6 ft or more. The texture is subject to considerable variation, and may contain an appreciable amount of fine material which has been windblown, giving it a sandy loam texture (U.S. Department of Agriculture) (USDA) (1917).

Honey Lake is the prominent surface water feature in the basin. It has a surface area of approximately 47,000 acres and is fed intermittently from more than 40 surface streams during snowmelt and infrequent rain events. The predominate groundwater flow pattern is toward the lake. In the Diesel Spill Area (Figure 5), the groundwater flow is primarily northwards at an average gradient of approximately 0.003, and localized gradients range from 0.001 to 0.01. The observed groundwater level in this area (from wells DSA-02-MWA and DF-01-MWA) is approximately 62 ft below ground surface and is unconfined (Montgomery Watson, Inc. 1993).

Site History

The site history of SIAD precedes World War II, when Honey Lake was used as a bombing range. In 1942 the Sierra Ordnance Depot was constructed. Several buildings and barracks have been added in subsequent years. The current mission of the SIAD is to receive, stockpile, maintain, and issue munitions, strategic materials, and war reserve material (USATHAMA 1979).

At the Diesel Spill Area, a leaking diesel fuel pipeline at the southwest corner of Building 403 was discovered on 3 March 1987. The pipeline ran underground between a tank south of Building 402 (Boiler Plant No. 3) and a boiler in Building 403. Approximately 5,000 gal of diesel was estimated to have been leaked prior to discovery. The underground storage tank has since been removed, and the spill area was excavated and backfilled with clean soil in 1987. Remnant soil is contaminated with diesel-related compounds (Montgomery Watson, Inc. 1993).

Two monitoring wells have been installed in the Diesel Spill Area. Well DF-01-MWA was installed by USAEHA, and well DSA-02-MWA was installed in 1991 by Montgomery Watson, Inc. During the groundwater

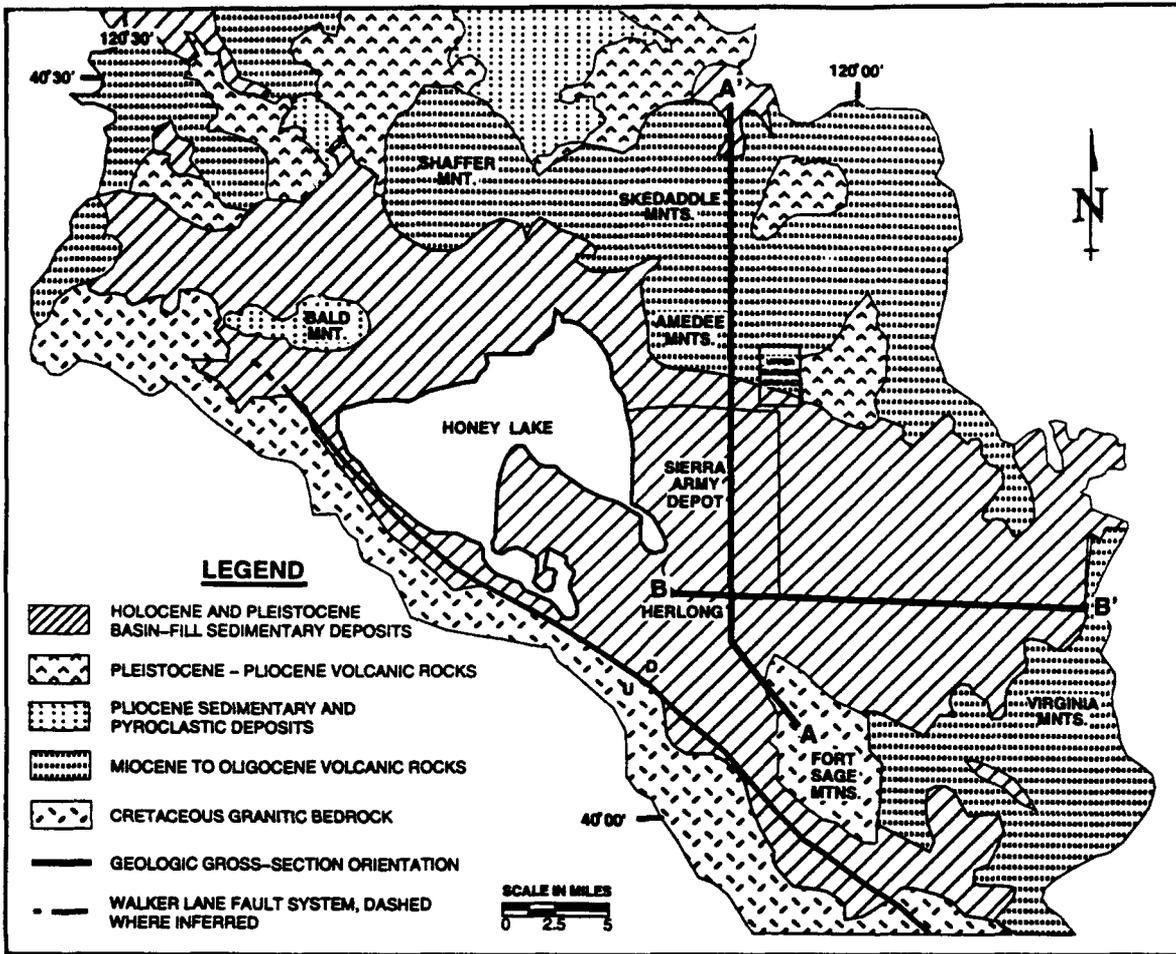


Figure 2. Geologic map of Honey Lake Valley (Source: Montgomery Watson, Inc. 1993)

sampling period of 1991 through 1992, four rounds of samples were analyzed from each of these wells. Total Petroleum Hydrocarbons (TPH-diesel) was detected in only one of the wells (DF-01-MWA), at a level of approximately 250 parts per million (ppm). TPH-diesel was not detected below a depth of 35 ft in a soil boring DSA-01-SB (approximately 20 ft west of well DF-01-MWA). Since no detectable concentrations of TPH-diesel were found in the downgradient well DSA-02-MWA, it is presumed that the diesel contamination has been confined to the spill area (or has been excavated and removed to a depth of 30 ft), and is not moving downgradient (Montgomery Watson, Inc. 1993).

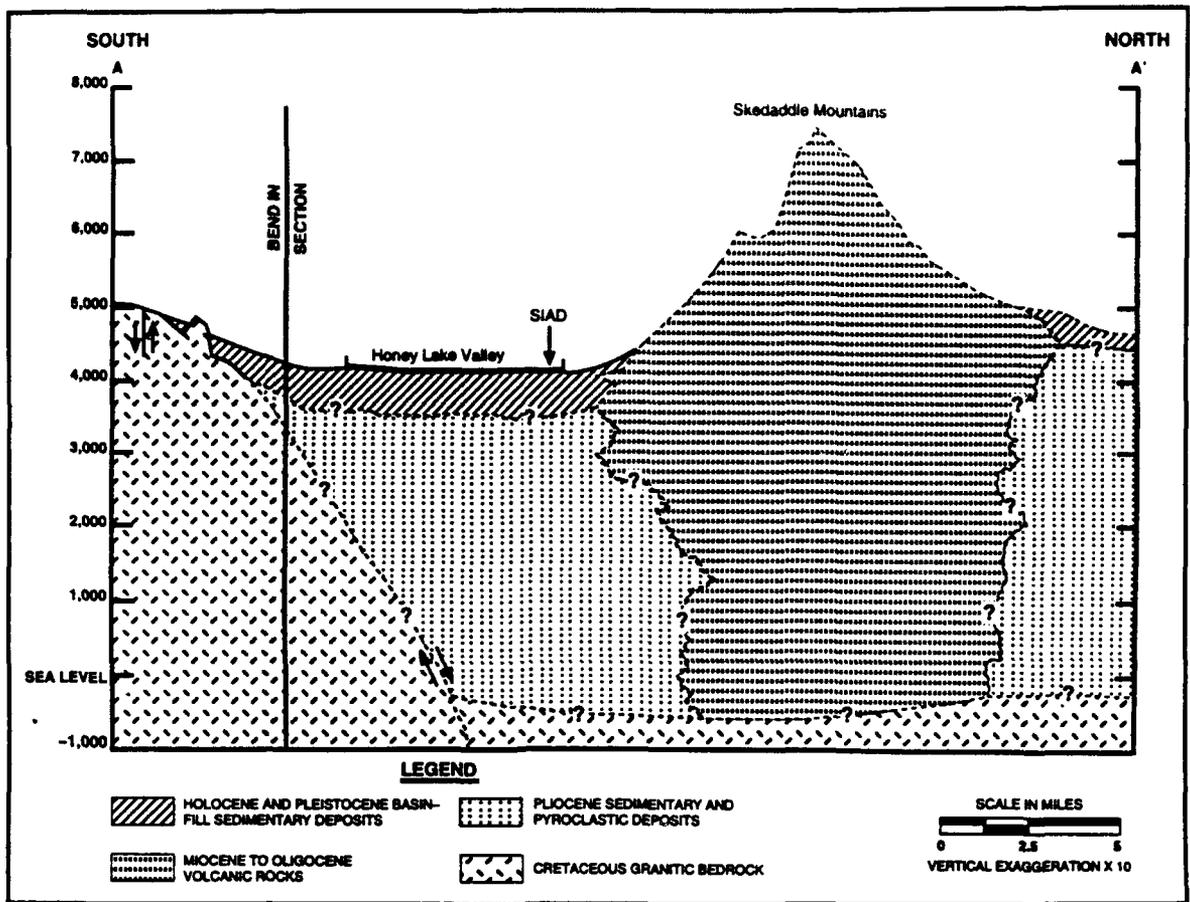


Figure 3. Geologic cross section A-A' (Source: Montgomery Watson, Inc. 1993)

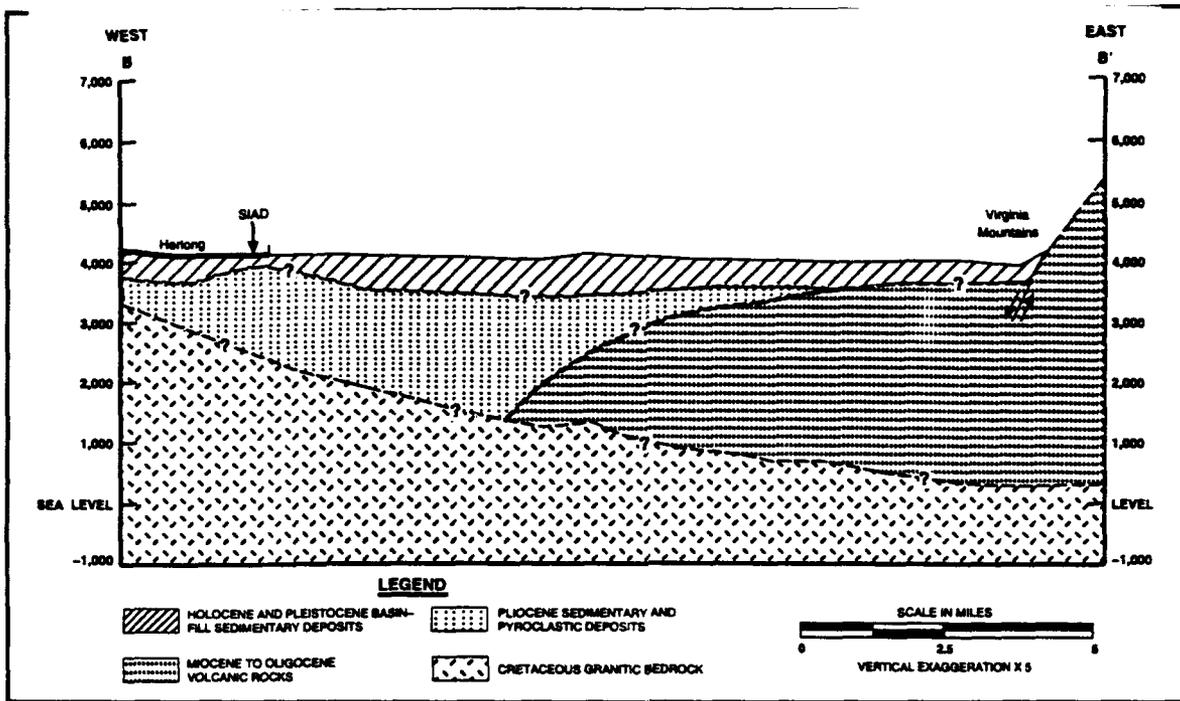


Figure 4. Geologic cross section B-B' (Source: Montgomery Watson, Inc. 1993)

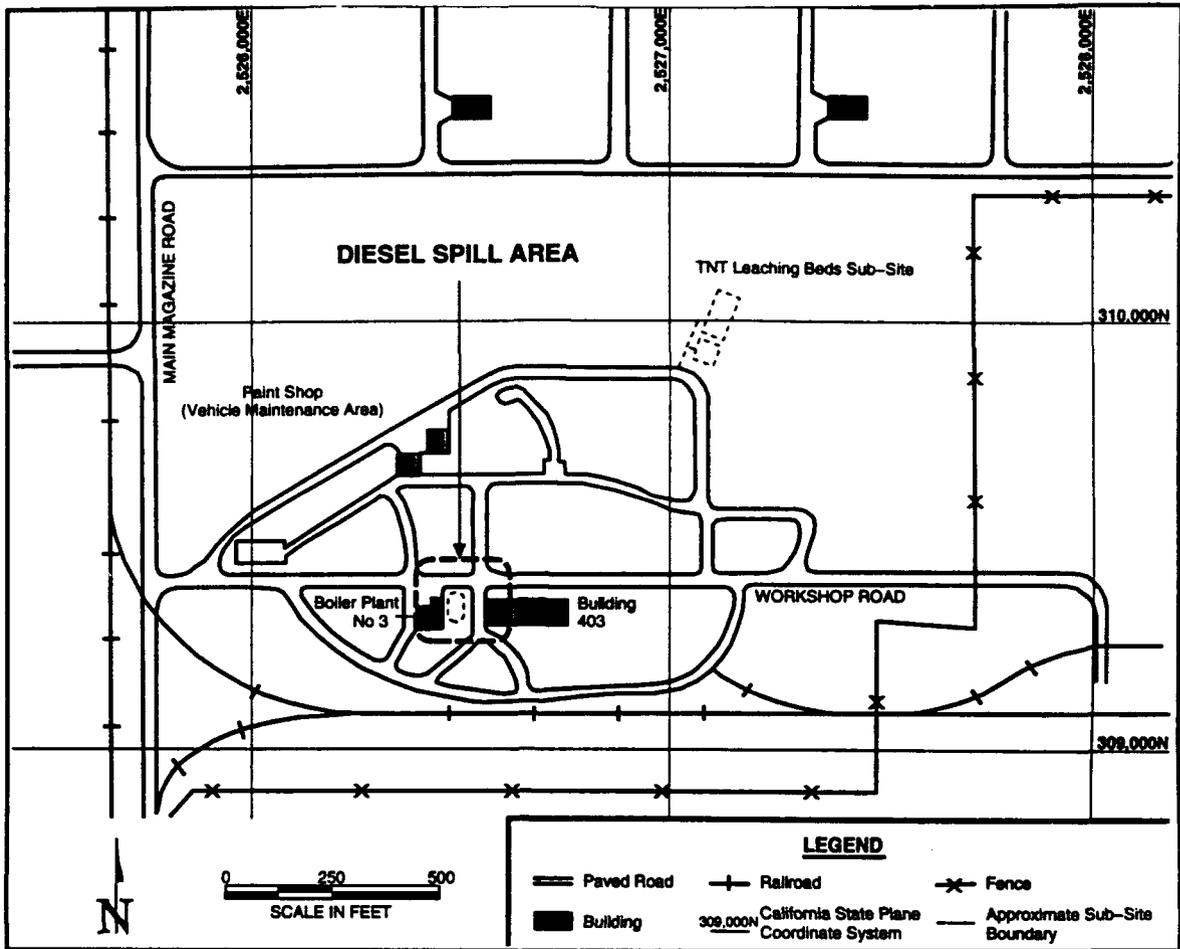


Figure 5. Site map of the Diesel Spill Area (Source: Montgomery Watson, Inc. 1993)

3 Investigation Equipment and Procedures

General Operation

The field investigation conducted at the SIAD was accomplished using SCAPS, consisting primarily of a penetrometer unit mounted in a specially engineered truck. The penetrometer unit is equipped with sensors that allow soil classification and soil fluorescence measurements to be taken as the tip is pushed directly into the subsurface environment. The penetrometer unit may also be equipped with soil or groundwater samplers to physically retrieve subsurface samples. For a complete description of the SCAPS equipment and capabilities, the reader is referred to previously published SCAPS site investigation reports (Sharp, Olsen, and Kala 1992; Koester, et al. 1993; Lee, et al. 1993). Figure 6 is a depiction of the SCAPS truck system.

Procedure for each direct push

The typical procedure used for each direct push (during sensor data collection efforts) follows, and details are discussed further in the body of this report:

- a. The truck was positioned at the location of interest flagged by Montgomery Watson, Inc. Pre-push operations consisted of truck leveling, sensor probe setup, sensor probe calibrations, and initializing the data collection software.
- b. The penetrometer probe was direct-pushed into the ground toward a maximum depth target. As the probe advanced, the sensor data was collected via the onboard computer data acquisition system. Data acquisition was then ended at the probe termination depth.
- c. Preparations to retract the probe were then accomplished. The hot pressure washer (also called the "steam cleaning system") was turned on (for the purpose of pushrod decontamination), and the grouting system was prepared for retraction grouting. The probe was then retracted by

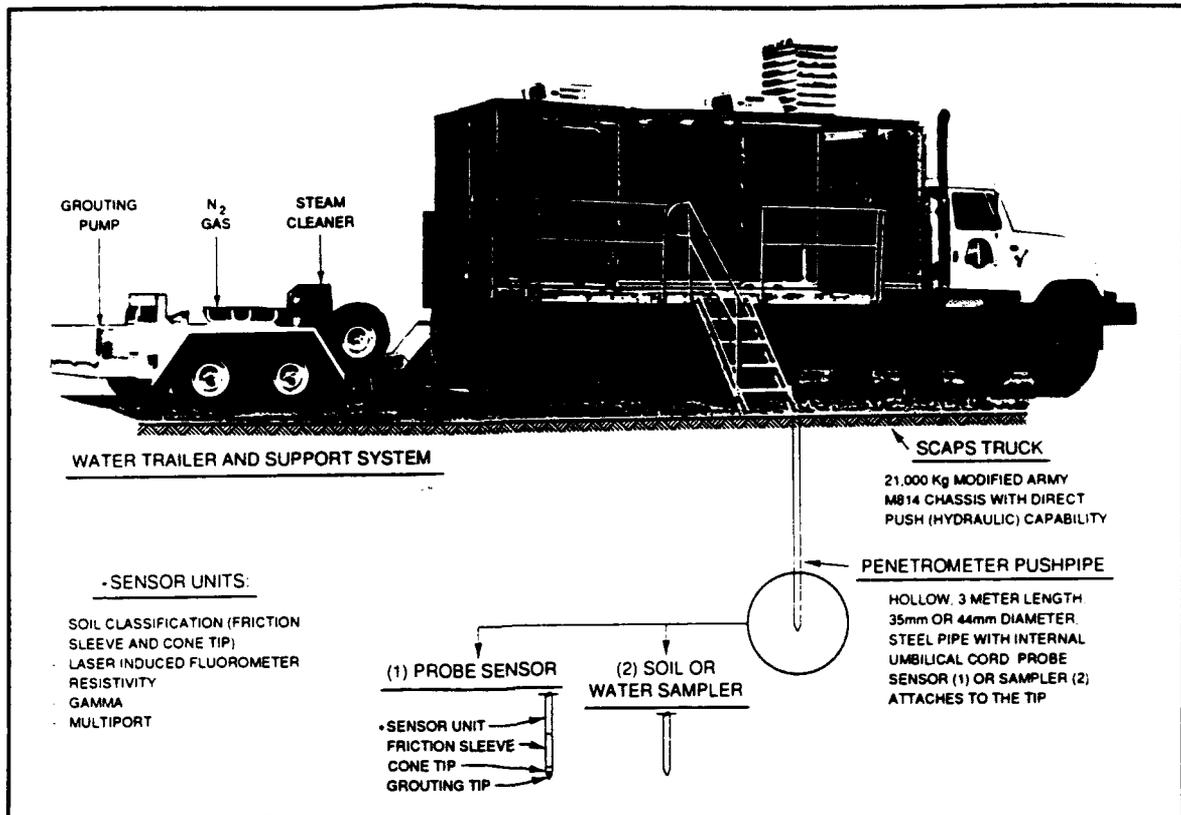


Figure 6. The SCAPS truck

sequentially withdrawing and disconnecting pushpipe sections. Concurrently, the grouting system injected grout into the open hole, and the steam cleaner (hot pressure washer) washed each pushpipe as it emerged from the ground. The contaminated wash water was barrelled for subsequent disposal per SIAD regulations.

- d. After the probe emerged from the ground, the steam cleaning and grouting systems were turned off. Postcalibration of the sensor(s) was then accomplished. After an initial onsite calibration of the soil classification sensor (cone tip and friction sleeve), no further calibrations were performed unless anomalies were observed in the collected data. The push plot showing the sensor data as a function of depth was then plotted on the postprocessing computer. Using a separate computer for postprocessing allowed for immediate reset of the data acquisition system. Data on the next push was collected while processing the data from the previous push. The previous push plot gave immediate information as to the soil stratigraphy and soil fluorescence locations within the push zone of influence. This information was useful in determining the locations for soil sampling.

Procedure for obtaining physical samples

The typical procedure used for obtaining physical samples follows:

- a.* The truck was positioned near a previous push point where sensor data had been collected. This procedure was followed in order to obtain representative samples from depths corresponding to the adjacent sensor probe push. In most cases, the sample location was within 1 to 2 ft of the original sensor push point. A closer location was not desired since the original sensor push point hole had been grouted, and samples influenced by the grout material were not desired.
- b.* The sampler was attached to the empty pushpipe (no umbilical cord was needed) and was hydraulically pushed directly into the ground in the same fashion as the sensor probe. The data acquisition computer system was utilized only to provide a depth display as the pushpipe was pushed to depth. At the target depth, the sampler was mechanically activated and a sample (soil or groundwater) was physically retrieved.
- c.* The sample was brought to the surface by sequentially retracting the pushpipe sections. The steam cleaning system (hot pressure washer) was used for pushpipe decontamination. At the surface, the sample was removed from the sampler and placed in the appropriate container for subsequent analysis and/or shipment. No retraction grouting was done due to the absence of the internal umbilical cord containing the grout tube. Manual grouting was performed by pouring the grout mixture down the open hole.

Penetrometer Sensors and Data Collection System

Penetrometer investigations at this site were performed utilizing two sensors: the soil classification sensor and the soil fluorescence sensor (LIF). Signal conditioning, data acquisition, and data processing constituted the data collection system that was employed with the sensors.

The soil classification sensor consists of separate electro-mechanical strain-gauged elements within the cone tip and the cone friction sleeve. The elements' responses to external soil stresses constitute the typical electrical cone penetrometer probe configuration for soil stratigraphy identification and subsequent classification. The reader is referred to previous SCAPS reports for a detailed explanation of the soil classification system (Sharp, Olsen, and Kala 1992; Koester et al. 1993, Lee, et al. 1993). Typically, the two elements sense the changes in soil stresses as the probe is pushed to depth. The electro-mechanical responses are translated into Soil Classification Numbers (SCN) via the computerized data collection system. Each SCN represents a soil type which corresponds to elementary soil classification descriptions (sand, silt, clay, etc.). The two elements (cone tip and friction

sleeve) independently respond to soil stresses, but the combined response contributes to the development of the SCN.

LIF consists of an onboard laser system pulsing ultraviolet light through optical fibers in the pushpipe umbilical cord, terminating in a 6.35 mm-diam sapphire window on the penetrometer probe. As the probe advances, the fired ultraviolet light (wavelength of 337 nanometers (nm)) pulses emanate through the window into the soil. The soil matrix reacts to the pulsed light, and the response signal (light) is returned through the window and a separate optical fiber up to an onboard optical analyzer. The return signal characteristics (peak wavelength and intensity) indicate the nature of fluorescent materials in the soil matrix. Since most hydrocarbon contaminants (diesel, oils, etc.) fluoresce under these conditions, the presence or absence of those contaminants is determined. In addition, the relative concentration levels of those contaminants may be ascertained when additional calibrations are performed. The fluorometer probe was attached to both the larger diameter (1.75 in.) pushpipe and the smaller diameter (1.4 in.) pushpipe at separate times during this investigation. The larger diameter pushpipe configuration had not been utilized during a site investigation prior to the SIAD site investigation. Discussions of the configurations used at the SIAD are detailed later in the body of this report.

The computerized data collection system is integral to all sensor systems. During the penetration event, it allows for real-time sensor performance evaluation and data acquisition. The "raw" signals acquired via the sensors are displayed on the computer monitors as the probe advances into the soil. The quality of the penetration event is assured, preventing unnecessary or erroneous data collection. After each penetration event, the data collected during the event is automatically distributed to appropriate data files for subsequent postprocessing and plotting as needed. The generation of three-dimensional (3-D) descriptions of acquired site data is integral to the postprocessing function, and is presently performed at WES after the field investigation is completed.

Support Systems

The support systems include auxiliary components of SCAPS not directly identifiable with the sensors or data collection system but required to make the SCAPS fully functional. These include site surveying, surface geophysics (locating buried utilities and other obstructions), soil and groundwater sampling, pushpipe decontamination, grouting, and other items necessary to complement the overall performance.

Surveying and geophysics

The site surveying and geophysics were accomplished at this site as at other sites, with the exception that the role of geophysics by SCAPS was less

prominent at the SIAD. The equipment and methods used for surveying and geophysics were similar to those used at previous sites (Sharp, Kala, and Powell 1992; Koester, et al. 1993a; Lee, et al. 1993). The SIAD provided underground utility location assistance to prevent disruptive outages of nearby electrical feeds and fuel lines caused by accidental penetration. SCAPS geophysics was limited to determining locations of any other possible underground obstructions.

Grouting

Grouting was performed to ensure that vertical cross contamination did not occur in the penetration holes. To accomplish this goal, a grout mixture consisting of Portland cement (Basalite™ brand), potable water, and sodium Bentonite was either automatically pumped into the hole as the penetrometer probe was retracted or manually placed into the hole after the sampler probe was withdrawn. In an attempt to achieve a grout mixture which met the regulatory requirements as closely as possible, yet be pumpable through the 3/8-in.-diam umbilical cord grout tube, several mixtures were tried. The accepted State of California grout mixture consists of one bag of Portland cement, 7 to 8 gal of potable water, and 5 percent Bentonite by weight. The required grout mixture consisted of 3 parts of cement to 2 parts of water by weight plus 5 percent Bentonite. The viscosity of this mixture was too high for adequate pumpability. The amount of Bentonite was reduced to approximately 2 percent by weight, and the mixture was pumpable, although frequent cleaning of the umbilical cord grout tube was required to prevent clogging. Tacit approval was given for this mixture, primarily due to the innovative technology being demonstrated. During physical sampling operations, the grout mixture (with 5 percent Bentonite) was manually placed in the open penetration hole after retraction since no umbilical cord grout tube arrangement was possible when using either the soil or water sampler (neither sampler accommodates an umbilical cord).

Soil and groundwater sampling

Both soil and groundwater samples were retrieved during this investigation. For soil sampling, both the Gouda™ (now available through Hogentogler, Inc., Columbia, Maryland) and Mostap™ (A. P. van den Berg, Heerenveen, Nederland) samplers were used interchangeably. For groundwater sampling, the Hydropunch™ (QED Groundwater Specialists, Ann Arbor, MI) Models I and II were used.

The Gouda™ sampler was utilized to obtain the soil samples for Montgomery Watson, Inc. It has an OD of approximately 1.75 in. and retrieves a sample of approximately 1-in. diam by 8-in. length (approximately 100 cm³ internal volume). It was connected to the smaller diameter (1.4 in.) pushpipe, and consists of a stab-type sampler which is mechanically activated by retracting the pushpipe string 10.5 in. and then pushing the extended sampler a

distance of 9.5 in. The soil is forced into the sampler tube over a depth interval of 8 in.

The Mostap™ 35 sampler is a larger sampler (approximately 2-in. OD by 24-in. length) which retrieves a sample of approximately 1.5-in. diam by 18-in. length (approximately 550-c m³ internal volume). It is also a stab-type sampler, but is mechanically activated by releasing the tip and pushing the tube past the tip, forcing the soil into the sampler over the 18-in. depth interval. It was interchangeably connected to both pushpipe sizes (1.4 in. and 1.75 in.), but was primarily used with the smaller diameter pushpipe. It was utilized to obtain soil samples for the penetrometer fluorometer sensor verification from the shallower depths where soil fluorescence had been observed (less than 20 ft).

The Hydropunch™ Models I and II were used for the purpose of obtaining groundwater samples. Both tools basically operate the same, by collecting in situ groundwater under hydrostatic pressure. The Model I collects approximately 500 ml of water, and the Model II collects approximately 1 l of water after being mechanically opened at depth (more than 5 ft below the water table). Both models are approximately 5 ft in length, but the Model I has a slightly smaller diameter than the Model II. One important distinction between the two models is that the Model II tip releases and remains in the hole after the sampler is retracted. It is thus not possible to obtain a deeper water sample from the same penetration hole. Both the smaller and larger diameter pushpipes were interchangeably used with the groundwater samplers at this site.

Penetrometer Fluorescence Verification

Laboratory calibration studies

Prior to the SCAPS truck deployment at SIAD, two uncontaminated soil samples (approximately 10 kg each) were obtained from the area at SIAD that was to be investigated. The samples were obtained by the AEC project officer from both an undisturbed area (Native SIAD) and an area where POL (diesel) contaminated soil had been excavated and the area backfilled (Fill SIAD). These samples were shipped to WES Environmental Chemistry Branch (ECB) and were fortified with diesel fuel at varying concentrations. The procedure used to fortify soil samples with petroleum, oil, and lubricant (POL) contaminants has been developed by WES ECB and is described in detail in Appendix A.

Soil samples were fortified at 100, 300, 500, 1,000, 2,000, 5,000, and 10,000-mg diesel fuel/kg dry weight soil. All soil samples fortified with diesel fuel were analyzed for petroleum contamination by the methods described below:

Analyte	Method
TRPH	Method 418.1/9073
TPH	EPA Method 8015
PAH's	EPA Method 8270

TRPH refers to total recoverable petroleum hydrocarbons, TPH refers to total petroleum hydrocarbons and PAH's refer to polynuclear aromatic hydrocarbons. It should be noted that the TPH measurements were made using the diesel fuel that was used to fortify the samples as the calibration standard for EPA Method 8015. The samples were also analyzed using the SCAPS POL sensor to determine the fluorescence response. The procedure consisted of triplicate fluorescence analysis of each fortified soil sample pressed against the window of the POL sensor probe. The data obtained from these analyses were used to develop laboratory calibration curves between the various measures of POL contamination and the LIF response.

Field soil sampling

The purposes of the verification soil sampling phase of the SIAD field investigation were multifold:

- a. An investigation of the utility of a field portable TRPH instrument for onsite verification of POL contamination identified by the SCAPS POL sensor.
- b. A collection of soil samples for laboratory analysis to verify POL contamination identified by the SCAPS POL sensor.
- c. An investigation of the feasibility of onsite POL sensor calibration with actual field contaminated soil samples using a field portable TRPH instrument.

Sampling sites for verification sampling were chosen based on previous SCAPS penetrations that had indicated LIF response at a particular depth. Soil sampling locations were generally 1 to 2 ft offset from the cone penetrometer push site of interest. Soil samples collected adjacent to a particular cone penetrometer push were denoted by prefixing the penetrometer push name with S (for soil). Thus, soil sample SCP-14-1 denotes the first soil sample obtained from sampling at a particular depth adjacent to cone penetration 14 (CP-14) (Appendix B). Samples were chosen based on a wide range of fluorescence response to provide a range of TRPH contaminated soil samples. The wide range of POL contamination was desired to investigate the performance of the field portable TRPH instrument for both POL verification and potential calibration of the POL sensor in the field.

Field sampling procedures are determined by the EPA analytical methods used to determine the concentration of the analytes of interest. The EPA soil

sampling protocols for the analytes of interest were followed at SIAD and are described in detail in the WES SCAPS Field Sampling Standard Operating Procedure (Appendix C). This procedure is excerpted from the "Operations Manual for the Site Characterization and Analysis Penetrometer System" (Koester et al. 1993b). Samples were collected using the Mostap soil sampling device pushed to depth using the SCAPS truck. Samples obtained in this manner were homogenized in the field (mixed in a clean stainless steel pan with a stainless steel spatula) and placed in 500-ml widemouth jars with Teflon-lined lids. Although not part of the sampling Standard Operating Procedure, homogenization was necessary for the field analysis for TRPH discussed below. These samples were analyzed in the field for TRPH and LIF as described below. The samples were then shipped to the WES ECB for TRPH (EPA Method 418.1), TPH (EPA Method 8015), and TPAH (EPA Method 8270) analysis.

LIF determination and field total petroleum hydrocarbon

Fluorescence emission spectra of the homogenized soil samples were obtained in the field by pressing the soil against the sapphire window of the SCAPS POL probe and collecting 10 replicated emission spectra. These 10 replicate measurements were averaged. This procedure was carried out in triplicate for each soil sample investigated. The standard operating procedure for the POL sensor operation includes analysis of rhodamine fluorescence dye immediately before and after each cone penetrometer push. This is accomplished by placing a cuvette containing the rhodamine dye solution in front of the sapphire window, recording 10 spectra and averaging these spectra. The rhodamine dye spectra are used to normalize the penetrometer push fluorescence data for any spectrometer system variation during a particular push. A similar procedure was used for the fluorescence emission spectra collected for the homogenized soil samples. Before and after each fluorescence analysis of a soil sample, triplicate measurements were made of the rhodamine dye solution. These data were used to normalize the LIF response obtained for the soil samples relative to the rhodamine response.

Field determination of the TRPH contamination of the homogenized soil samples was carried out using a Horiba Model OCMA 220 TRPH analyzer. This instrument is a field portable fixed wavelength (3.4-3.5 microns, 3,000 to 2,850 cm^{-1}) infrared detector designed to measure TRPH contamination in water. A procedure was used to adapt the instrument for use as a detector for hydrocarbons contained in solvent extracts of soil. Ten grams of soil (wet weight) were weighed (electronic balance, accurate to 0.001 g) into a 250 ml jar equipped with a Teflon-lined cap (I-Chem #320-0250). Two grams anhydrous Na_2SO_4 were added to the soil and the sample was thoroughly mixed using a stainless steel spatula. Two grams of silica gel (60-80 mesh) were added to the soil and it was again mixed with a stainless steel spatula. Fifty ml of solvent (Flon-316) was added and the mixture was agitated in an ultrasonic bath for 2 min. The extract was then filtered (Gelman-type A/E, glass fiber filters) using a vacuum filtration apparatus (VWR #KT93750-47) to separate the soil from the solvent extract. The

filtrate (solvent extract) was then analyzed for hydrocarbons using the Horiba Model OCMA 220. The Model OCMA 220 has a limited linear range that was often exceeded by the soil extracts at SIAD. Samples that exceeded the Model OCMA 220 linear range were diluted with additional solvent (generally in the range of 1:10 or 1:100, weight to weight) using the balance.

4 Results and Discussion

General

The SCAPS system was deployed at the SIAD Diesel Spill Area for a duration of approximately 18 days. The five objectives listed in Chapter 1 of this report were sought and met with general success. The first objective (Collecting sensing data) was met for depths to 68 ft below ground surface.

The second objective (Collecting soil and groundwater samples) was met with partial success. The soil sampling program objective was achieved, but the groundwater sampling program objective was not. Only one groundwater sample was obtained, due to the problems encountered with pushing the groundwater samplers (Model I and II) deep enough into the water table. The soil samples obtained were taken with the smaller soil sampler (discussed previously), and the resulting soil sample quantities were smaller than had been originally planned. Here again, the problems encountered with pushing the larger diameter soil sampler (Mostap™) to the targeted "smear zone" depth (approximately 60 ft below ground surface) prevented retrieval of soil samples larger than 100 cm³ (approximately 300 grams of soil) each.

The third objective (Conducting a robust sensor verification program) was a complete success. Onsite comparisons between the soil fluorometer sensor response and retrieved soil sample TRPH concentrations were conducted for a majority of the locations where subsurface soil fluorometer sensor response had been observed. Further laboratory analyses provided a complete data set for the field verification program.

The fourth objective (Continued compilation of system demonstrated capabilities and recommendations for improvements) was also met with success. No enervating conditions (weather, mechanical problems, etc.) prevented overall operational capabilities other than minor problems to be discussed further in the body of this report. The major factor impacting operations and performance at the SIAD was the soil stratigraphy encountered at this site.

The fifth objective (Field evaluation of the larger diameter pushpipe) met with general success. The larger diameter (1.75-in.) pushpipe was successfully deployed at this site, but soil penetration resistance limited its use to shallower depths than those accomplished with the smaller diameter (1.4-in.) pushpipe. Subsequent to its demonstration, the 1.75-in. diam pushpipe was

shelved, and the 1.4-in. diam pushpipe was utilized due to its higher efficiency in achieving deeper penetrations (Objective one above). The hydraulic ram gripping chuck utilized for the 1.75-in. diam pushpipe was also field-tested at this site. It differed from the gripping chuck utilized with the 1.4-in. diam pushpipe in the following ways:

- a. It required input via a manually operated actuating lever.
- b. It required "notchless," or smooth circumference, pushpipe. The 1.4-in. diam pushpipe was notched, thus requiring a different gripping chuck configuration.
- c. It caused minor inaccuracies in the cumulative depth measurement during penetration, due to necessary operator input at each push cycle termination.

Figure 7 provides an illustration of the pushpipes, probes, and attachments utilized at this site, and Figure 8 is a site map of the Diesel Spill Area indicating locations where probe sensor data and physical samples were collected. The approximate area of the investigation covered 5 acres. Each numbered point represents a penetration, and each point is designated in Table 1. The labels CP-01 through CP-22 indicate sensor data pushpoint locations. The labels prefixed "SCP" indicate locations where the soil samples for the WES analyses were taken. The labels prefixed "DSA" indicate locations where the samples for the Montgomery Watson, Inc. analyses were taken. The sequence of operations at this site began with conducting the sensor probe penetrations first (to obtain soil classification and soil fluorescence data), and then conducting physical sampling.

Soil Classification Measurements

Penetration resistance

The first penetrations were conducted on the north side of Building 403. The first penetration was located near CP-04 off the road shoulder, and the probe was connected to the large diameter (1.75-in.) pushpipe. After pushing to a depth of approximately 13 ft below ground surface (bgs), the reaction force on the hydraulic rams was not high enough to overcome the soil resistance. Several further attempts were conducted at adjacent locations, and deeper penetrations with the 1.75-in. diam pushpipe were not successful. The soil classification displayed at the point of refusal typically was between SCN 3 and 4, indicating the presence of sand layers.

To determine if deeper penetration could be achieved, two methods were utilized: prepushing with a "dummy" tip, and field-modifying the pushpipe. Prepushing consisted of pushing a 1.4-in. or 1.75-in. diam empty pushpipe string (no sensor probe attached) to a refusal depth, either once or twice in the

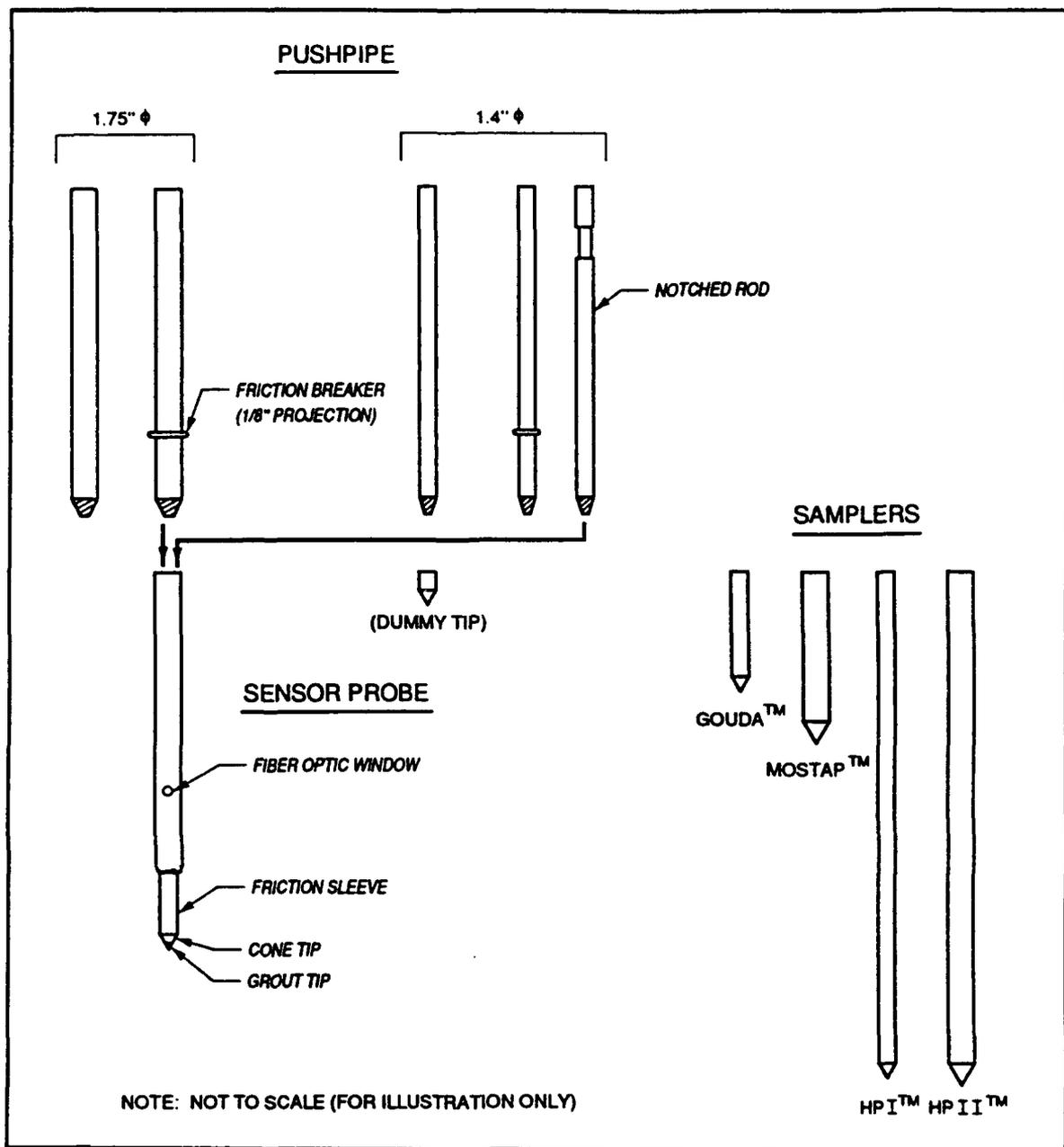


Figure 7. Pushpipe configurations

same hole. Field-modifying the pushpipe consisted of welding "friction breakers" around the pipe circumference, approximately 1 ft above the tip. The friction breaker pushpipe was used in both a "dummy" configuration and with the sensor probe attached. Figure 7 indicated the relative sizes of the pushpipes and attachments utilized during this site investigation. The 1.4-in. diam notched pushpipe with attached sensor probe was the configuration used for all sensor data collection pushes (CP-01 through CP-22). All samples were taken using the 1.4-in. diam notched and unnotched pushpipe configurations.

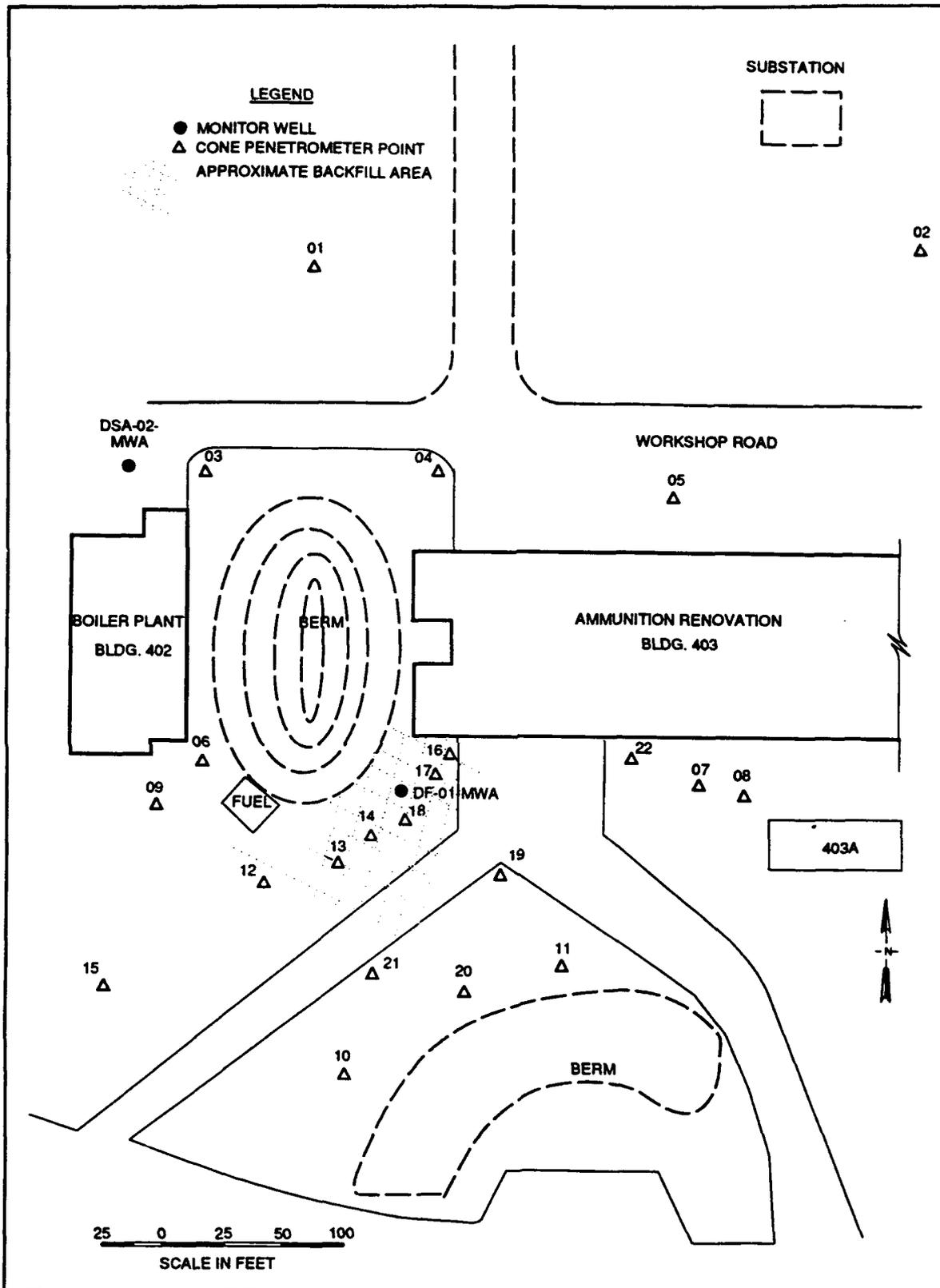


Figure 8. Site map of the Diesel Spill Area penetrations

**Table 1
Penetration Points**

The points listed below are referenced to the Figure 8 site map:

Point	Penetration number and adjacent sample points
01	CP-01, SCP-01
02	CP-02, SCP-02
03	CP-03
04	CP-04
05	CP-05, SCP-05
06	CP-06, SCP-06
07	CP-07
08	CP-08, SCP-08
09	CP-09, SCP-09
10	CP-10
11	CP-11
12	CP-12, SCP-12
13	CP-13, DSA-04-SC
14	CP-14, SCP-14, DSA-03-SC
15	CP-15, SCP-15
16	CP-16, DSA-01-SC, HP-1
17	CP-17, SCP-17, DSA-02-SC
18	CP-18
19	CP-19, SCP-19, DSA-05-SC
20	CP-20, SCP-20
21	CP-21
22	CP-22

Legend:

CP = Cone penetrometer point.
 SCP = Soil sample (WES).
 DSA = Soil sample (MW).
 HP = Water sample.

Several attempts to achieve deeper penetration with the 1.75-in. diam pushpipe were attempted using different combinations of the above two methods. The maximum depth achieved with the 1.75-in. diam pushpipe with sensor probe attached (for data collection) was approximately 30 ft bgs. The 1.4-in. pushpipe configuration was used for the remainder of the site investigation, and depths to 71 ft bgs were successfully achieved.

Several items were observed during the attempt to achieve deeper penetrations:

- a. The friction breaker arrangement achieved an approximately 100 percent increase in depth. Pushpipe vibration and "chatter" during penetration was significantly reduced when using the friction breaker.
- b. Pushing the sensor probe down a prepushed hole required the prepushed hole to be less than the diameter of the sensor probe if fluorometer sensor data were to be collected (assuming the prepushed hole remained open, and the soil or contaminant characteristics were not compromised).
- c. Achieving true vertical alignment of the pushpipe as it penetrated the soil surface was critical for subsequent alignment as the pushpipe penetrated further into the subsurface. Small objects such as irregularly shaped surface gravels easily deflected the pushpipe tip from true vertical alignment immediately prior to penetration.
- d. The soil resistance to penetration was a result of accumulated "skin friction" (shear stresses around the pushpipe shaft circumference) and point resistance. The observed pushpipe behavior when pushed into prepushed holes led to the assumption that skin friction played a major role; the cone tip and friction sleeve sensor outputs were in the normal (or below normal) ranges, while the hydraulic ram force gage indicated excessive resistance (typically 35,000 lb at the point of "refusal"). In general, the larger the diameter of pushpipe and attachments (probes and samplers), the shallower the achieved penetration depth. The circumferential area of the 1.75-in. pushpipe was 0.458 ft²/ft of length, the 1.4-in. pushpipe was 0.364 ft²/ft of length, and the surface area difference between the two pipe sizes was approximately 20 percent. Assumptions that the 1.4-in. diam pushpipe would achieve approximately 20 percent greater depth than the 1.75-in. pushpipe for a given ram force were observed not to be valid. The smaller pushpipe achieved approximately 100 percent deeper penetration prior to "refusal," based on several comparison observations.

The small diameter (1.4-in.) pushpipe configuration was utilized for the remainder of the sensor probe pushes. The deepest penetration achieved was 68-ft bgs (CP-10). The typical penetration depth was approximately 40 to 50-ft bgs, and the shallowest was 23-ft bgs (CP-02). All probes were pushed to "refusal." At that point, the hydraulic ram force gage registered 35,000 lb, the cone tip resistance reading ranged from 300 to 400 tons/ft² (600,000-800,000 lb/ft²), and the friction sleeve resistance reading ranged from 3 to 8 tons/ft² (6,000-16,000 lb/ft²). The cone tip reading was typically 400 tons/ft² at the refusal force of 35,000 lb, indicating that cone tip resistance played a major role in penetration depth ability. Figure 9 indicates the termination ("refusal") values for the penetrations using the 1.4-in. diam pushpipe with attached sensor probe. The soil type at the termination point was typically sand (SCN 3 to SCN 4).

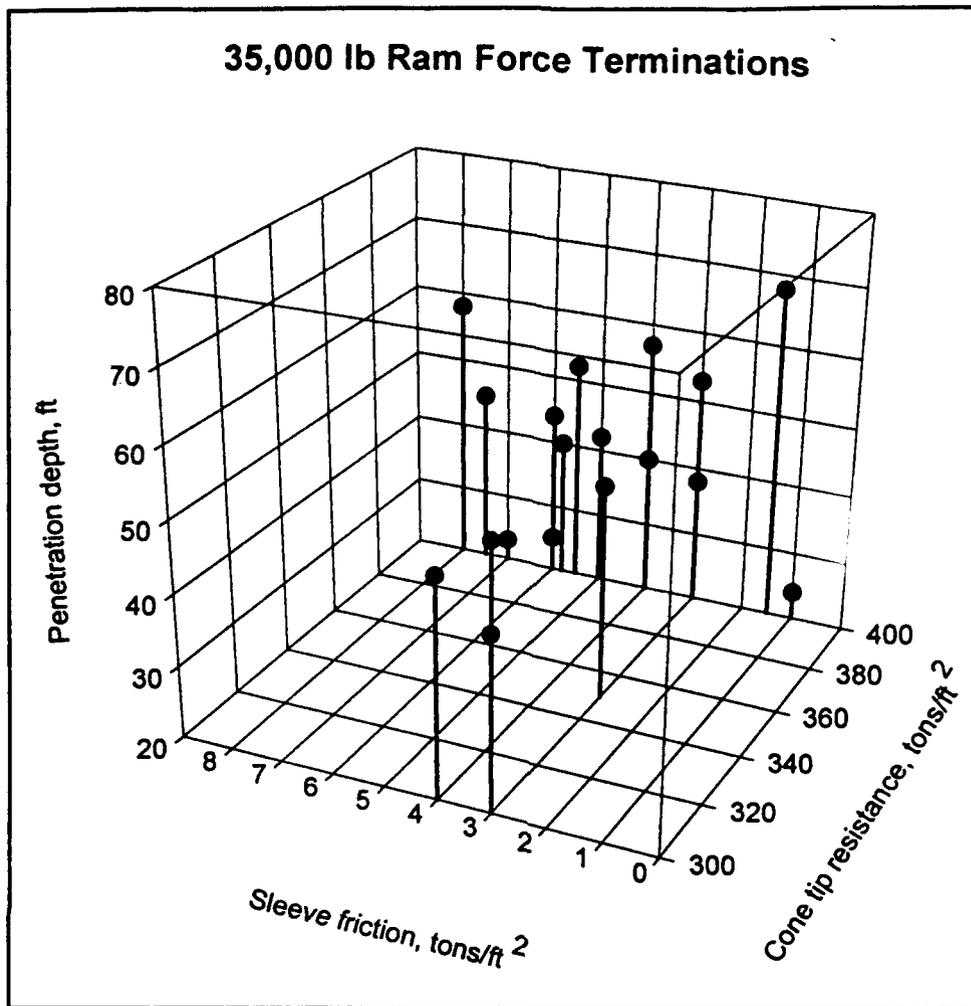


Figure 9. Penetration termination values

A set of laboratory direct shear tests was performed on typical sand material (SM) sampled on both the north side (near CP-01) and south side (near DSA-SB-01) of the investigation site. The samples were shear tested separately, and the results are listed in Appendix E. The samples were tested under natural moisture conditions (unsaturated), in a consolidated - drained state, with a molding density of 95 percent. The applied normal stresses imitated in situ natural overburden confining pressures. The friction angle was determined to be 35 deg for each sample.

The friction angle (angle of internal friction) depends on the density or relative density and the confining pressures on the sand, and is a direct indication of the shear strength (or shear resistance) of the sand (Bowles 1988). As the penetrometer advances through the sand, the sand's resistance to shearing and deformation plays a most important role in determining the penetration depth. The shearing resistance of soil depends on many factors (stress history, void ratio, composition, temperature, strain rate, and soil structure), and the interrelationships between these factors are not all known (Mitchell 1976).

A peak friction angle of 35 deg indicates an approximate relative density of 60 percent for a uniform fine sand (U.S. Dept. of Transportation 1978). Neither one of these values is relatively large, and by themselves would not explain the high resistance to penetration encountered at this site. All of the samples were "disturbed," i.e. were not in the in situ state of stress at the time of analysis.

The resistance to penetration was observed to be a function of the accumulated "skin friction" during several penetrations into prepunched holes (as previously detailed) and also a function of achieving maximum cone tip resistance (400 tons/ft²) at the termination point in the remainder of the penetrations. Based on the limited number of laboratory tests for physical and mechanical properties of the soils, it is probable that the high resistance to penetration was due to in situ properties not observed in the laboratory samples. Sand cementation or other structural variations may also be responsible for the penetration resistance behavior. Preliminary studies have indicated that even a small degree of sand cementation increases the tip and friction resistance during a penetration event (Puppala, Acar, and Senneset 1993).

Soil classification

The data plots showing the soil classification and soil fluorescence sensor responses for penetrations CP-01 through CP-22 are included in Appendix D. Except for the northernmost penetrations (CP-01 and CP-02), the surface elevation variation for the remainder of the penetrations was within 3 ft. CP-01 and 02 surface elevations were approximately 4 ft lower than the remainder of penetrations. The deepest depth achieved was 68 ft bgs (CP-10), and the shallowest depth was 23 ft bgs (CP-02).

The predominant stratigraphy consisted of coarser-grained deposits (sands) with interbedded finer-grained deposits (silts and clays). A very general trend was the presence of sands above the depths of 19-22 ft bgs, a 1-4 ft layer of finer-grained material, then a 10-ft layer of sand underlain by another finer-grained layer.

Penetrations CP-01 and CP-02 indicated a finer-grained layer located approximately 4-ft bgs. A hand auger was used adjacent to those penetrations for the purpose of visual soil classification to depths of approximately 15 ft. The type of soil encountered (below the loose sand/gravel surface) was predominately uniform fine sand, brown in color, and with varying (visual) moisture contents. A finer-grained (white silty material with very small rock fragments) layer was observed at approximately 4 ft bgs, and was approximately 2 ft thick. The soil type visual classification matched the penetrometer sensor classification to a depth of 15 ft. Penetrations CP-04 and CP-05 indicated the presence of this silty layer at the same elevations as seen in CP-01 and CP-02.

The CP-03 data log indicated a clay layer at 9 ft bgs overlain by finer-grained material. The clay "spike" at 9 ft was in reality an abandoned 12-in.

diam steam line (traced back into Building 402), and was overlain by backfill material. The old metal pipe was penetrated without damage to the penetrometer probe.

Both CP-03 and CP-04 logs indicated a clay layer between 30 and 35 ft bgs. CP-05 was the deepest penetration on the north side of Building 403 (to a depth of 50 ft), and indicated another (lower) clay layer at 46 ft bgs. No data were collected in the first 5 ft of CP-05 due to the necessity of using a "dummy" probe to penetrate the asphalt pavement and subbase materials.

The remainder of penetrations (CP-06 through CP-22) surrounded the original diesel spill site. Parts of the site had been previously excavated and backfilled with "clean" materials up to depths of 30 ft. The exact extent of the excavation and the contractual specifications for the backfill operation were for the most part unknown, based on conversations with site personnel. The approximate extent is indicated in Figure 8.

The backfill limits were presumed from the penetrometer data, based on the presence of three "fingerprints": the cone tip response, the friction sleeve response, and their combined response indicating a fairly prominent clay layer at approximately 20 ft bgs. The presence of backfill materials was presumed when the cone tip and friction sleeve response exhibited a curved pattern of low stress that increased sharply with depth. This type of response is exhibited if granular materials are loose or if cohesive materials are underconsolidated (U.S. Dept. of Transportation 1978). The connection between backfill limits and low stress response from the sensors is tenuous if the backfill material was densely compacted. The presence of the clay layer at approximately 20 ft deep appears to be the uppermost confining layer (possible aquitard) and is composed of a 1- to 2-ft thick clay layer. The presence of this clay layer in all penetration logs noted (with the possible exceptions of CP-13 and CP-21) indicated that it most likely was a natural, not backfilled, layer.

A silty layer with imbedded small rock fragments approximately 1- to 2-ft thick was observed at depths ranging from 5 to 10 ft bgs at penetrations CP-10, 15, 21, and 22. This layer appeared similar to the silty material observed at penetrations CP-01, 02, 04, and 05 on the north side of Building 403. A sample retrieved from this layer at CP-15 served to verify the penetrometer sensor soil classification and also correlated with the hand-augered samples taken at CP-01 and 02. It was assumed that this layer was another indicator of the undisturbed soil surrounding the backfilled area. Due to the presence of fluorescence observed in this soil layer (discussed in a later section of this report), the particles in this material were analyzed by stereoscopic microscope and X-ray diffraction examinations. The conglomeratic particles consisted of rounded fragments of sand and pebbles, cemented with a clay-sized calcite material. After chemically removing the calcite (calcium carbonate), the remaining minerals were observed to be quartz, potassium feldspar, plagioclase feldspar, and monoclinic amphibole. Quartz and feldspar were the major minerals present. Figure 10 shows a representative X-ray diffraction pattern of this material.

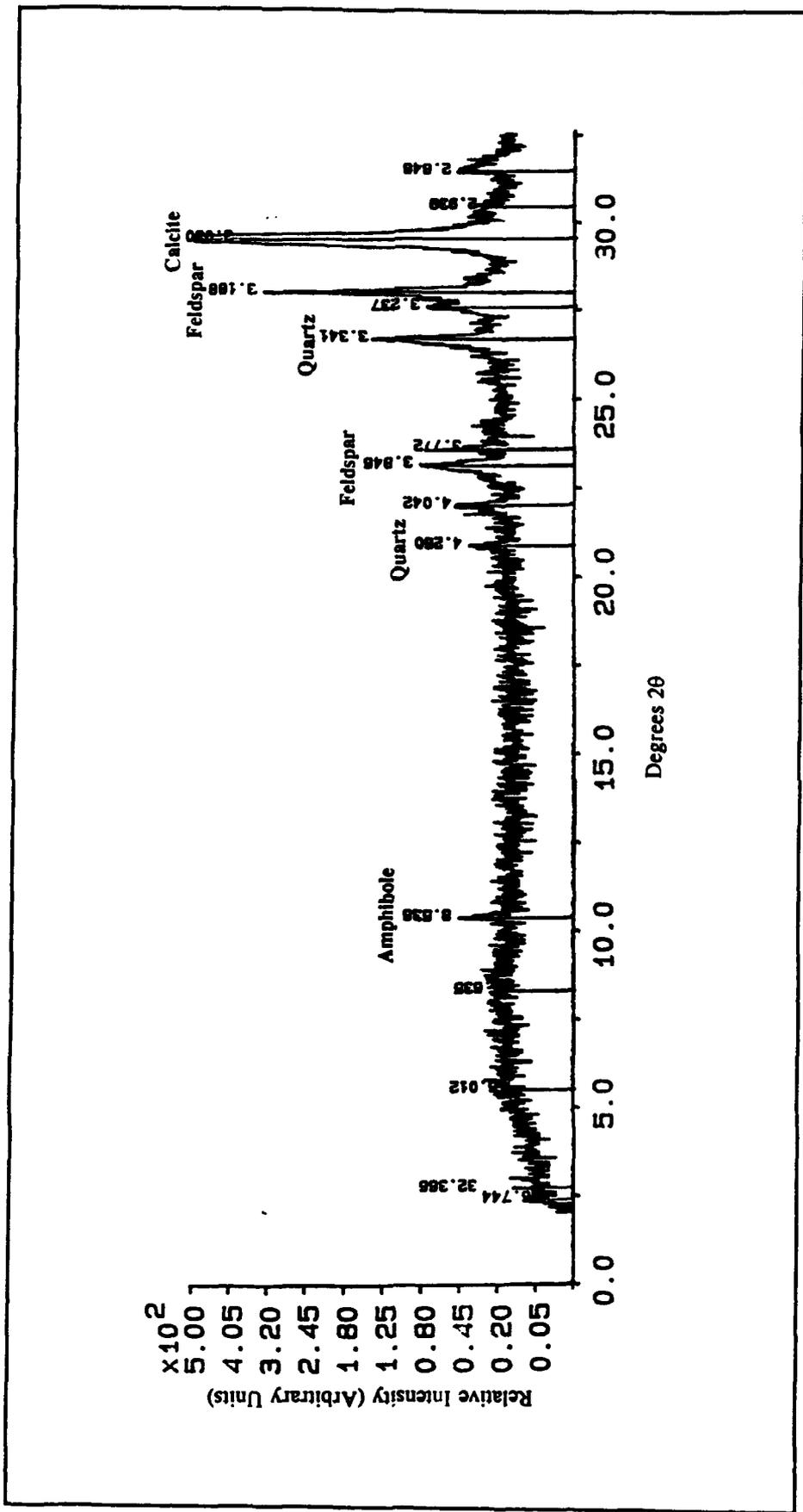


Figure 10. X-ray diffraction pattern.

Figures 11 and 12 show the postprocessed soil stratigraphy data presented as a three-dimensional model visualization. The general trends correlate fairly well with the stratigraphy indicated by the individual push plots.

The retrieved soil samples were laboratory-analyzed for soil classification information. The gradation curves and soil classification information for representative soil samples are shown in Appendix E. Note that the predominant soil type was poorly graded sand (SM to SP). The silt layer containing calcite fragments was a sandy silt (ML). The dominant sand particle shape was subangular.

Soil Fluorescence

Soil fluorescence background level was typically less than 100 counts intensity. Fluorescence greater than that level was observed at various depths during all penetrations CP-01 through CP-22. The data plots for each penetration are shown in the Appendix D.

Fluorescence peaks up to approximately 550 counts (intensity) were observed in some of the penetrations on the north side of the Building 403 diesel spill site. The maximum intensity occurred in the silt layer previously discussed in the Soil Classification section above. This layer occurred at depths between 3 to 9 ft bgs. Samples taken from the silt layer were analyzed as discussed in the Soil Classification section above. These retrieved samples were also analyzed by the fluorometer, and fluorescence matching the in situ response was observed. The X-ray diffraction pattern (shown in Figure 10) indicated that the conglomeratic pebble fragments were coated with the mineral calcite. Calcite is a known ultraviolet fluorescent mineral (Dana 1959).

The remainder of penetrations (closer to the diesel spill area) indicated fluorescence levels above background at depths typically between 5 to 20 ft bgs. Maximum fluorescence intensity in the area closest to the spill site was approximately 700 counts at peak wavelengths around 450 nanometers. Fluorescence responses were not observed at deeper depths with the exception of CP-16 and CP-17. These two locations are immediately adjacent to the presumed original source of the diesel spill (south of the Bldg. 403 mechanical room). Fluorescence patterns were observed in an approximate interval of 12- to 45-ft bgs at these penetration locations. CP-17 penetrated to within 3 ft above the presumed water table elevation (62 ft), and no fluorescence was noted at that depth. The only other penetration which went to the water table depth was CP-10 (approximately 150 ft southwest of CP-17); no fluorescence was observed in the water table zone.

Figures 13 and 14 are the postprocessed fluorometer data presented as three-dimensional model visualizations. The total fluorescence was gridded as a function of spatial distribution, and the visualizations represent all fluorescence sources observed. No distinction is made between contamination fluorescence and other source fluorescence.

Figures 15 through 22 are the three-dimensional visualizations with the interference fluorescence patterns subtracted (filtered out). The interference patterns were identified from onsite POL verification sampling and analysis (discussed in detail in a later section of this report). The visualizations indicated in Figures 15 through 22 represent probable POL contamination at the site based on the results of the verification soil sample analyses. Four orientations are presented; view "a" represents intensities above 100 normalized counts, and view "b" represents intensities above 200 normalized counts. Note the difference between Figures 13 and 14 (total fluorescence) and Figures 15 through 22 (filtered fluorescence).

Support Systems

Data collected from some of the support systems (site surveying and sampling) were for the purpose of complementing the primary data collection efforts using the probe sensors. The remainder of support systems data collection efforts was mostly observational (geophysics, probe decontamination, and grouting) and served specific functions.

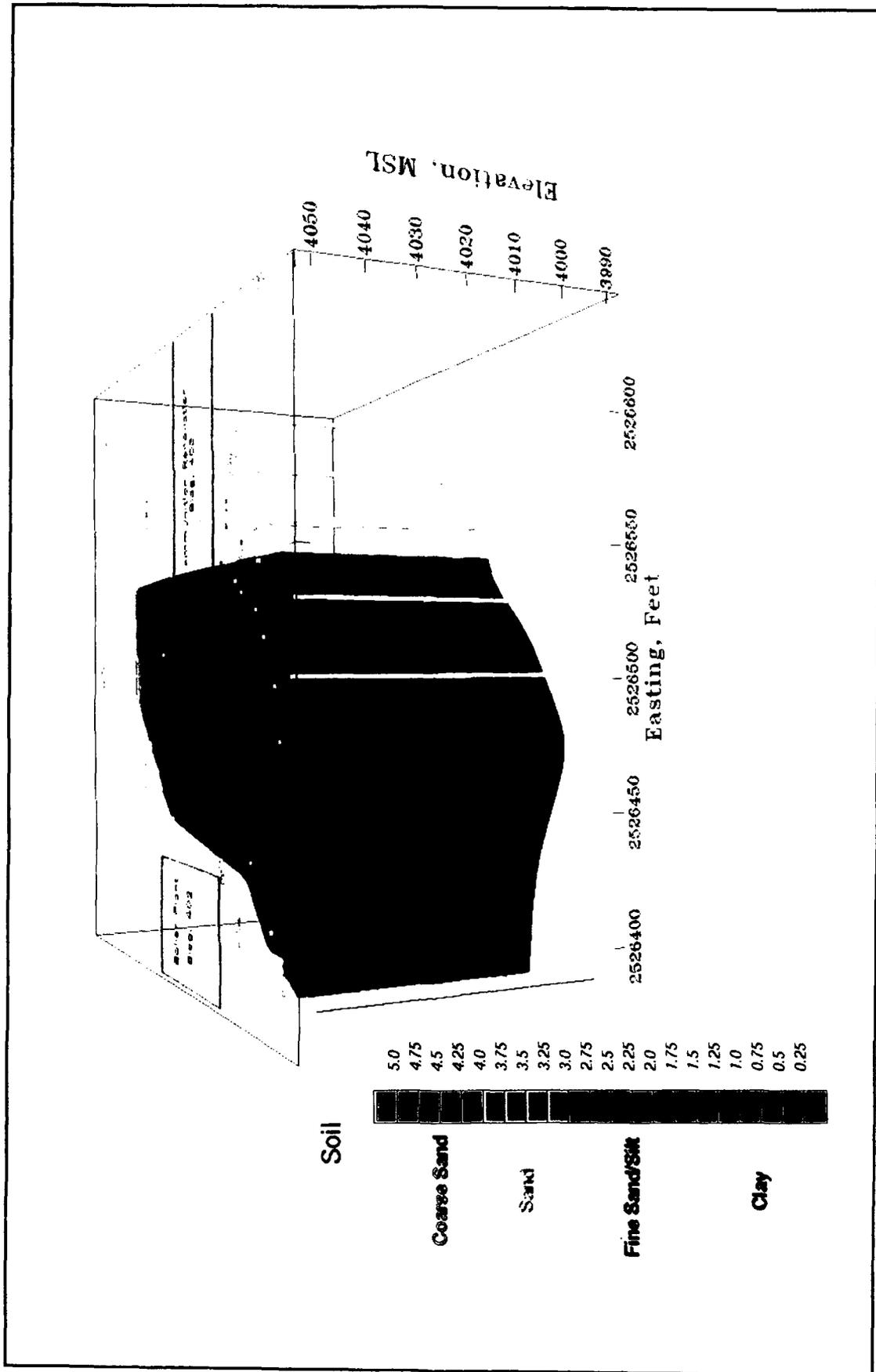
Surveying and geophysics

The site surveying data were obtained by establishing a central point from which sideshots were taken. Known x and y coordinates (California State Plane Zone 1) and ground elevations (referenced to mean sea level) of monitoring wells DF-01-MWA and DSA-02-MWA provided reference points for a two-point resection which located a central surveying point on top of the berm between Buildings 402 and 403. Multiple sideshots were taken to determine the coordinates and elevations of penetration points. A traverse was not performed to determine the data precision and accuracy, but repeated sideshots obtained over the project duration served to validate the data quality. Accuracy of surveying data was expected to be within plus or minus 2 in. The data (coordinates and elevation) are shown in Appendix B.

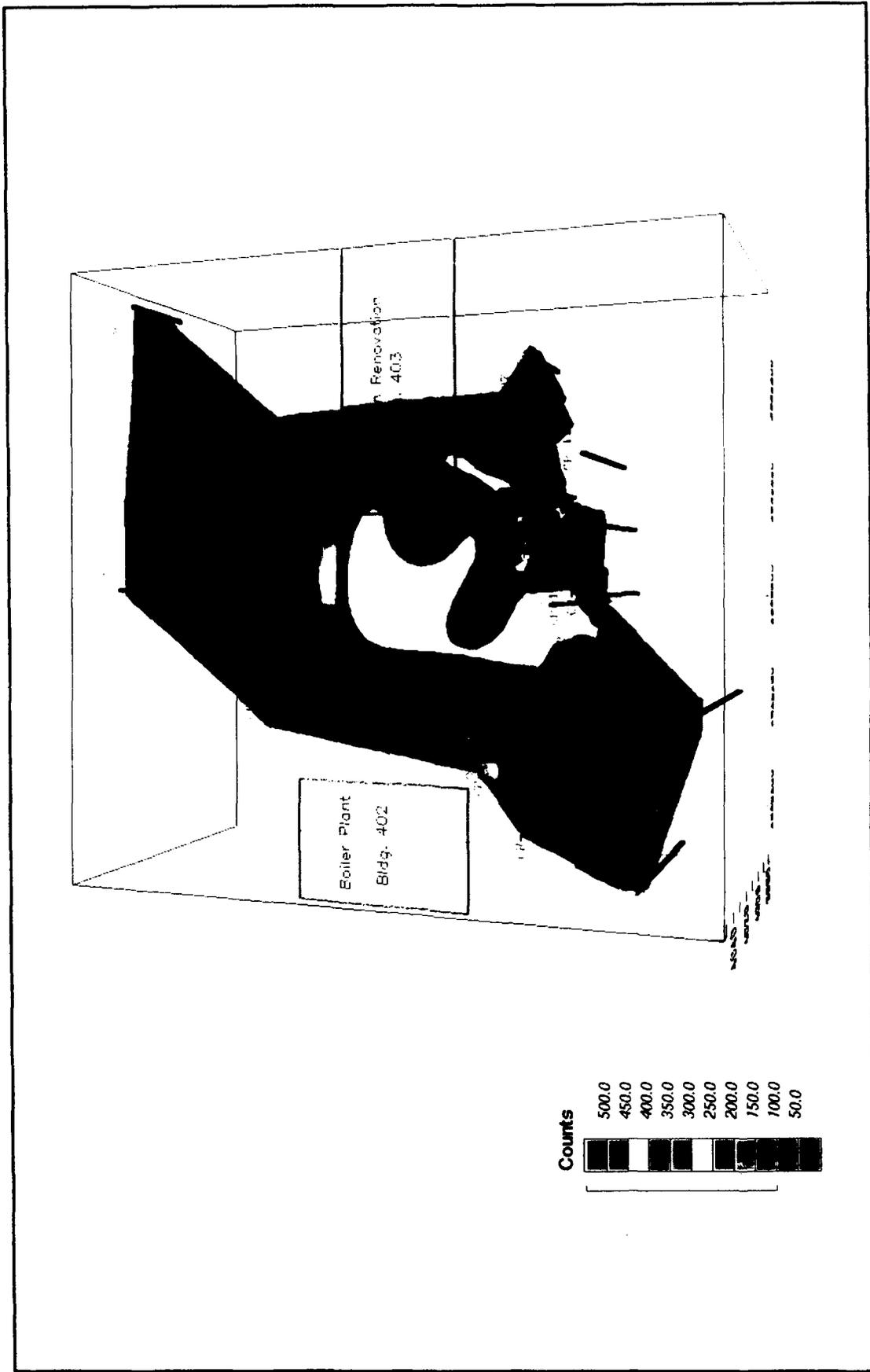
A very limited geophysics program for locating underground obstacles was performed. The SIAD assistance efforts in locating utility and fuel lines in the vicinity of proposed penetrations minimized these requirements. An electrical duct bank near CP-05 and possible buried debris near CP-09 constituted the primary targets for SCAPS geophysics. The area near CP-03 was not a targeted area due to prior SIAD clearance from presence of active utility lines.

Grouting

Grouting through the umbilical cord grout tube was performed at the penetration locations. The grout formulation used (a portland cement material with bentonite added) was a successful first-time achievement at a SCAPS site. The penetrations for sampling soil or groundwater were manually grouted (due



33 Figure 12. Soil stratigraphy 3-D model visualization, View 2



35 Figure 13. Soil fluorescence 3-D visualization, total fluorescence, View 1

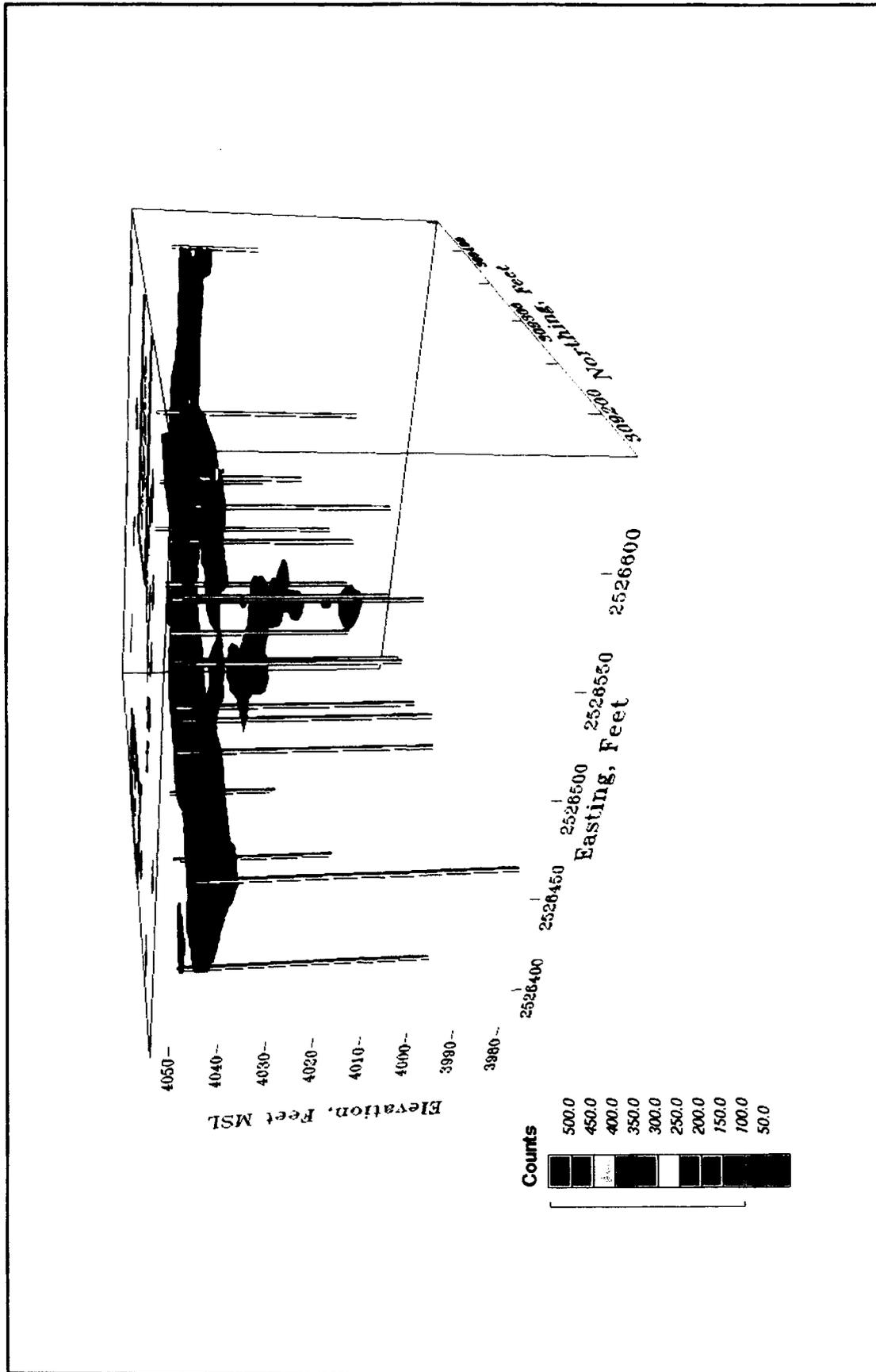
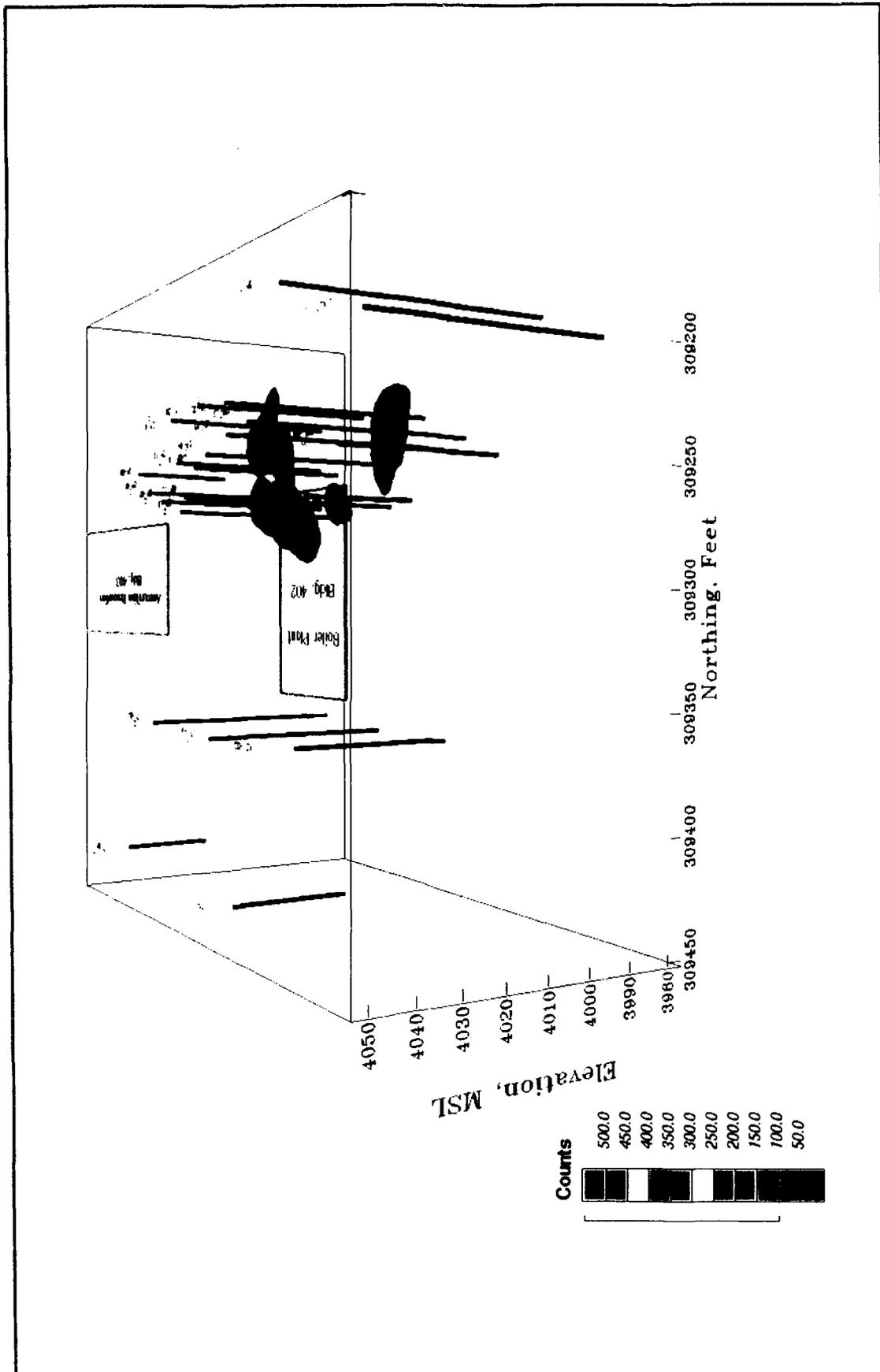
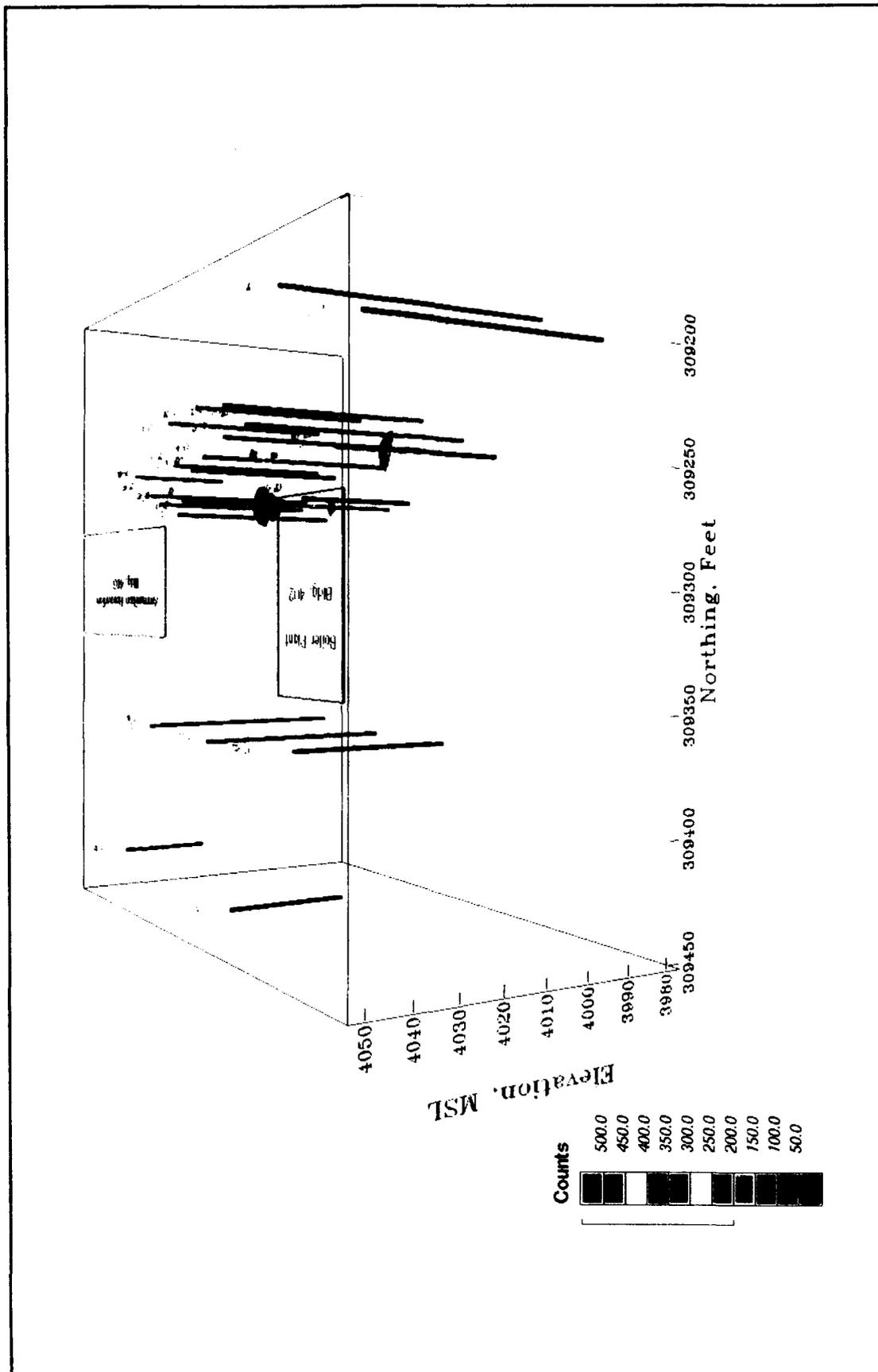


Figure 14. Soil fluorescence 3-D visualization, total fluorescence, View 2



39 Figure 15. Soil fluorescence 3-D visualization, View 1a



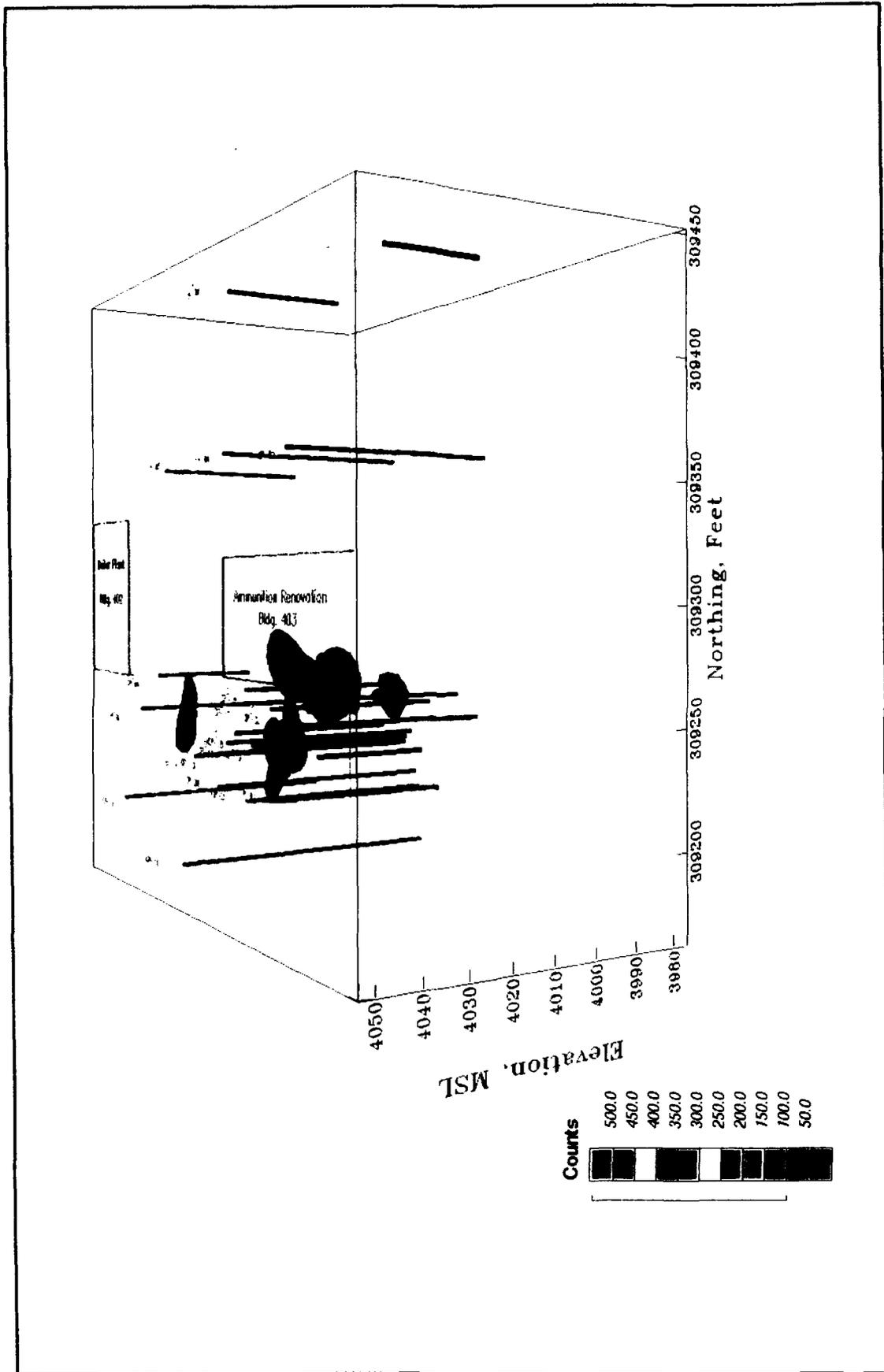


Figure 17. Soil fluorescence 3-D visualization, View 2a

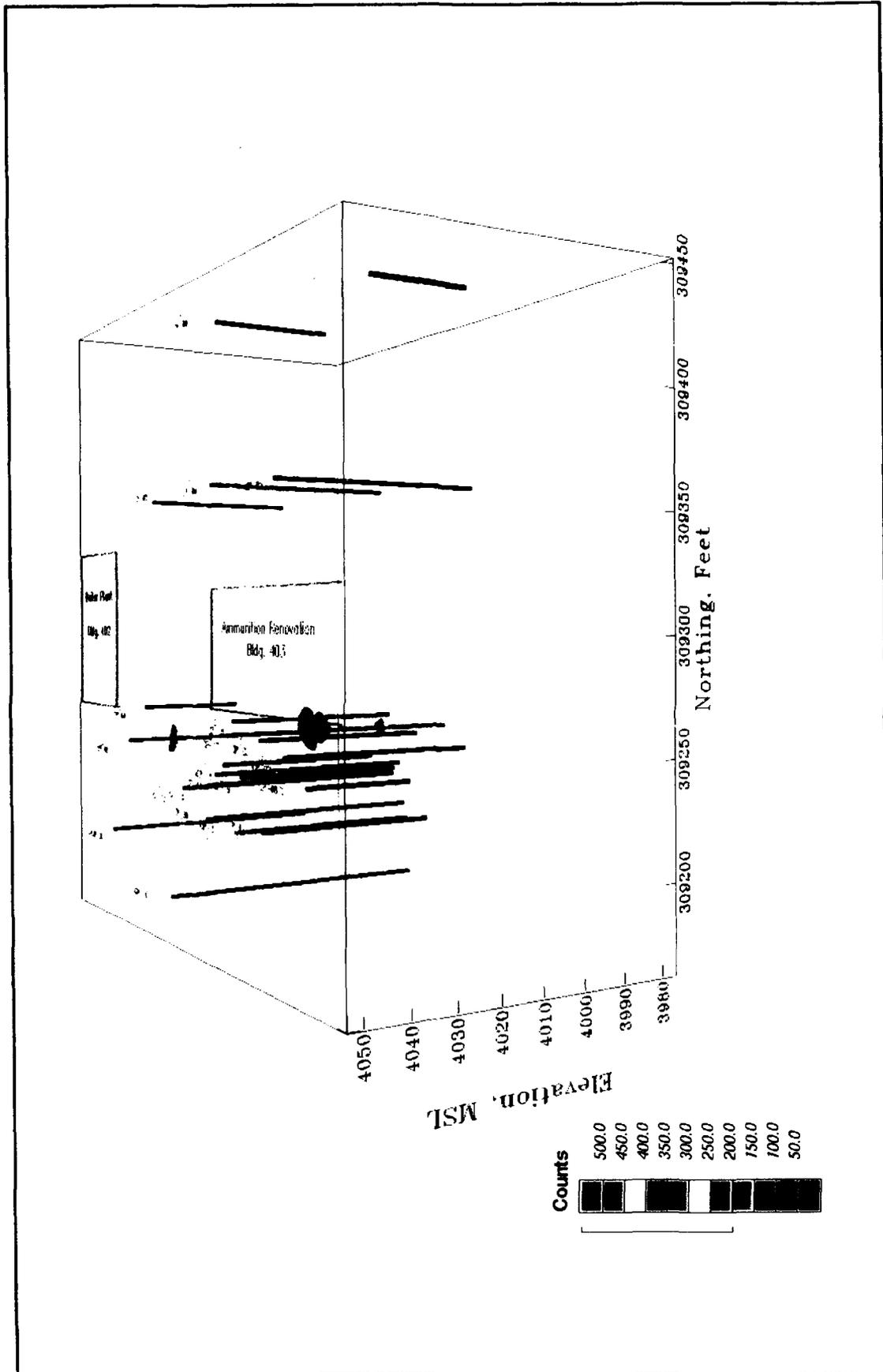


Figure 18. Soil fluorescence 3-D visualization, View 2b

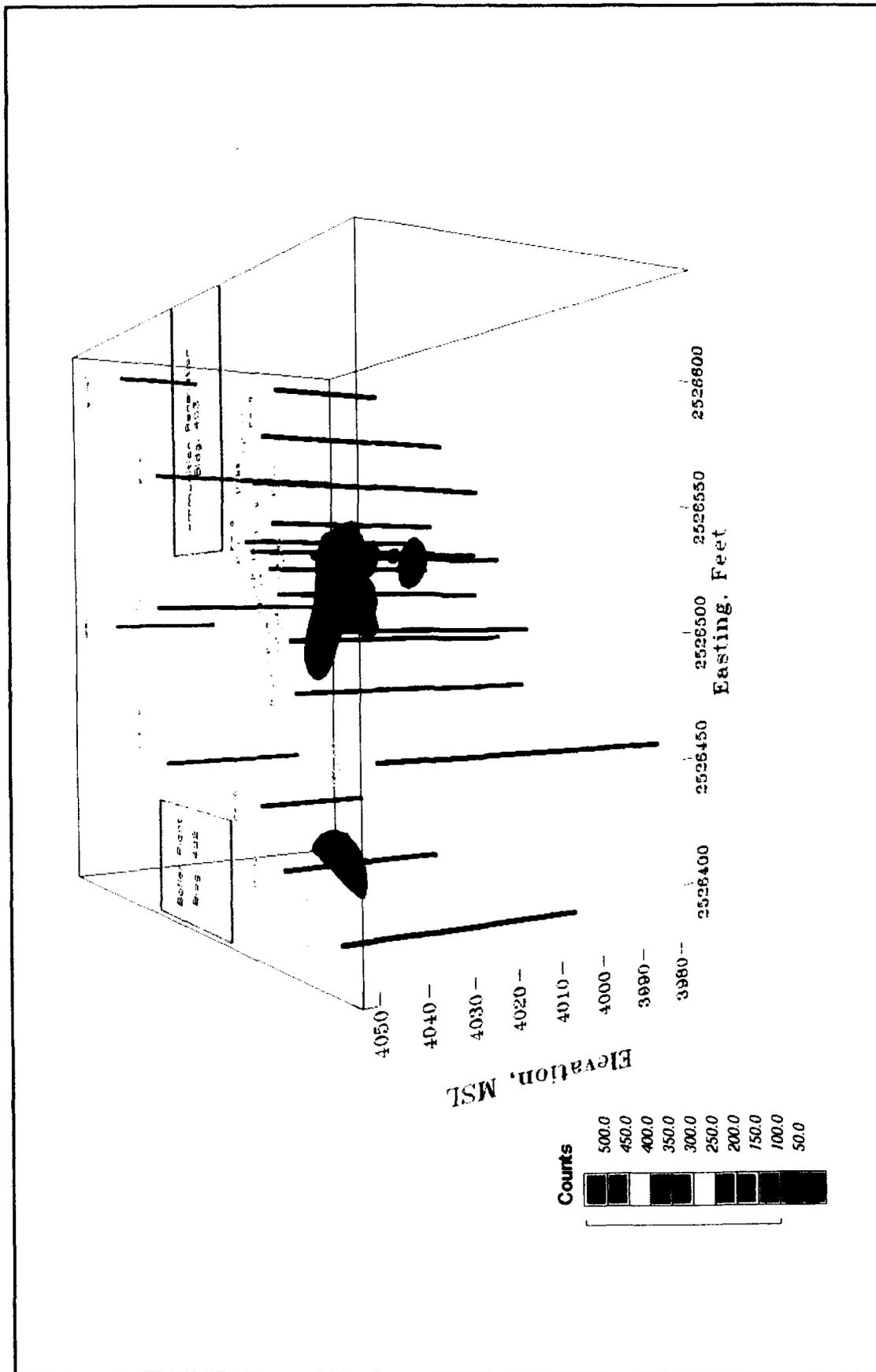


Figure 19. Soil fluorescence 3-D visualization, View 3a

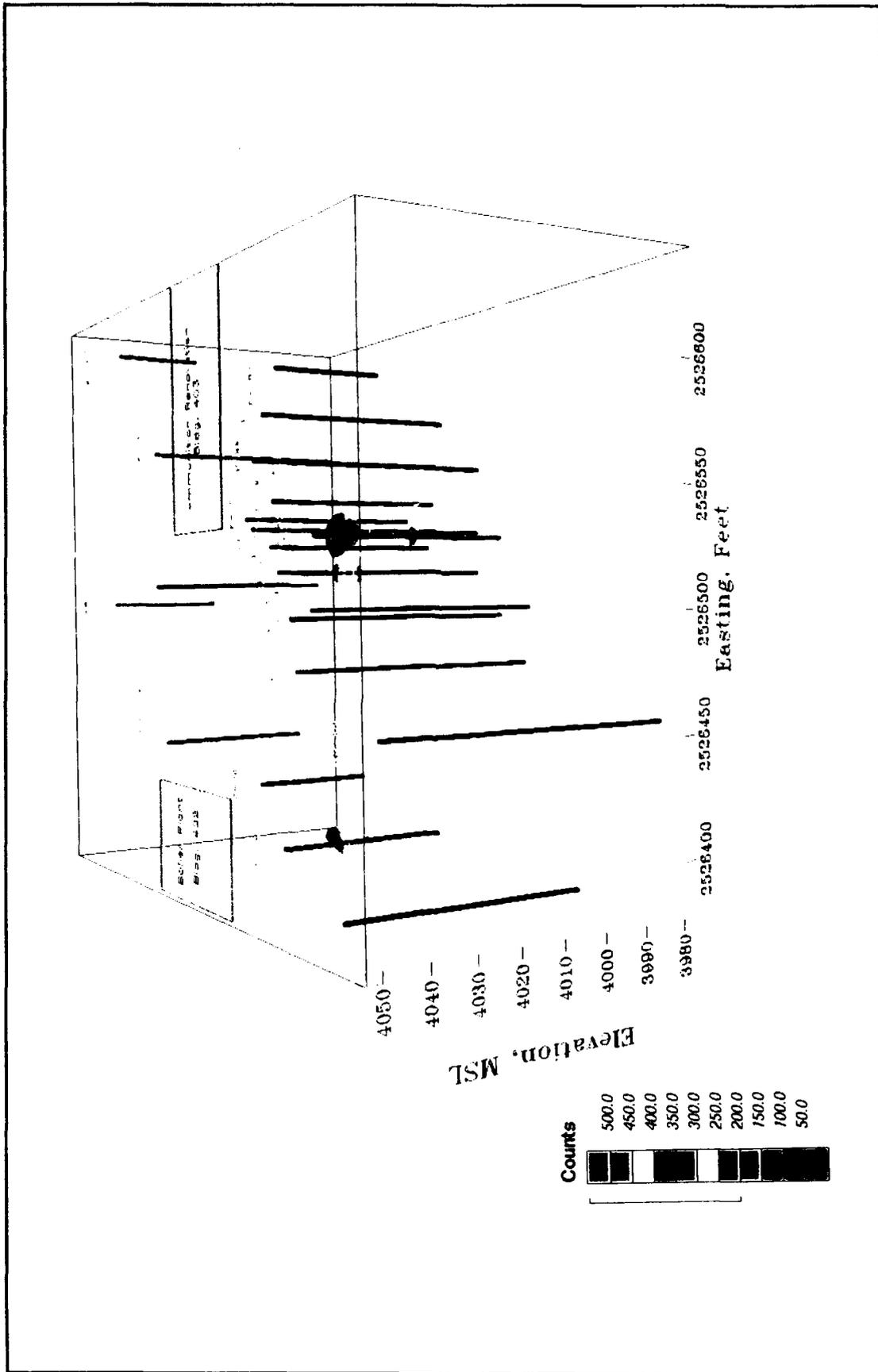
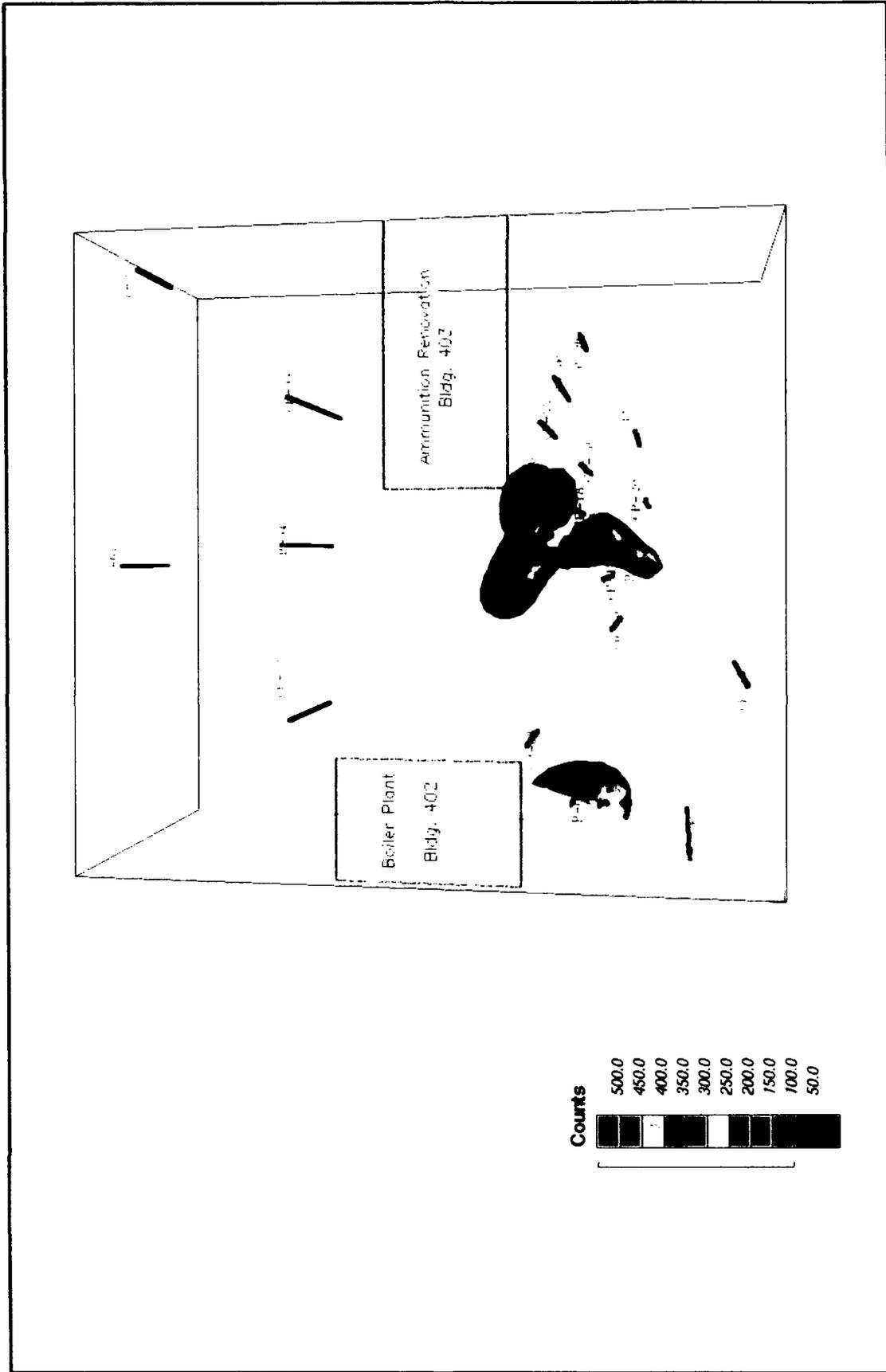
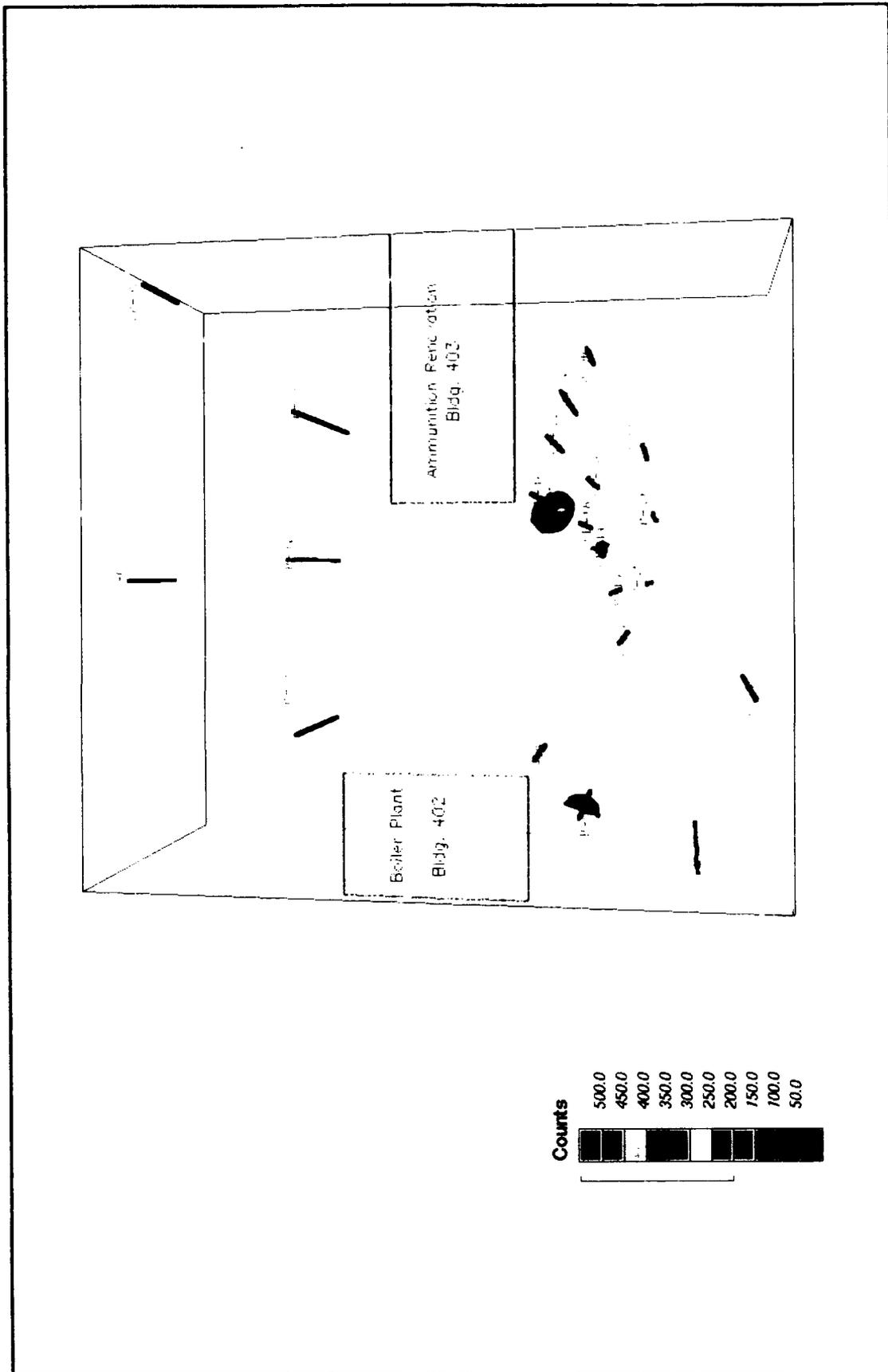


Figure 20. Soil fluorescence 3-D visualization, View 3b



51 Figure 21. Soil fluorescence 3-D visualization, View 4a



53 Figure 22. Soil fluorescence 3-D visualization. View 4b

to the lack of an umbilical cord) with a thicker consistency of grout. The grout mixture with bentonite added (3:2 cement to water ratio by weight, plus 2 percent bentonite) tended to slowly clog the pump output line, especially at the connection points where turbulent flow occurred. The grout tended to "settle out" at those points, probably due to minute changes in velocity, and frequent cleaning and tube clearing had to be accomplished.

Tube clearing (a standard procedure to prevent clogging) was done by pumping fresh water through to gradually dilute the slurry. The tube was considered clean when clear water was seen shooting out the probe tip (as the probe was hanging underneath the truck).

Soil and groundwater sampling

Sampling operations encountered the same problem as the sensor penetrations, namely that the soil resistance prevented most of the samplers from reaching targeted depths. The small diameter (1.4-in.) pushpipe was used to push the soil and groundwater samplers previously listed.

The Gouda™ sampler was pushed to the target depths (approximately 61-ft bgs into the "smear zone" above the water table) for retrieving the samples for Montgomery Watson, Inc. analyses, but its small size prevented large samples from being retrieved. The Mostap™ sampler would have retrieved an ideal larger sample size, but its larger diameter (2 in. versus the Gouda's 1.75 in.) could not overcome the soil resistance for penetration to 61-ft bgs. Once the sample was retrieved, extricating it from the sampler tube was tedious and time consuming.

The Mostap™ sampler was pushed to the target depths (approximately 4- to 20-ft bgs) for the sample verification project discussed in other sections of this report. Since the sample tube was a split tube arrangement, extricating the sample was not difficult. Some mechanical elements within the sampler were more delicate than those in the Gouda™ sampler, however.

The Hydropunch™ Models I and II were used for obtaining groundwater samples. Only the smaller Model I (1.75 in. outside diameter) achieved the target sampling depth (below the water table), and only one sample was retrieved. The maximum sample size using the Model I is about 500 ml, which falls short of the standard testing laboratory requirement of 1 l minimum. After several attempts which took approximately one working day, it was decided that further attempts to collect groundwater samples in this site environment would be futile. Groundwater samples could have been obtained from the upper portion of the unconfined aquifer, but the efforts to retrieve them would have not been cost effective.

The practice of "prepushing" a hole prior to penetration with a sampler was attempted and was not as practical as doing so with the sensor probe. Both soil samplers would automatically engage into the open position when lowered into a prepushed hole. The groundwater samplers had more

resistance to such engagement, but on occasion they would engage prior to reaching the termination depth of the prepushed hole. Even when the prepushed hole penetrated well below the water table elevation, the groundwater sampler, in most cases, either did not reach that depth or prematurely engaged.

Cleaning and decontaminating each soil and groundwater sampler was required after its use. The steam cleaner (hot pressure washer) was utilized for cleaning, and distilled water rinsedown provided decontamination. In general, the groundwater samplers were more delicate than the soil samplers. They contained more intricate mechanisms which provided greater maintenance and cleaning challenges.

Penetrometer Fluorescence Verification

Laboratory calibration studies

The results of analysis of the laboratory fortified soil samples (Native and Fill) obtained from SIAD prior to the SCAPS deployment are summarized in Table 2. This table only contains a TPAH value which is the sum of all polynuclear aromatic hydrocarbons (PAH's) detected for a particular sample. The levels of the individual PAH's in the soil samples are presented in Table 3. The triplicate analyses of each fortification level indicate that the samples contain homogeneously distributed POL contamination. These data support the efficacy of the WES soil POL fortification procedure for construction of samples with diesel fuel.

The data indicate strong linear relationships between the different parameters (TRPH, TPH and TPAH) investigated as measures of POL contamination. The Native soil sample exhibited strong linear correlations between TRPH and TPH ($r^2 = 0.99$, Figure 23); TRPH and TPAH ($r^2 = 0.99$, Figure 24) and TPAH and TPH ($r^2 = 0.99$, Figure 25). The Fill sample also exhibited strong linear correlations between these parameters: TRPH and TPH ($r^2 = 0.97$, Figure 26); TRPH and TPAH ($r^2 = 0.98$, Figure 27) and TPAH and TPH ($r^2 = 0.97$, Figure 28). The strong linear correlations between these different measures of POL contamination indicate that, for this set of fortified soil samples, these different measures of POL contamination are all comparable to one another. This result is not surprising since all the soil samples were fortified with aliquots of the same diesel fuel. Lower correlation coefficients between these measures of POL contamination would be expected for soils that contain mixtures of different POL types or a single POL type that has been allowed to age in the soil. The TPH procedure (EPA Method 8015) includes calibration with a particular fuel (EPA 1984), thus a mixture of POL types or an aged single fuel would cause biased results in this method.

Table 2
POL Parameters for Laboratory Fortified Samples, SN = Native and SF = Fill

Name ¹	TRPH mg/kg	TPH mg/kg	TPAH ² mg/kg	Fluorescence ³	Name	TRPH mg/kg	TPH mg/kg	TPAH ² mg/kg	Fluorescence ³	TPH mg/kg	TPAH ² mg/kg	Fluorescence ³
SN-0-1	0	0	0.00	233	SF-0-1	0	0	0.00	172	0	0.00	172
SN-0-2	0	0	0.00	233	SF-0-2	0	0	0.00	172	0	0.00	172
SN-0-3	0	0	0.00	233	SF-0-3	0	0	0.00	172	0	0.00	172
SN-100-1	120	93	0.24	234	SF-100-1	84	118	0.19	175	118	0.19	175
SN-100-2	110	89	0.23	234	SF-100-2	100	130	0.23	175	130	0.23	175
SN-100-3	110	100	0.22	234	SF-100-3	90	129	0.21	175	129	0.21	175
SN-300-2	330	273	0.66	242	SF-300-1	300	320	0.72	188	320	0.72	188
SN-300-2	330	264	0.73	242	SF-300-2	260	322	0.68	188	322	0.68	188
SN-300-3	340	254	0.71	242	SF-300-3	300	322	0.57	188	322	0.57	188
SN-500-1	540	434	1.04	247	SF-500-1	510	544	1.13	187	544	1.13	187
SN-500-2	520	456	1.11	247	SF-500-2	500	497	1.10	187	497	1.10	187
SN-500-3	530	438	1.08	247	SF-500-3	500	482	1.06	187	482	1.06	187

(Continued)

¹ Sample names include the spike concentration, i.e. SN-2000-1 denotes replicate #1 of the 2000 mg/kg native soil sample.

² TPAH values are the sum of all PAH's detected for a particular sample.

³ Fluorescence response for each spike level is the average of 9 replicate measurements.

Table 2 (Concluded)

Name ¹	TRPH mg/kg	TPH mg/kg	TPAH ² mg/kg	Fluorescence ³	Name	TRPH mg/kg	TPH mg/kg	TPAH ² mg/kg	Fluorescence ³	TRPH mg/kg	TPH mg/kg	TPAH ² mg/kg	Fluorescence ³
SN-1000-	950	876	2.22	272	SF-1000-	980	968	2.29	189				
SN-1000-	930	940	2.03	272	SF-1000-	100	966	1.81	189				
SN-1000-	960	909	2.07	272	SF-1000-	980	968	1.64	189				
SN-2000-	1,880	1,790	4.25	315	SF-2000-	1,900	1,960	4.20	213				
SN-2000-	1,890	2,000	4.30	315	SF-2000-	1,900	2,060	4.10	213				
SN-2000-	1,890	1,890	3.91	315	SF-2000-	2,000	2,080	4.38	213				
SN-5000-	5,100	4,890	10.13	474	SF-5000-	4,500	5,780	11.35	257				
SN-5000-	4,800	4,840	11.06	474	SF-5000-	5,600	6,100	10.41	257				
SN-5000-	5,200	4,960	10.46	474	SF-5000-	4,800	6,230	9.94	257				
SN-10000	11,000	10,300	17.62	740	SF-10000	11,000	9,990	24.06	403				
SN-10000	11,000	10,900	19.60	740	SF-10000	10,000	12,600	25.37	403				
SN-10000	11,000	11,300	20.42	740	SF-10000	9,100	9,880	24.93	403				

Table 3
Polynuclear Aromatic Hydrocarbon Analysis of Laboratory Fortified Soil Samples

Name	Spike mg/kg	NAPHTH ¹ mg/kg	ACEANY mg/kg	ACENAP mg/kg	FLUORE mg/kg	PHENAN mg/kg	ANTRAC mg/kg	FLANTH mg/kg	PYRENE mg/kg	CHRYSE mg/kg	BAANTH mg/kg	BBFLAN mg/kg	BKFLAN mg/kg	BAPYRE mg/kg	1123PYR mg/kg	DBAHAN mg/kg	B-GHI-PY mg/kg	2MENAP mg/kg
SN-0-1	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN-0-2	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN-0-3	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN-100-1	100	0.05	0.00	0.00	0.03	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12
SN-100-2	100	0.05	0.00	0.00	0.02	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11
SN-100-3	100	0.04	0.00	0.00	0.02	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11
SN-300-2	300	0.14	0.00	0.02	0.06	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.32
SN-300-2	300	0.15	0.00	0.02	0.07	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.35
SN-300-3	300	0.15	0.00	0.02	0.06	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.34
SN-500-1	500	0.20	0.00	0.03	0.10	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.48
SN-500-2	500	0.23	0.00	0.04	0.10	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.52
SN-500-3	500	0.20	0.00	0.04	0.10	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.52
SN-1000-1	1000	0.42	0.00	0.08	0.22	0.41	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.07
SN-1000-2	1000	0.39	0.00	0.07	0.20	0.40	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.95
SN-1000-3	1000	0.42	0.00	0.08	0.19	0.38	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
SN-2000-1	2000	0.89	0.05	0.16	0.48	0.98	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.82
SN-2000-2	2000	0.76	0.05	0.15	0.49	0.94	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.85
SN-2000-3	2000	0.71	0.04	0.13	0.43	0.89	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.66
SN-5000-1	5000	1.63	0.13	0.35	1.09	2.04	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.78
SN-5000-2	5000	1.83	0.12	0.44	1.21	2.36	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.97
SN-5000-3	5000	1.65	0.14	0.40	1.18	2.29	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.67
SN-10000-1	10000	2.56	0.21	0.68	2.11	3.80	0.00	0.06	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.97
SN-10000-2	10000	2.91	0.23	0.66	2.22	4.11	0.00	0.05	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.17
SN-10000-3	10000	3.51	0.25	0.75	2.24	4.03	0.00	0.07	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.34

(Continued)

¹ Abbreviations for PAH's are as follows: NAPHTH = naphthalene; ACEANY = acenaphthalene; ACENAP = acenaphthalene; FLUORE = fluorene; PHENAN = phenanthrene; ANTRAC = anthracene; FLANTH = fluoranthene; PYRENE = pyrene; CHRYSE = chrysene; BAANTH = benzofluoranthene; BBFLAN = benzofluoranthene; BKFLAN = benzofluoranthene; BAPYRE = benzofluoranthene; 1123PYR = indeno(1,2,3-C)Dipyrrene; DBAHAN = dibenzo(A,H)anthracene; B-GHI-PY = benzo(G,H,I)perylene; 2MENAP = 2-methylnaphthalene.

Table 3 (Concluded)

Name	Spike mg/kg	NAPHTH ¹ mg/kg	ACEANY mg/kg	ACENAP mg/kg	FLUORE mg/kg	PHEIAN mg/kg	ANTRAC mg/kg	FLAMTH mg/kg	PYRENE mg/kg	CHRYSE mg/kg	BAAMTH mg/kg	BBFLANT mg/kg	BEFLAN mg/kg	BAPYRE mg/kg	1123PYR mg/kg	DBAHAN mg/kg	B-OM-PY mg/kg	ZMENAP mg/kg
SF-0-1	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SF-0-2	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SF-0-3	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SF-100-1	100	0.02	0.00	0.00	0.02	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11
SF-100-2	100	0.06	0.00	0.00	0.02	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12
SF-100-3	100	0.04	0.00	0.00	0.02	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10
SF-300-1	300	0.15	0.00	0.02	0.06	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.35
SF-300-2	300	0.13	0.00	0.03	0.07	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33
SF-300-3	300	0.11	0.00	0.02	0.06	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28
SF-500-1	500	0.25	0.00	0.04	0.10	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.53
SF-500-2	500	0.23	0.00	0.04	0.11	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.51
SF-500-3	500	0.21	0.00	0.04	0.11	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.48
SF-1000-1	1000	0.45	0.00	0.06	0.22	0.44	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.09
SF-1000-2	1000	0.32	0.00	0.06	0.20	0.42	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.78
SF-1000-3	1000	0.26	0.00	0.06	0.19	0.42	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.68
SF-2000-1	2000	0.73	0.00	0.15	0.48	0.93	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.85
SF-2000-2	2000	0.67	0.00	0.14	0.48	0.94	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.82
SF-2000-3	2000	0.61	0.00	0.15	0.50	0.98	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.98
SF-5000-1	5000	3.01	0.00	0.41	1.27	2.15	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.41
SF-5000-2	5000	1.60	0.00	0.40	1.14	2.09	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.05
SF-5000-3	5000	1.42	0.00	0.31	1.16	2.00	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.76
SF-10000-1	10000	3.78	0.00	0.79	2.68	4.57	0.00	0.00	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.00
SF-10000-2	10000	3.82	0.00	0.85	2.83	4.78	0.00	0.00	0.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.70
SF-10000-3	10000	4.12	0.00	1.00	2.69	4.26	0.00	0.00	0.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.60

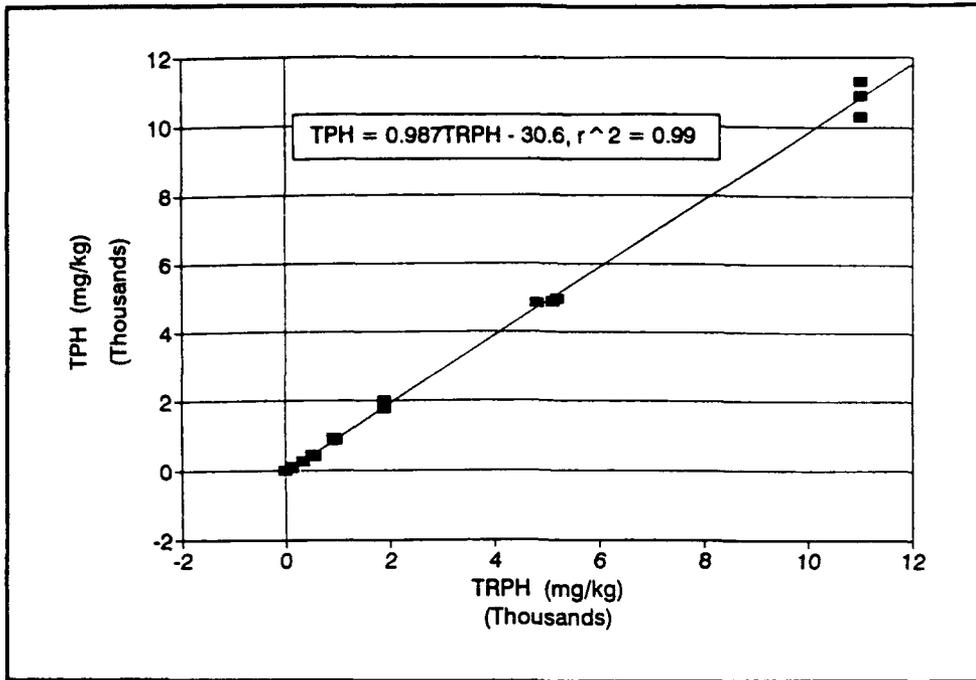


Figure 23. Sierra Native TRPH versus TPH

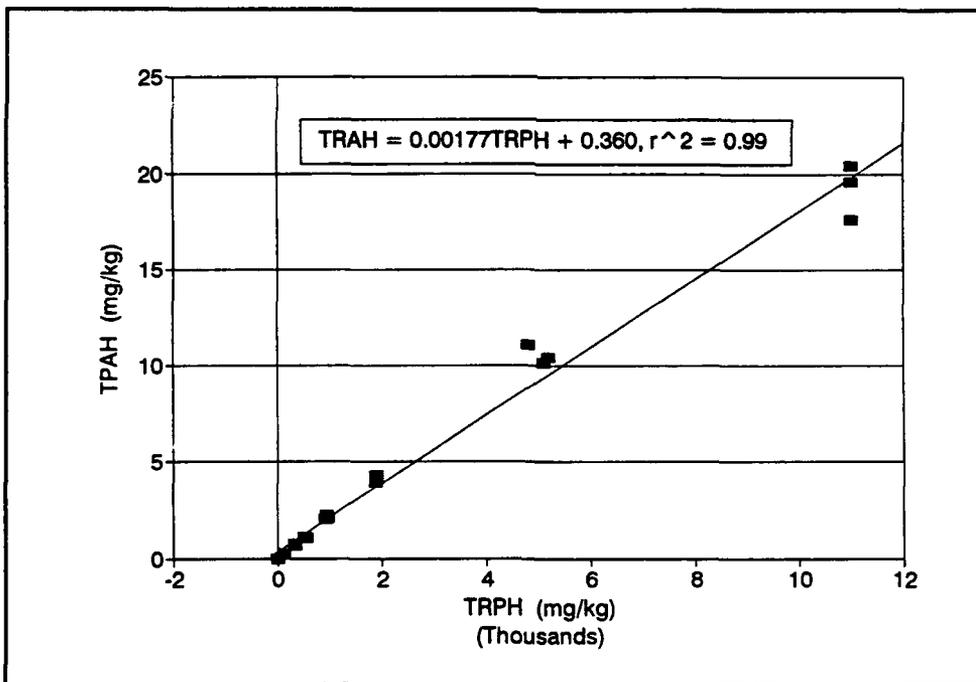


Figure 24. Sierra Native TRPH versus TPAH

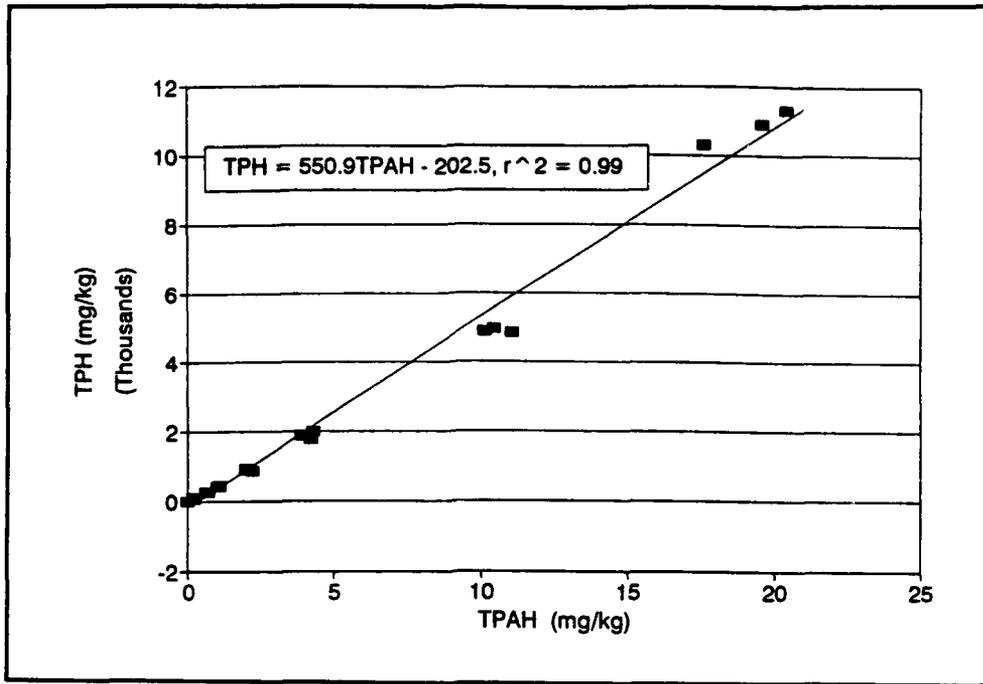


Figure 25. Sierra Native TPAH versus TPH

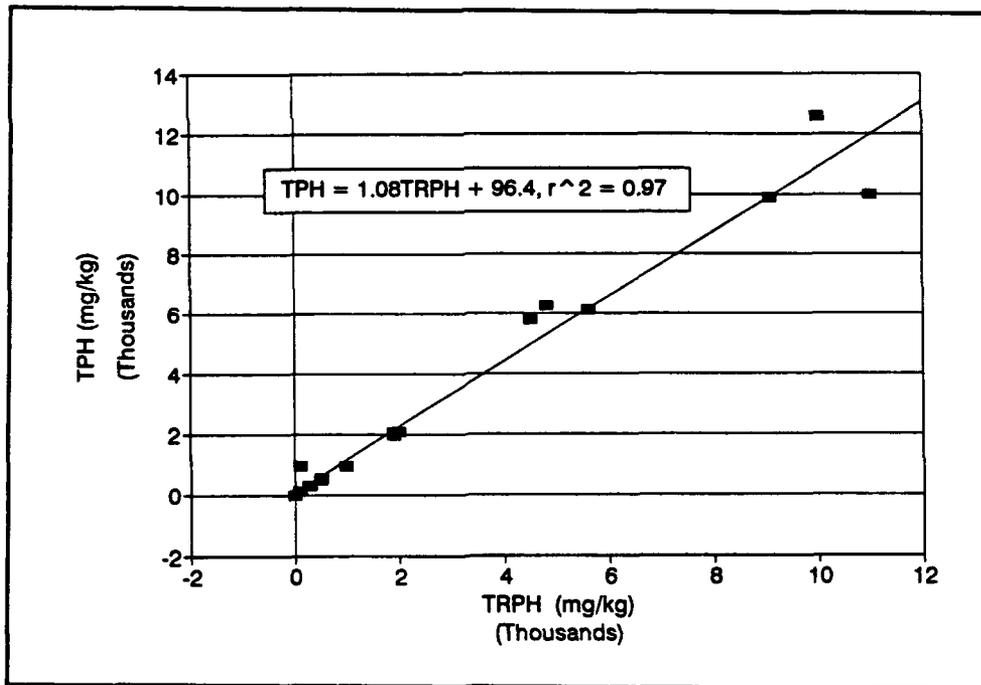


Figure 26. Sierra Fill TRPH versus TPH

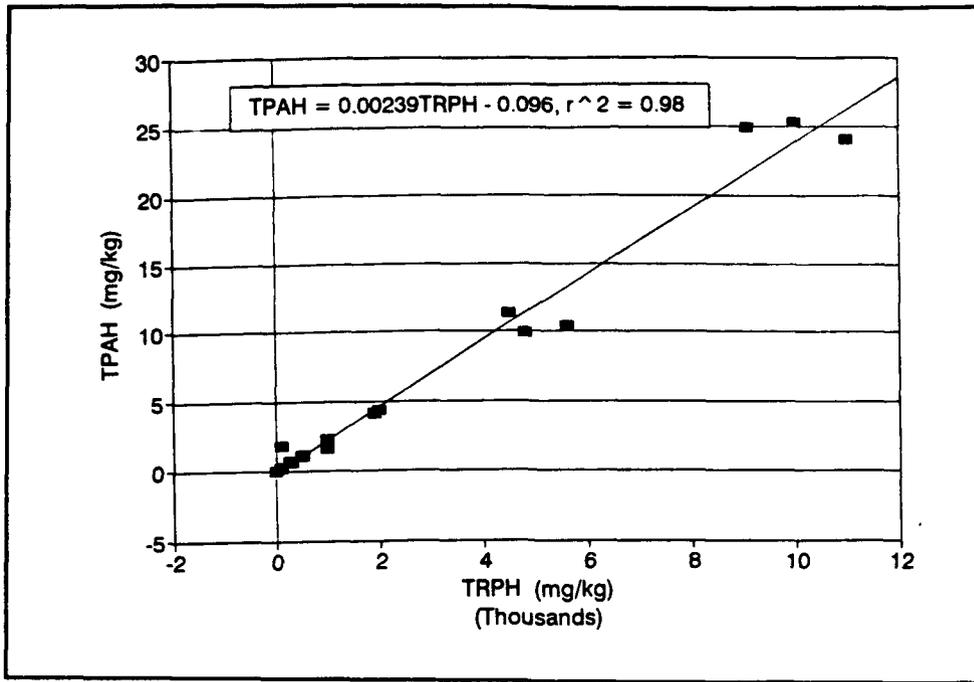


Figure 27. Sierra Fill TRPH versus TPAH

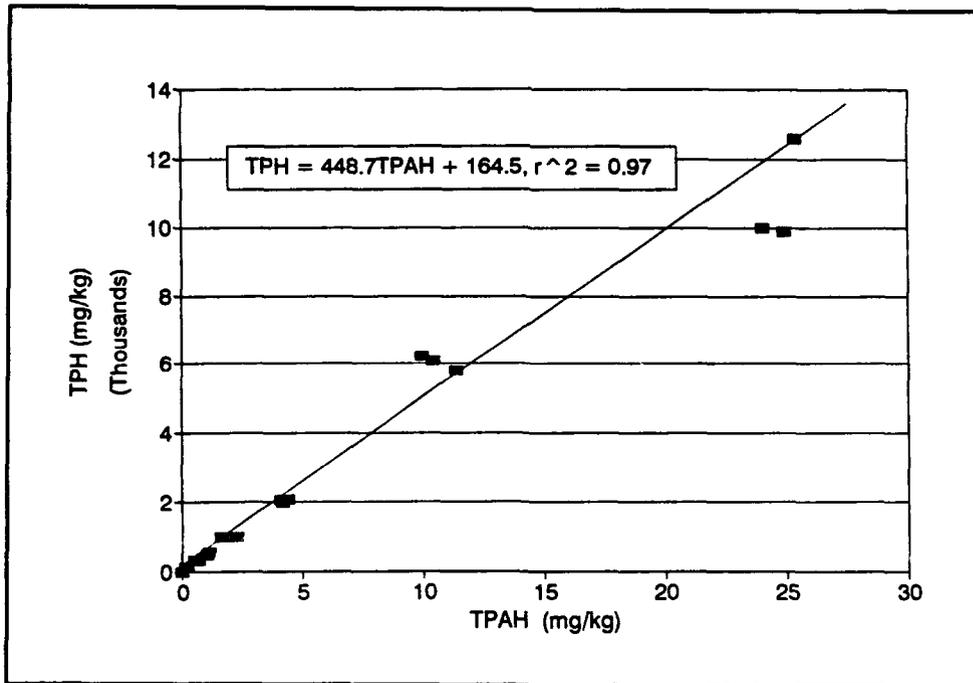


Figure 28. Sierra Fill TPAH versus TPH

Linear relationships were also obtained for both the Native and Fill fortified soil samples when the POL measures were correlated with the LIF data collected from these samples. The Native soil showed stronger linear correlations between the POL measures and LIF than did the Fill soil. The correlations between LIF and TRPH (Figure 29), TPH (Figure 30) and TPAH (Figure 31) for the fortified Native soil samples were very strong ($r^2 = 0.99$ in all cases). The correlations between LIF and the POL measures for the Fill soil samples were also strong but were weaker than those observed for the Native soil samples (TRPH (Figure 32), $r^2 = 0.97$), TPH (Figure 33, $r^2 = 0.95$) except for the TPAH (Figure 34, $r^2 = 0.99$). Figures 29 through 34 are considered laboratory calibration curves for the SCAPS POL sensor and may be used to predict the POL concentration of soils in the field based on the soil LIF response.

The lower levels of correlation observed for the Fill soil between the fluorescence and the parameters used to measure the POL may be the result of a matrix effect in this sample compared with the Native soil sample. The Fill sample appeared to have a higher clay content compared with the very sandy Native soil. The lower level of correlation between the POL parameters and the fluorescence for the Fill sample may be the result of less homogeneous mixing of the Fill soil samples than the Native samples at the micro level. It should be noted that the LIF sensor only views a very small sample area adjacent to the SCAPS sapphire window while the POL measurements of TRPH, TPH and TPAH all use sample sizes of 20 to 30 g.

Another difference observed between the Native and Fill LIF results is that the slope of the regression equation between fluorescence and any of the POL parameters is always lower for the Fill samples than for the Native. This is illustrated by comparing the slopes for the relationship between TRPH and fluorescence in Figures 29 and 32 for the Native (0.0468) and Fill (0.0216), respectively. The units of the slope of this line are fluorescence counts/(mg/kg TRPH). Since the slope of the Native soil is over twice the value of the Fill soil, this means that the Native soil yields over twice the fluorescence per unit POL contamination compared with the Fill soil. The slopes of the lines for the other POL parameters with fluorescence are also over twice as high for the Native soil as for the Fill (see Figures 30, 31, 33, and 34). Apitz et al. (1992) has reported significantly reduced fluorescence of POL's as the clay content of the soil matrix increases. Therefore, these results are consistent with the Fill soil containing more clay than the Native soil.

Field and laboratory analysis of field soil samples

Soil samples were collected at SIAD by WES to investigate the feasibility of field calibration and verification of the SCAPS POL sensor LIF response. As discussed earlier, the purpose of this investigation were multiple including:

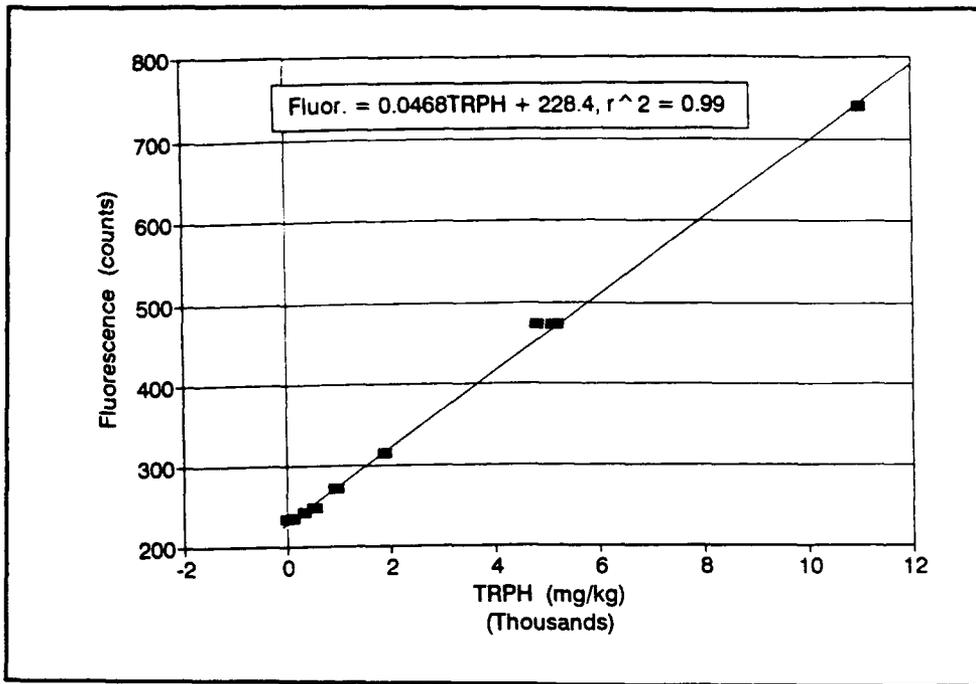


Figure 29. Native TRPH versus fluorescence

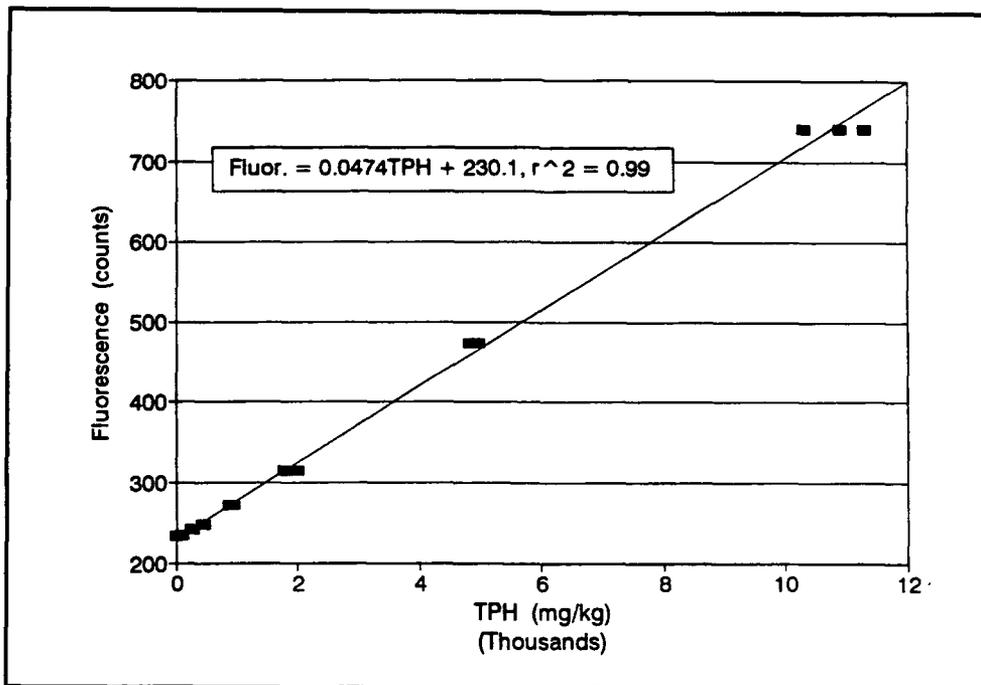


Figure 30. Native TPH versus fluorescence

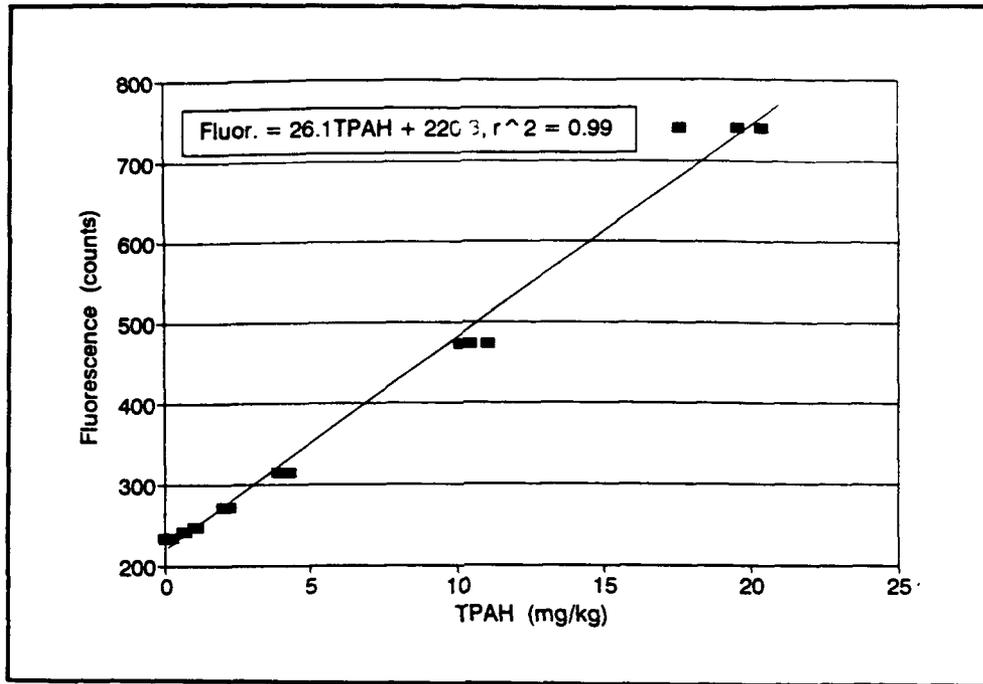


Figure 31. Native TPAH versus fluorescence

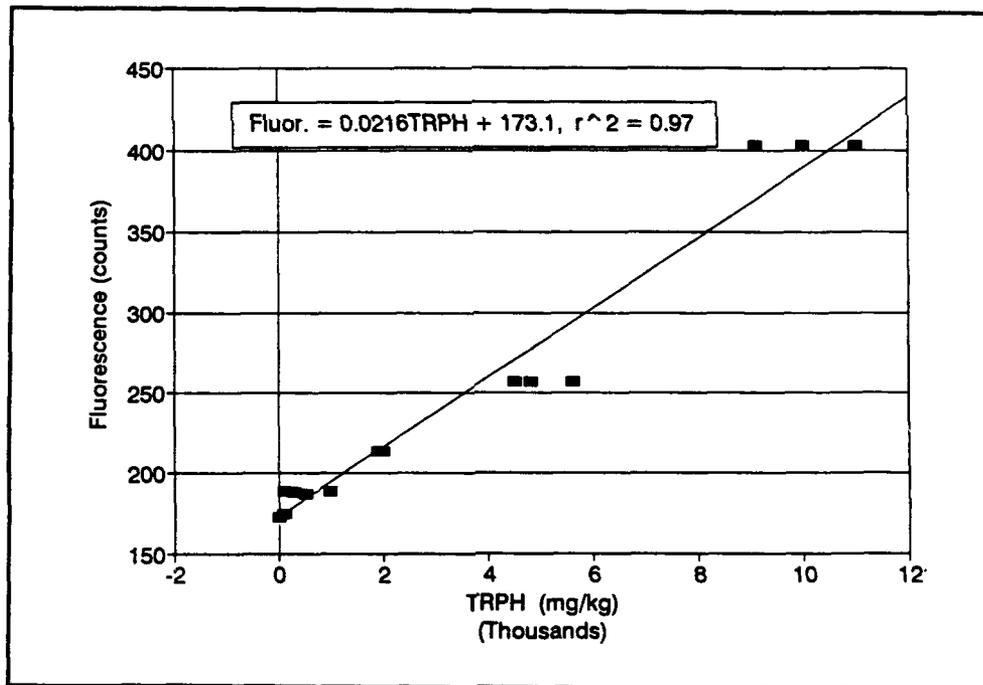


Figure 32. Fill TRPH versus fluorescence

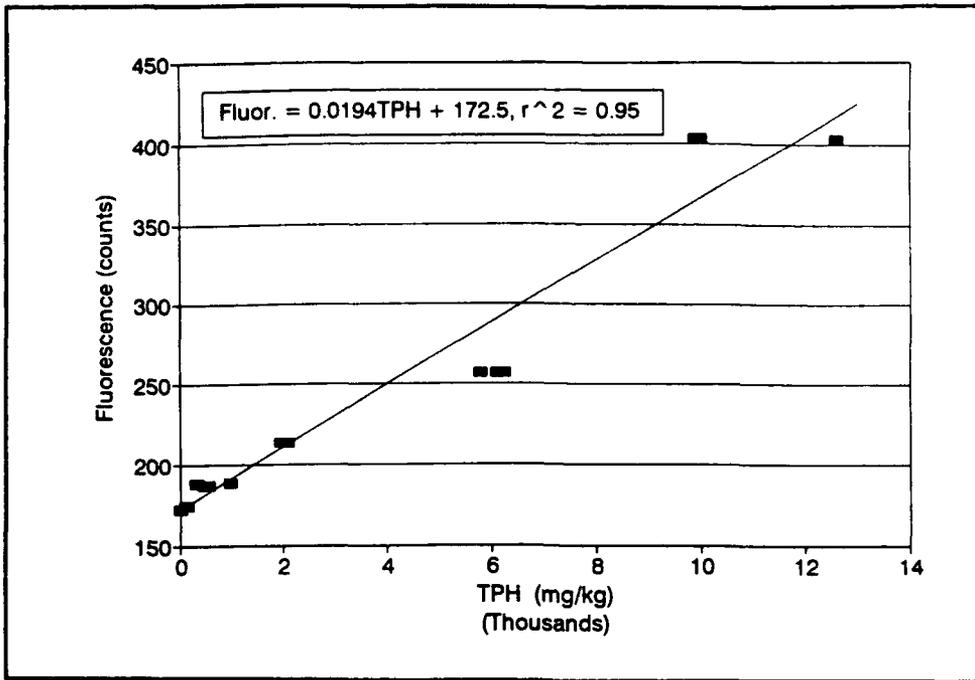


Figure 33. Fill TPH versus fluorescence

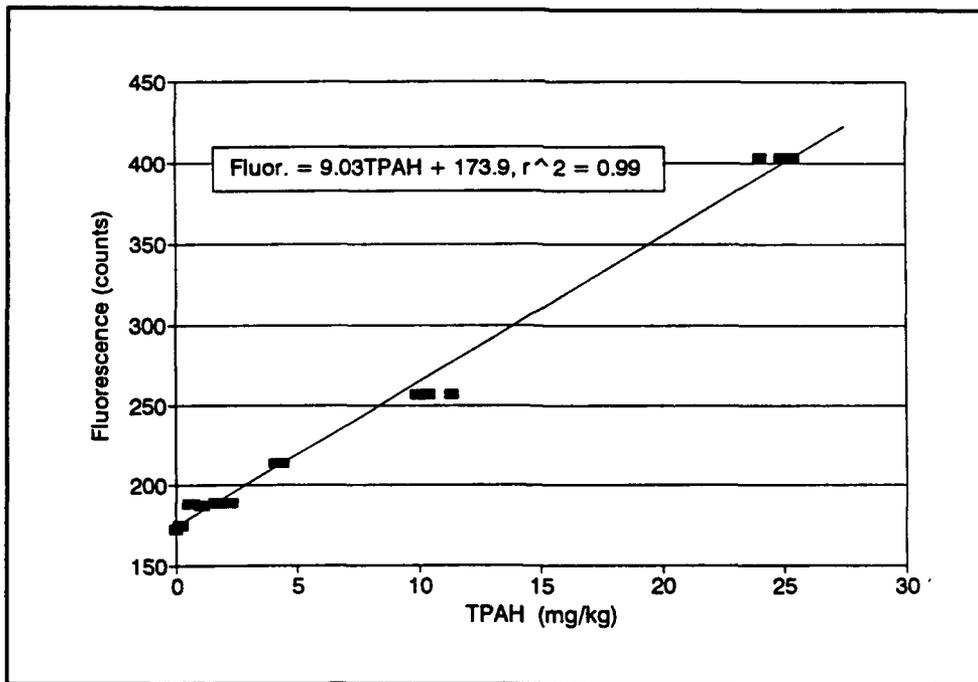


Figure 34. Fill TPAH versus fluorescence

- a. Investigation of the utility of a field portable TRPH instrument for onsite verification of POL contamination identified by the SCAPS POL sensor.
- b. Collection of soil samples for laboratory analysis to verify POL contamination identified by the SCAPS POL sensor.
- c. Investigation of the feasibility of onsite POL sensor calibration with actual field contaminated soil samples using a field portable TRPH instrument.

Twenty-two samples were obtained from locations at SIAD that had produced LIF response on initial SCAPS POL sensor pushes. The samples were homogenized in the field, analyzed for TRPH using a field portable fixed wavelength IR detector (Horiba Model OCMA 220), analyzed in the field for LIF response, and analyzed in the laboratory for TRPH, TPH and TPAH. The results of the analysis of these field soil samples are summarized in Table 4. This table only contains a TPAH value for each sample that is the sum of all PAH's detected. The levels of the individual PAH's in the soil samples are presented in Table 5.

Verification of POL sensor LIF response

All soil samples obtained for field verification yielded detectable fluorescence when analyzed in the field with the SCAPS POL sensor by pressing the homogenized soil sample against the probe window. The LIF data presented in Table 4 and the Appendix D indicate that the field samples were indeed obtained from depths that exhibited fluorescent response. However, comparison of the LIF response with the TRPH (both field and laboratory determinations), TPH and TPAH data obtained from analysis of the field samples leads to the conclusion that some of the soil samples obtained exhibited significant LIF response in the absence of POL contamination. These samples can be considered false positives for POL contamination based on their positive LIF sensor response and lack of detectable POL contamination. The fluorescence response of these samples was suspected in the field of originating from minerals present in the soil. This was based on their high fluorescence response and their low TRPH values measured with the Horiba OCMA 220. Analysis of the fragment particles in those samples confirmed the presence of calcite, a mineral known to fluoresce.

Total recoverable petroleum hydrocarbons

The determination of TRPH on soil samples in the field using the Horiba OCMA 220 allowed the onsite discrimination of fluorescence that was truly the result of POL contamination from the LIF response due to mineral fluorescence. The field TRPH measurements indicated that 13 of the 22 samples obtained were positive for TRPH. The remaining 9 soil samples yielded LIF response but appeared to contain no or very low level (< 10 mg/kg) TRPH.

Table 4
Sierra Army Depot Verification Samples POL Measures

Sample Name	Depth, BGS ft	Drifting Horiba	Horiba TRPH mg/kg	TRPH, 418.1 mg/kg	TPAH EPA 8270 mg/kg	TPH mg/kg	Fluorescence normalized	Fluorescence raw
SCP12-1	4041.02-4042.20	Y	<15	<25	<0.41	<10		
SCP12-1	4041.02-4042.20	Y	<15	<25	<0.41	<10		
SCP14-1	4035.09-4036.59	N	98	203.2	<0.41	200	186	186
SCP14-2	4031.59-4032.09	N	29603	2151	82.9	16000	422	575
SCP14-3	4030.09-4030.59	N	11820	11445	28.6	8420	218	303
SCP17-1	4029.58-4030.08	N	5795	7228	3.29	5040	170	224
SCP17-2	4027.08-4027.58	N	2468	1784	1.25	1360	125	167
SCP15-1	4041.33-4041.83	Y	15	<25	<0.41	<10		
SCP09-1	4034.79-4035.29	N	634	845.9	17.97	1060	218	270
SCP06-1	4040.87-4041.87	Y	<15	<25	<0.41	<10		
SCP20-1	4040.65-4041.15	Y	<15	<25	<0.41	<10		
SCP19-1	4045.77-4046.77	Y	<15	<25	<0.41	<10		
SCP08-1	4046.13-4046.63	N	<15	<25	<0.41	<10		
SCP08-2	4041.13-4041.63	N	<15	<25	<0.41	<10		
SCP05-1	4041.95-4042.45	N	<15	<25	<0.41	<10		
SCP05-2	4040.95-4041.45	N	<15	<25	<0.41	<10		
SCP01-1	4040.55-4041.55	N	<15	<25	<0.41	<10		
SCP02-1	4040.98-4041.98	Y	<15	<25	<0.41	<10		
SCP02-2	4037.23-4037.98	Y	<15	<25	<0.41	<10		
SCP02-3	4036.48-4037.23	Y	<15	<25	<0.41	<10		
SCP02-4	4034.98-4036.48	Y	<15	<25	<0.41	<10		
SCP17-3	4030.08-4030.58	N	6294	5817	3.03	4250	276	324
SCP17-4	4029.08-4029.58	N	2198	1847	<0.41	1070	74	85

Note: An entry of yes (Y) in the Horiba drifting column indicates a probable false positive for TRPH.

Table 5
Polynuclear Aromatic Hydrocarbon Analysis of Field Soil Samples

Name	NAPHTH ¹ mg/kg	ACEANY mg/kg	ACENAP mg/kg	FLUORE mg/kg	PHENAN mg/kg	ANTHAC mg/kg	FLANT mg/kg	PYRENE mg/kg	CHRYSE mg/kg	BAANTH mg/kg	BBFLANT mg/kg	BKFLAN mg/kg	BAPYRE mg/kg	1123PYR mg/kg	DBAHAN mg/kg	8-GH-PY mg/kg	2MENAP mg/kg
SCP12-1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SCP12-1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SCP14-1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SCP14-2	14.40	0.21	1.15	2.75	9.48	0.00	0.00	0.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	34.20
SCP14-3	8.11	0.10	0.52	1.15	5.24	0.00	0.00	0.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.10
SCP17-1	0.16	0.06	0.25	0.53	1.86	0.00	0.04	0.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13
SCP17-2	0.04	0.00	0.06	0.24	0.83	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SCP15-1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SCP08-1	0.00	0.00	0.10	0.05	0.42	0.41	2.33	4.70	2.87	2.17	1.00	0.93	1.35	0.88	0.25	0.72	0.02
SCP06-1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SCP20-1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SCP19-1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SCP08-1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SCP08-2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SCP05-1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SCP05-2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SCP01-1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SCP02-1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SCP02-2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SCP02-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SCP02-4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SCP17-3	0.10	0.05	0.24	0.53	1.72	0.00	0.00	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20
SCP17-4	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

¹ Abbreviations for PAH's are as follows: NAPHTH = naphthalene; ACEANY = acenaphthalene; ACENAP = acenaphthalene; FLUORE = fluorene; PHENAN = phenanthrene; ANTRAC = anthracene; FLANT = fluoranthene; PYRENE = pyrene; CHRYSE = chrysenes; BAANTH = benz(a)anthracene; BBFLANT = benz(b)fluoranthene; BKFLAN = benz(k)fluoranthene; BAPYRE = benz(a)pyrene; 1123PYR = indeno(1,2,3-c)pyrene; DBAHAN = dibenz(a,h)anthracene; 8-GH-PY = benzo(g,h,i)perylene; 2MENAP = 2-methylanthracene.

It should be noted that these false positive samples were all sampled in one elevation zone (see Table 4) and were suspected in the field of resulting from a soil strata that contained a fluorescing mineral.

The samples that resulted in suspected false positive LIF response behaved in an anomalous manner during the TRPH analysis in the field. Specifically, the solvent extracts from these samples did not give a stable reading on the Horiba OCMA 220. The samples' initial low response on the Horiba OCMA 220 continually drifted downward approaching zero mg/kg TRPH. It is hypothesized that this behavior was due to fine particles not removed during filtration causing scattering of the incident IR radiation. This scatter would cause the initial Horiba OCMA 220 response and the drifting signal would result from the particles setting in the detector cell. This hypothesis will be tested by repeating extractions on some of these samples and using a more rigorous filtration (0.20 μm) designed to remove very fine particles.

The ALG TRPH data indicate that 8 of the 13 soil samples found to contain TRPH by field measurement contained > 25 mg/kg TRPH (method detection limit) when analyzed by EPA Method 418.1. The additional five samples that were determined to contain low levels of TRPH by the Horiba OCMA (< 10 mg/kg) contained < 25 mg/kg TRPH by EPA Method 418.1. As discussed earlier, the remaining nine samples yielded anomalous response on the Horiba OCMA 220. The ALG analysis of these same samples indicated that they contained < 25 mg/kg TRPH by EPA Method 418.1.

The validity of in field determination of POL contamination using the Horiba OCMA 220 for TRPH determination was examined by comparing the TRPH results obtained in the field with the TRPH data obtained by the WES ALG for these same samples. This comparison yields a strong linear correlation (Figure 35, $r^2 = 0.98$) between the TRPH measured in the field and in the laboratory. The linear relationship illustrated in Figure 35 has a non-zero intercept (213), but this is relatively small when considering the wide range of these data. These data cover over two orders of magnitude in concentration (97.8 to 29,600 mg/kg). The strong correlation observed in Figure 35 supports the conclusion that the field portable TRPH data obtained with the Horiba OCMA 220 are valid measures of the POL contamination in these samples. The potential utility of a field portable verification device for quantitative (i.e. correlation between lab and field TRPH) and qualitative (i.e. identification of LIF false positive response) data collection has been demonstrated by these results.

Other measures of POL contamination

The twenty two soil samples collected at SIAD for SCAPS POL sensor LIF verification were analyzed for TPH and PAH's (Table 4) in addition to the two different methods used to determine the TRPH contamination. The results of these analyses confirm the finding discussed above for the TRPH. The eight samples determined to be contaminated at > 25 mg/kg TRPH by EPA Method 418.1 all contained TPH contamination > 100 mg/kg and all

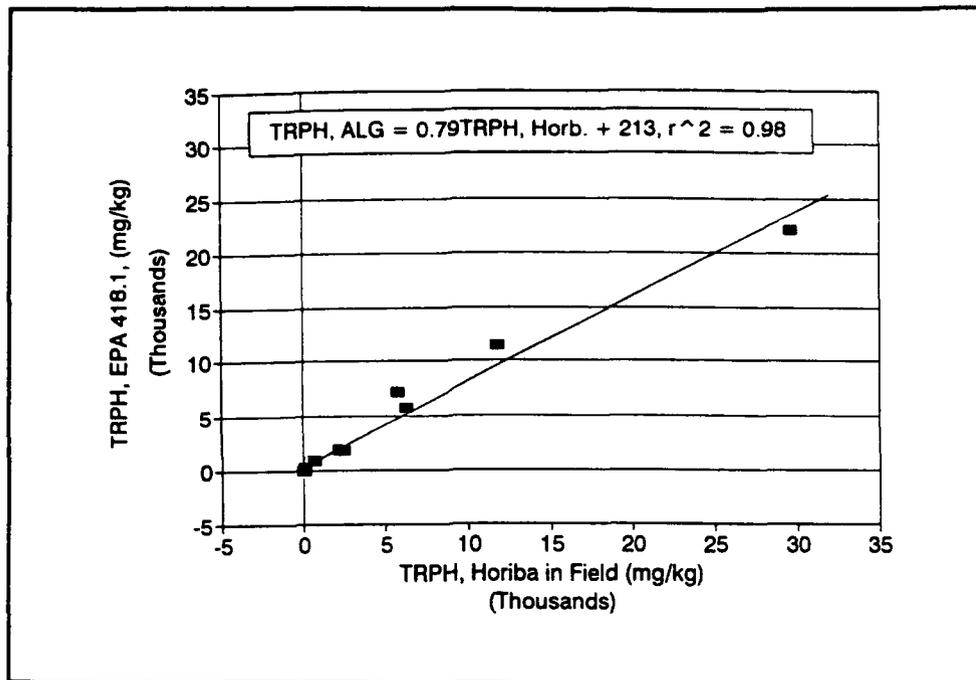


Figure 35. Horiba TRPH versus EPA 418.1, field samples

but the sample with lowest TRPH (SCP15-1) had detectable levels of TPAH. Further, the samples determined to contain < 10 mg/kg TRPH by the Horiba OCMA 220 and < 25 mg/kg TRPH by EPA Method 418.1 all contained < 10 mg/kg TPH and were also below the detection limit for TPAH.

Linear relationships were observed between the different measures of POL contamination for the field samples that were found to contain > 25 mg/kg TRPH. Strong linear correlations were obtained for TPH with TRPH (Figure 36) measured by the Horiba OCMA 220 ($r^2 = 0.97$) and EPA Method 418.1 ($r^2 = 0.99$). These results are similar to those observed for the laboratory fortified Native and Fill soil samples. The results of correlations between TPAH and TRPH were not as strong as those observed between TPH and TRPH. The correlation of TPAH with TRPH (Figure 37) measured with the Horiba OMCA 220 ($r^2 = 0.85$) was stronger than that for the TRPH measured by EPA Method 418.1 ($r^2 = 0.80$).

The relationship between TPAH and TPH (Figure 38, lower curve, $r^2 = 0.83$) is similar to the relationships observed for TRPH and TPAH. However, the results of the TPH analysis indicate that the POL contamination in sample SCP09-1 may not be diesel fuel. The chromatogram for the TPH analysis of this sample does not match the chromatogram for diesel fuel. The individual PAH data for this sample (Table 5) also indicated a significant difference in the distribution of analyte PAH's in this sample compared with the other POL contaminated soil samples. Most of the TPAH in the samples consisted of lower molecular weight PAH's from naphthalene up to pyrene (two to four aromatic rings). The PAH's detected in sample SCP09-1 included most of these lower molecular weight PAH's, but also contained

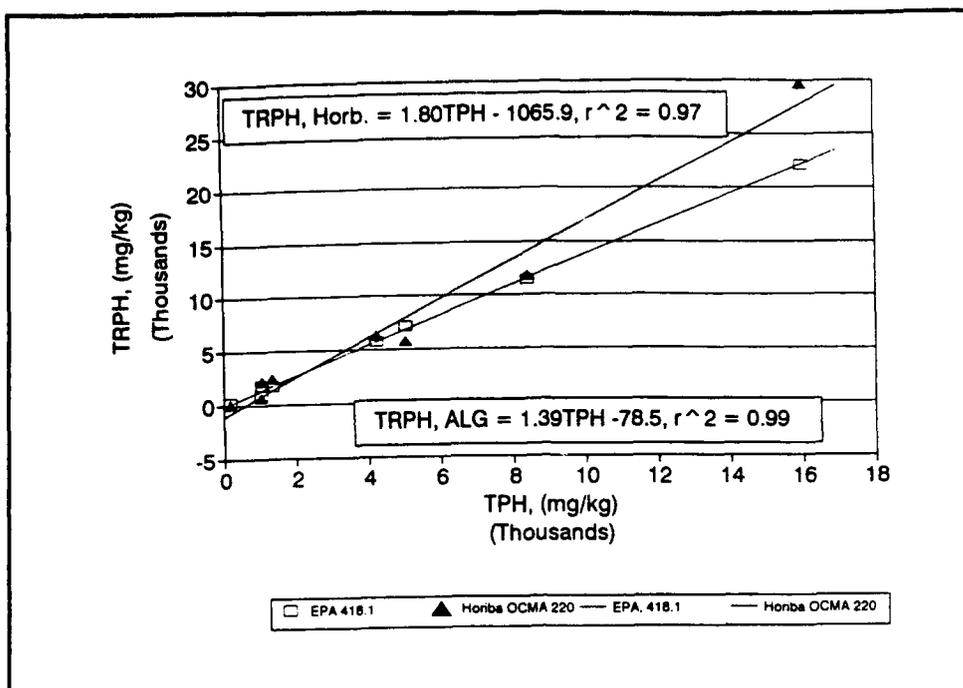


Figure 36. TPH versus TRPH, field samples

significant amounts of the higher molecular weight PAH's (Table 5). The TPH chromatogram suggested that the POL might be a lubricating oil or heavier fuel oil. Another explanation for the difference in PAH distribution for this sample compared with the others is that this sample may represent an older fuel spill and the PAH distribution is the result of aging. The correlation between TPAH and TPH is significantly improved ($r^2 = 0.93$) when the data for sample SCP09-1 is excluded from the correlation (Figure 38). This improved correlation, combined with the TPH chromatographic profile indicative of a POL type other than diesel fuel, suggest that a knowledge of fuel type is required before conclusions can be drawn from correlations between LIF response and POL contaminant concentration.

Laser induced fluorescence as a quantitative measure of POL contamination

The 22 soil samples obtained for validation of the SCAPS POL sensor were analyzed in the field for LIF response in a manner analogous to the procedure used to analyze the laboratory-fortified soil samples. It should be noted that this procedure included normalizing the soil sample LIF response to the response of a Rhodamine standard solution analyzed before and after the soil sample. The LIF response of the soil samples summarized in Table 4 includes both Rhodamine normalized and raw LIF data. As discussed earlier, some of these samples were determined to be false positive samples for POL (yielding LIF sensor response, but analytical results (TRPH) indicated no POL contamination). The samples that were determined to contain POL

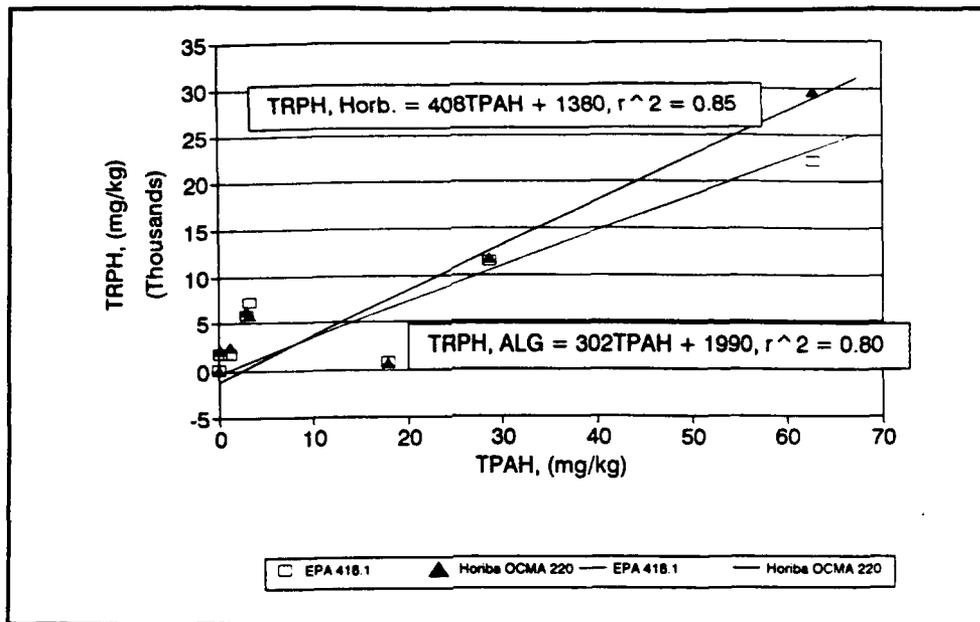


Figure 37. TPAH versus TRPH, field samples

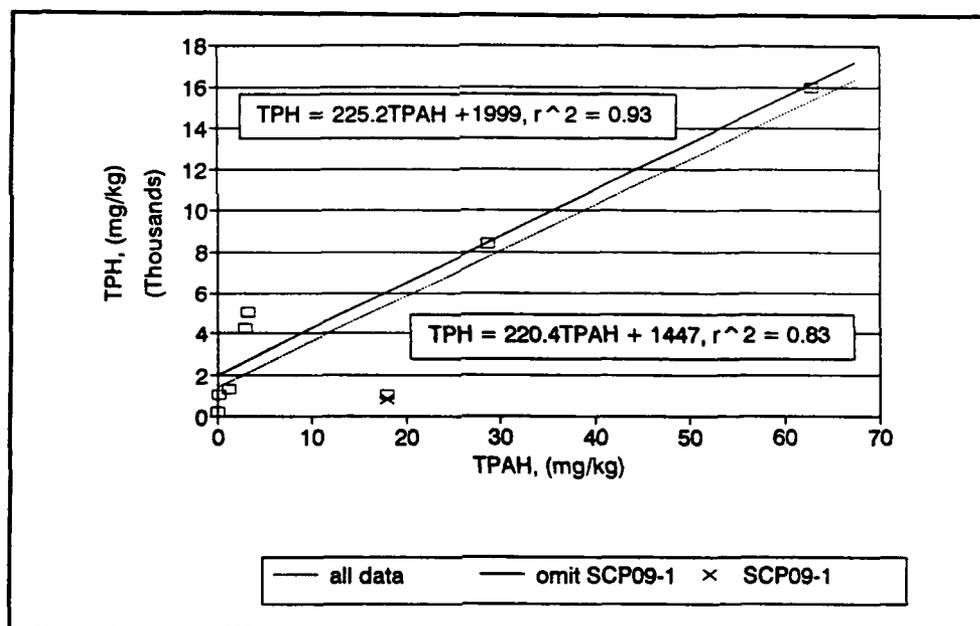


Figure 38. TPAH versus TPH, field samples

contamination by TRPH, TPH, and TPAH analyses also yielded positive LIF response (Table 4).

Linear relationships were observed for the correlation of LIF response with all three POL parameters used as measures of soil contamination. The soil sample fluorescence correlated with the TRPH measured in the field with the Horiba OCMA 220 (Figure 39) and TRPH measured by EPA Method 418.1

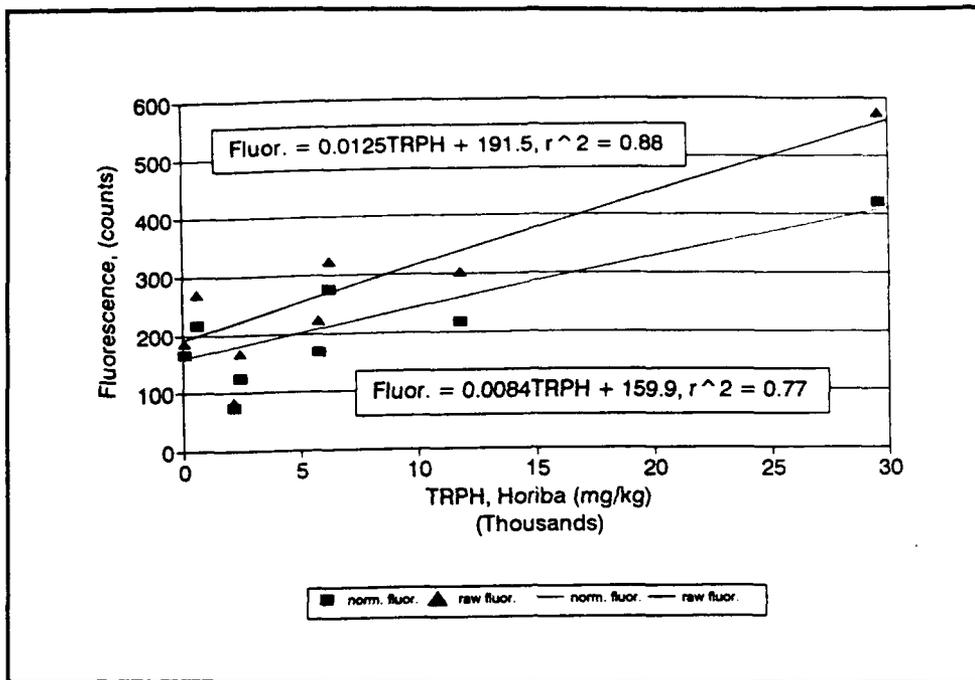


Figure 39. TRPH, Horiba versus fluorescence

(Figure 40). It is interesting to note that the correlation of LIF response with TRPH (by both Horiba OCMA 220 and EPA Method 418.1) is stronger for the raw LIF response (Figure 39, $r^2 = 0.88$ and Figure 40, $r^2 = 0.78$) than for the normalized fluorescence data (Figure 39, $r^2 = 0.77$ and Figure 40, $r^2 = 0.70$). These data suggest that the Rhodamine normalization procedure may introduce bias into the LIF response data.

The raw fluorescence response of the soil samples is also correlated more strongly with the other two parameters (TPH and TPAH) used to measure POL contamination in this study. The raw fluorescence was correlated with the TPH at $r^2 = 0.80$, while the normalized fluorescence correlated with TPH at $r^2 = 0.70$ (Figure 41). Very similar results were obtained for the relationship between TPAH with both the raw and normalized fluorescence (Figure 42, $r^2 = 0.81$ and 0.72 , respectively).

Validity of laboratory calibration of SCAPS POL sensor

The linear relationships observed for the SCAPS POL sensor LIF response with each of the three different parameters used to verify POL contamination in both field and laboratory fortified samples illustrate the potential efficacy of LIF for in situ detection of POL contamination. These same data also point to some potential limitation of this technology that must be defined and understood before the full benefits of the SCAPS POL sensor can be realized.

The lower slopes of the Fill versus the Native laboratory-fortified soils for the regressions of the LIF response with each of the POL parameters

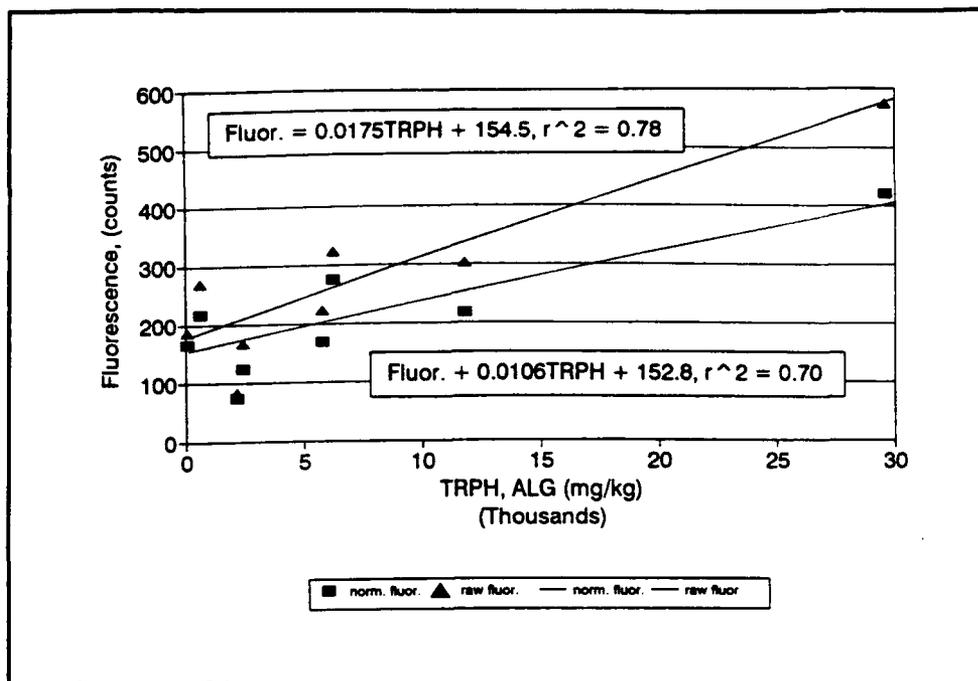


Figure 40. TRPH, EPA418.1 versus fluorescence

(Figures 29-34) are the result of a soil matrix effect. As discussed earlier, increased soil clay content causes a decrease in the fluorescence per unit POL contamination (Aptiz et al. 1992). This matrix effect is also illustrated with data obtained from the field samples. Sample SCP17-4 was determined to have significant POL contamination (1,847 mg/kg TRPH, Table 4) but had a very low LIF response (74 counts normalized fluorescence, Table 4). This compares with a significantly higher LIF response for sample SCP17-2 (125.1 counts normalized fluorescence, Table 4) for a comparable level of POL contamination (1,784 mg/kg TRPH, Table 4). The two soil samples were observed to be different types of soil; SCP17-4 (4029.08 to 4029.58 ft msl) was a clay material while SCP17-2 (4027.08 to 4027.58 ft msl) was a sand (see Appendix D panel plot for CP17).

Based on the above discussion, soil matrix effects will have a direct impact on the validity of any attempt to calibrate the SCAPS POL sensor based on the analysis of laboratory-fortified soil samples. This is illustrated for the verification samples obtained at SIAD in Table 6. The data contained in Table 6 were calculated from the LIF response (normalized) from the calibration curves (Figures 29-34) for the different POL measures for both the Native and Fill fortified soil samples. It should be noted that no calculations were performed for the samples that were known to be false positives. The data in Table 6 do not compare well with the actual values of the different POL parameters measured for these samples.

For laboratory fortification calibration approach to be valid, it would require that every known or anticipated soil type present on a given site be fortified over a range of POL concentrations and analyzed by LIF and for the

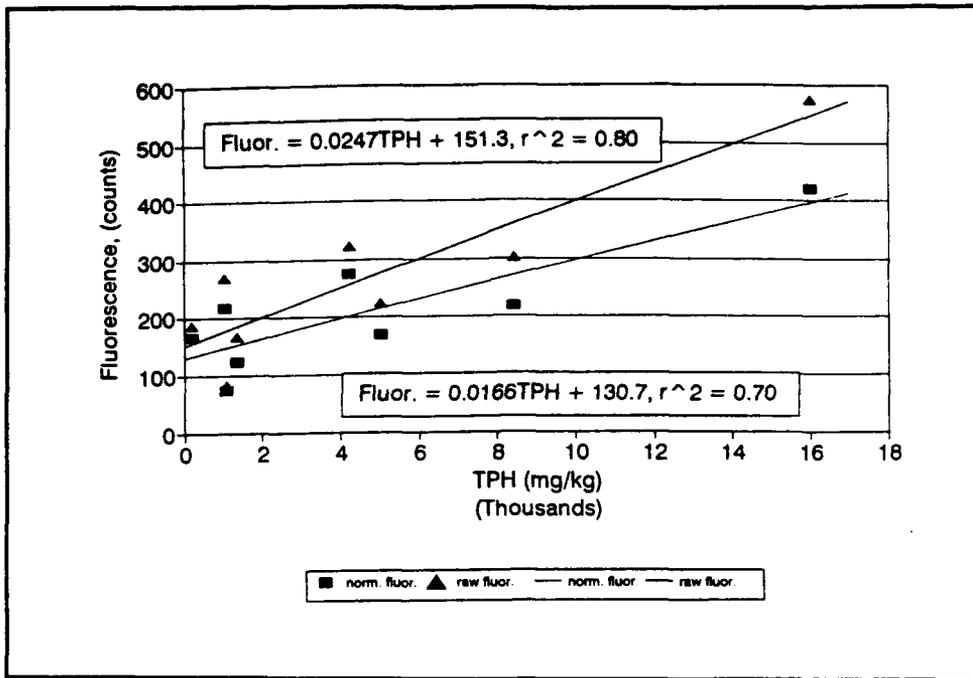


Figure 41. TPH versus fluorescence

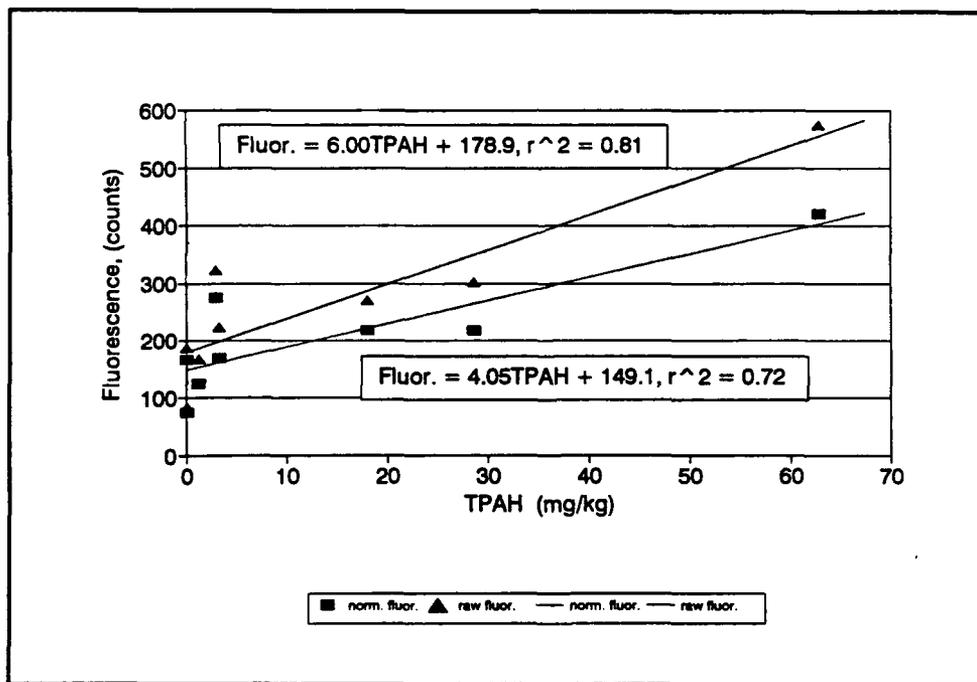


Figure 42. TPAH versus fluorescence

Table 6
Comparison of Predicted POL based on Laboratory Calibrations with Measured POL

Sample Name	Native Calibration			Fill Calibration			Actual Measured Values		
	TRPH mg/kg	TPAH mg/kg	TPH mg/kg	TRPH mg/kg	TPAH mg/kg	TPH mg/kg	TRPH mg/kg	TPAH mg/kg	TPH mg/kg
SCP14-1	-1331.1	-2.1	-1350	-323.9	-8.6	-324.5	203.2	<0.41	200
SCP14-2	4128.8	7.7	4040.7	11506.0	274.3	12847	22151	62.9	16000
SCP14-3	-224.6	-0.1	-257.6	2073.5	48.7	2344.8	11445	28.6	8420
SCP17-1	-1255.3	-1.9	-1275	-159.6	-4.7	-141.6	7228	3.29	5040
SCP17-2	-2207.1	-3.6	-2215	-2221.9	-54.0	-2438	1784	1.25	1360
SCP09-1	-223.9	-0.1	-256.9	2075.0	48.7	2346.4	845.9	17.97	1060
SCP17-3	1010.0	2.1	961.32	4748.4	112.7	5323	5817	3.03	4250
SCP17-4	-3300.1	-5.6	-3294	-4590.0	-110.7	-5074	1847	<0.41	1070

POL parameters of interest. These different calibration curves could then be used to convert the LIF response obtained on field pushes to a quantitative measure of POL contamination, depending on the soil type indicated at any given depth. The cost of obtaining, construction and analyzing the fortified soil samples for a single soil type are non-trivial (\$17,000 analytical cost for TRPH, TPH and TPAH).

Implications of in-field measurement of TRPH for SCAPS POL sensor verification and calibration

The results from the onsite determination of TRPH in SIAD soil samples using the Horiba OCMA 220 combined with the strong correlation between these data and the TRPH data and the TRPH measured by WES using EPA Method 418.1 (Figure 35) illustrate two important advantages of onsite determination of POL contamination as an adjunct to the LIF data provided by the SCAPS POL sensor. First, the Horiba OCMA 220 provided rapid identification of potential false positive LIF responses of the SCAPS POL sensor. Identification of false positive SCAPS POL sensor response based on laboratory TRPH measurement of field samples generally takes weeks to obtain.

Another important benefit of the onsite determination of POL contamination is the verification of true positive SCAPS POL sensor LIF responses. The eight soil samples obtained at SIAD that were determined in the field to contain > 15 mg/kg TRPH (Table 4) exemplify the utility of this approach to timely verification of SCAPS POL sensor response. This type of information will also assist the site engineer in decisions about where to sample to characterize POL contamination. An important additional use of this technology is the use of a field portable TRPH detector to verify true negative LIF response

and determination of POL contamination at detection levels below the sensitivity of the SCAPS POL sensor.

The results of the correlations between LIF response and the TRPH data obtained in the field (Figure 39) illustrate the potential utility of this technique for onsite calibration of the SCAPS POL sensor. Calibration using actual contaminated soil has the advantage that the matrix effects due to soil properties should be implicit in the samples. For example, the SCAPS soil classification could be used to identify soil-type matrix effects. Also, fuel-aging effects for a particular spill should not cause the bias often encountered with laboratory calibration (using fresh fuel).

The use of a field portable instrument like the Horiba OCMA 220 would not completely replace laboratory analysis of field samples for SCAPS POL sensor verification. Standard quality control practices require verification of some portion (generally 10 percent) of samples analyzed. If normal QC practices are followed, every tenth sample analyzed in the field for POL contamination using a field portable instrument would have to be verified by laboratory analysis.

The onsite verification of LIF "false positives" enabled the development of the three-dimensional model visualization of the contaminant "plume" shown previously in Figures 15 through 22. The use of the Horiba OCMA 220 to differentiate the POL LIF response for the mineral fluorescence is an important improvement in the onsite verification of the SCAPS POL LIF sensor. However, the use of the fluorescence emission spectra collected in the normal SCAPS LIF penetration to differentiate POL fluorescence from mineral fluorescence may be possible. The spectral signatures of the POL fluorescence at SIAD were significantly different from the mineral fluorescence signatures (Figure 43). The POL fluorescence peaked in the 400-nm range while the mineral fluorescence peaked in the 450-nm region of the fluorescence emission spectra. The emission profiles for the POL and mineral fluorescence are also quite different.

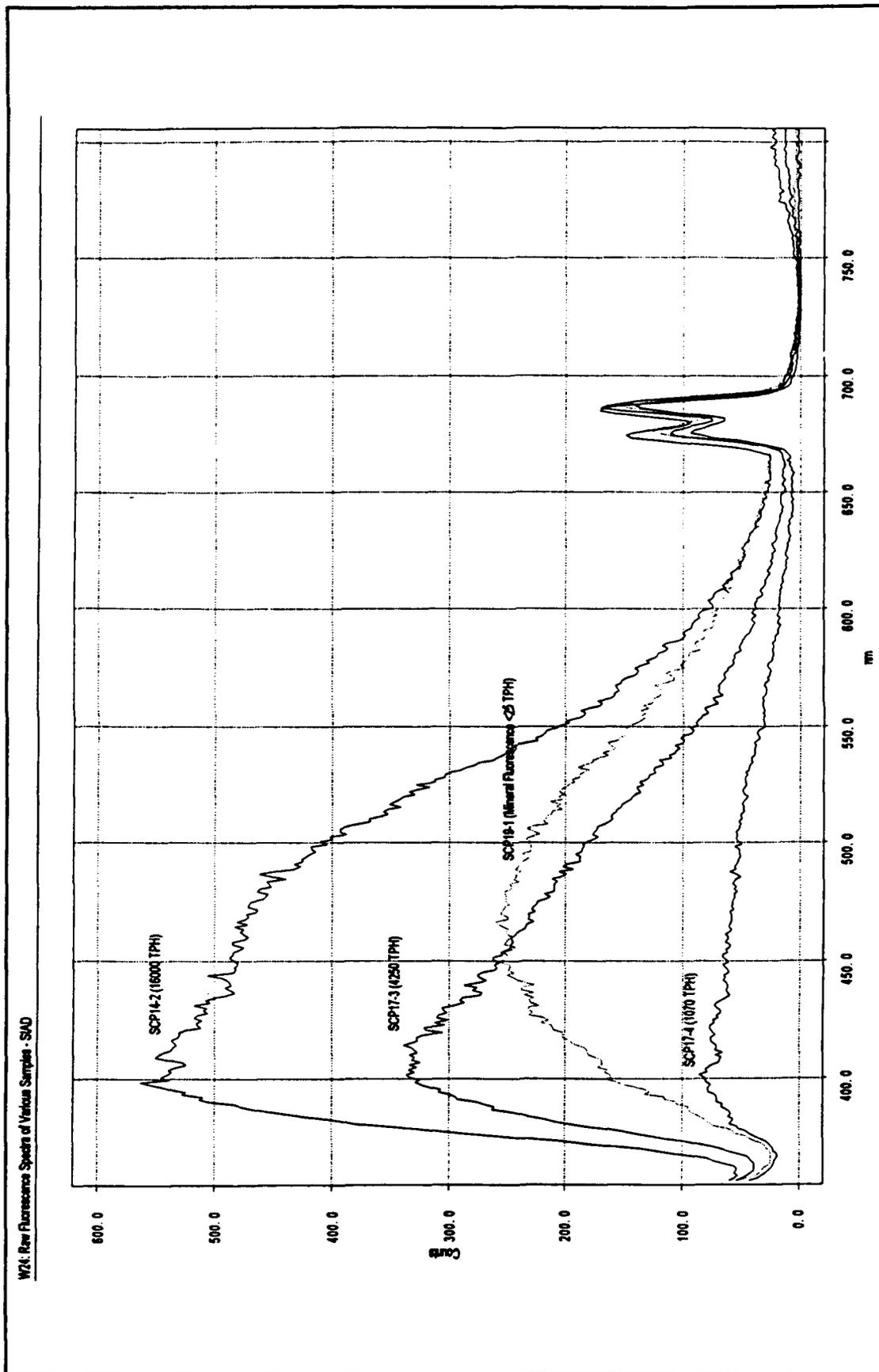


Figure 43. Comparison of fluorescence emission spectra for various samples

5 Summary, Conclusions, and Recommendations

Summary

The SCAPS visited the SIAD Diesel Spill Area near Building 403 (approximately 5 acres in area) during the period 28 September through 15 October 1993. The objectives of the SCAPS investigation are summarized below:

Objectives

- a. Collect and interpret penetrometer sensor data. A total of 22 penetrations were accomplished for this purpose. The locations had been predesignated, but minor adjustments were made to accommodate the truck accessibility and to provide better spatial distribution of data points. The depth limitations caused by the soil resistance to penetration restricted most of the penetrations to depths above the groundwater table. The data collected were analyzed and postprocessing 3-D visualization technology enabled large scale interpretations for soil stratigraphy patterns and soil fluorescence patterns.
- b. Collect subsurface soil and groundwater samples for analysis by the AEC site environmental contractor, Montgomery Watson, Inc. Five soil sample sets and one groundwater sample were collected. The depth limitations played a major role in this objective, especially for groundwater sampling. The inability of the groundwater samplers to penetrate significantly below the groundwater surface elevation was a limitation for SCAPS at this site.
- c. Collect subsurface soil samples for fluorescence and soil classification verification efforts. A total of 22 soil samples were retrieved for subsequent field laboratory and WES laboratory analyses. Since the targeted depths were relatively shallow (coincidental with soil fluorescence activity), this objective was fully achieved. The results of the in-field laboratory validation studies provided insight into the capabilities of the SCAPS POL (LIF) sensor for in situ detection of POL contamination. The use of a field portable instrument for TRPH determination

demonstrated the potential utility of onsite verification of LIF response. The identification of false positive LIF response due to fluorescing minerals was illustrated. The onsite determination of false positive SCAPS POL sensor response will allow the project engineer to make more informed decisions about the location of contaminants at the site. The strong correlation between the Horiba OCMA 220 and EPA Method 418.1 TRPH results for field soil samples obtained at the SIAD support the efficacy of the in-field determination of POL contamination with this technology. The correlations observed between the Horiba OCMA 220 TRPH measurements and the SCAPS POL sensor LIF response illustrated the potential for onsite POL sensor LIF calibration.

- d. Continuation of the SCAPS field activities demonstration phase. All the SCAPS systems involving the above objectives were demonstrated at this site. The 1.75-in. diam pushpipe was demonstrated at this site. The depth limitations previously discussed constituted the primary challenge for SCAPS system improvements. Other challenges for improvement were also noted.

Conclusions

Soil classification and fluorescence

Soil classifications based on visual and laboratory analyses closely matched those indicated by the in situ sensor probe. The predominant soil type was sand (fine to coarse gradations) with interbedded finer-grained silts and clays. Sands provided the greatest penetration resistance, and their physical attributes (matrix structure, particle size, shape, and strength properties) were responsible for the relatively shallow depths (less than 68 ft) achieved by the penetrations at this site.

Soil fluorescence response was observed at depths above approximately 20-ft bgs. It was interesting to note that the fluorescence occurred within or near the previously excavated and backfilled area immediately south of the Building 403 mechanical room, and at a separate location south of the old Boiler Plant (Building 402). No fluorescence was observed at deeper depths within the "smear zone" just above the water table elevation (approximately 62-ft bgs). A larger number of penetrations into the water table aquifer would have served to identify the presence (or absence) of POL contaminants at those depths, but, as previously discussed, were not possible.

The presence of fluorescence response interference (due to calcite minerals) was not entirely unanticipated due to the significant geological history of the SIAD area. This site was the second SCAPS site visited west of the Mississippi River, and the first site in the Great Basin and Range physiographical region west of the Rockies. The diverse geology (volcanoes, earthquakes, and

various depositional and erosional patterns) of this area increased the possibility of encountering challenging subsurface conditions.

Sampling efforts

The Mostap™ soil sampler is well-suited for relatively shallow sampling to approximately 20-ft bgs (in similar subsurface environments). The Gouda™ soil sampler is better suited for deeper penetrations, but its internal volume does not allow a sample size large enough for standard laboratory analysis.

The Hydropunch™ Model I penetrates deeper than the Model II, but its internal volume does not allow for an adequate sampling size. It offers one advantage in that it may be lowered into the same penetration hole repetitively (if operational care is taken to prevent premature engagement). The Model II expendable tip prevents repetitive sampling in the same hole. If the targeted depth may be reached without repetitive attempts, the Model II is the preferred choice.

Sampling verification

The data presented in Table 6 support the conclusion that the use of laboratory fortified soil samples for calibration of the SCAPS POL sensor for field determination of POL concentrations may be of only limited utility. Based on the cost of laboratory fortified samples, the laboratory fortification calibration approach is probably not feasible for multiple soil types at a given site or a complex stratigraphy at a site to be characterized using the SCAPS POL sensor.

The validation data obtained at SIAD from field soil samples indicate that there is a relationship between the intensity of the SCAPS POL sensor LIF sensor response and soil POL contamination, when soil matrix effects are taken into account. Although the field verification sampling uncovered the presence of "false positives" (fluorescent minerals), no instance of non-fluorescing (above a normal background fluorescence level) POL contamination was observed. All POL contamination observed in field and laboratory analysis also indicated fluorescence responses. Knowing the locations of "false fluorescence" responses (i.e. fluorescent mineral layers) enabled a more accurate 3-D modeling visualization of the contaminant plume. The data presented in Figure 43 indicate that differentiation of POL and mineral fluorescence based on LIF profiles may be possible.

SCAPS demonstration

The soil penetration resistance provided the major challenge at this site and (as previously discussed) was a function of the soil type. The capability of the SCAPS truck to achieve deeper penetrations while pushing through sand layers with a cone tip resistance between 200 to 400 tons/ft² has already been

demonstrated (for example, at a Coastal Plain site where depths down to 150 ft bgs were reached prior to "refusal" (Koester et al. 1993a)). However, the larger diameter (1.75 in.) pushpipe had not been used prior to the SIAD site investigation, and it was concluded that improvements are needed if it is to achieve depths similar to the normally-used smaller diameter (1.4 in.) pushpipe.

Recommendations

Site specific

The presence of remnant hydrocarbon contamination was confirmed, based on the probe fluorescence sensor and verification sampling. Additional soil sampling at deeper depths near the water table elevation and additional groundwater samples are needed to determine the extent of contaminant transport (if any). In addition to the POL contamination observed south of Building 403, the presence of a separate source south of Building 402 may warrant further investigation. Soil and groundwater monitoring efforts should be targeted in the area between Buildings 402 and 403.

SCAPS system

Additional development is needed to enhance methods for increasing penetration depth. Specifically, friction breakers, air injection, and/or other techniques must be tested with the pushpipe, the sensor probe, and the sampler units in order to overcome penetration resistance forces.

Methods and equipment to improve the capabilities of the support systems are needed. Specifically, the grout system needs to be tailored for full operational capability during inclement weather, i.e. it needs to be weatherproofed against wet and cold conditions. Improved methods for sampler cleaning are needed. A method to ensure true vertical alignment of the pushpipe at the ground surface is needed. Incorporation of a Global Positioning System surveying system will increase the efficiency and capabilities of the data processing system.

The SIAD validation study was a strong step in the validation of the SCAPS POL sensor. Additional site investigations with onsite verification of SCAPS POL sensor LIF response with field portable POL instrumentation is required before the general applicability of the findings reported here can be confirmed. A larger database that includes many different fuel and soil types is needed to better define the capabilities of this new technology for determination of POL contamination. Further investigation of mineral fluorescence signatures should be carried out to determine the feasibility of differentiation of POL and mineral fluorescence based solely on emission profiles. Incorporation of onsite 3-D visualization capability integrated with onsite verification

procedures will enhance the efficiency of contaminant plume identification and spatial location.

Bibliography

- Apitz, S. E., Brobridge, L. M., Theriault, G. A., and Lieberman, S. H. (1992). "Remote in situ determination of fuel products in soils: field results and laboratory investigations." *Analisis*, Vol. 20, pp. 461-474.
- Benioff, P., Filley, T., and Tsai, S. Y. (1988). "Master Environmental Plan for the Sierra Army Depot," October 1988.
- Bowles, J. E. (1988). "Foundation Analysis and Design," 4th Edition. McGraw-Hill, Inc., New York.
- Dana, J. D. (1959). *Dana's Manual of Mineralogy*, 17th Edition. John Wiley and Sons, Inc., New York.
- Handman, E. H., Londquist, C. J., and Maurer, D. K. (1990). "Groundwater Resources of Honey Lake Valley, Lassen County, California, and Washoe County, Nevada," USGS Water-Resources Investigations Report 90-4-5.
- Koester, J. P., Lee, L. T., Olsen, R. S., Douglas, D. H., Comes, G. D., Cooper, S. S., and Powell, J. F. (1993a). "Field Trials of the Site Characterization and Analysis Penetrometer System at the Savannah River Site (SRS)." Technical Report GL-93-16. U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
- Koester, J. P., Lee, L. T., Powell, J. F. and Goodson, R. (1993b). "Operations Manual for the Site Characterization and Analysis Penetrometer System," (in preparation) U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
- Lee, L. T., Chrestman, A. M., Douglas, D. H., Powell, J. F., and Malone, P. G. (1993). "Site Investigations with the Site Characterization and Analysis Penetrometer System at Fort Dix, New Jersey." Technical Report GL-93-17. U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

- Lee, L. T., and Powell, J. F. (1993). "Use of the Site Characterization and Analysis Penetrometer System at the Walnut Creek Watershed, Ames, Iowa." Miscellaneous Paper GL-93-12. U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
- Mitchell, J. K. (1976). "Fundamentals of Soil Behavior." John Wiley & Sons, Inc., New York.
- Montgomery Watson, Inc. (1993). "Sierra Army Depot Group I Remedial Investigation/Feasibility Study, Draft Final," Prepared for USATHAMA, Aberdeen Proving Ground, Maryland, April 1993.
- Puppala, A. J., Acar, Y. B., and Senneset, K. (1993). "Cone Penetration in Cemented Sands: Bearing Capacity Interpretations," American Society of Civil Engineers Journal of Geotechnical Engineering, Vol. 119, No. 12, December 1993, pp. 1990-2001.
- Sharp, M. K., Kala, R., and Powell, J. F. (1992). "Use of the Site Characterization and Analysis Penetrometer System at the Grandville Superfund Site, Grandville, Michigan." Miscellaneous Paper GL-92-38. U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
- Sharp, M. K., Olsen, R. S., and Kala, R. (1992). "Field Evaluation of the Site Characterization and Analysis Penetrometer System at the Philadelphia Naval Shipyard, Pennsylvania." Miscellaneous Paper GL-92-39. U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
- U.S. Army Toxic and Hazardous Materials Agency (USATHAMA). (1979). "Installation Assessment of Sierra Army Depot, Report No. 149"; Aberdeen Proving Ground, Maryland, December 1979.
- U.S. Department of Agriculture. (1917). "Soil Survey of the Honey Lake Area, California." Washington, DC: Government Printing Office.
- U.S. Environmental Protection Agency. (1984). "Test Methods for Evaluating Solid Waste; Physical/Chemical Methods," SW-846 Third Edition. U.S. EPA, Washington, DC.
- U.S. Department of Transportation. (1978). "Guidelines for Cone Penetration Testing, Performance, and Design." Publication No. FHWA-TS-78-209. Washington, DC: Federal Highway Administration.

Appendix A Standard Practice for Preparation of Calibration Soil Samples for the SCAPS Laser- Induced Fluorescence Sensor

**STANDARD PRACTICE FOR THE PREPARATION OF CALIBRATION SOIL SAMPLES
FOR THE SCAPS LASER INDUCED FLUORESCENCE DETECTOR**

1. SCOPE

1.1 This practice establishes uniform procedures for the development, preparation, and use of soil samples for the calibration of the SCAPS laser-induced fluorescence (LIF) detector. The LIF detector calibration will be oriented toward the evaluation of semi-volatile compounds that are most commonly found at military sites requiring cleanup.

1.2 Calibration samples are prepared using soil samples that best represent the soil type(s) found at the site. This enables the calibration procedure to compensate for any matrix effects found in the soil samples. Whenever possible, calibration soils should be spiked with the pure products (i.e. diesel, kerosene, jet fuel, etc.) taken from the site to eliminate any manufacturing differences.

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 the user of this standard to establish appropriate safety and health practices.

2. REFERENCED DOCUMENTS

2.1 ASTM STANDARD D-3975, PRACTICE FOR PREPARATION OF SAMPLES FOR COLLABORATIVE TESTING OF METHODS FOR ANALYSIS OF SEDIMENTS

3. SUMMARY OF PRACTICE

3.1 Soil samples of adequately defined composition and homogeneity are required for calibrating the LIF detector for field use with the SCAPS system. The ideal calibration system would utilize naturally contaminated soils at various concentrations to measure the quantitative responses of the system. Since this is not a feasible option, soils must be adequately prepared to ensure homogeneous spiking of contaminants. The soil must be ground to a standard particle size to eliminate the settling out of denser particles thereby changing the concentration of contaminants in the calibration samples.

3.2. Samples spiked at several concentrations spanning the expected concentration range are prepared to test the linearity of the system. Samples will also be analyzed by a proven laboratory method to insure the bias and precision of the spiking technique. Samples will also be analyzed over time to test the stability of the spiked compounds in the soil matrix.

4. SIGNIFICANCE AND USE

4.1 The objective of this practice is to provide guidelines for the preparation of soil samples for use in calibrating the LIF detector for use with the SCAPS and for determining the precision and bias associated with the process.

5. PREPARATION OF CALIBRATION SAMPLES

5.2 In preparation of the soil samples for grinding, the samples are cleaned of any vegetation, large rocks, or other extraneous materials. At this point, the percent moisture in the sample is measured to enable the adding back of moisture to the sample to represent the field situation. A sufficient quantity of soil to produce approximately 10 Kg of dry soil is oven dried at 106°C for 18 hours in a vented oven. After cooling, the sample is ground using a Brinkmann Model ZM-1 centrifuged grinder at 20000 rpm to a particle size of less than 0.5 micron. The ground soil is collected in a 5-gallon glass carboy and tumbled for 18 hours to ensure homogeneous soil for spiking. Aliquots weighing one thousand ± 0.2 grams are weighed into $\frac{1}{4}$ gallon pre-cleaned glass jars with teflon-lined lids.

5.3 Calibration samples are prepared in concentrations of 0, 100, 300, 500, 1000, 2000, 5000, and 10000 mg/kg using the site contaminant(s). The 1000 gram calibration samples at each level provide sufficient material for triplicate analysis by laboratory methods and by LIF to assess precision and accuracy. The calibration samples are prepared by spiking each of the 1000 gram ground site soil samples with 0, 100, 300, 500, 1000, 2000, 5000, and 10000 mg of contaminant(s). The contaminant spikes are distributed as uniformly as possible over the surface of the soil. The spiked soils are tumbled for 92 hours to ensure homogeneous distribution and equilibration of the contaminant throughout the soil particles. Based on the previously determined moisture content, reagent water is added to each of the individual samples and tumbled for an additional 72 hours.

Appendix B Surveying Data

SIERRA ARMY DEPOT SCAPS INVESTIGATION, CALIFORNIA STATE PLANE COORDINATES			
DESCRIPTION	NORTHING	EASTING	ELEVATION, FT MSL
TOP OF BERM	309305.143	2526488.359	4074.59
DF-1 MONITOR WELL	309253.145	2526526.005	4050.24
DSA-2 MONITOR WELL	309351.177	2526418.573	4047.78
SENSOR PROBE PUSHPOINTS			
CP-01	309438.336	2526503.622	4045.55
CP-02	309431.956	2526632.016	4044.98
CP-03	309363.39	2526438.61	4047.68
CP-04	309365.464	2526512.583	4049.46
CP-05	309362.917	2526574.429	4049.95
CP-06	309264.365	2526429.698	4047.87
CP-07	309252.709	2526580.574	4049.48
CP-08	309242.344	2526597.862	4049.13
CP-09	309246.388	2526405.774	4047.29
CP-10	309176.117	2526455.093	4046.74
CP-11	309220.313	2526558.227	4048.86
CP-12	309230.067	2526477.727	4048.52
CP-13	309233.231	2526498.223	4048.84
CP-14	309240.055	2526516.41	4049.59
CP-15	309199.207	2526385.403	4047.83
CP-16	309264.439	2526538.793	4050.57
CP-17	309258.357	2526534.252	4050.58
CP-18	309245.172	2526526.822	4050.00
CP-19	309241.555	2526544.756	4050.27
CP-20	309216.495	2526530.272	4048.15
CP-21	309218.927	2526501.821	4048.31

SIERRA ARMY DEPOT COORDINATES, CONTINUED			
CP-22	309258.145	2526562.204	4050.28
WES VERIFICATION SOIL SAMPLE POINTS			
SCP-15(8 OCT)	309196.71	2526384.4	4047.80
SCP-09(9 OCT)	309245.49	2526404.07	4047.30
SCP-06(9 OCT)	309263.36	2526429.1	4047.80
SCP-12(8 Oct)	309229.47	2526475.23	4048.50
SCP-20(9 OCT)	309214.99	2526529.77	4048.15
SCP-14(8 Oct)	309239.25	2526515.41	4049.60
SCP-17(8 OCT)	309257.35	2526535.25	4050.60
SCP-17-3(10 OCT)	309257.35	2526536.25	4050.60
SCP-19(9 OCT)	309242.06	2526544.26	4050.30
SCP-08(9 OCT)	309240.84	2526597.86	4049.13
SCP-05(9 OCT)	309361.92	2526573.43	4049.95
SCP-02(10 OCT)	309431.45	2526632.01	4044.90
SCP-01(10 OCT)	309437.83	2526504.12	4045.60
MONTGOMERY WATSON SAMPLE POINTS			
SOIL SAMPLES			
DSA-01-SC(11 OCT)	309262.94	2526542.29	4050.60
DSA-02-SC(12 OCT)	309257.35	2526538.75	4050.60
DSA-03-SC(12 OCT)	309240.55	2526517.41	4049.60
DSA-04-SC(13 OCT)	309233.23	2526501.22	4048.80
DSA-05-SC(13 OCT)	309240.55	2526545.75	4050.30
DSA-02-SB (Drill Rig)	309245.15	2526526.75	4050.00
WATER SAMPLE			
HP-1(11 OCT)	309262.94	2526542.29	4050.60

Appendix C

SCAPS Field Sampling Standard

Operating Procedure

SCAPS Field Sampling Standard Operating Procedures

General

The intention of penetrometer sampling operations is to obtain a representative sample of the candidate solid or liquid for laboratory analysis to determine the type and concentration of contaminants present. Three different types of sampling are potentially necessary with any particular SCAPS site investigation. These three types of sampling include:

(1) pre-deployment sampling of contaminated soil and free POL. In addition, uncontaminated soil should be obtained for preparation of LIF laboratory calibration samples. Procedures for preparation of laboratory calibration sample will be discussed in detail later.

(2) field samples for laboratory verification of a minimum of 10% of LIF positive SCAPS pushes during SCAPS site investigations.

(3) regulatory samples for laboratory analysis for regions of the site where POL contamination is below the detection limit for the LIF sensor for the POL/soil matrix of interest at a particular site.

Although only the type (3) samples will generally be of direct regulatory interest, all SCAPS sampling procedures will follow those specified by EPA in Test Methods for Evaluation of Solid Waste. In addition, all SCAPS samples will be subject to a standard chain of custody sample tracking procedure.

The SCAPS is equipped with special penetrometer devices to obtain samples of soil and water at depths within the limit of current system performance. The devices are not designed to acquire any penetration resistance data, nor are they capable of grouting the hole on withdrawal. Both soil and water samplers require dedicated penetration operations; the soil sampler will not operate properly in previously pushed holes, and the water sampler must be operated at full depth, i.e., at the bottom of a push. This section begins with a discussion of sample handling protocol for contaminated soil studies, as dictated by the issues particular to laboratory analysis to identify and quantify contaminants in soil.

Do not spray hot water to clean the samplers (soil or water) on withdrawal from the ground. The heater on the high-pressure washer should be turned down so that water sprayed to clean the outside of the soil or water sampler is cool. As the last push rod removed from the ground is cleaned, the cleaner system should be flushed until the effluent is cool. Someone should watch the soil sampler as it is pulled from the ground and tell the push room operator to stop spraying cleaning water before the open end of the sampler enters the cleaning collar beneath the truck. The soil sample may be washed out if water is sprayed across the open end of the sampler. After the soil or water sample has been removed from the sampler, the device should be disassembled and separately cleaned with water over an open drum or other, suitable container so that the cleaning water may be collected and

disposed of as required by site officials.

Sample handling considerations

General. Once the sample has been collected using the SCAPS subsurface sampling equipment, it must be stored and preserved to maintain the chemical and physical properties that it possessed at the time of collection, to the extent physically possible. The sample type, type of containers and their preparation, possible forms of contamination, and preservation methods are all items which must be thoroughly examined in order to maintain the integrity of the samples. The sampling procedure (including containers, preservation and holding times) and required sample size are determined by the EPA Method that will be used for analysis of the contaminants of interest at a particular site. This section discusses considerations which must be addressed in order to maintain a sample's integrity for contaminant analysis. This information is excerpted in part (where indented) from *EPA Test Methods for Evaluating Solid Waste, Volume 1B: Laboratory Manual Physical/Chemical Methods*.

Sample handling and preservation.

This section deals separately with volatile and semi-volatile organics. Refer to Table 3-2 for recommended sample containers, sample preservation, and sample holding times.

Volatile organics. Standard, 40 ml glass screw-cap VOA vials with Teflon-lined, silicone septa may be used for both liquid and solid samples. The vials and septa should be soap-and-water washed and then rinsed with distilled deionized water prior to use. After the vials and septa have been thoroughly cleaned, they should be placed in a muffle furnace and dried at 105 °C for approximately one hour.

NOTE: Do not heat the septa for extended periods of time (i.e. more than one hour, because the silicone begins to slowly degrade at 105 °C).

As an alternate, sample containers which have been previously cleaned to the desired EPA specifications are commercially available (i.e I-Chem Protocol B, 300 series, or equivalent).

When collecting the samples, liquids and solids should be introduced into the vials gently to reduce agitation which might drive off volatile compounds. Liquid samples should be poured into the vial without introducing any air bubbles within the vial as it is being filled. If a sample preservative is required, it should be added at this time. Should bubbling occur as a result of violent pouring, the sample must be poured out and the vial refilled (**NOTE FOR SCAPS APPLICATION:** the penetrometer water sampler does not afford the luxury of unlimited liquid sample volume; the Hydropunch II™ device described later collects no more than 1.2 liters under the best of circumstances - exercise caution not to violate this procedure). Each VOA vial should be

filled until there is a meniscus over the lip of the vial. The screw-top lid with the septum (Teflon side toward the sample) should then be tightened onto the vial. After tightening the lid, the vial should be inverted and tapped to check for air bubbles. If there are any air bubbles present the sample must be retaken. Two VOA vials should be filled per sample location.

VOA vials for samples with solid or semi-solid (sludges) matrices should be completely filled to the extent possible. The vials should be tapped slightly as they are filled to try and eliminate as much free air space as possible. Two vials should also be filled per sample location.

VOA vials should be filled and labeled immediately at the point at which the sample is collected. They should **NOT** be filled near a running motor or any type of exhaust system because discharge fumes and vapors may contaminate the samples. The two vials from each sampling location should then be sealed in separate plastic bags to prevent cross-contamination between samples particularly if the sampled waste is suspected of containing high levels of volatile organics. (Activated carbon may also be included in the bags to prevent cross-contamination from highly contaminated samples). VOA samples may also be contaminated by diffusion of volatile organics through the

**Table 3-2
Required Containers, Preservation Techniques, and Holding Times (Excerpted in
part from Table 2-20; EPA Test Methods for Evaluating Solid Waste Vol 1B)**

Name	Container ¹	Preservation	Sample Volume Required	Maximum Holding Time
Oil and grease EPA Method 9071A	G	Cool, 4°C, H ₂ SO ₄ to pH < 2	aqueous: 1 L solid: 20-30 g	28 days
Total Recoverable Petroleum Hydrocarbons EPA Method 418.1	G, Teflon-lined cap	Cool, 4°C, HCl to pH < 2	aqueous: 1 L solid: 20-30 g	28 days
Organic carbon, total (TOC)	P, G	Cool, 4°C, H ₂ SO ₄ to pH < 2		28 days
Polynuclear aromatic hydrocarbons	G, Teflon-lined cap	Cool, 4°C, 0.008% Na ₂ S ₂ O ₃ store in dark	aqueous: 1 L solid: 50-100 g	7 days until extraction, 40 days after extraction
Chlorinated hydrocarbons	G, Teflon-lined cap	Cool, 4°C		7 days until extraction, 40 days after extraction
Volatile Organics				
Water Samples	2 40-ml vials with Teflon lined septum	4 drops conc. HCl, Cool, 4°C	aqueous: 40 mL	14 days
Soil/Sediments and Sludges EPA Method 8020	4-oz (120-ml) wide mouth glass with Teflon liner	Cool, 4°C	solid: 50-80 g	14 days
Semi-volatile Organics, Organochlorine Pesticides, PCBs				
Water Samples	1-gal. or 2 1/2-gal. amber glass with Teflon™ liner	Cool, 4°C	aqueous: 1 to 2.5 gal.	7 days until extraction, 40 days after extraction
Soil/Sediments and Sludges EPA Methods 8100 and 8270	8-oz. wide mouth glass with Teflon™ liner	Cool, 4°C	solid: 50-100 g	14 days until extraction, 40 days after extraction

¹Polyethylene (P) or Glass (G)

septum during shipment and storage. To monitor possible contamination, a trip blank prepared from distilled deionized water should ALWAYS be carried throughout the sampling, storage, and shipping process.

Semi-volatile organics (includes pesticides and herbicides). Containers used to collect samples for the determination of semi-volatile organic compounds should be soap-and-water washed followed by methanol (or isopropanol) rinsing. The sample containers should be of glass or Teflon and have screw-caps with Teflon lined septa. In situations where Teflon is not available, solvent-rinsed aluminum foil may be used as a liner. Highly acidic or basic samples may react with the aluminum foil, causing eventual contamination of the sample. Plastic containers or lids may NOT be used for the storage of samples due to the possibility of sample contamination from the phthalate esters and other hydrocarbons within the plastic. Sample containers should be filled with care so as to prevent any portion of the collected sample coming in contact with the sampler's gloves, thus causing contamination. Samples should not be collected or stored in the presence of exhaust fumes. If the sample comes in contact with the sampler (e.g. if an automatic sampler is used), run reagent water through the sampler and use as a field blank.

It should be noted that sample bottles are available commercially that have been precleaned to EPA specifications (i.e. I-Chem Protocol B, series 300 or equivalent).

Safety

Safety should always be the primary consideration in the collection of samples. A thorough understanding of the waste production process as well as all of the potential hazards making up the waste should be investigated whenever possible. The site should be visually evaluated just prior to sampling to determine additional safety measures. Minimum protection of gloves and safety glasses should be worn to prevent sample contact with the skin and eyes. A respirator should be worn even when working outdoors if organic vapors are present. More hazardous sampling missions may require the use of supplied air and special clothing.

Chain-of-custody

The following information on chain of custody procedures is excerpted from EPA-CLP SOW 390 (where indented). For application of this information to SCAPS site investigations, the Contractor will refer to the WES SCAPS Team and the Laboratory will refer to WES ECB.

A sample is physical evidence collected from a facility or from the environment. Controlling evidence is an essential part of the hazardous waste investigation effort. To accomplish this, Contractors are required to develop

and implement the following sample identification, chain-of-custody, sample receiving, and sample tracking procedures.

Sample identification. To assure traceability of the samples while in possession of the Contractor, the Contractor shall have a specified method for maintaining identification of samples throughout the laboratory.

Each sample and sample preparation container shall be labeled with the EPA number or a unique laboratory identifier. If a unique laboratory identifier is used, it shall be cross-referenced to the EPA number.

Chain-of-custody procedures. Because of the nature of the data being collected, the custody of EPA samples must be traceable from the time the samples are collected until they are introduced as evidence in legal proceedings. The Contractor shall have procedures ensuring that EPA sample custody is maintained and documented. A sample is under custody if:

- It is in your possession, or
- It is in your view after being in your possession, or
- It was in your possession and you locked it up, or
- It is in a designated secure area. (Secure areas shall be accessible only to authorized personnel.)

Sample receiving procedures

The Contractor shall designate a sample custodian responsible for receiving all samples.

The Contractor shall designate a representative to receive samples in the event that the sample custodian is not available.

The condition of the shipping containers and sample bottles shall be inspected upon receipt by the sample custodian or his/her representative.

The condition of the custody seals (intact/not intact) shall be inspected upon receipt by the sample custodian or his/her representative.

The sample custodian or his/her representative shall check for the presence or absence of the following documents accompanying the sample shipment:

- Airbills or airbill stickers

- Custody seals
- EPA custody records
- EPA traffic reports or SAS packing lists
- Sample tags

The sample custodian or his/her representative shall sign and date all forms (e.g., custody records, traffic reports or packing lists, and airbills) accompanying the samples at the time of sample receipt.

The Contractor shall contact the Sample Management Office (SMO) to resolve discrepancies and problems such as absent documents, conflicting information, broken custody seals, and unsatisfactory sample condition (e.g., leaking sample bottle).

The Contractor shall record the resolution of discrepancies and problems on Telephone Contact Logs.

The following information shall be recorded on Form DC-1 by the sample custodian or his/her representative as samples are received and inspected:

- Condition of the shipping container
- Presence or absence and condition of custody seals on shipping and/or sample containers
- Custody seal numbers, when present
- Condition of the sample bottles
- Presence or absence of airbills or airbill stickers
- Airbill or airbill sticker numbers
- Presence or absence of EPA custody records
- Presence or absence of sample tags
- Sample tag identification numbers cross-referenced to the EPA sample numbers
- Verification of agreement or non-agreement of information recorded on shipping documents and sample containers

● *Problems or discrepancies*

Sample Tracking Procedures

The Contractor shall maintain records documenting all phases of sample handling from receipt to final analysis.

SCAPS soil samplers

The Hogentogler™ Penetrometer Soil Sampler, a stab-type penetrometer sampler, is provided with the SCAPS. Soil samples obtained using this sampler or the one described in the next paragraph are typically smaller than those provided from drilling, but the profound advantage of speed and the elimination of the need for recirculating drilling fluid makes this capability extremely useful.

An alternate device is the Mostap™ sampler, which is designed to recover soil samples in a configuration similar to the split spoon penetrometer used in standard penetration tests (i.e., as driven by multiple 30-inch drops of a 140-lb safety hammer during conventional drilling and sampling operations), in that the soil is contained within a split cylindrical sleeve (and liners, if desired). The Mostap™ sampler has a conical tip that is released at the starting depth for sampling to remain in place as the sampler cutting edge and barrel, or tube, is pushed to the final sampling depth. The Mostap™ device requires that a lanyard cable is strung through all push rods prior to sampling, and that this lanyard must be pulled firmly upward at the beginning depth desired for sampling to effect tip release. The device has several removable parts, all of which must be decontaminated (currently, this is accomplished by high-pressure hot water cleaning) prior to reassembly for subsequent sampling.

The Hogentogler™ sampler provided with the SCAPS truck is simpler to operate than the Mostap™ device, and has fewer removable parts. Manufacturer documentation is provided for this sampler. The Hogentogler™ device recovers a smaller sample than does the Mostap™ unit. It is recommended that only stainless steel liners be used with the sampler barrel, and that upon recovery of the sampler from the ground, the ends of the liner be capped and sealed for delivery to a facility where the sample may be properly containerized (see *Sample handling* discussions, above). The Hogentogler™ sampler is simply driven by hydraulic pushing into the ground to the depth desired for sampling, whereupon the push rod string must be hydraulically lifted 10.5 inches (26.7 cm) and then pushed back down 9.5 inches (24.1 cm) with the push truck rams. This procedure causes the device to retract the tip of the sampler at the upper end of the sampler barrel and the sampler is then pushed in an extended configuration to obtain a soil sample.

SCAPS water sampler

The SCAPS is equipped with the HydroPunch II™ (QED Groundwater Specialists, Ann Arbor, MI) drive-type water sampler. The HydroPunch II™ is a specialized field screening tool that is capable of collecting a representative ground water sample without requiring the installation of a ground water monitoring well.

The HydroPunch II™, as operated with the SCAPS, is driven with the hydraulic penetrometer pushing rams and rods into undisturbed soil to the desired sampling depth from the surface. It is then pulled back about two feet to open the device to accept groundwater. Soil friction holds the drive cone in place, which in turn pulls the intake screen out of the sample chamber and exposes it to the soil formation. Once the O-ring seal on the cone is broken, ground water flows through the intake screen, past the lower check valve and into the sample chamber. Once open, the HydroPunch II™ fills from the bottom with no aeration and minimal agitation of the sample. When the tool is full, the sample is collected by pulling the tool towards the surface. This increases the hydrostatic pressure within the tool, closing the two check valves. At the surface, the HydroPunch II™ is inverted and the sample is decanted through an upper discharge valve and tubing into a sample container.

As mentioned above, the fact that the tool fills only by in-situ hydrostatic head means that the top of the sample chamber must be below the groundwater table to collect a sample. Since the HydroPunch II™ is approximately five feet long, the intake screen must be five feet below the water table to collect a full sample. Often this is too deep to collect floating product, or, if the water bearing strata are less than one foot thick, it puts the intake screen below the aquifer.

The open intake area for the HydroPunch II™ is about 11 inches long. Water bearing zones may be missed by the intake screen when sampling in soils where thinner water bearing zones are interbedded between low permeability material. In some cases the water bearing zones may not be thick enough or have enough hydraulic pressure to fill the tool. The user should reference the *HydroPunch User's Guide*, for more information concerning this device.

Soil Sampling Procedures

Soil sampling procedures to be used for the three different types of samples discussed earlier will be described in detail. The field sampling procedures for each sample type will be similar. However, the treatment of the sample in the field and the laboratory will vary depending on the sample type.

Soil samples obtained during the pre-deployment site visit (type (1)) will generally not be sampled using the SCAPS truck and sampler. These samples are likely to be obtained with either a hand auger or a trowel. The samples obtained of contaminated soils (v. 1e of

soil required depends on EPA Method of analysis, see Table 3-2) should be placed in the appropriate containers (see Table 3-2). The sample container should be pre-labeled (as described in the chain-of-custody section) and the sample recorded on the chain-of-custody form. Contaminated soil samples should be placed in a cooler for shipment to WES. Uncontaminated soil samples obtained for generation of the laboratory LIF calibration samples should be obtained in quantities that provide the WES Environmental Laboratory ECB with sufficient soil to prepare the desired number of spiked soil samples. The SCAPS project officer should ALWAYS check with the analyst in ECB before the pre-site visit to determine the quantity of uncontaminated soil required for this purpose (generally on the order of 10 Kg). Uncontaminated soil samples can be stored in plastic bags for shipment to the laboratory if the analytes of interest at a particular site are those covered by EPA Methods 418.1 (TRPH) and 9071A (O&G). If semi-volatile contaminants are to be spiked into the uncontaminated soil samples, they should be stored in glass containers with teflon lined caps.

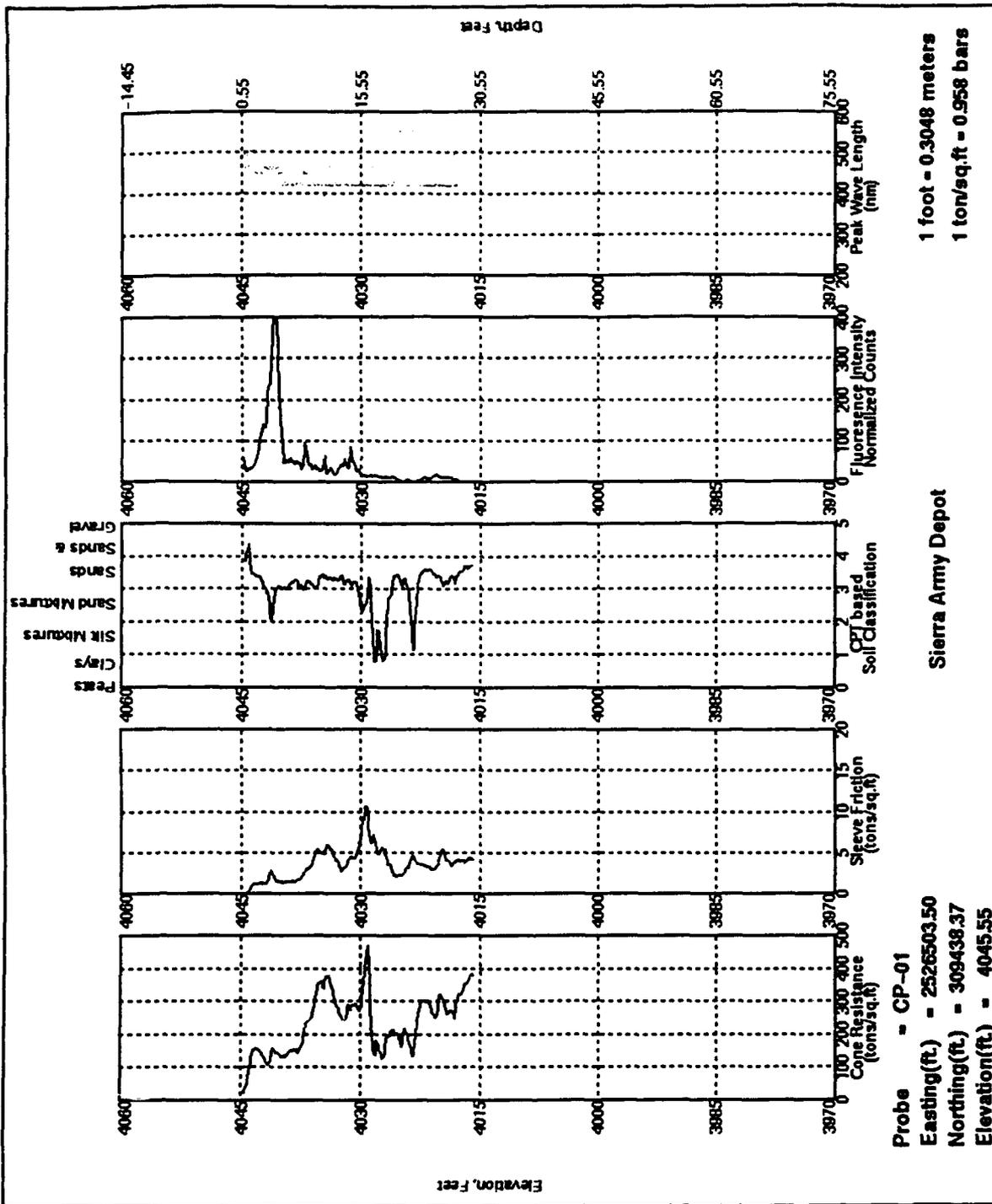
Soil samples obtained from either the Hogentogler™ or Mostap™ samplers should be extruded directly into the sample container (see Table 3-2) whenever possible. The sample container should be pre-labeled (as described in the chain-of-custody section) and the sample recorded on the chain-of-custody form. When it is not possible to place the sample directly from the sampling device into the sample bottle, extrude the sample into a stainless steel pan and scoop the soil into the sample container using a stainless steel spatula. The pan and spatula should be thoroughly washed with distilled water between each sample.

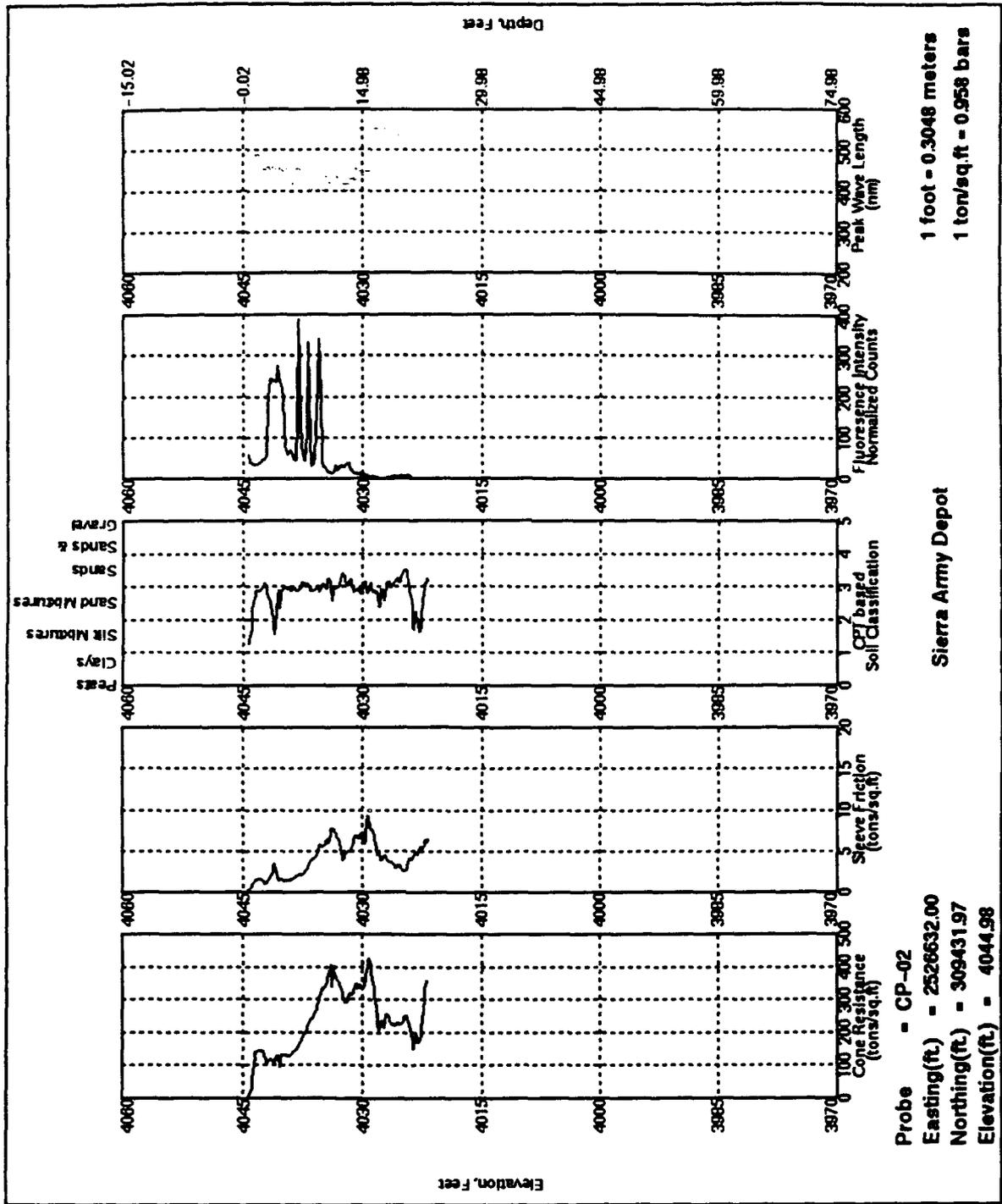
Once the sample has been placed in the sample container, it should be placed in a cooler until it is either shipped to the laboratory for analysis (sample types (1) and (3)) or processed further for LIF analysis in the field (sample type (2)). When sampling is complete at a particular site and/or an individual cooler holding samples is full, sign, date and place the chain-of-custody form in a plastic ziplock bag in the cooler. The cooler should then be sealed with two chain-of-custody seals in preparation for shipment to the laboratory. In addition, seal the cooler with packing tape by wrapping several layer of tape around the cooler body. Be sure to tape up the drain spout of the cooler to prevent leaking in shipment. Use arrows or labels to indicate the direction the cooler should sit (i.e. "this side up"). If glass sample containers are to be shipped, place a fragile label on the cooler.

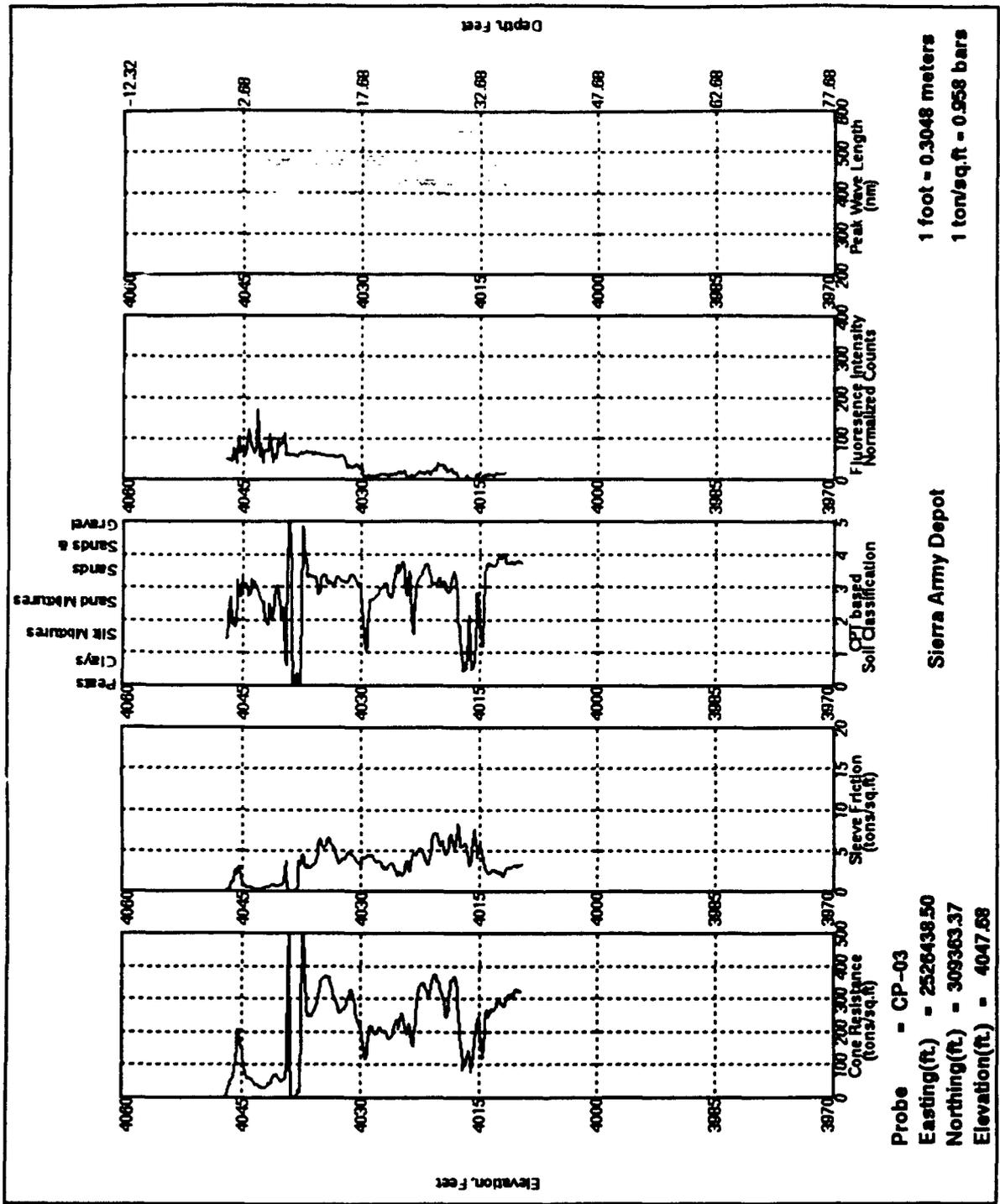
Samples should be shipped to the laboratory for analysis in a timely manner. The holding times for extraction and analysis vary depending on the analytes of interest and the EPA Method of analysis (see Table 3.2). Depending on the quantity of samples produced at a given site and the length of time a particular site investigation is likely to require, samples should normally be shipped to the lab daily or every other day by overnight express.

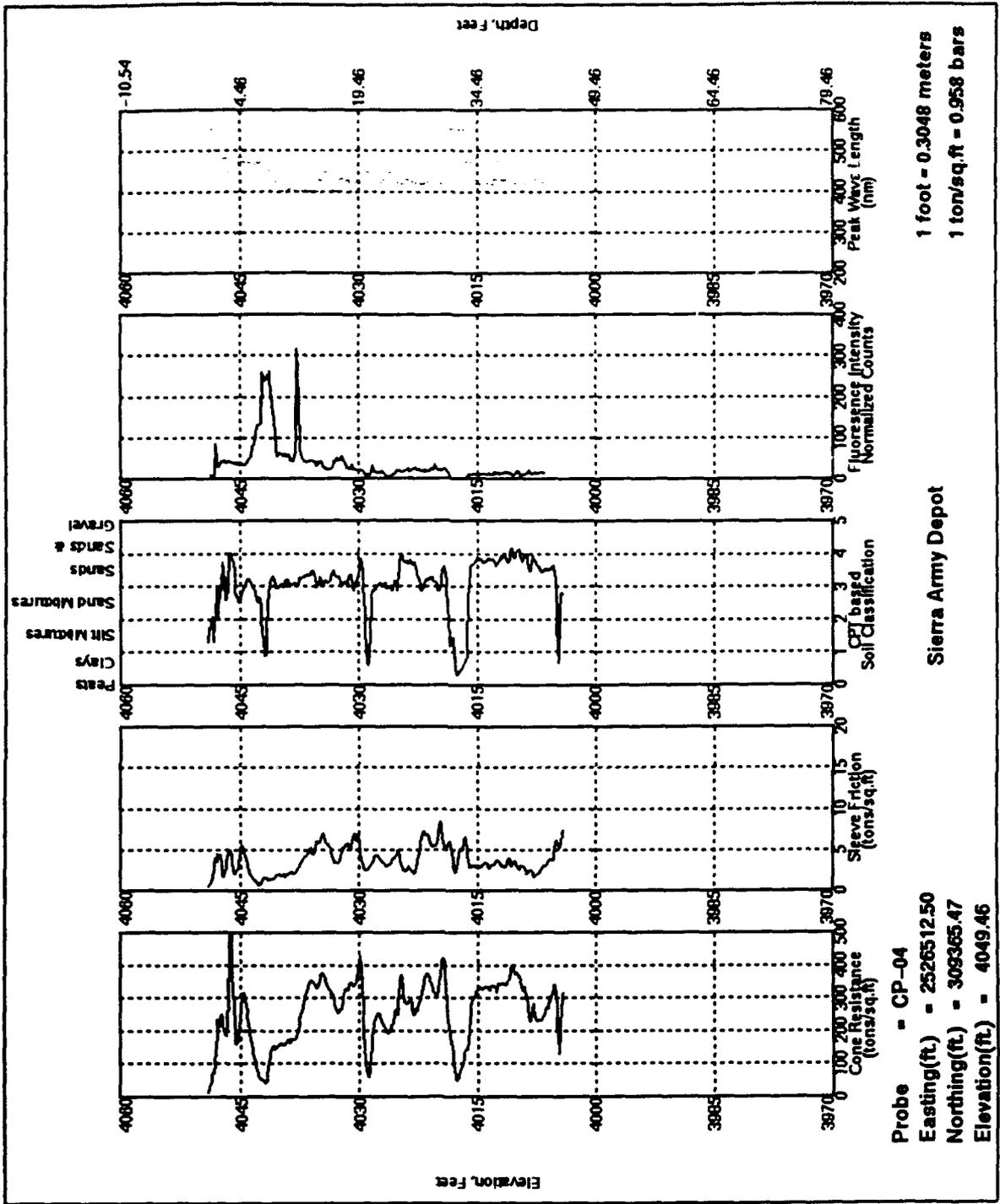
Appendix D

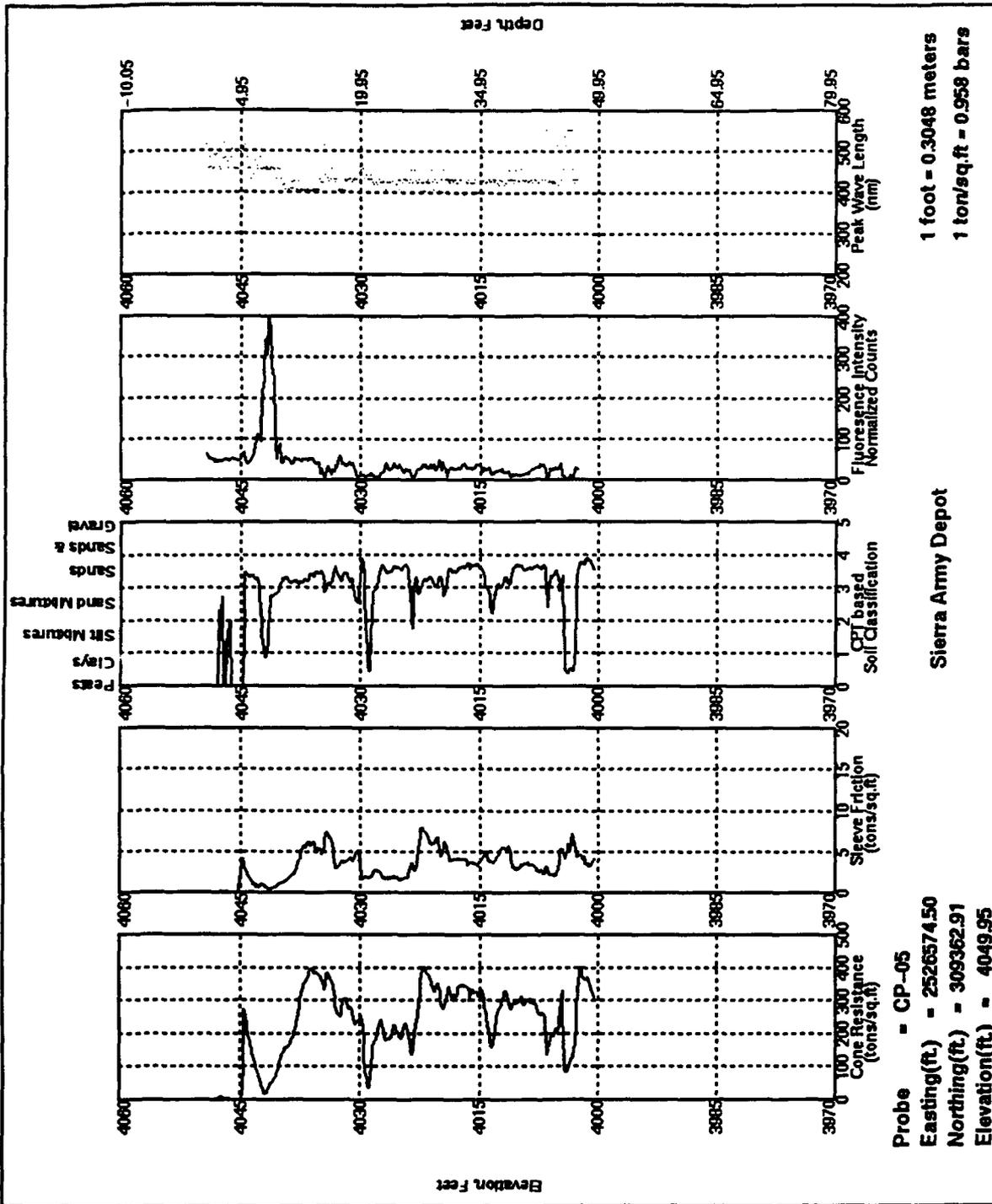
Data Plots from Penetrometer Pushes

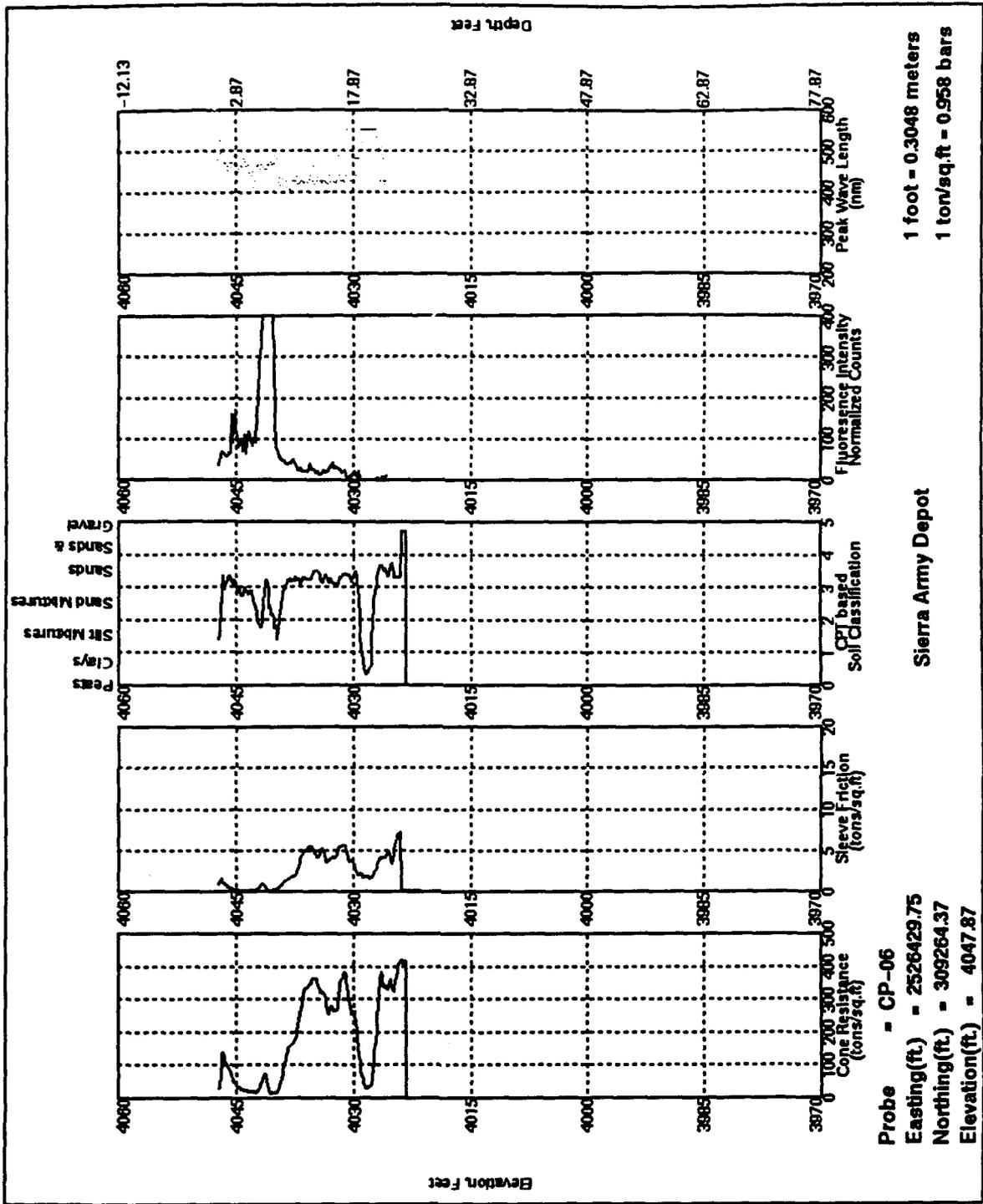


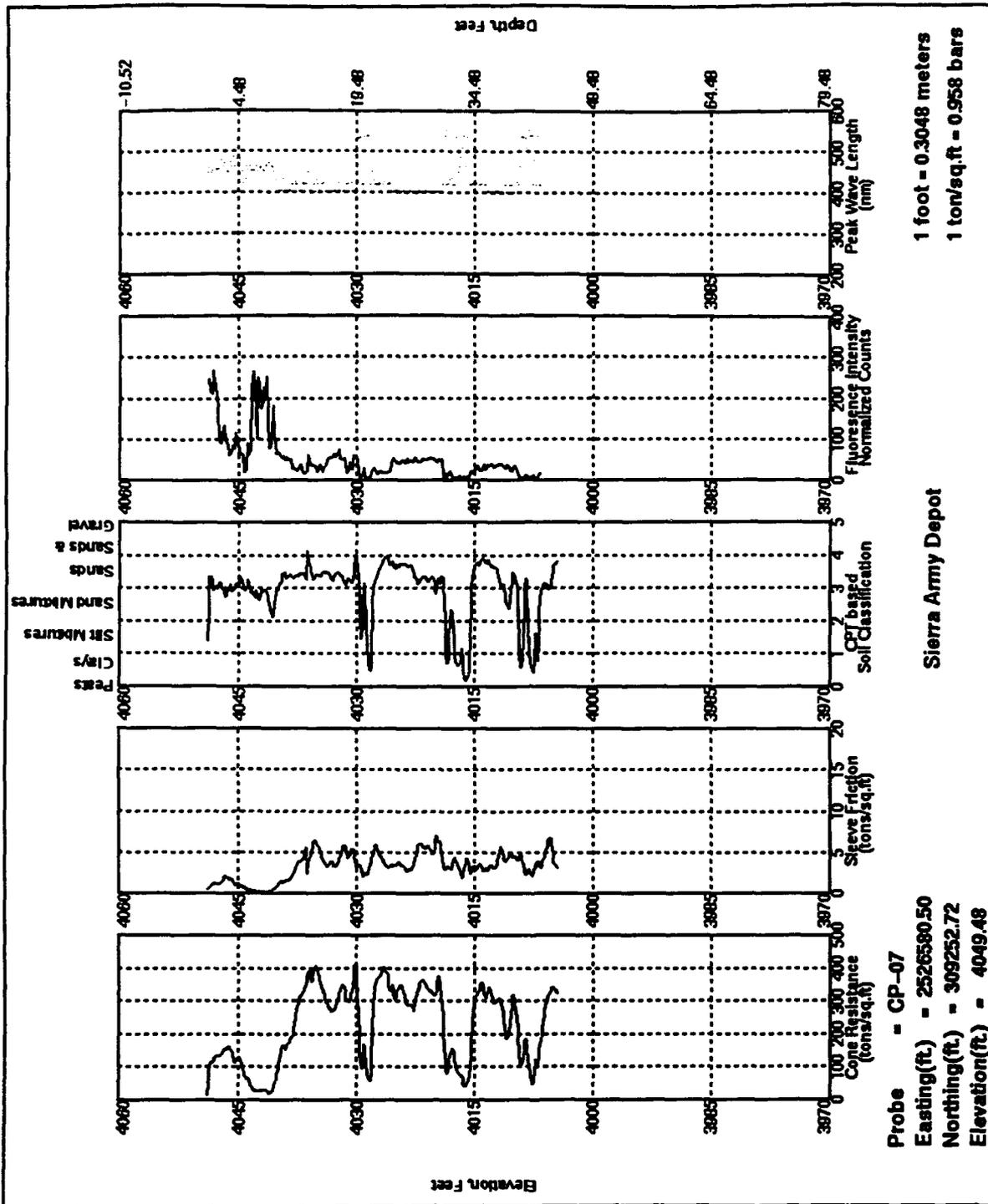


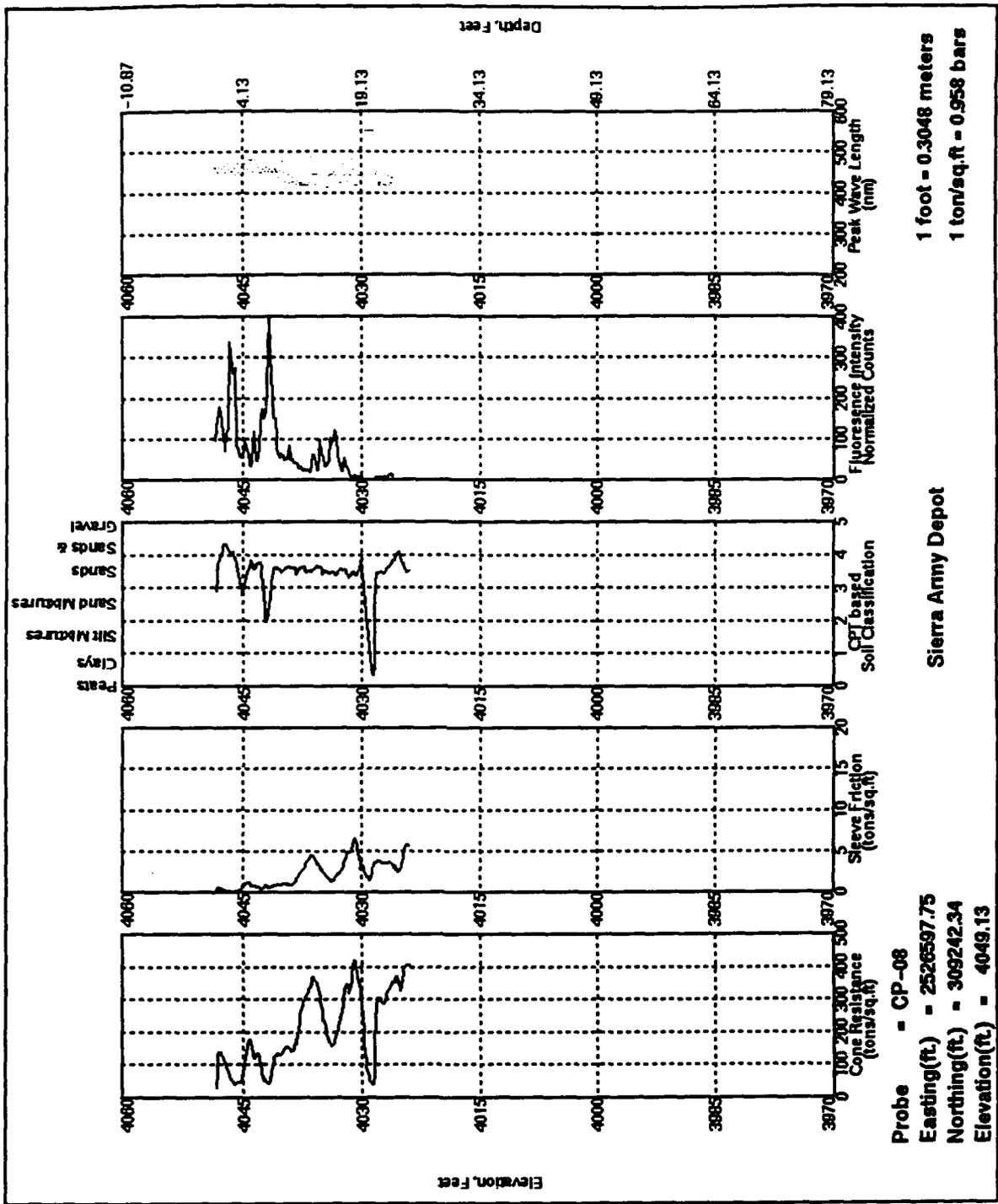


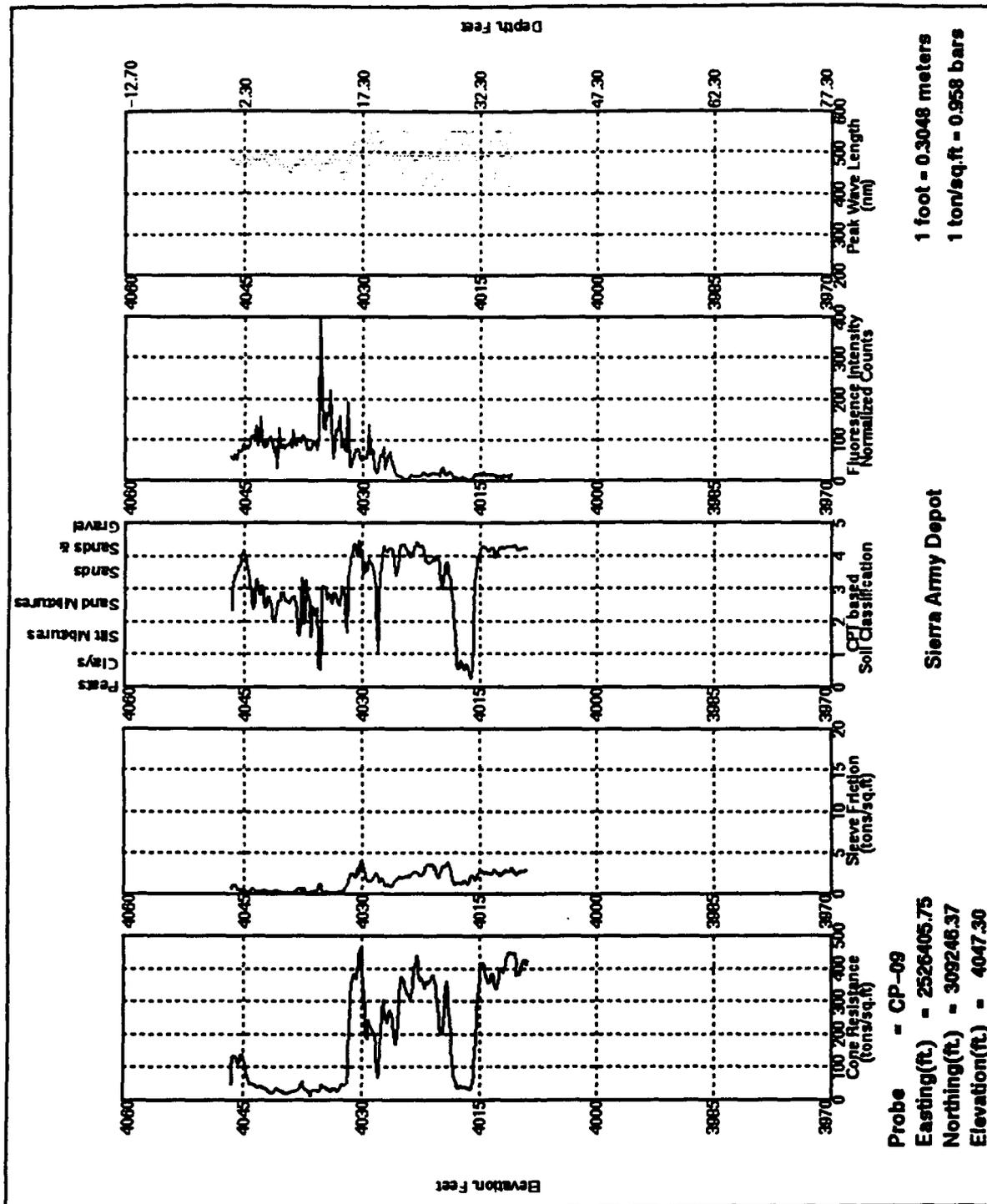


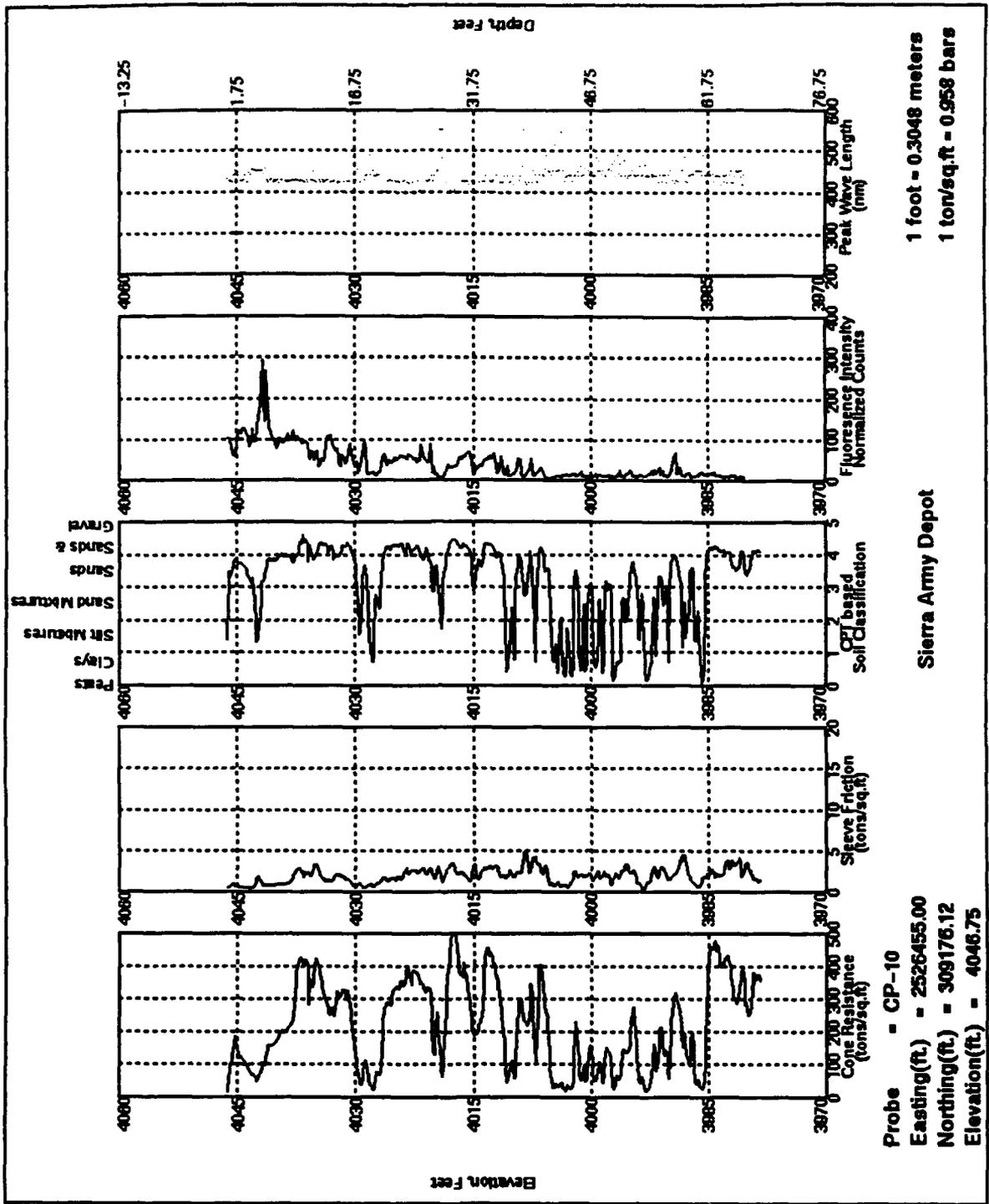


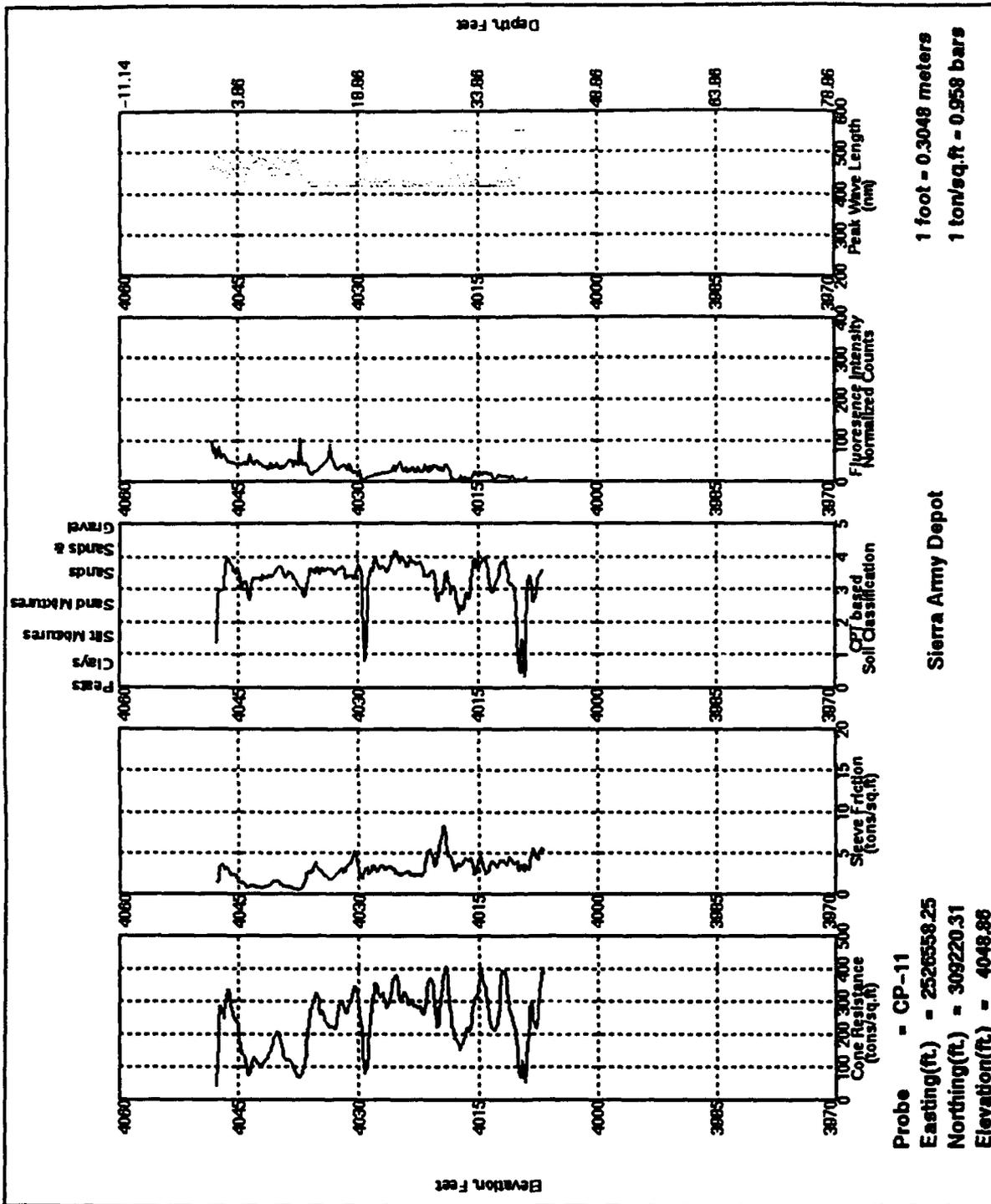


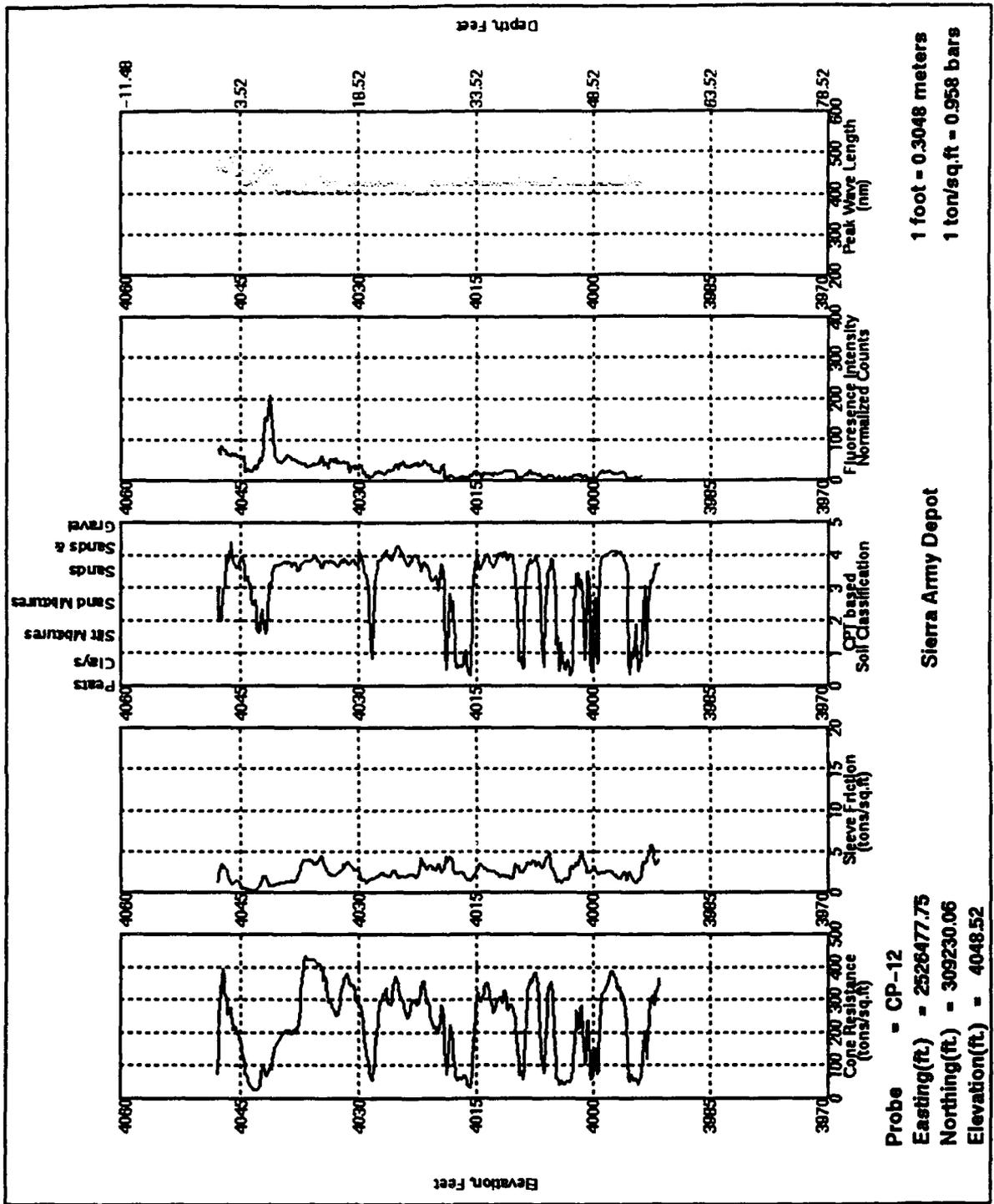


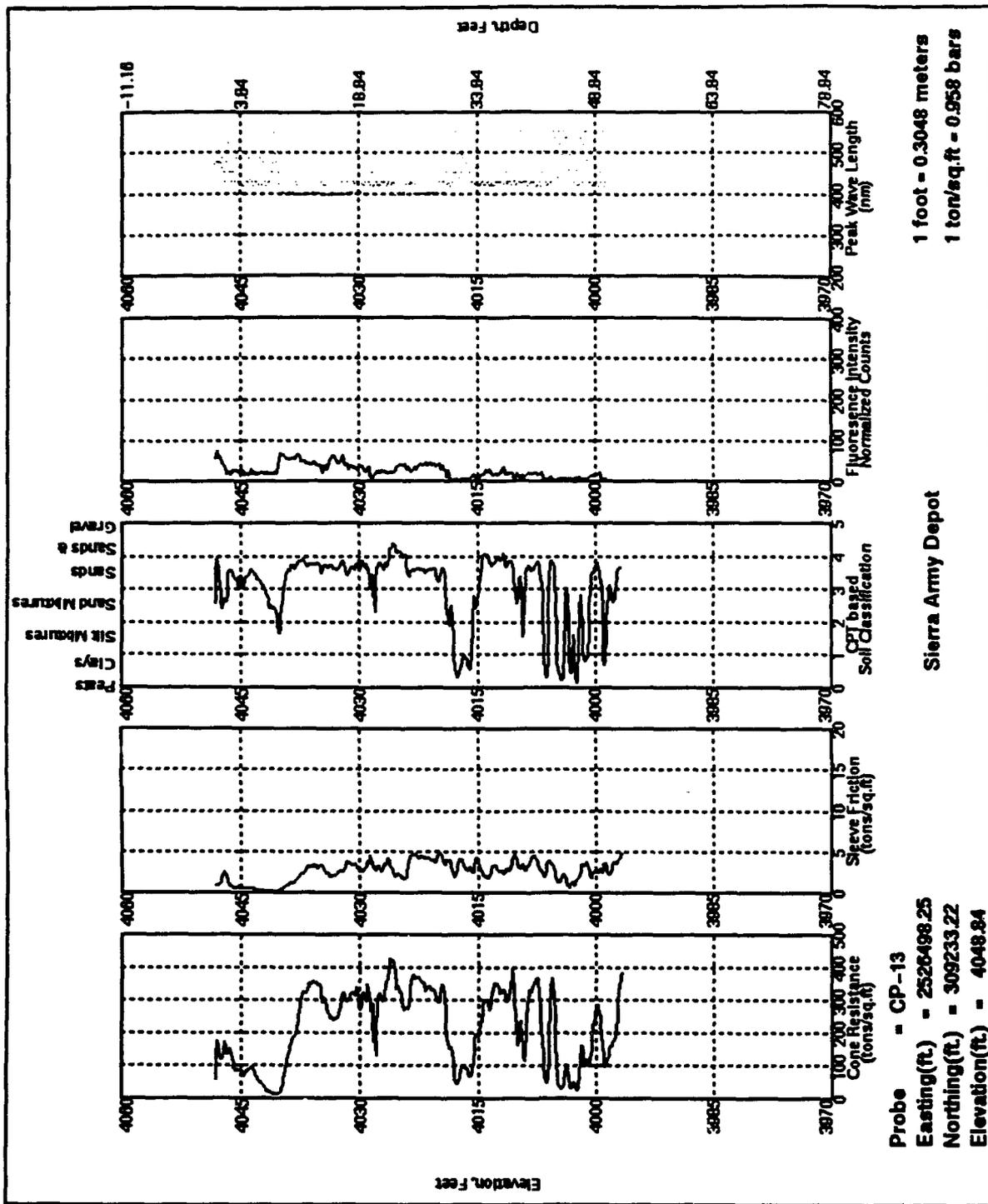


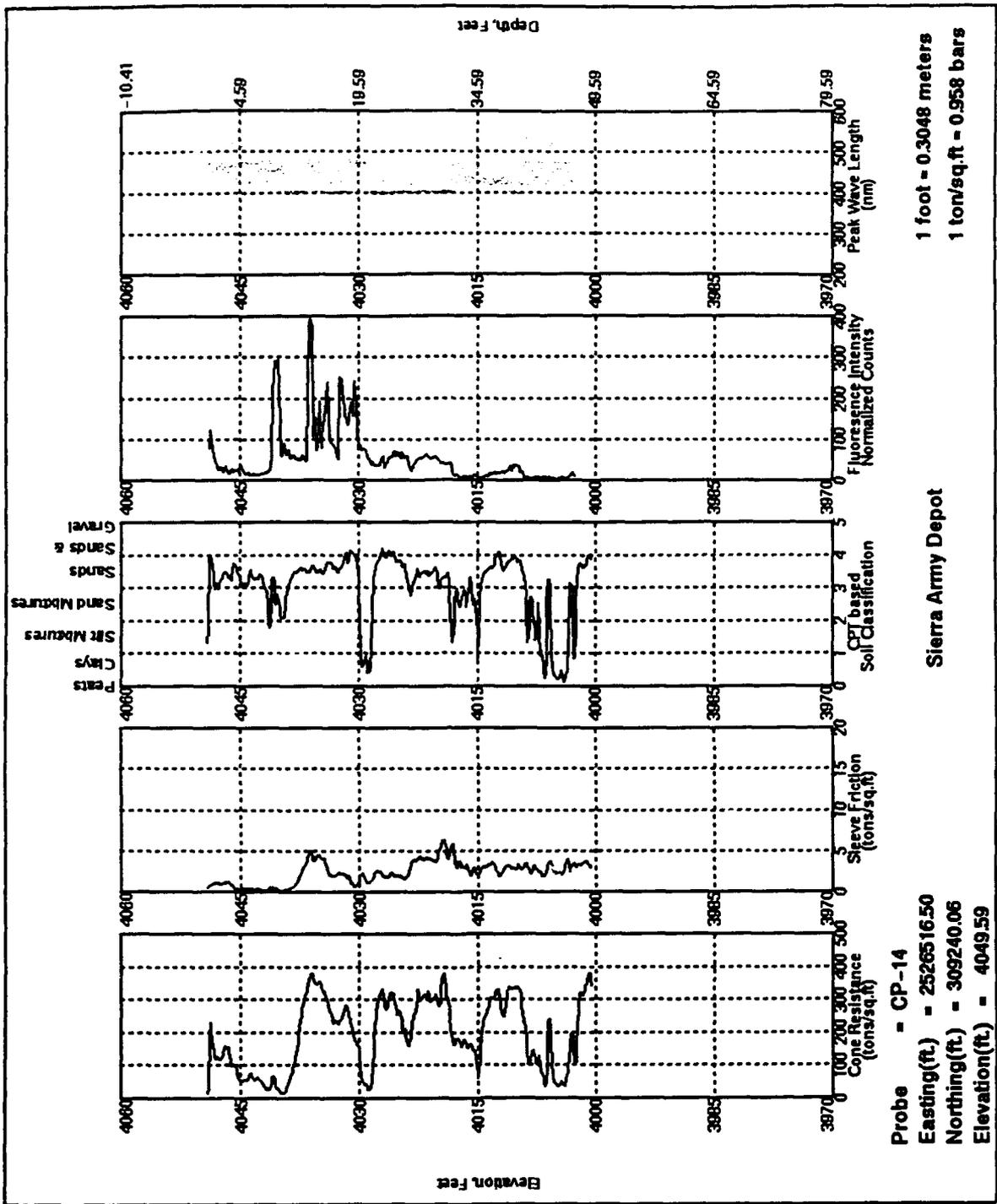


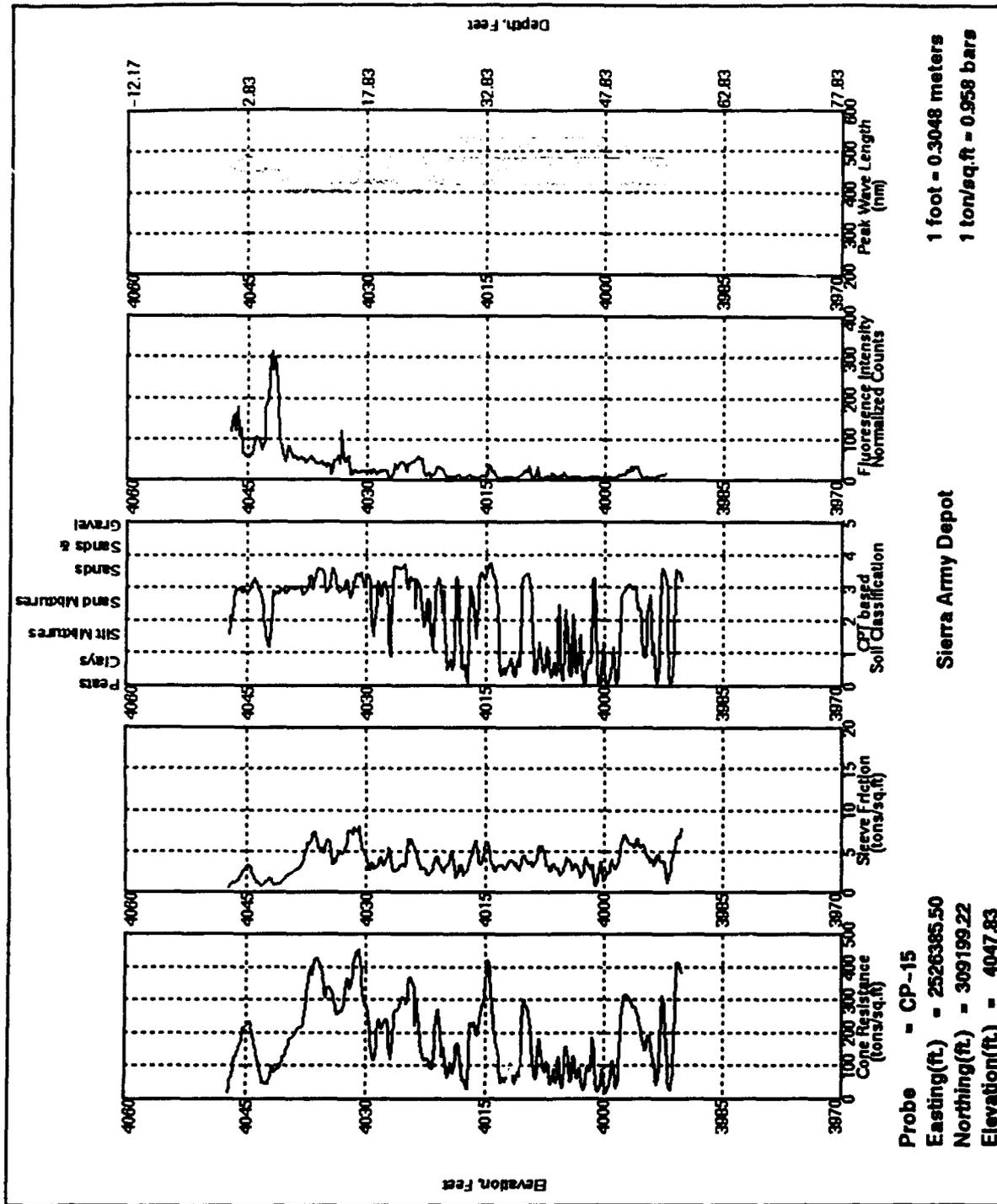


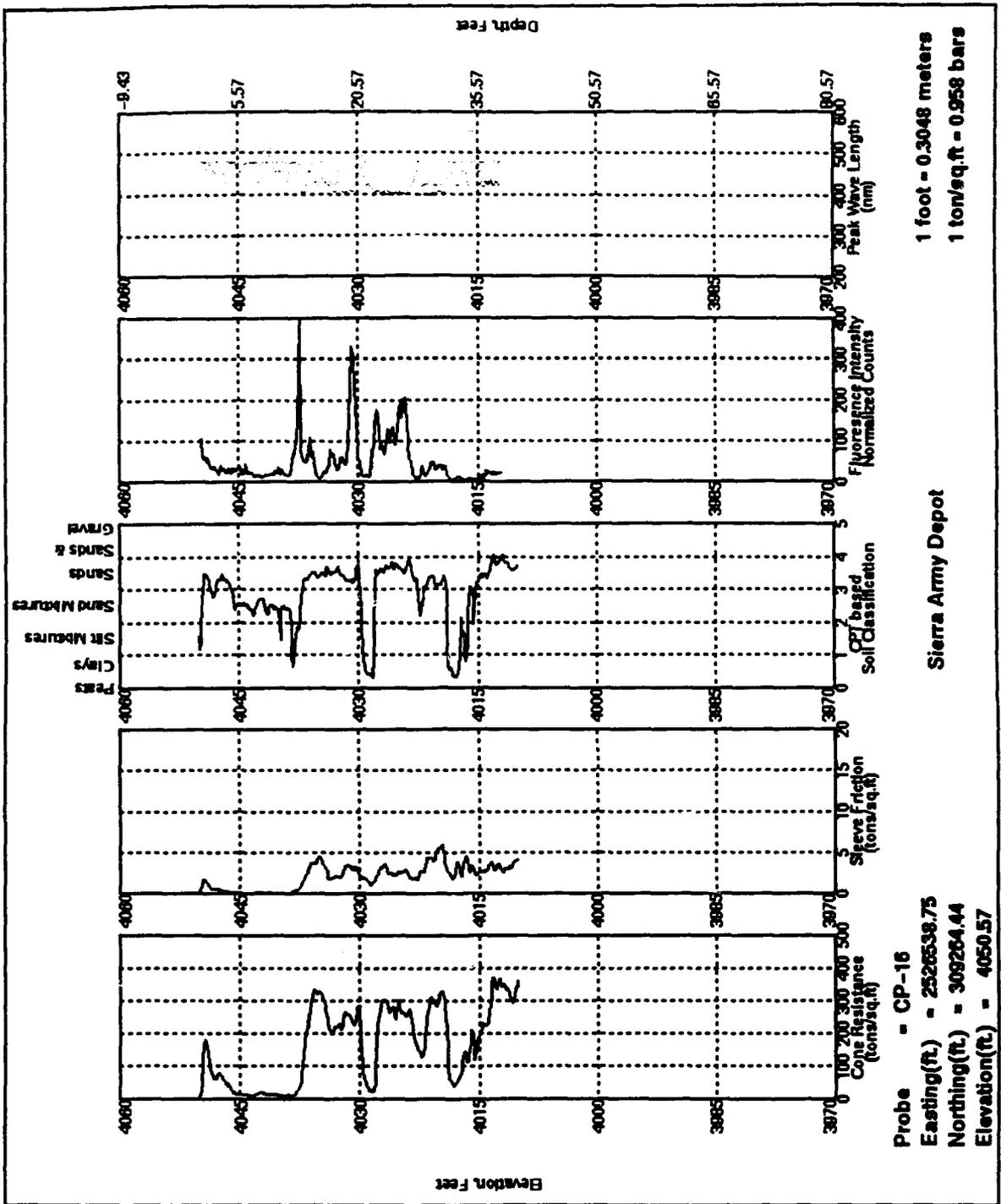






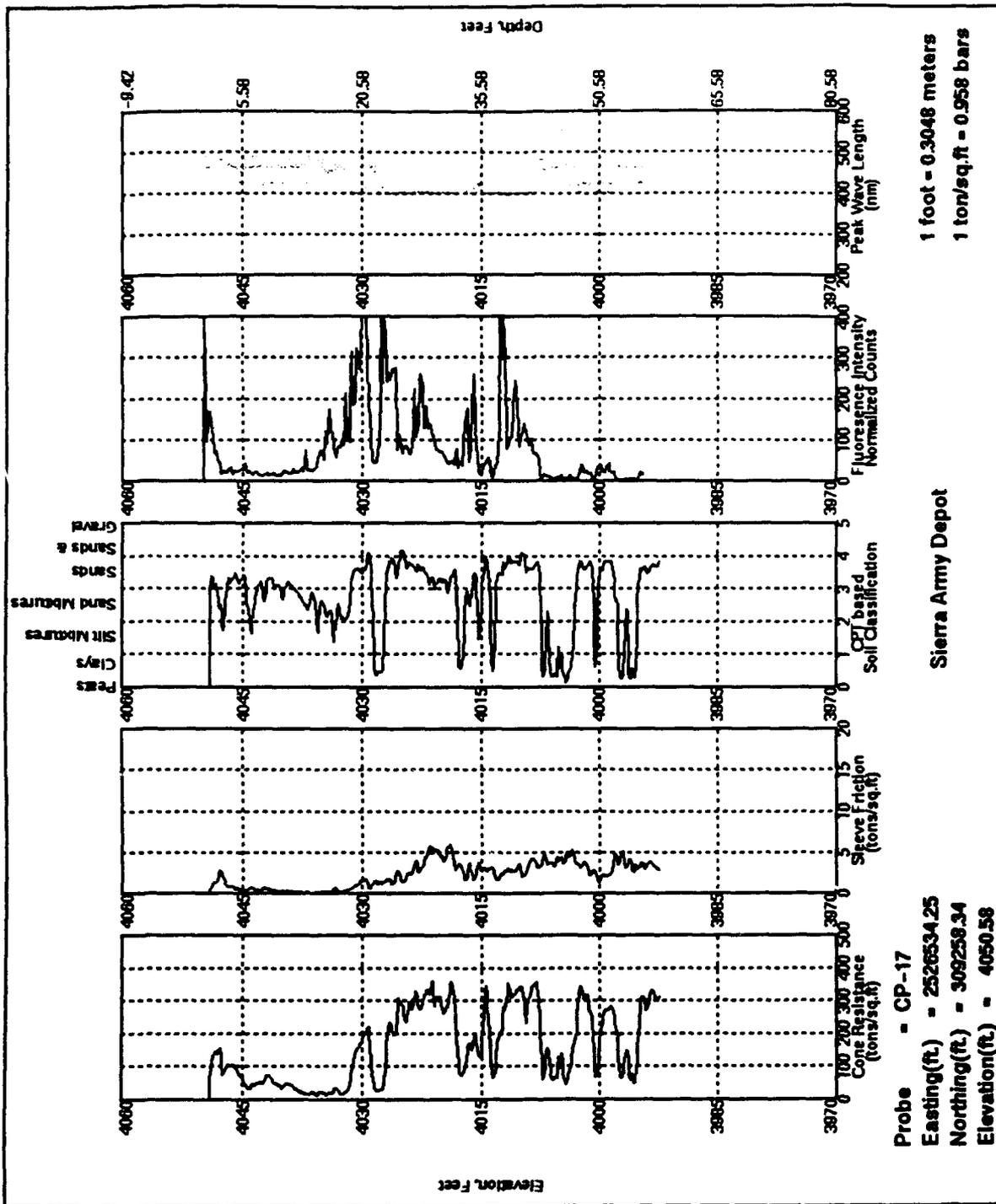


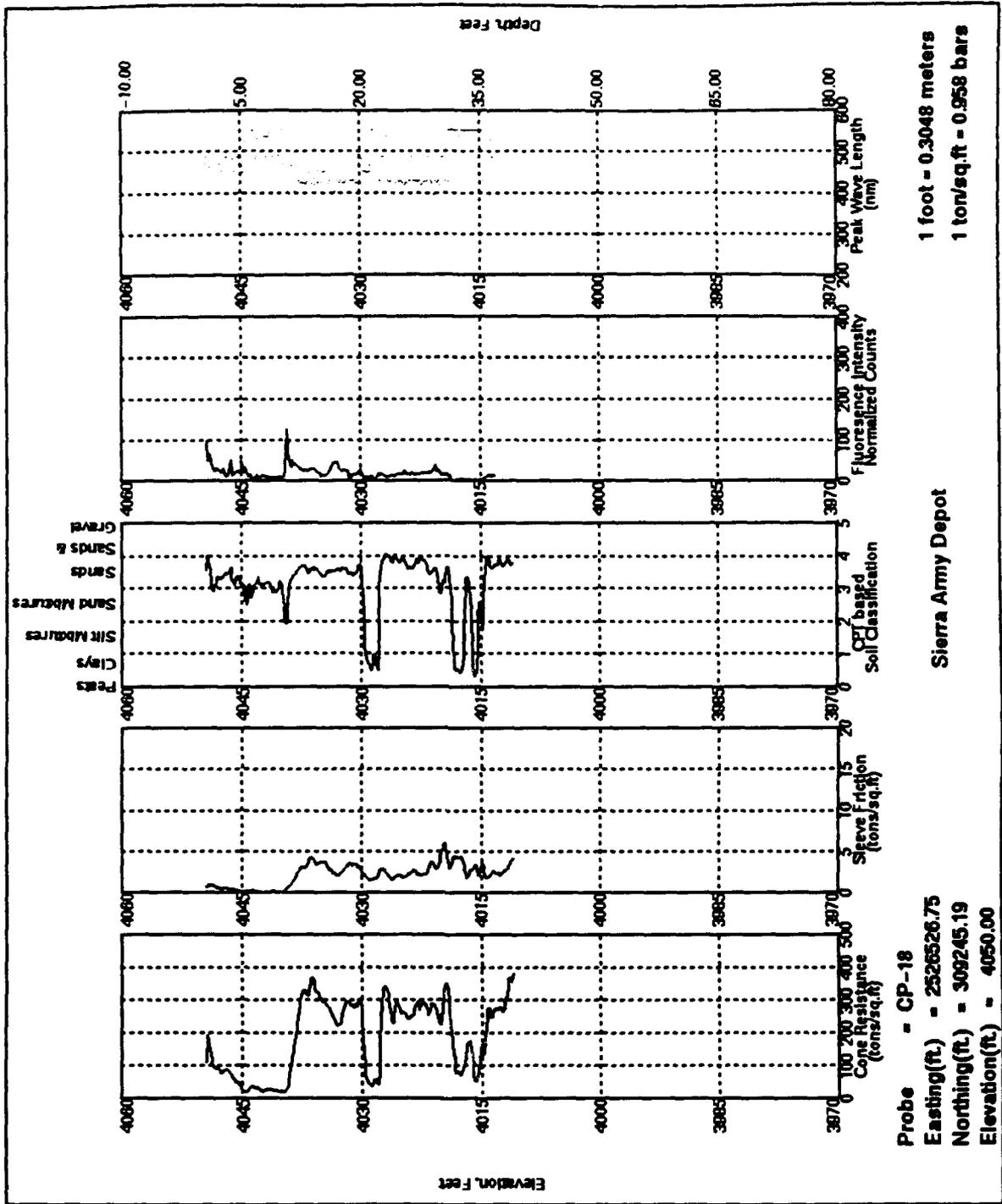


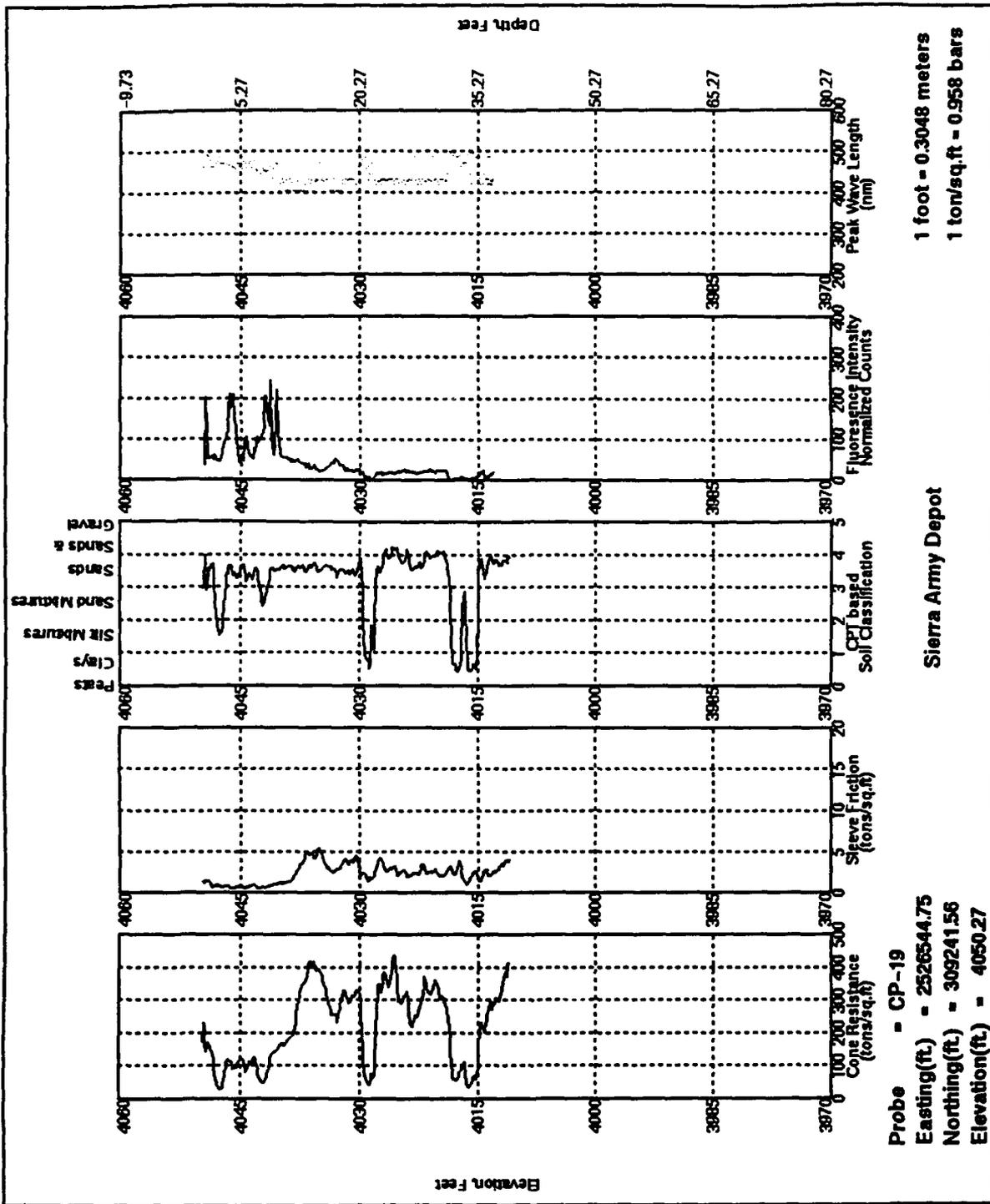


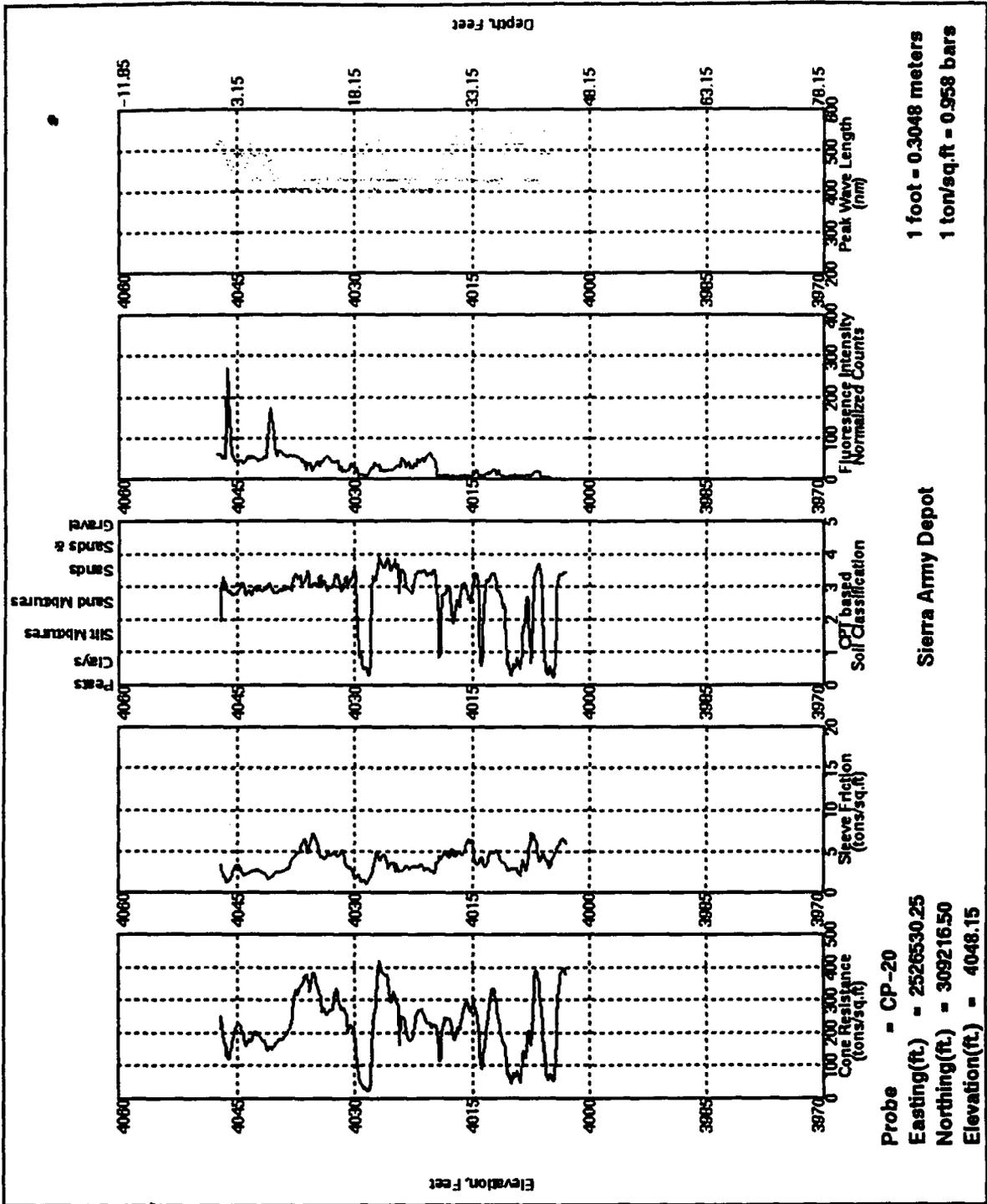
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 Easting(ft.) = 2326538.75
 Northing(ft.) = 309264.44
 Elevation(ft.) = 4050.57

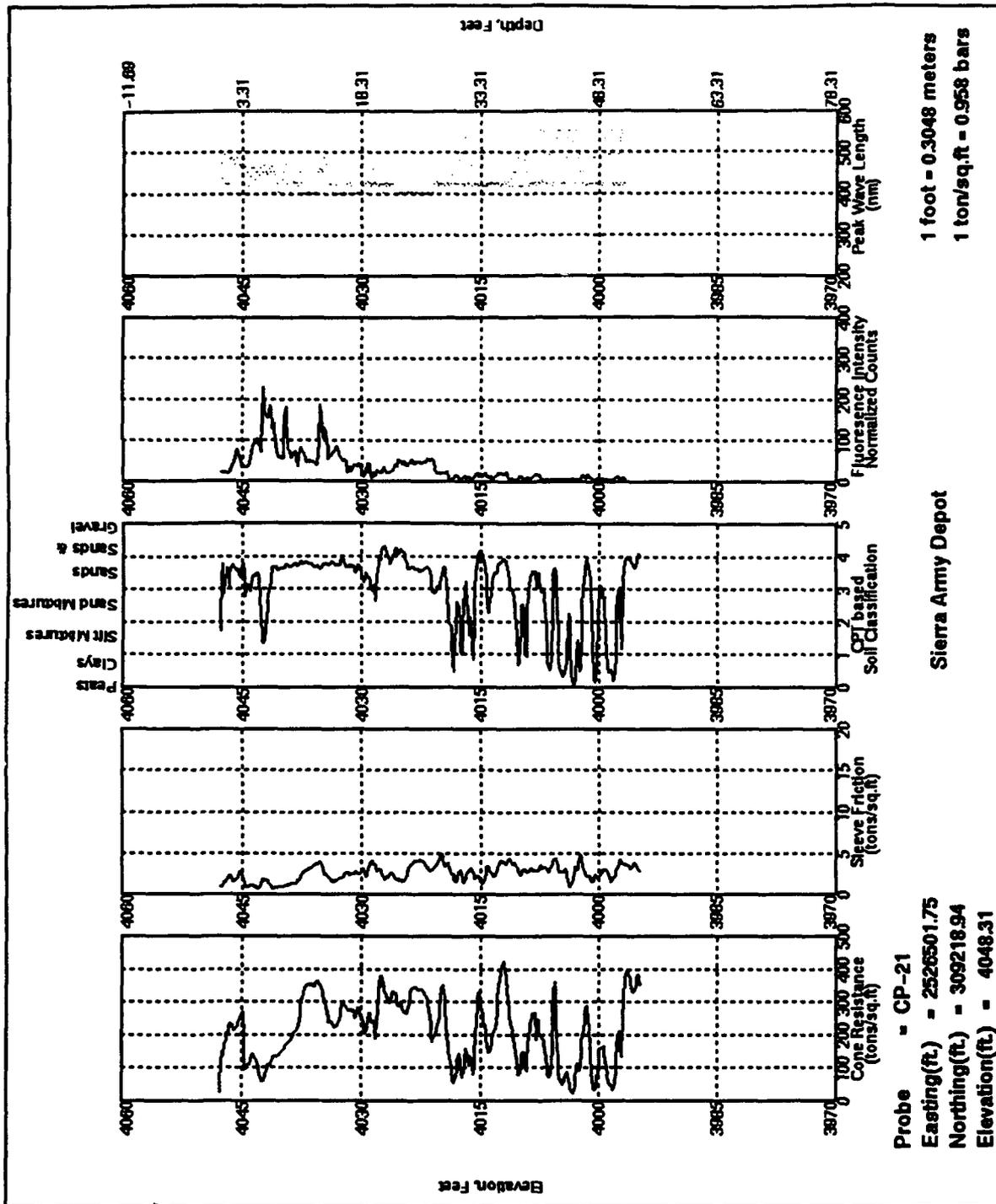
Sierra Army Depot
 1 foot = 0.3048 meters
 1 ton/sq.ft = 0.958 bars







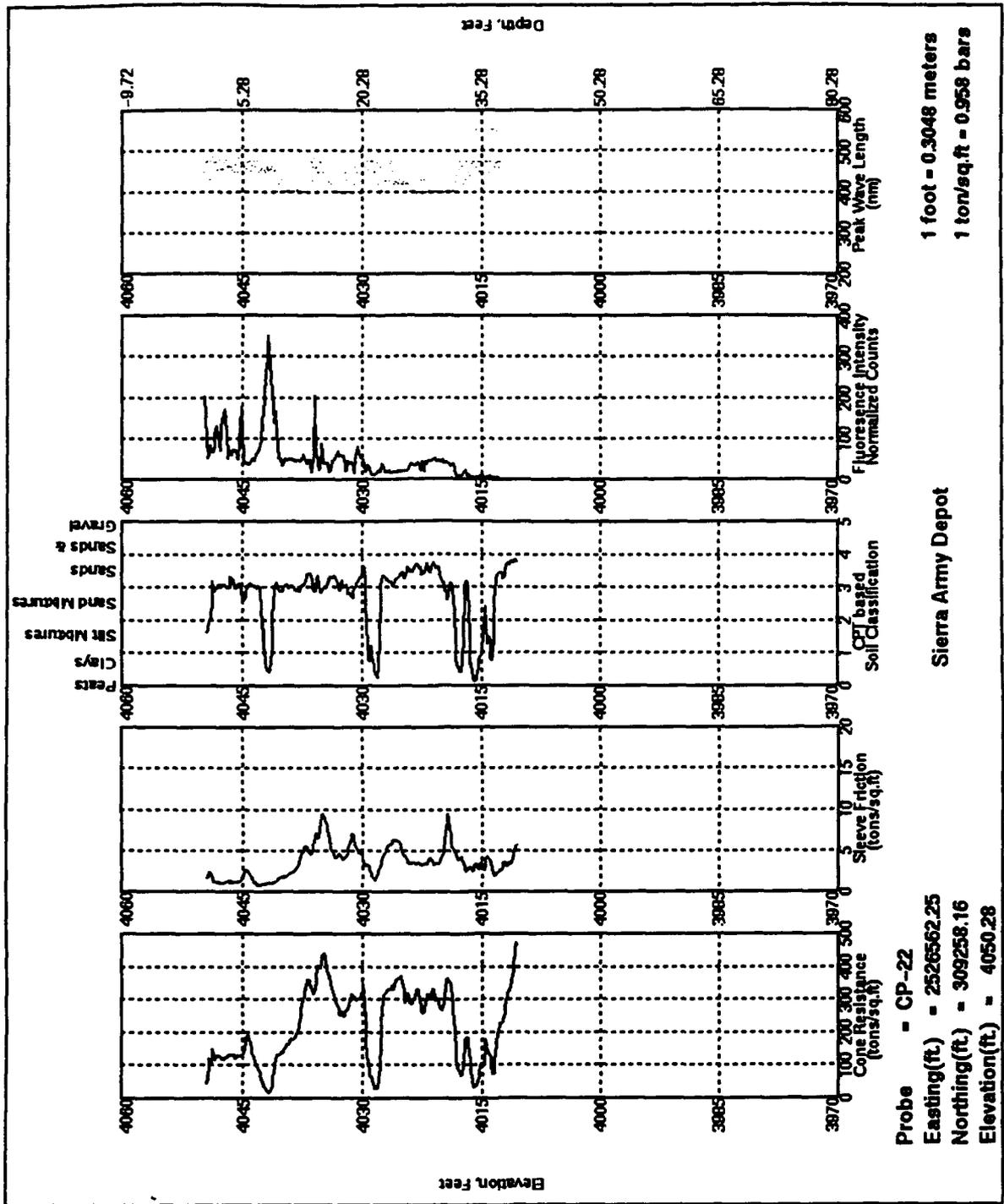




Probe = CP-21
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 Northing(ft.) = 309218.94
 Elevation(ft.) = 4048.31

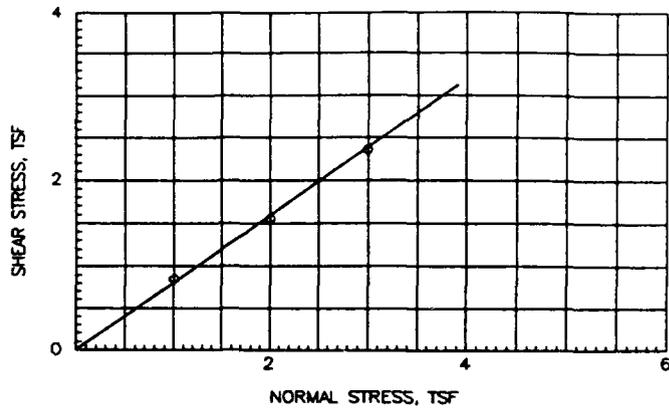
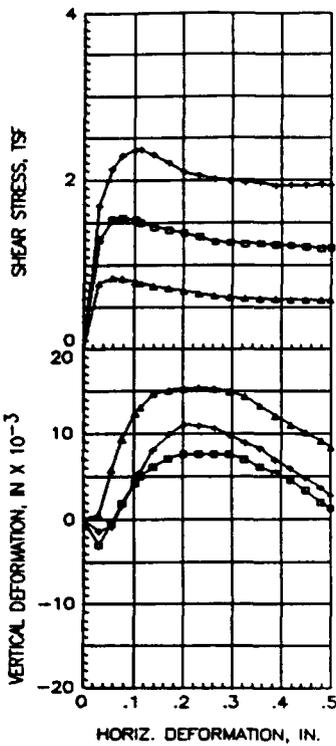
1 foot = 0.3048 meters
 1 ton/sq.ft = 0.958 bars

Sierra Army Depot



Appendix E

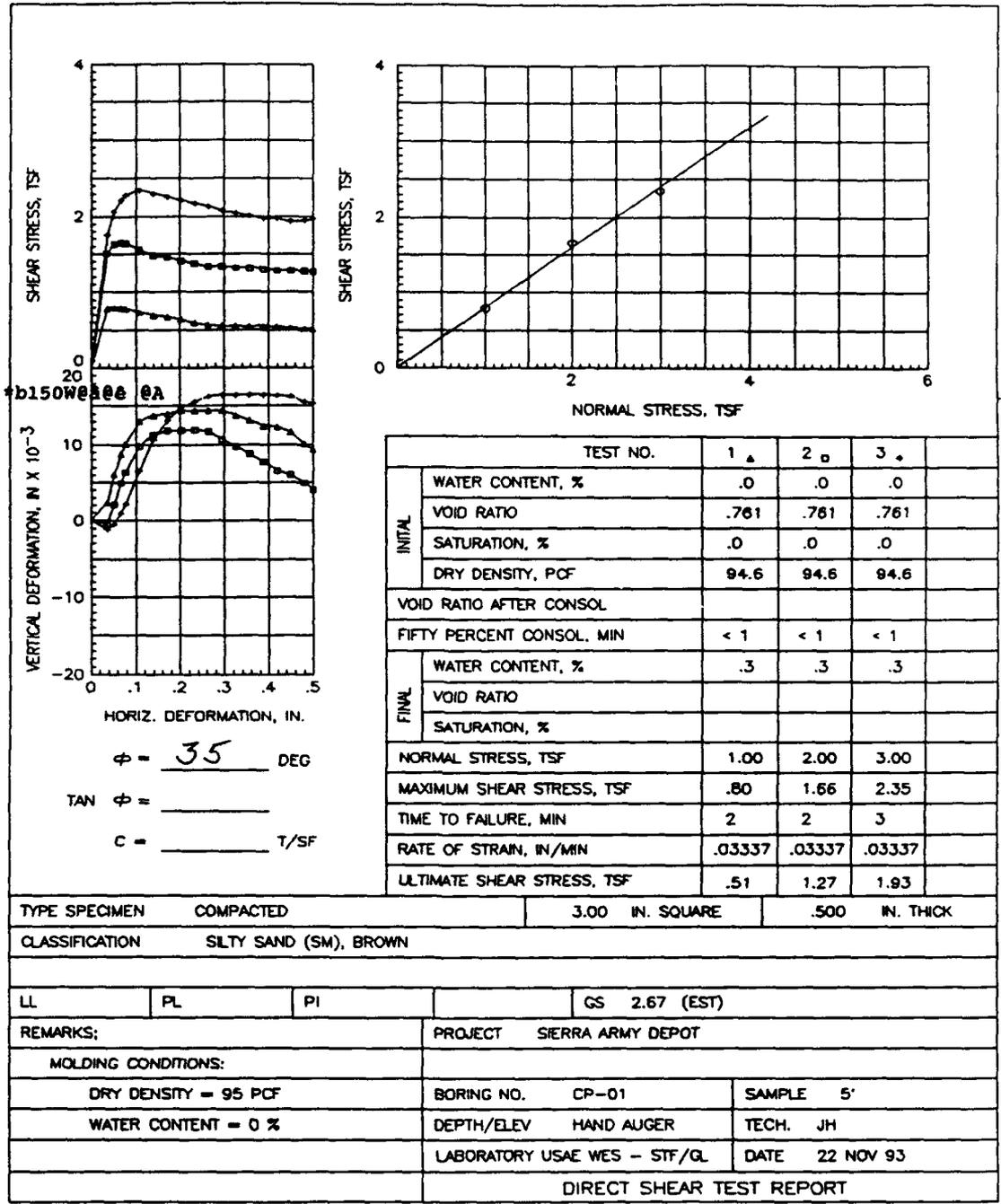
Verification Sample Information



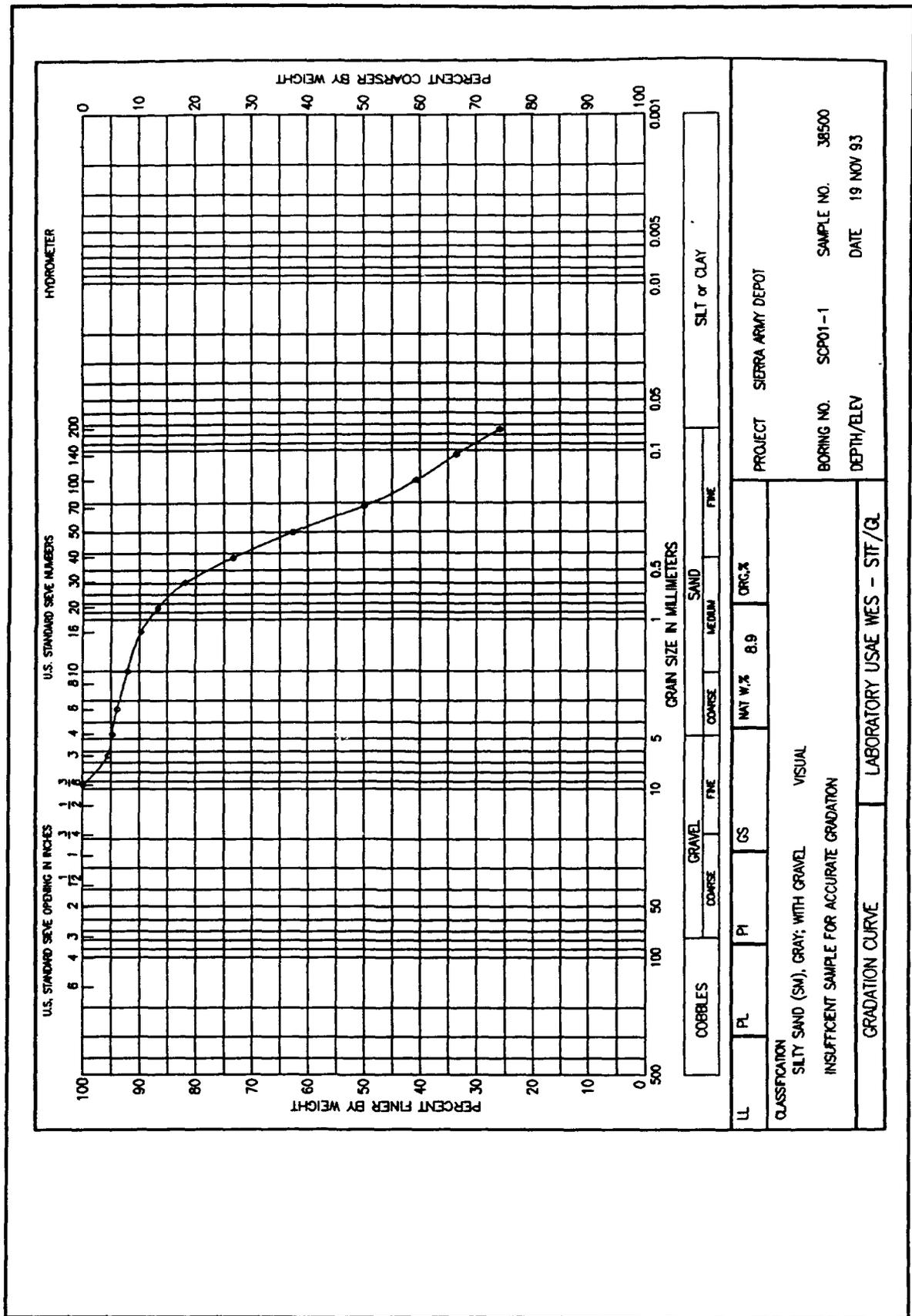
$\phi = 35$ DEG
 TAN $\phi =$ _____
 C = _____ T/SF

TEST NO.		1 Δ	2 \square	3 \circ
INITIAL	WATER CONTENT, %	.0	.0	.0
	VOID RATIO	.761	.761	.761
	SATURATION, %	.0	.0	.0
	DRY DENSITY, PCF	94.6	94.6	94.6
VOID RATIO AFTER CONSOL				
FIFTY PERCENT CONSOL. MIN		< 1	< 1	< 1
FINAL	WATER CONTENT, %	.3	.3	.3
	VOID RATIO			
	SATURATION, %			
NORMAL STRESS, TSF		1.00	2.00	3.00
MAXIMUM SHEAR STRESS, TSF		.86	1.56	2.36
TIME TO FAILURE, MIN		2	2	3
RATE OF STRAIN, IN/MIN		.03339	.03339	.03339
ULTIMATE SHEAR STRESS, TSF		.59	1.21	1.93

TYPE SPECIMEN		COMPACTED		3.00 IN. SQUARE		.500 IN. THICK	
CLASSIFICATION		SILTY SAND (SM), BROWN					
LL	PL	PI	GS 2.67 (EST)				
REMARKS:		PROJECT SIERRA ARMY DEPOT					
MOLDING CONDITIONS:							
DRY DENSITY = 95 PCF		BORING NO. DSA-SB-01		SAMPLE 25'			
WATER CONTENT = 0 %		DEPTH/ELEV HOLL. STEM		TECH. JH			
		LABORATORY USAE WES - STF/GL		DATE 23 NOV 93			
DIRECT SHEAR TEST REPORT							



<u>SAMPLE</u>	<u>GRAIN SHAPE DESCRIPTION</u>
SCP-01-1	Mostly angular and subangular with a few subrounded particles
SCP-02-1	Mostly angular and subangular with a few subrounded particles
SCP-02-2	Mostly subangular with a few subrounded particles
SCP-02-3	Mostly subangular and subrounded particles
SCP-06-1	Mostly subangular and subrounded particles
SCP-08-1	Mostly subangular and subrounded particles
SCP-15-1	Mostly subangular and subrounded particles
SCP-20-1	Mostly subangular and subrounded particles
CP-02 (hand augered)	Mostly subangular and subrounded particles



SIEVE ANALYSIS

PROJECT: SIERRA ARMY DEPOT

BORING: SCP01-1 SAMPLE: 38500 DF: MD0894 .DAT
 DEPTH: DATE: 19 NOV 93

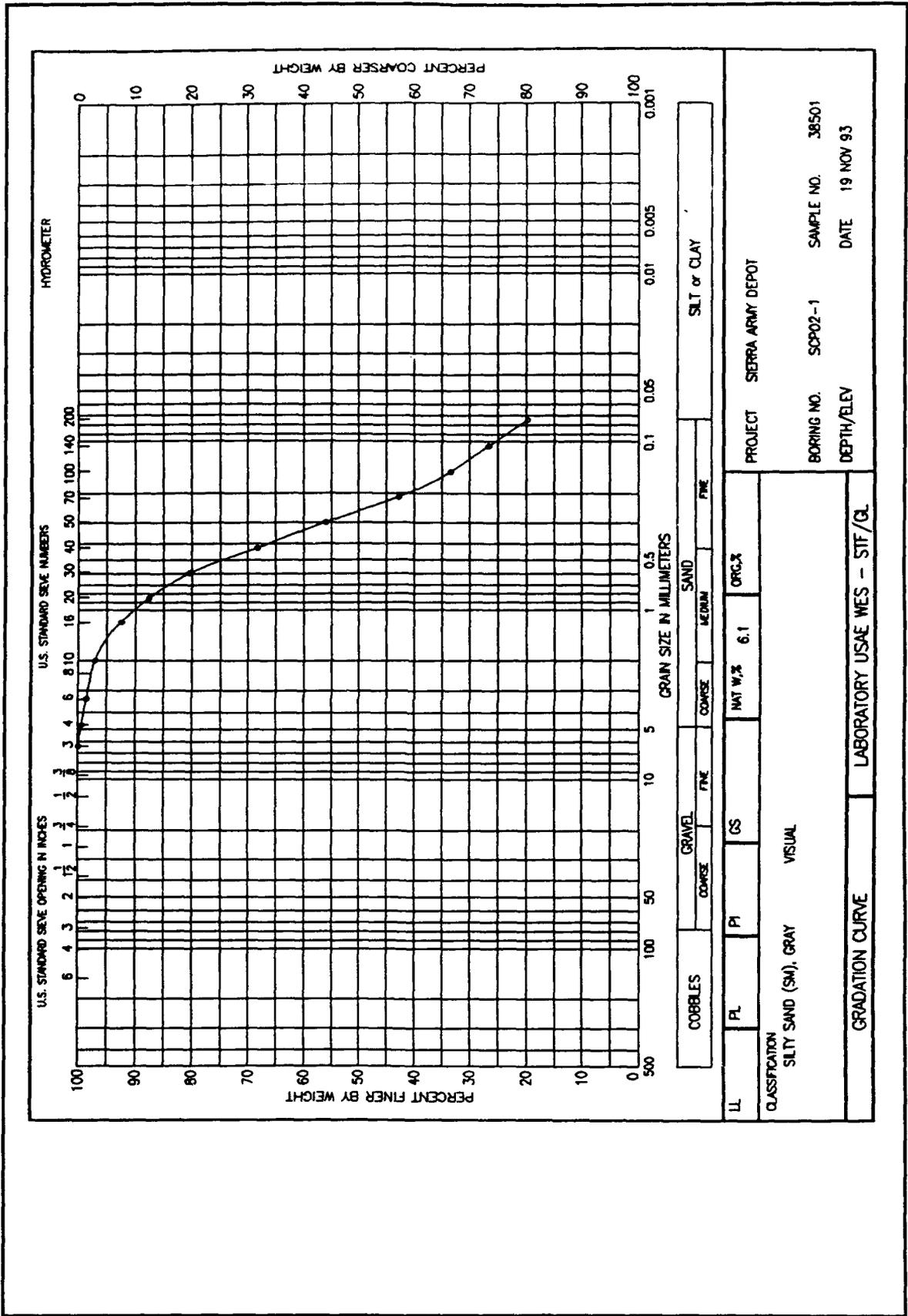
NO-LIMITS-RAN GS: .00 WC: 8.90
 CLASSIFICATION: 108
 SILTY SAND (SM), GRAY; WITH GRAVEL VISUAL

TOTAL WEIGHT OF SAMPLE: 43.2 gms.
 PARTIAL WEIGHT AFTER SPLIT: 41.0 gms.
 INSUFFICIENT SAMPLE FOR ACCURATE GRADATION

WEIGHTS gm.	SIEVE SIZE or NUMBER	OPENING mm	PERCENT FINER	PERCENT COARSER
.0	3/8 in	9.500	100.0	.0
1.9	No 3	6.350	95.6	4.4
.3	No 4	4.750	94.9	5.1
.4	No 6	3.350	94.0	6.0
1.2	No 10	2.000	92.1	7.9
2.2	No 16	1.180	89.8	10.2
3.5	No 20	.850	86.8	13.2
5.6	No 30	.600	81.9	18.1
9.3	No 40	.425	73.4	26.6
13.9	No 50	.300	62.7	37.3
19.4	No 70	.212	50.0	50.0
23.4	No 100	.150	40.7	59.3
26.5	No 140	.106	33.6	66.4
29.8	No 200	.075	25.9	74.1

PERCENT GRAVEL = 5.1
 PERCENT SAND = 69.0
 PERCENT FINES = 25.9

EDE



U.S. STANDARD SEVE OPENING IN INCHES		U.S. STANDARD SEVE NUMBERS		HYDROMETER	
6	4	3	2	1	1/2
100	50	10	5	2	1
4	3	2	1	1/2	3/4
6	4	3	2	1	1/2
10	5	2	1	1/2	3/4
20	10	5	2	1	1/2
40	20	10	5	2	1
80	40	20	10	5	2
160	80	40	20	10	5
300	150	75	37	18	9
600	300	150	75	37	18
1000	500	250	125	63	31
2000	1000	500	250	125	63
4000	2000	1000	500	250	125
8000	4000	2000	1000	500	250
16000	8000	4000	2000	1000	500
32000	16000	8000	4000	2000	1000
64000	32000	16000	8000	4000	2000
128000	64000	32000	16000	8000	4000
256000	128000	64000	32000	16000	8000
512000	256000	128000	64000	32000	16000
1024000	512000	256000	128000	64000	32000
2048000	1024000	512000	256000	128000	64000
4096000	2048000	1024000	512000	256000	128000
8192000	4096000	2048000	1024000	512000	256000
16384000	8192000	4096000	2048000	1024000	512000
32768000	16384000	8192000	4096000	2048000	1024000
65536000	32768000	16384000	8192000	4096000	2048000
131072000	65536000	32768000	16384000	8192000	4096000
262144000	131072000	65536000	32768000	16384000	8192000
524288000	262144000	131072000	65536000	32768000	16384000
1048576000	524288000	262144000	131072000	65536000	32768000
2097152000	1048576000	524288000	262144000	131072000	65536000
4194304000	2097152000	1048576000	524288000	262144000	131072000
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SIEVE ANALYSIS

PROJECT: SIERRA ARMY DEPOT

BORING: SCP02-1 SAMPLE: 38501 DF: MD0894 .DAT
DEPTH: DATE: 19 NOV 93

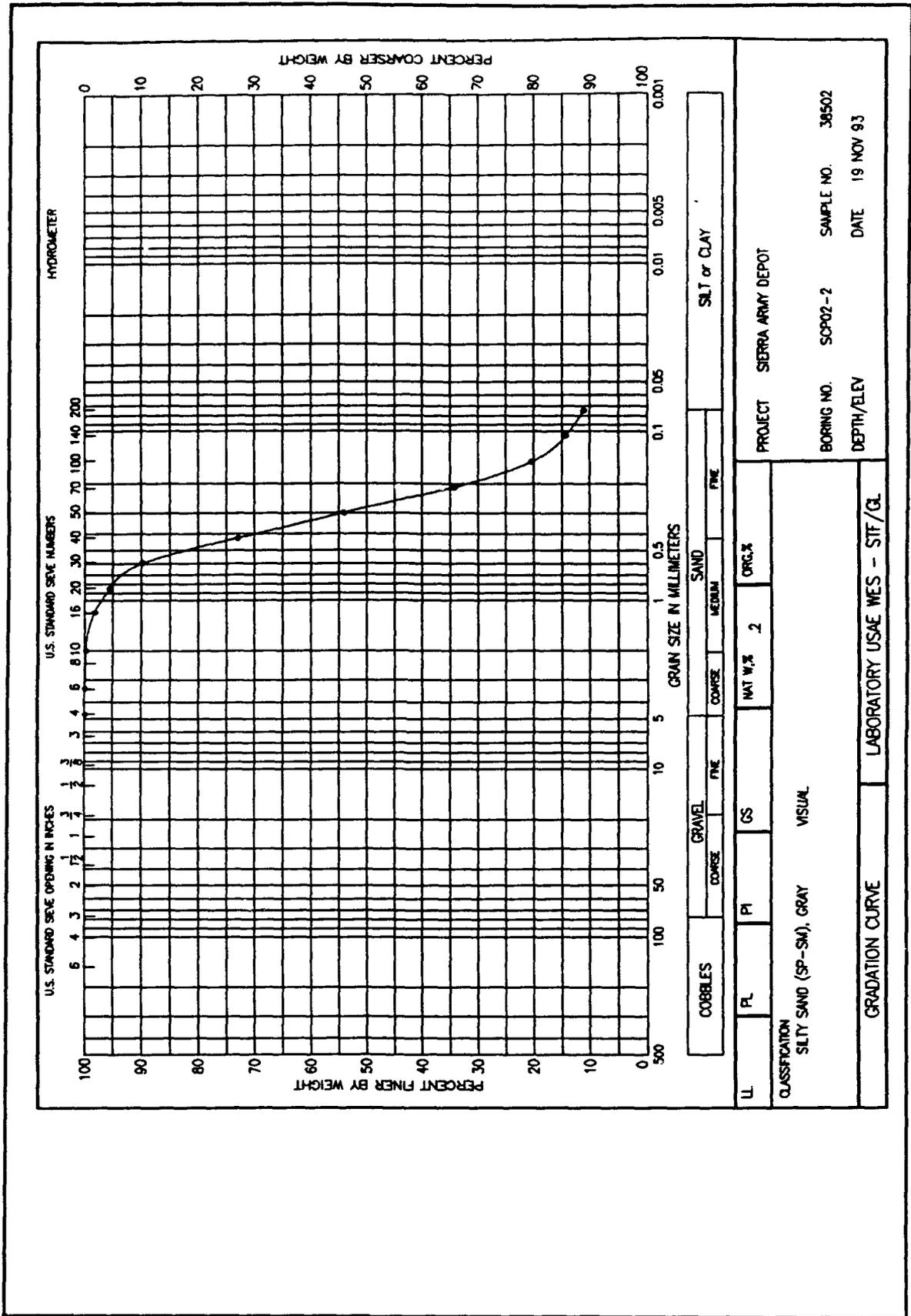
NO-LIMITS-RAN GS: .00 WC: 6.10
CLASSIFICATION: 120
SILTY SAND (SM), GRAY VISUAL

TOTAL WEIGHT OF SAMPLE: 112.4 gms.
PARTIAL WEIGHT AFTER SPLIT: 56.4 gms.

WEIGHTS gm.	SIEVE SIZE or NUMBER	OPENING mm	PERCENT FINER	PERCENT COARSER
.0	No 3	6.350	100.0	.0
.6	No 4	4.750	99.5	.5
.5	No 6	3.350	98.6	1.4
1.3	No 10	2.000	97.2	2.8
3.9	No 16	1.180	92.6	7.4
6.7	No 20	.850	87.7	12.3
10.8	No 30	.600	80.4	19.6
17.6	No 40	.425	68.4	31.6
24.6	No 50	.300	56.1	43.9
32.1	No 70	.212	42.9	57.1
37.4	No 100	.150	33.5	66.5
41.3	No 140	.106	26.6	73.4
45.2	No 200	.075	19.8	80.2

PERCENT GRAVEL = .5
PERCENT SAND = 79.7
PERCENT FINES = 19.8

EDE



COBBLES	GRAVEL	SAND		SILT or CLAY	
	COARSE	FINE	COARSE	MEDIUM	FINE
LL	PL	PI	CS	ORG. %	
			NAT. W. %	2	
CLASSIFICATION					
SILTY SAND (SP-SM), GRAY			VISUAL		
GRADATION CURVE			LABORATORY USAE WES - STF/GL		
PROJECT			SIERRA ARMY DEPOT		
BORING NO.			SOP02-2		
DEPTH/ELEV			DATE		
			19 NOV 93		
			SAMPLE NO. 38502		

SIEVE ANALYSIS

PROJECT: SIERRA ARMY DEPOT

BORING: SCP02-2 SAMPLE: 38502 DF: MD0894 .DAT
 DEPTH: DATE: 19 NOV 93

NO-LIMITS-RAN GS: .00 WC: .20
 CLASSIFICATION: 132
 SILTY SAND (SP-SM), GRAY VISUAL

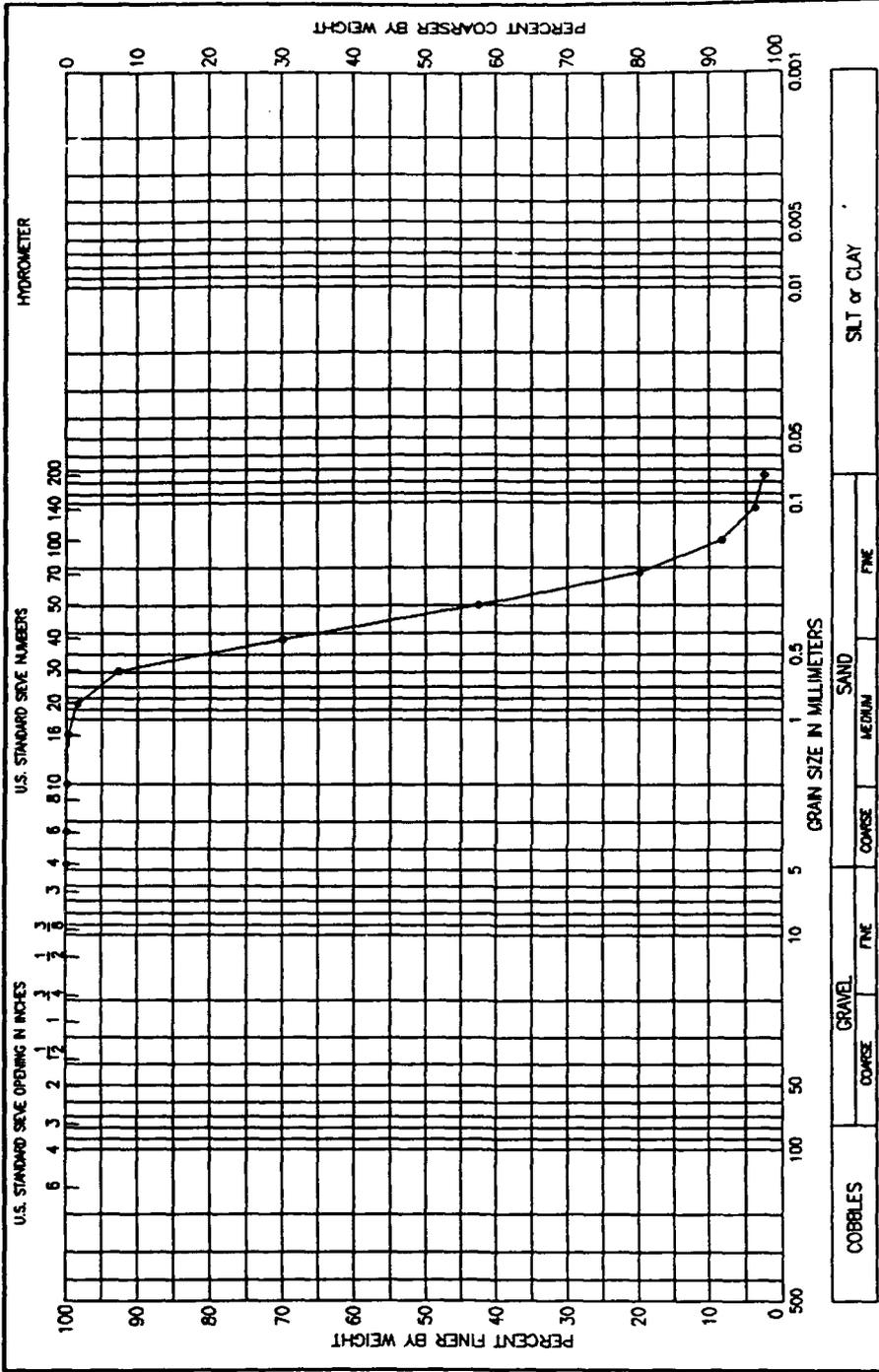
TOTAL WEIGHT OF SAMPLE: .0 gms.
 PARTIAL WEIGHT AFTER SPLIT: 66.3 gms.

WEIGHTS gm.	SIEVE SIZE or NUMBER	OPENING mm	PERCENT FINER	PERCENT COARSER
.0	No 4	4.750	100.0	.0
.0	No 6	3.350	100.0	.0
.1	No 10	2.000	99.8	.2
1.1	No 16	1.180	98.3	1.7
2.9	No 20	.850	95.6	4.4
6.7	No 30	.600	89.9	10.1
17.9	No 40	.425	73.0	27.0
30.4	No 50	.300	54.1	45.9
43.5	No 70	.212	34.4	65.6
52.8	No 100	.150	20.4	79.6
56.8	No 140	.106	14.3	85.7
58.9	No 200	.075	11.2	88.8

PERCENT GRAVEL = .0
 PERCENT SAND = 88.8
 PERCENT FINES = 11.2

D60 = .34
 D30 = .19
 D10 = .06
 CU = 5.32
 CC = 1.72

EDE



COBBLES		GRAVEL		SAND		SILT or CLAY	
COARSE		FINE		COARSE		FINE	
LL	PL	PI	CS	NAT W.%	2.3	ORG.%	
CLASSIFICATION SAND (SP), GRAY							
GRADATION CURVE				LABORATORY USAE WES - SIT/GL			
PROJECT				SIERRA ARMY DEPOT			
BORING NO.				SCP02-3		SAMPLE NO. 38503	
DEPTH/ELEV				DATE 19 NOV 93			

SIEVE ANALYSIS

PROJECT: SIERRA ARMY DEPOT

BORING: SCP02-3 SAMPLE: 38503 DF: MD0894 .DAT
 DEPTH: DATE: 19 NOV 93

NO-LIMITS-RAN GS: .00 WC: 2.30
 CLASSIFICATION: 142
 SAND (SP), GRAY

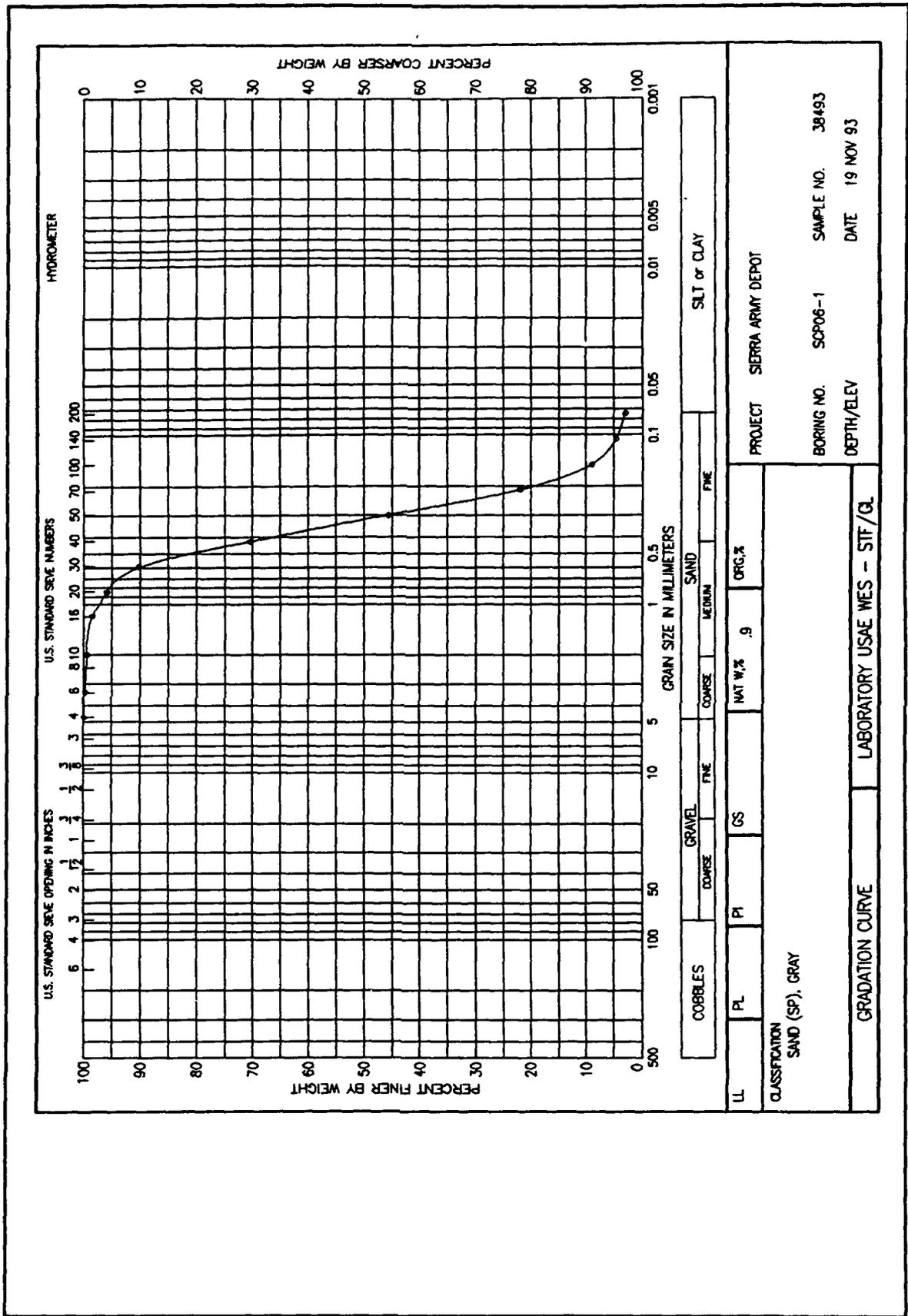
TOTAL WEIGHT OF SAMPLE: .0 gms.
 PARTIAL WEIGHT AFTER SPLIT: 53.8 gms.

WEIGHTS gm.	SIEVE SIZE or NUMBER	OPENING mm	PERCENT FINER	PERCENT COARSER
.0	No 4	4.750	100.0	.0
.0	No 6	3.350	100.0	.0
.0	No 10	2.000	100.0	.0
.1	No 16	1.180	99.8	.2
.8	No 20	.850	98.5	1.5
3.9	No 30	.600	92.8	7.2
16.1	No 40	.425	70.1	29.9
30.9	No 50	.300	42.6	57.4
43.1	No 70	.212	19.9	80.1
49.3	No 100	.150	8.4	91.6
51.7	No 140	.106	3.9	96.1
52.4	No 200	.075	2.6	97.4

PERCENT GRAVEL = .0
 PERCENT SAND = 97.4
 PERCENT FINES = 2.6

D60 = .38
 D30 = .25
 D10 = .16
 CU = 2.39
 CC = 1.05

EDE



SIEVE ANALYSIS

PROJECT: SIERRA ARMY DEPOT

BORING: SCP06-1 SAMPLE: 38493 DF: MD0894 .DAT
 DEPTH: DATE: 19 NOV 93

NO-LIMITS-RAN GS: .00 WC: .90
 CLASSIFICATION: 152
 SAND (SP), GRAY

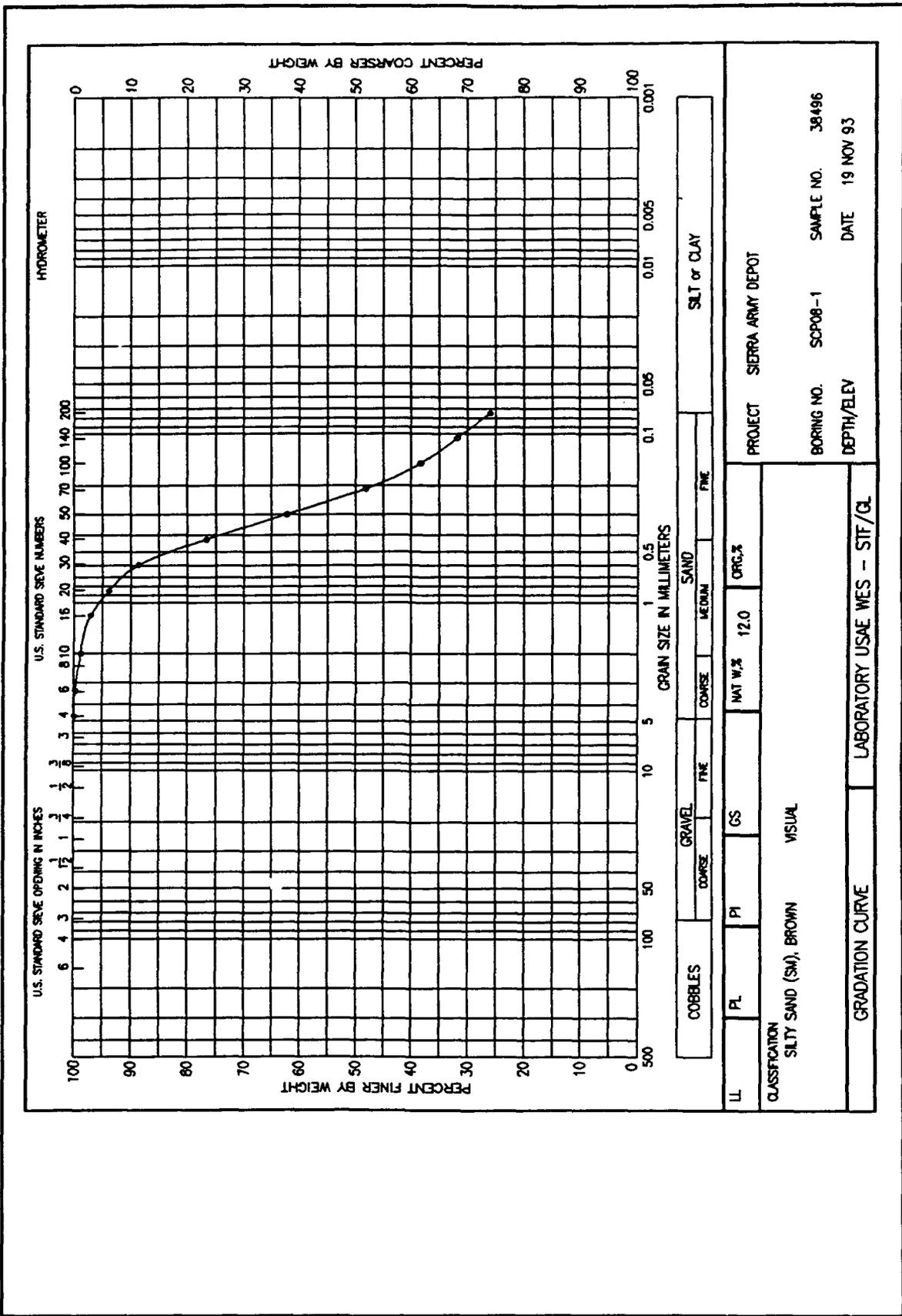
TOTAL WEIGHT OF SAMPLE: .0 gms.
 PARTIAL WEIGHT AFTER SPLIT: 61.9 gms.

WEIGHTS gm.	SIEVE SIZE or NUMBER	OPENING mm	PERCENT FINER	PERCENT COARSER
.0	No 4	4.750	100.0	.0
.1	No 6	3.350	99.8	.2
.3	No 10	2.000	99.5	.5
.9	No 16	1.180	98.5	1.5
2.5	No 20	.850	96.0	4.0
6.0	No 30	.600	90.3	9.7
18.3	No 40	.425	70.4	29.6
33.6	No 50	.300	45.7	54.3
48.3	No 70	.212	22.0	78.0
56.3	No 100	.150	9.0	91.0
59.0	No 140	.106	4.7	95.3
60.0	No 200	.075	3.1	96.9

PERCENT GRAVEL = .0
 PERCENT SAND = 96.9
 PERCENT FINES = 3.1

D60 = .37
 D30 = .24
 D10 = .15
 CU = 2.41
 CC = 1.02

EDE



SIEVE ANALYSIS

PROJECT: SIERRA ARMY DEPOT

BORING: SCP08-1 SAMPLE: 38496 DF: MD0894 .DAT
 DEPTH: DATE: 19 NOV 93

NO-LIMITS-RAN GS: .00 WC: 12.00
 CLASSIFICATION: 162
 SILTY SAND (SM), BROWN VISUAL

TOTAL WEIGHT OF SAMPLE: .0 gms.
 PARTIAL WEIGHT AFTER SPLIT: 52.3 gms.

WEIGHTS gm.	SIEVE SIZE or NUMBER	OPENING mm	PERCENT FINER	PERCENT COARSER
.0	No 4	4.750	100.0	.0
.1	No 6	3.350	99.8	.2
.6	No 10	2.000	98.9	1.1
1.5	No 16	1.180	97.1	2.9
3.2	No 20	.850	93.9	6.1
5.9	No 30	.600	88.7	11.3
12.2	No 40	.425	76.7	23.3
19.7	No 50	.300	62.3	37.7
27.1	No 70	.212	48.2	51.8
32.2	No 100	.150	38.4	61.6
35.6	No 140	.106	31.9	68.1
38.7	No 200	.075	26.0	74.0

PERCENT GRAVEL = .0
 PERCENT SAND = 74.0
 PERCENT FINES = 26.0

EDE

SIEVE ANALYSIS

PROJECT: SIERRA ARMY DEPOT

BORING: SCP15-1 SAMPLE: 38491 DF: MD0894 .DAT
 DEPTH: DATE: 19 NOV 93

NO-LIMITS-RAN GS: .00 WC: 7.70
 CLASSIFICATION: 172
 SILTY SAND (SP-SM), BROWN VISUAL

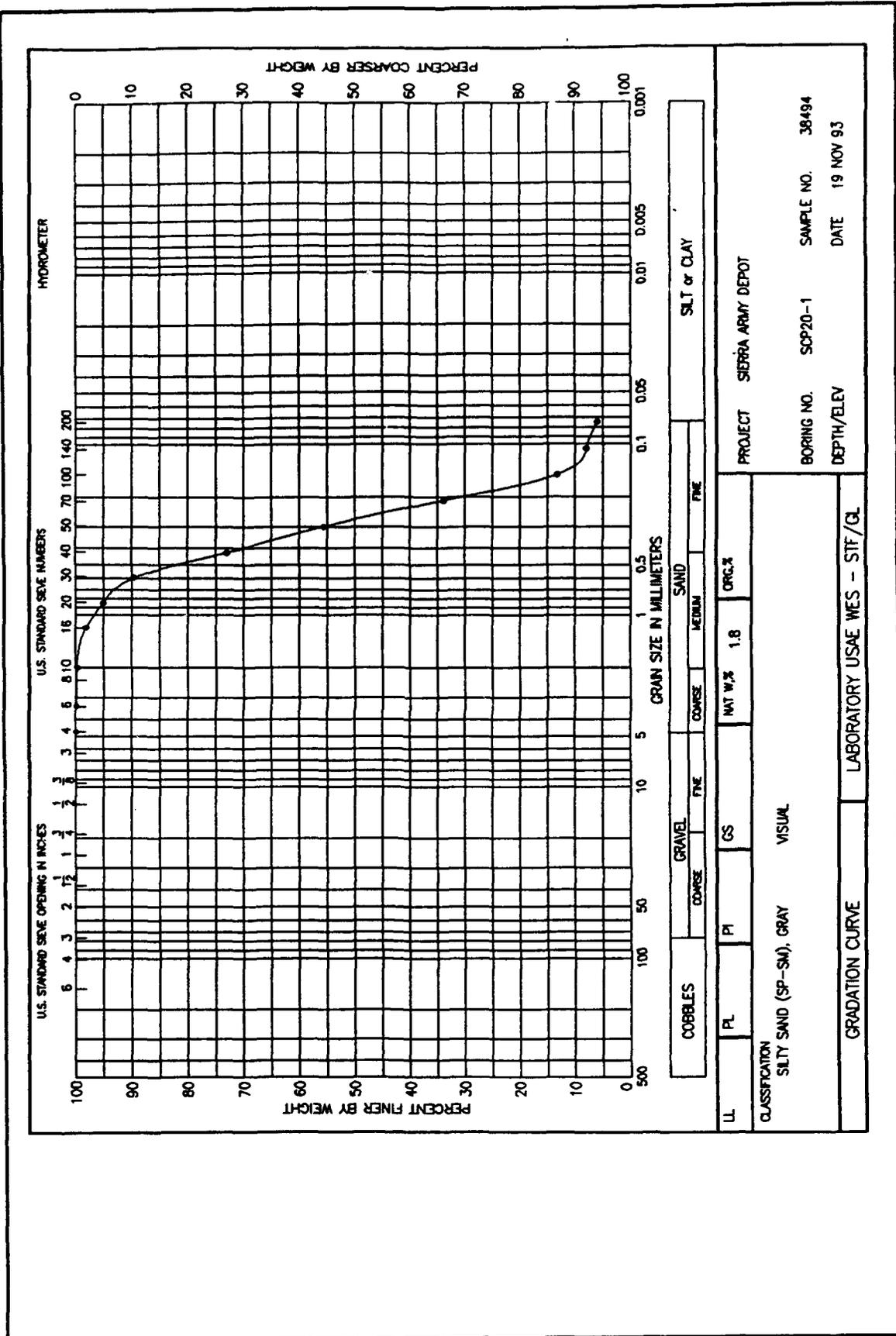
TOTAL WEIGHT OF SAMPLE: .0 gms.
 PARTIAL WEIGHT AFTER SPLIT: 51.2 gms.

WEIGHTS gm.	SIEVE SIZE or NUMBER	OPENING mm	PERCENT FINER	PERCENT COARSER
.0	No 4	4.750	100.0	.0
.1	No 6	3.350	99.8	.2
.6	No 10	2.000	98.8	1.2
2.0	No 16	1.180	96.1	3.9
3.8	No 20	.850	92.6	7.4
7.1	No 30	.600	86.1	13.9
15.1	No 40	.425	70.5	29.5
24.1	No 50	.300	52.9	47.1
34.3	No 70	.212	33.0	67.0
40.3	No 100	.150	21.3	78.7
43.0	No 140	.106	16.0	84.0
45.2	No 200	.075	11.7	88.3

PERCENT GRAVEL = .0
 PERCENT SAND = 88.3
 PERCENT FINES = 11.7

D60 = .35
 D30 = .20
 D10 = .06
 CU = 5.60
 CC = 1.75

EDE



COBBLES		GRAVEL		SAND		SILT or CLAY	
		COARSE	FINE	COARSE	MEDIUM	FINE	
LL	PL	PI	GS	MAT W.%		ORG.%	
				1.8		0.0	
CLASSIFICATION				VISUAL			
SILTY SAND (SP-SM), GRAY							
GRADATION CURVE				LABORATORY USAE WES - STI/GL			
PROJECT				SIERRA ARMY DEPOT			
BORING NO.				SCP20-1		SAMPLE NO.	
						38494	
DEPTH/ELEV				DATE			
				19 NOV 93			

SIEVE ANALYSIS

PROJECT: SIERRA ARMY DEPOT

BORING: SCP20-1 SAMPLE: 38494 DF: MD0894 .DAT
 DEPTH: DATE: 19 NOV 93

NO-LIMITS-RAN GS: .00 WC: 1.80
 CLASSIFICATION: 182
 SILTY SAND (SP-SM), GRAY VISUAL

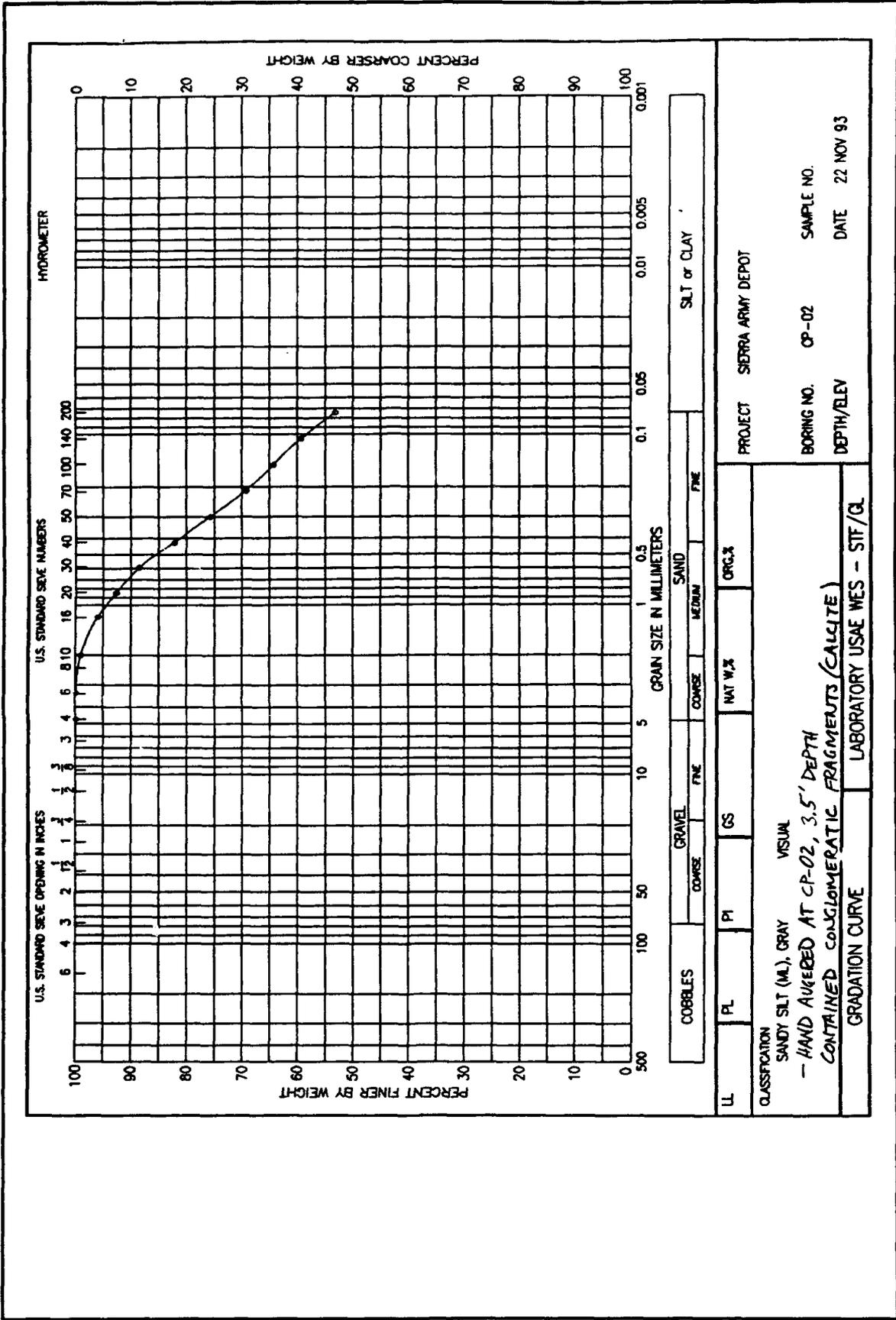
TOTAL WEIGHT OF SAMPLE: .0 gms.
 PARTIAL WEIGHT AFTER SPLIT: 54.2 gms.

WEIGHTS gm.	SIEVE SIZE or NUMBER	OPENING mm	PERCENT FINER	PERCENT COARSER
.0	No 4	4.750	100.0	.0
.0	No 6	3.350	100.0	.0
.1	No 10	2.000	99.8	.2
1.0	No 16	1.180	98.2	1.8
2.6	No 20	.850	95.2	4.8
5.6	No 30	.600	89.7	10.3
14.6	No 40	.425	73.1	26.9
24.0	No 50	.300	55.7	44.3
35.8	No 70	.212	33.9	66.1
47.0	No 100	.150	13.3	86.7
49.8	No 140	.106	8.1	91.9
50.9	No 200	.075	6.1	93.9

PERCENT GRAVEL = .0
 PERCENT SAND = 93.9
 PERCENT FINES = 6.1

D60 = .33
 D30 = .20
 D10 = .12
 CU = 2.71
 CC = .99

EDE



SIEVE ANALYSIS

PROJECT: SIERRA ARMY DEPOT

BORING: CP-02 SAMPLE: DF: MD0894A .DAT
 DEPTH: DATE: 22 NOV 93

NO-LIMITS-RAN GS: .00 WC: .00
 CLASSIFICATION: 122
 SANDY SILT (ML), GRAY VISUAL

TOTAL WEIGHT OF SAMPLE: .0 gms.
 PARTIAL WEIGHT AFTER SPLIT: 55.2 gms.

WEIGHTS gm.	SIEVE SIZE or NUMBER	OPENING mm	PERCENT FINER	PERCENT COARSER
.0	No 4	4.750	100.0	.0
.0	No 6	3.350	100.0	.0
.5	No 10	2.000	99.1	.9
2.2	No 16	1.180	96.0	4.0
4.0	No 20	.850	92.8	7.2
6.3	No 30	.600	88.6	11.4
9.8	No 40	.425	82.2	17.8
13.4	No 50	.300	75.7	24.3
16.9	No 70	.212	69.4	30.6
19.7	No 100	.150	64.3	35.7
22.4	No 140	.106	59.4	40.6
25.8	No 200	.075	53.3	46.7

PERCENT GRAVEL = .0
 PERCENT SAND = 46.7
 PERCENT FINES = 53.3

EDE

Verification Sample Information			
Sample Number	SCP-15-1	SCP-09-1	SCP-06-1
Sample Type and Date	Soil 8 Oct 93	Soil 9 Oct 93	Soil 9 Oct 93
TRPH (ppm)	<25	845.9	<25
TPH (ppm)	-	-	-
TPAH (ppm)	-	17.97	-
Sample Depth, ft	6.0-6.5	12.0-12.5	6.0-7.0
Sample Coordinates Northing and Easting	N 309196.71 E 2526384.40	N 309245.49 E 2526404.07	N 309263.36 E 2526429.10
Soil Classification	Brown, SP 7 percent W	SP	Gray SP, 1 percent W
Sample fluoresced?	No	Yes	No
Intensity (counts)	N/A	N/A	N/A
Wavelength (nm)	N/A	N/A	N/A
Sample offset from nearest probe, ft	2'SW	1'W	1'SW
Nearest probe	CP-15	CP-09	CP-06
Probe Coordinates Northing and Easting	N 309199.207 E 2526385.403	N 309246.388 E 2526405.774	N 309264.365 E 2526429.698
Probe fluoresced at Sample depth?	Yes	Yes	Yes
Intensity range	265-298	122-644	332-629
Wavelength (nm)	446-459	453-478	453-464
Probe Soil Class	Sand SCN 3	Sand SCN 3	Sand SCN 2.5
<p>TRPH = Total Recoverable Petroleum Hydrocarbons TPH = Total Petroleum Hydrocarbons TPAH = Polynuclear Aromatic Hydrocarbons TOC = Total Organic Carbon OG = Oil and Grease ppm = Parts per million SP = Poorly graded sand SM = Silty sand ML = Sandy silt W = Moisture content</p>			

Verification Sample Information			
Sample Number	SCP-14-3	SCP-17-1	SCP-17-2
Sample Type and Date	Soil 8 Oct 93	Soil 8 Oct 93	Soil 8 Oct 93
TRPH (ppm)	11445	7228	1784
TPH (ppm)	-	-	-
TPAH (ppm)	28.6	3.29	1.25
Sample Depth, ft	19.0-19.5	20.5-21.0	23.0-23.5
Sample Coordinates Northing and Easting	N 309239.25 E 2526515.41	N 309257.35 E 2526535.25	N 309257.35 E 2526535.25
Soil Classification	Tan SP	Tan SP	Brown SP
Sample fluoresced?	Yes	Yes	Yes
Intensity (counts)	N/A	N/A	N/A
Wavelength (nm)	N/A	N/A	N/A
Sample offset from nearest probe, ft	1'SW	2'S	2'S
Nearest probe	CP-14	CP-17	CP-17
Probe Coordinates Northing and Easting	N 309240.055 E 2526516.410	N 309258.357 E 2526534.252	N 309258.357 E 2526534.252
Probe fluoresced at Sample depth?	Yes	Yes	Yes
Intensity range	83-241	447-579	357-664
Wavelength (nm)	452-473	399-409	394-411
Probe Soil Class	Sand SCN 3	Sand SCN 2.5	Sand SCN 3.5
<p> TRPH = Total Recoverable Petroleum Hydrocarbons TPH = Total Petroleum Hydrocarbons TPAH = Polynuclear Aromatic Hydrocarbons TOC = Total Organic Carbon OG = Oil and Grease ppm = Parts per million SP = Poorly graded sand SM = Silty sand ML = Sandy silt W = Moisture content </p>			

Verification Sample Information			
Sample Number	SCP-02-3	SCP-02-4	SCP-17-3
Sample Type and Date	Soil 10 Oct 93	Soil 10 Oct 93	Soil 10 Oct 93
TRPH (ppm)	<25	<25	5817
TPH (ppm)	-	-	-
TPAH (ppm)	-	-	3.03
Sample Depth, ft	7.75-8.5	8.5-10.0	20.0-20.5
Sample Coordinates Northing and Easting	N 309431.45 E 2526632.01	N 309431.45 E 2526632.01	N 309257.35 E 2526536.25
Soil Classification	Gray SP, 2 percent Water	Gray SP	Gray SP
Sample fluoresced?	No	No	Yes
Intensity (counts)	N/A	N/A	N/A
Wavelength (nm)	N/A	N/A	N/A
Sample offset from nearest probe, ft	1'S	1'S	2'SE
Nearest probe	CP-02	CP-02	CP-17
Probe Coordinates Northing and Easting	N 309431.956 E 2526632.016	N 309431.956 E 2526632.016	N 309258.357 E 2526534.252
Probe fluoresced at Sample depth?	Yes	Yes	Yes
Intensity range	38-331	28-340	270-549
Wavelength (nm)	413-475	398-480	398-409
Probe Soil Class	Sand SCN 3	Sand SCN 3	Sand SCN 3.5
<p>TRPH = Total Recoverable Petroleum Hydrocarbons TPH = Total Petroleum Hydrocarbons TPAH = Polynuclear Aromatic Hydrocarbons TOC = Total Organic Carbon OG = Oil and Grease ppm = Parts per million SP = Poorly graded sand SM = Silty sand ML = Sandy silt W = Moisture content</p>			

Verification Sample Information			
Sample Number	SCP-12-1	SCP-14-1	SCP-14-2
Sample Type and Date	Soil 8 Oct 93	Soil 8 Oct 93	Soil 8 Oct 93
TRPH (ppm)	< 25	203.2	22151
TPH (ppm)	-	-	-
TPAH (ppm)	-	0	62.9
Sample Depth, ft	6.5-7.5	13.0-14.5	18.0
Sample Coordinates Northing and Easting	N 309229.47 E 2526475.23	N 309239.25 E 2526515.41	N 309239.25 E 2526515.41
Soil Classification	Brown SP-SM	Brown SP	Brown SP
Sample fluoresced?	No	Yes	Yes
Intensity (counts)	N/A	N/A	N/A
Wavelength (nm)	N/A	N/A	N/A
Sample offset from nearest probe, ft	2'W	1'SW	1'SW
Nearest probe	CP-12	CP-14	CP-14
Probe Coordinates Northing and Easting	N 309230.067 E 2526477.727	N 309240.055 E 2526516.410	N 309240.055 E 2526516.410
Probe fluoresced at Sample depth?	Yes	Yes	Yes
Intensity range	112-207	46-393	132-241
Wavelength (nm)	445-461	399-476	398-477
Probe Soil Class	Sand SCN 2.5	Sand SCN 3.5	Sand SCN 3.5
<p>TRPH = Total Recoverable Petroleum Hydrocarbons TPH = Total Petroleum Hydrocarbons TPAH = Polynuclear Aromatic Hydrocarbons TOC = Total Organic Carbon OG = Oil and Grease ppm = Parts per million SP = Poorly graded sand SM = Silty sand ML = Sandy silt W = Moisture content</p>			

Verification Sample Information			
Sample Number	SCP-01-1	SCP-02-1	SCP-02-2
Sample Type and Date	Soil 10 Oct 93	Soil 10 Oct 93	Soil 10 Oct 93
TRPH (ppm)	<25	<25	<25
TPH (ppm)	-	-	-
TPAH (ppm)	-	-	-
Sample Depth, ft	4.0-5.0	3.0-4.0	7.0-7.75
Sample Coordinates Northing and Easting	N 309437.83 E 2526504.12	N 309431.45 E 2526632.01	N 309431.45 E 2526632.01
Soil Classification	Gray SM, 9 percent W	Gray SM, 6 percent W	Gray SP, 0.2 percent W
Sample fluoresced?	No	No	No
Intensity (counts)	N/A	N/A	N/A
Wavelength (nm)	N/A	N/A	N/A
Sample offset from nearest probe, ft	1'S	1'S	1'S
Nearest probe	CP-01	CP-02	CP-02
Probe Coordinates Northing and Easting	N 309438.336 E 2526503.622	N 309431.956 E 2526632.016	N 309431.956 E 2526632.016
Probe fluoresced at Sample depth?	Yes	Yes	Yes
Intensity range	234-414	197-243	40-139
Wavelength (nm)	457-467	450-457	422-452
Probe Soil Class	Silt SCN 2	Silt SCN 2	Sand SCN 3
<p>TRPH = Total Recoverable Petroleum Hydrocarbons TPH = Total Petroleum Hydrocarbons TPAH = Polynuclear Aromatic Hydrocarbons TOC = Total Organic Carbon OG = Oil and Grease ppm = Parts per million SP = Poorly graded sand SM = Silty sand ML = Sandy silt W = Moisture content</p>			

Verification Sample Information			
Sample Number	SCP-08-2	SCP-05-1	SCP-05-2
Sample Type and Date	Soil 9 Oct 93	Soil 9 Oct 93	Soil 9 Oct 93
TRPH (ppm)	< 25	< 25	< 25
TPH (ppm)	-	-	-
TPAH (ppm)	-	-	-
Sample Depth, ft	7.5-8.0	7.5-8.0	8.5-9.0
Sample Coordinates Northing and Easting	N 309240.84 E 2526597.86	N 309361.92 E 2526573.43	N 309361.92 E 2526573.43
Soil Classification	Gray SP-SM	Gray SM-ML	Brown SM
Sample fluoresced?	No	No	No
Intensity (counts)	N/A	N/A	N/A
Wavelength (nm)	N/A	N/A	N/A
Sample offset from nearest probe, ft	1'SE	2'W	2'W
Nearest probe	CP-08	CP-05	CP-05
Probe Coordinates Northing and Easting	N 309242.344 E 2526597.862	N 309362.917 E 2526574.429	N 309362.917 E 2526574.429
Probe fluoresced at Sample depth?	Yes	Yes	Yes
Intensity range	151-305	215-343	246-495
Wavelength (nm)	447-456	453-458	453-458
Probe Soil Class	Silt SCN 3	Silty Sand SCN 2	Sand SCN 2.5
<p>TRPH = Total Recoverable Petroleum Hydrocarbons TPH = Total Petroleum Hydrocarbons TPAH = Polynuclear Aromatic Hydrocarbons TOC = Total Organic Carbon OG = Oil and Grease ppm = Parts per million SP = Poorly graded sand SM = Silty sand ML = Sandy silt W = Moisture content</p>			

Verification Sample Information			
Sample Number	SCP-20-1	SCP-19-1	SCP-08-1
Sample Type and Date	Soil 9 Oct 93	Soil 9 Oct 93	Soil 9 Oct 93
TRPH (ppm)	< 25	< 25	< 25
TPH (ppm)	-	-	-
TPAH (ppm)	-	-	-
Sample Depth, ft	7.0-7.5	3.5-4.5	2.5-3.0
Sample Coordinates Northing and Easting	N 309214.99 E 2526529.77	N 309242.06 E 2526544.26	N 309240.84 E 2526597.86
Soil Classification	Gray SP, 2 percent W	Tan SP	Brown SM, 12 percent W
Sample fluoresced?	No	No	No
Intensity (counts)	N/A	N/A	N/A
Wavelength (nm)	N/A	N/A	N/A
Sample offset from nearest probe, ft	1'W	0.6'N	1'SE
Nearest probe	CP-20	CP-19	CP-08
Probe Coordinates Northing and Easting	N 309216.495 E 2526530.272	N 309241.555 E 2526544.756	N 309242.344 E 2526597.862
Probe fluoresced at Sample depth?	Yes	Yes	Yes
Intensity range	95-171	99-209	258-338
Wavelength (nm)	451-485	457-488	452-455
Probe Soil Class	Sand SCN 3	Sand SCN 3	Sand SCN 3
<p> TRPH = Total Recoverable Petroleum Hydrocarbons TPH = Total Petroleum Hydrocarbons TPAH = Polynuclear Aromatic Hydrocarbons TOC = Total Organic Carbon OG = Oil and Grease ppm = Parts per million SP = Poorly graded sand SM = Silty sand ML = Sandy silt W = Moisture content </p>			

Verification Sample Information			
Sample Number	SCP-17-4		
Sample Type and Date	Soil 10 Oct 93		
TRPH (ppm)	1847		
TPH (ppm)	-		
TPAH (ppm)	0.14		
Sample Depth, ft	21.0-21.5		
Sample Coordinates Northing and Easting	N 309257.35 E 2526536.25	N E	N E
Soil Classification	Tan SP		
Sample fluoresced?	Yes		
Intensity (counts)	N/A		
Wavelength (nm)	N/A		
Sample offset from nearest probe, ft	2'SE		
Nearest probe	CP-17		
Probe Coordinates Northing and Easting	N 309258.357 E 2526534.252	N E	N E
Probe fluoresced at Sample depth?	Yes		
Intensity range	153-494		
Wavelength (nm)	399-483		
Probe Soil Class	Sand SCN 3		
<p> TRPH = Total Recoverable Petroleum Hydrocarbons TPH = Total Petroleum Hydrocarbons TPAH = Polynuclear Aromatic Hydrocarbons TOC = Total Organic Carbon OG = Oil and Grease ppm = Parts per million SP = Poorly graded sand SM = Silty sand ML = Sandy silt W = Moisture content </p>			

Verification Sample Information			
Sample Number	DSA-01-SC	DSA-02-SC	DSA-03-SC
Sample Type and Date	Soil 11 Oct 93	Soil 12 Oct 93	Soil 12 Oct 93
TRPH (ppm)	-	-	-
TPH (ppm)	<21.0	<21.0	<21.0
TPAH (ppm)	-	-	-
Sample Depth, ft	61.5-62.0	63.0-63.5	61.0-61.5
Sample Coordinates Northing and Easting	N 309262.94 E 2526542.29	N 309257.35 E 2526538.75	N 309240.55 E 2526517.41
Soil Classification	Moist Brown CL	Moist coarse sand	Moist coarse sand
Sample fluoresced?	No	No	No
Intensity (counts)	N/A	N/A	N/A
Wavelength (nm)	N/A	N/A	N/A
Sample offset from nearest probe, ft	2'SE	4'W	3'S
Nearest probe	CP-16	CP-17	CP-14
Probe Coordinates Northing and Easting	N 309264.439 E 2526538.793	N 309258.357 E 2526534.252	N 309240.055 E 2526516.410
Probe fluoresced at Sample depth?	Not reached	Not reached	Not reached
Intensity range	N/A	N/A	N/A
Wavelength (nm)	N/A	N/A	N/A
Probe Soil Class	N/A	N/A	N/A
<p>TRPH = Total Recoverable Petroleum Hydrocarbons TPH = Total Petroleum Hydrocarbons TPAH = Polynuclear Aromatic Hydrocarbons TOC = Total Organic Carbon OG = Oil and Grease ppm = Parts per million SP = Poorly graded sand SM = Silty sand ML = Sandy silt W = Moisture content</p>			

Verification Sample Information			
Sample Number	DSA-04-SC	DSA-05-SC	HP-1
Sample Type and Date	Soil 13 Oct 93	Soil 13 Oct 93	Water 11 Oct 93
TRPH (ppm)	-	-	N/A
TPH (ppm)	<21.0	<21.0	N/A
TPAH (ppm)	-	-	N/A
Sample Depth, ft	61.0-61.5	61.0-61.5	70.0-71.0
Sample Coordinates Northing and Easting	N 309233.23 E 2526501.22	N 309240.55 E 2526545.75	N 309262.94 E 2526542.29
Soil Classification	Wet coarse sand	Moist coarse sand	N/A
Sample fluoresced?	No	No	N/A
Intensity (counts)	N/A	N/A	N/A
Wavelength (nm)	N/A	N/A	N/A
Sample offset from nearest probe, ft	1'E	1'S	2'SE
Nearest probe	CP-13	CP-19	CP-16
Probe Coordinates Northing and Easting	N 309233.231 E 2526498.223	N 309241.555 E 2526544.756	N 309264.439 E 2526538.793
Probe fluoresced at Sample depth?	Not reached	Not reached	Not reached
Intensity range	N/A	N/A	N/A
Wavelength (nm)	N/A	N/A	N/A
Probe Soil Class	N/A	N/A	N/A
<p>TRPH = Total Recoverable Petroleum Hydrocarbons TPH = Total Petroleum Hydrocarbons TPAH = Polynuclear Aromatic Hydrocarbons TOC = Total Organic Carbon OG = Oil and Grease ppm = Parts per million SP = Poorly graded sand SM = Silty sand ML = Sandy silt W = Moisture content</p>			

PAGE 1

Environmental Science & Engineering DATE 11/10/93 STATUS :
 PROJECT NUMBER 79308610 0201 PROJECT NAME H-W SIERRA
 FIELD GROUP HUSAS1 PROJECT MANAGER K.L. HANFIELD
 ALL LAB COORDINATOR KAREM HATFIELD

SAMPLE ID'S PARAMETERS	UNITS	DSA-01-SC HUSAS1	DSA-02-SC HUSAS1	DSA-03-SC HUSAS1	DSA-04-SC HUSAS1	DSA-05-SC HUSAS1
DATE		10/11/93	10/12/93	10/13/93	10/13/93	10/13/93
TIME		14:05	11:45	15:45	09:00	11:00
TPH, AS GAS	UG/G	96020	<21.0	<21.0	<21.0	<21.0
TPH, AS DIESEL	UG/G	F1	<21.0	<21.0	<21.0	<21.0
		F1				

Environmental Science & Engineering DATE 11/09/93 STATUS : PAGE 1
 PROJECT NUMBER 79348540 0201 PROJECT NAME H-W SIERRA
 FIELD GROUP MVSASI PROJECT MANAGER K.L. WHITFIELD
 ALL LAD COORDINATOR KAREN HATFIELD

SAMPLE ID'S PARAMETERS	UNITS	DATE TIME	TPH, AS GAS	TPH, AS DIESEL LB/0	STORRT METHOD	BU1-33-SS MVSASI	BU1-34-SS MVSASI	BU1-35 MVSASI	BU1-36 MVSASI	BU1-37 MVSASI	BU1-38 MVSASI	BU1-39 MVSASI	BU1-40 MVSASI	BU1-41 MVSASI	BU1-42 MVSASI	BU1-43 MVSASI	BU1-44 MVSASI	BU1-45 MVSASI	BU1-46 MVSASI	BU1-47 MVSASI	BU1-48 MVSASI	BU1-49 MVSASI	BU1-50 MVSASI	BU1-51 MVSASI	BU1-52 MVSASI	BU1-53 MVSASI	BU1-54 MVSASI	BU1-55 MVSASI	BU1-56 MVSASI	BU1-57 MVSASI	BU1-58 MVSASI	BU1-59 MVSASI	BU1-60 MVSASI	BU1-61 MVSASI	BU1-62 MVSASI	BU1-63 MVSASI	BU1-64 MVSASI	BU1-65 MVSASI	BU1-66 MVSASI	BU1-67 MVSASI	BU1-68 MVSASI	BU1-69 MVSASI	BU1-70 MVSASI	BU1-71 MVSASI	BU1-72 MVSASI	BU1-73 MVSASI	BU1-74 MVSASI	BU1-75 MVSASI	BU1-76 MVSASI	BU1-77 MVSASI	BU1-78 MVSASI	BU1-79 MVSASI	BU1-80 MVSASI	BU1-81 MVSASI	BU1-82 MVSASI	BU1-83 MVSASI	BU1-84 MVSASI	BU1-85 MVSASI	BU1-86 MVSASI	BU1-87 MVSASI	BU1-88 MVSASI	BU1-89 MVSASI	BU1-90 MVSASI	BU1-91 MVSASI	BU1-92 MVSASI	BU1-93 MVSASI	BU1-94 MVSASI	BU1-95 MVSASI	BU1-96 MVSASI	BU1-97 MVSASI	BU1-98 MVSASI	BU1-99 MVSASI	BU1-100 MVSASI																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			
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TOTAL P.04

REPORT DOCUMENTATION PAGE

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6. AUTHOR(S) Landris T. Lee, Jr., William M. Davis, Ricky A. Goodson, Jeff F. Powell, and Bryan A. Register	
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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army Engineer Waterways Experiment Station Geotechnical Laboratory, Environmental Laboratory Instrumentation Services Division 3909 Halls Ferry Road, Vicksburg, MS 39180-6199	8. PERFORMING ORGANIZATION REPORT NUMBER Technical Report GL-94-4
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11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.	12b. DISTRIBUTION CODE
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13. ABSTRACT (Maximum 200 words)

The WES Site Characterization and Analysis Penetrometer System (SCAPS) investigated a diesel spill site at the Sierra Army Depot near Herlong, California. The truck-mounted laser-induced fluorometer packaged with the conventional cone penetrometer was utilized for this mission. Soil and groundwater verification sampling for onsite and laboratory analyses was also conducted. Extensive comparisons of verification sampling data were performed, and POL contamination was detected in some of those samples and in situ.

14. SUBJECT TERMS Cone penetrometer Soil stratigraphy Laser-induced fluorometer Verification sampling POL contamination	15. NUMBER OF PAGES 165
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT UNCLASSIFIED	18. SECURITY CLASSIFICATION OF THIS PAGE UNCLASSIFIED	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
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