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Vol IV of V

Part 2 of 2



**AIR FORCE SITE CHARACTERIZATION AND ANALYSIS PENETROMETER SYSTEM (AFSCAPS): LASER-INDUCED FLUORESCENCE CONE PENETROMETER - CPT PROFILES, BORING LOGS AND DT&E PLANS  
(VOL IV OF V - PART 2 OF 2)**

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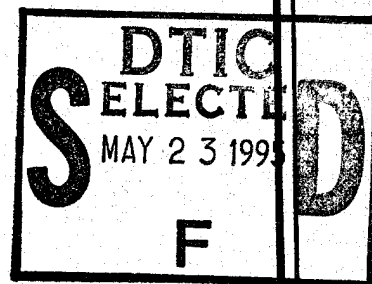
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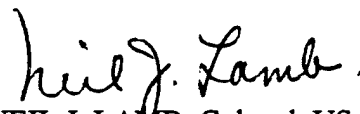
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| 19. ABSTRACT (Continue on reverse if necessary and identify by block number)<br>A prototype Laser-Induced Fluorescence-Electric Cone Penetrometer Test (LIF-CPT) system was demonstrated at Tinker Air Force Base (Tinker AFB), Oklahoma as an innovative technology for delineating soil contamination resulting from fuel spills. Applied Research Associates, Inc. (ARA) and the North Dakota State University (NDSU) conducted the development program for the Air Force using LIF-CPT components developed within the Triservice Site Characterization and Analysis Penetrometer System (SCAPS) effort. Major components of the system consisted of ARA's cone penetrometer system coupled with NDSU's tunable laser fluorimeter. To enable rapid, efficient and minimally invasive site characterization, the LIF-CPT probe data output was linked to ARA's real-time analysis system with three-dimensional modeling and scientific visualization capabilities. Field testing at Tinker AFB was conducted to evaluate the LIF-CPT probe. During the testing program, 112 soundings at eight contaminated sites were conducted. At select locations, soil and water samples were obtained with CPT or drilling technologies, and tested using analytical procedures to confirm the presence of fuel contamination.<br><br>This volume presents the LIF-CPT profiles that were generated along with boring logs from the drilling program, gas chromatograph results from the field analytical testing, and the work plans for the demonstration program. |       |                                                |                                                                                                      |                                                        |                            |
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## APPENDIX K

### LABORATORY VALIDATION TEST PLAN

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**LABORATORY VALIDATION TEST PLAN**  
**AIR FORCE SITE CHARACTERIZATION AND ANALYSIS**  
**PENETROMETER SYSTEM (AFSCAPS)**  
**PROTOTYPE ACQUISITION AND FIELD DEMONSTRATION/VALIDATION OF**  
**AFSCAPS**  
**FOR FUEL-CONTAMINATED SITE CHARACTERIZATION**

**Applied Research Associates, Inc.**  
**Project Number 5735**

**June 30, 1992**

**Revised July 31, 1992**

## 1.0 INTRODUCTION

This test plan outlines the objectives and procedures of Task 4 of the AFSCAPS project: laboratory studies to validate the prototype laser-induced fluorescence (LIF) spectrometer and electronic cone penetrometer testing (CPT) system. As part of the AFSCAPS project, the LIF-ECPT system is to be developed, validated and field-evaluated as a real-time, in situ environmental screening device for detecting petroleum, oil, and lubricant (POL) contamination in subsurface soils. The main objective of the laboratory testing is to optimize the quality, quantity and usefulness of LIF data collected during the field demonstration program at Tinker Air Force Base (AFB). This requires a series of validation tests to evaluate the instrument accuracy, response, specificity, and detection limits of the LIF-ECPT probe.

The laboratory validation tests, described herein, will be carried out jointly by Applied Research Associates, New England Division (ARA) and the North Dakota State University (NDSU) group lead by Dr. Gillispie and Mr. St. Germain. The laboratory experimental setup consists of a "dummy probe" with sapphire optical windows and a fiber optic probe connection to a laser spectrometer system. NDSU will use existing fiber optic spectroscopy equipment to measure spectral data for "fresh" jet fuel (JP-4 and JP-5) and fuel oil No. 2, released at the North Tank Area of Tinker AFB, in air-water-soil mixtures. ARA will construct the soil mold to be used as the "dummy probe" and measure relevant physical properties of the "clean" Tinker AFB soil obtained from shallow excavations at the North Tank Area (NTA).

NDSU will use a wavelength tunable pulsed laser spectrometer system to measure LIF of the soil mold samples. Various aromatic hydrocarbons commonly associated with fuels, such as BTEX compounds (Benzene, Toluene, Ethylbenzene, and Total Xylene) and polycyclic aromatic hydrocarbon (PAH) compounds (e.g., naphthalene, anthracene, phenanthrene), are detected using excitation wavelengths in the near ultraviolet (250-350 nm) range. BTEX compounds tend to have maximum fluorescence intensity for excitation wavelengths near 266 nm, producing emission maxima near 290 nm. PAHs fluoresce over a broader range of UV excitation wavelengths and generally have a higher fluorescent response than the BTEX. Naphthalene has maximum emission intensity at 335 nm produced with an 280 nm excitation wavelength. Preliminary examination of JP-4 and JP-5 samples reveals that the naphthalene fluorescence dominates the BTEX fluorescence.

Speciation of these aromatic compounds is possible by characterizing fluorescent signature of the analytes from the excitation spectra, emission spectra and lifetime profiles. Wavelength time matrices (WTM) consisting of fluorescence time decay profiles for a series of emission wavelengths have been used by NDSU to obtain multi-dimensional LIF datasets (e.g., Gillispie and Germain, 1992). Advanced processing of the WTM data potentially enables the analyst to specify the types and concentrations of various aromatic hydrocarbons.

## 2.0 BACKGROUND

Prior LIF studies for environmental analysis have mainly dealt with aqueous media (e.g., Gillispie and St. Germain, 1992). However, the WES and NOSC group (Apitz, Theriault, and Lieberman, 1992) have shown that LIF results of soils are dependent on a larger set of variables compared to LIF measurements of aqueous solutions.

For the simplest case (i.e., aqueous solutions), LIF intensity,  $I$ , can be related to analyte concentration (single compound, e.g., benzene) in aqueous solution,  $C$ , according to the following formula:

$$I = \alpha C + \beta$$

where  $\alpha$  is related to the sensitivity of the measurement to the concentration and  $\beta$  corresponds to the background noise. Ideally, a plot of the intensity versus concentration yields a straight line. The detection limit is determined by the data scatter and background noise level.

Environmental uncertainties for ground water measurements arise if unknown fluorescent compounds exist in the solution or if the water has turbidity which decreases the effective excitation energy due to scattering (producing a lower measured intensity). Corrections for these effects may be made, depending on the development of LIF signal processing and analysis techniques or synergistic technologies.

For soil media, uncertainties in fluorescent response are more complex. Generally, the sensitivity appears to be dependent on soil type (e.g., surface area, grain size, mineralogy, and degree of soil aggregation), porosity, moisture content, saturation level and LIF response of natural fluorophores (e.g., humic acid). The presence of solids increases the amount of backscattering and decreases the effective penetration depth of the excitation energy. For a given fiber optic spectrometer system, the effective signal attenuation, due to back scattering, is up to 3 orders of magnitude higher for soil versus aqueous media.

Additionally, LIF-ECPT systems involve attenuation due to UV transmission losses within the fiber optic train. Cone penetrometer systems introduce sharp bends as the fiber optic cable is threaded through 1-m push rods. These small bending radii, in addition to a long cable length, can increase the signal attenuation (Boechat et. al., 1991).

This laboratory test plan serves to lay the foundation for calibration routines and detection limits for LIF-ECPT investigations. Although the NOSC group (Apitz et. al., 1992) performed numerous laboratory experiments to assess the dependence of LIF signal on contaminant concentration, grain size and specific surface area, some critical geotechnical factors, applicable to cone penetrometer testing, were not considered, i.e. saturation and porosity changes induced by cone penetration. The NOSC group also found low LIF response for clay soils which suggests that soil LIF measurements may not be able to resolve low concentrations of POL for soils with greater than a few percent clay.

Effects of degree of saturation and porosity will be examined within this test matrix as these parameters are expected to have a measurable influence on LIF-ECPT readings. Since there appears to be a strong dependence on soil type, this test matrix will focus on the subject soils at Tinker AFB. The effects of clay present in NTA soils (approximately 50 percent) on LIF response can readily be compared to the NOSC results for clays. Variability in LIF intensity for three different contaminant types will also be examined. The tunable nature of NDSU's laser spectrometer system, compared to the NOSC study, allows for optimization of LIF intensity for particular contaminant types. The experimental setup and procedures are developed to address these concerns.

### 3.0 SOIL CHARACTERIZATION

#### 3.1 Background Data

NTA soils will be characterized for mineralogic composition and physical properties. Four 5-gallon buckets of NTA soil were collected in late May, 1992. The soil was taken from stockpiles of soil excavated from above the 50-foot diameter underground fuel oil storage tank. Consequently, it has been reworked with some possible addition of fill. However, visual inspection of the soil by Tinker AFB environmental specialists and ARA personnel confirms that the samples are representative of native fine-grained (sandy clay to clayey sand) soils found throughout Tinker AFB.

Review of environmental studies performed at Tinker AFB provides some background data on the weathered sandy clay to clayey sand sampled at the NTA. Geologic maps indicate that native surficial soils are derived from the Hennessey Group, a Permian-age deep-red clay shale with thin beds of fine-grained sandstone. The unsaturated soils appear to have an average moisture content of 15 percent. This moisture content probably corresponds closely with the specific moisture retention for the soil. Penetration resistance as N values (blows/ft) are available from shallow borings in silt-clays located 200 m south of the fuel purge area (Waste Pit #1). From 0 to 5 feet below ground surface, the N values increase from 7 to 25, indicating clays of medium to very stiff consistency with an unconfined compressive strength of 1.0 to 3.0 tons/ft<sup>2</sup>. High N values (> 30) are typically encountered at soil depths greater than 5 to 10 feet throughout Tinker AFB. From CPT demonstrations at the IWTP site (Fall, 1991), average tip stresses increase from 500 to 1,500-3,000 psi during the first 5 feet of penetration, indicating the influence of sandstone or sand-rich weathered shale at depth.

#### 3.2 Geotechnical Laboratory Testing

Geotechnical laboratory tests, using appropriate ASTM methods, are to be performed by ARA. These tests include grain size distribution using sieve and hydrometer analyses, Atterberg limits, soil grain specific gravity, and water content. The grain size distribution and Atterberg limits will be used for soil classification purposes. The grain size curve will also be integrated

to yield an approximate specific surface area for the soil. Specific gravity will be used with water content to accurately estimate the porosity. Additionally, percent saturation and bulk density of soil samples in the calibration chamber may be calculated based on the grain and water density and the soil volume.

A phase-relationship spreadsheet has been developed to calculate the soil moisture and percent saturation for different compaction states in the uniaxial chamber. A sample output from the phase-relationship spreadsheet is provided in Attachment 1. Relevant formula for determination of these relationships is attached (Attachment 2; from Lambe and Whitman, 1969). A specific density of 2.68 has been measured for NTA soils and is incorporated in the spreadsheet.

Compositional analyses of the sand, silt, and clay fractions will be performed by the Solids Testing Lab at NDSU. The mineralogy will be obtained using standard X-ray diffraction methods. Loss on ignition for total organic content will be performed as well.

#### 4.0 EXPERIMENTAL SETUP

A soil calibration chamber or "dummy probe" was designed to allow simulation of possible LIF-ECPT probe and soil interface conditions. The chamber consists of a steel cylinder with steel pistons inserted at both ends. The lower piston has 3 sapphire windows and is stationary relative to the cylindrical sleeve. The upper piston compresses the soil in a uniaxial manner by screwing down on bolts connecting both the upper and lower piston base plates. The screw assembly is capable of transmitting uniaxial stresses of 2,000 psi. Both pistons have ports to allow interstitial fluid to pass to and from the soil chamber, with the lower port being sealed for this experiment. Filter paper is to be placed over the grooved piston head surfaces to prevent soil from entering the ports. Both pistons have O-ring seals to the cylinder.

The mold has a 5.08-cm (2-inch) diameter and 20.27 cm<sup>2</sup> (3.15 in<sup>2</sup>) cross-sectional area. The lower piston has height of 2.35 cm (0.93 inches) above the base plate and the upper piston has a 2.10-cm (0.83-inch) height. Short and long versions of the cylindrical sleeve are available, with lengths of 6.04 and 8.59 cm (2.38 and 3.38 inches), respectively. The short cylinder allows a sample height range of 3.69 to 0.60 (1.45 to 0.63 inches), corresponding to a volume range of 74.85 cm<sup>3</sup> to 32.39 cm<sup>3</sup> (4.58 in<sup>3</sup> to 1.98 in<sup>3</sup>). The short cylinder is to be used in this test program. The maximum volume for each sleeve is reduced by about 16 cm<sup>3</sup> (1 in<sup>3</sup>) to allow the upper piston O-ring to seal against the cylinder.

Soil about the probe is deformed during penetration owing to compressional and shear forces generated at the cone tip. Cone penetration creates a reduction in porosity equivalent to volumetric strains of 10 percent or greater (Gupta, 1989). This deformation also momentarily generates excessive pore pressures in the adjacent soil, with a decay rate dependent on the maximum pore pressure anomaly, volumetric strain, and hydraulic conductivity.

Compressive deformation of soil in the calibration chamber is achieved by decreasing the sample volume by screwing down the upper piston. Maximum axial strains of 57 percent and 33 percent are possible with the short and long cylinders, respectively. Soil density, porosity, and saturation levels are varied, akin to actual soil conditions near the cone penetrometer.

Sapphire windows for the calibration chamber are 0.08-inch thick and have a 3/8-inch diameter. Each window is mounted within a 3/8-inch diameter inset above a 1/4-inch diameter port in the lower piston unit. The hydrostatic burst pressure for the window is 2,700 psi, but the presence of the 1/16-inch lip and the decrease in effective surface area should double that limit (see manufacturer's data charts). The uniaxial chamber allows soils to be pressed against the window with pressures similar to CPT push conditions.

Prior to emplacement in the mold, soil will be mixed with water and contaminant by mechanical mixing and tumbling. A tumbler has been designed to rotate eight (8) 250-ml wide-mouth jars at a time, and is similar in design to those used in extraction procedures for TCLP tests. A rate of 20 revolutions per minute is used with the tumbler.

A modification of NDSU's fiber optic ground water probe is to be used for measurement of fluorescent response of soils through the sapphire windows. The probe consists of a delivery fiber surrounded by 6 collection fibers. Each fiber has a silica core diameter of 0.6 mm with a plastic cladding and buffer jacket making the total fiber diameter 0.8 mm. Alternative types optical fiber may be used depending on further analysis of the optical fiber specifications and requirements for the CPT. The cable length used for experimentation will be on the order of 20 meters, similar to the LIF-ECPT cable design length.

The laser spectrometer system, described in detail elsewhere (Gillispie and St. Germain, 1992), is a pulsed Nd:YAG laser which pumps a tunable dye laser and delivers single-wavelength UV/visible excitation energy. A photomultiplier tube and digital oscilloscope are used to characterize the UV fluorescence emission spectra and fluorescence lifetime decays.

## 5.0 SOIL SAMPLE PREPARATION

In order to measure LIF response of contaminated soils in the laboratory, batch samples of soil, water, and fuel are to be prepared. Individual soil samples will be spiked with known weight fractions of water and fuel. Sample preparation which minimizes the loss of volatile organic compounds (VOCs) during the sample preparation but also allows a homogeneous distribution of analyte throughout the soil and reproducibility in LIF results will be used. The mixing process will cause volatilization of BTEX, thereby reducing the percent recovered during chemical testing. Since LIF is nondestructive, repeated LIF measurements of progressively disturbed samples will quantify any errors due to sample recovery, or at least characterize the time required for stabilization of results (see following section).

Due to the high clay content (50 percent), NTA soils tend to bind to various degrees

during sample preparation. For example, the NTA soil forms sand to gravel size aggregates after oven-drying. Additionally, the moist clayey soil forms spherical aggregates during tumbling. This aggregation effects the distribution of water and analyte within the sample, as the center of the aggregate tends to be relatively unaffected by moisture and analyte, if additional mixing methods are not used. The heterogeneous distribution of fuel contaminant can be readily verified by illuminating the spiked sample with a hand-held long-wavelength UV light. The following procedure minimizes formation of aggregates and is to be used for all soil samples except as noted in the testing procedure:

- 1) Oven-dry the NTA soils at a temperature of 105 °C for 12 hours or until constant weight. Drying in a shallow pan and occasionally mixing will decrease the drying time. Approximately 1 kilogram of natural NTA soil is an adequate quantity for 8 batch samples.
- 2) Gently crush the dried soil sample with a rubber-tipped pestle and bowl. This step reduces the size of the clay-aggregates caused by the desiccation.
- 3) Obtain a minus-#40 mesh sieve sample (grain diameter < 0.025 inch). The sieving ensures that the test sample will not contain any appreciably large clay aggregates (< one-tenth of sapphire window diameter). A small percentage of coarse sand and gravel (10 percent total) will be removed as a result of the sieving.
- 4) Each batch sample consists of 80 g of oven-dried sample. Apply water to the soil sample as required to achieve the desired water content (% dry weight, see Attachments 1 and 2). Place each soil batch sample in a clean 250-ml wide-mouth jar, and label each jar as necessary. The water-soil mixture is gently mixed and allowed to cure for 8 hours to allow the clay to re-adsorb moisture.
- 5) Add analyte (jet fuel, etc.) to obtain the desired weight fraction of contaminant (% total dry soil weight) and gently mix for 1 minute. Label jars as necessary.
- 6) Tumble the soil-water-contaminant mixture for 1 hour. Gently crush aggregate within the test jar using a small spatula for approximately 1 minute. Minimize the exposure of the soil to the atmosphere. Tumble the soils for 1 hour longer and repeat mixing procedure with the spatula. Store the jars in a cool location and note time of storage until testing. Note any lack of absorbance of water or analyte to the soil due to saturation.
- 7) Prepare the soil mold by placing filter paper over the upper and lower piston surfaces, with paper cut out above the window. Recalculate the initial soil water content if free water or analyte is not absorbed by the soil. Place the soil in the mold (short cylinder) and compress the soil column to 2.95 cm (1.16 inch) where the porosity equals 50 percent. This is the initial condition for variable density tests. Attachment 1 illustrates that for a 15 percent water content, the sample height must decrease from 2.95 to 2.06

cm to reach the saturation limit. The saturation limit is dependent on the porosity and moisture content (see Attachment 2). The sample height is determined by subtracting 4.45 cm (1.750 inches) from the distance between the upper piston base and the lower piston base.

- 8) Perform LIF measurements at each of the three windows for each density state, thereby providing three independent measurements for each batch sample at a particular moisture-density state.
- 9) To increase the density and saturation level, screw the upper piston down by turning each bolt (@13 threads/inch) approximately 1/3 of a revolution in a sequential manner until the desired height is reached. Sample heights are based on porosity, with 10 percent porosity changes normally used in the variable density tests. If the LIF readings are sensitive to density or saturation levels, 5 percent porosity increments may be used.
- 10) When saturation is achieved, monitor the effects of pore pressure on LIF. A valve and pore pressure gauge extension is attached to the pore pressure port located on the upper piston. Water is added to the chamber until remaining air in the port is displaced. Subsequent pore pressure increases corresponding to cone penetrometer situations can be simulated by closing the pore pressure valve and screwing down the upper piston to pore pressures in excess of 50 psi. Perform LIF measurements during this high pore pressure state. Open the valve to relieve the elevated pressure and allow expulsion of pore water. Compare the high pore pressure LIF reading with a second reading at normal pore pressure. With the valve open, compress the sample to the next density state and repeat the pore pressure cycling.
- 11) Decontaminate all laboratory equipment (bottles, bowls, spatulas, choppers, soil chamber, sapphire window surface, etc.) before reuse. A methanol wash, rinse with steaming water, a mild detergent bath and final rinse with distilled water is recommended to clean all wet laboratory equipment used for the LIF.

## 6.0 EXPERIMENTAL PROCEDURE

### 6.1 Series A: LIF Response to POL Aqueous Solutions

Measure pure product, saturated and aqueous solutions of JP-4, JP-5 and NTA fuel oil in a container equipped with a sapphire window. LIF measurements of aqueous solutions saturated with each analyte (JP-4, JP-5, and NTA fuel oil) will be analyzed using the WTM approach. An adequate technique for establishing the solubility of the fuel in water will be developed. Examination of pure product will assess the capability of detecting floating product in the subsurface. These tests will also address the difference in soil versus solution testing using LIF with a sapphire window.

The optimal excitation wavelength(s) will be established via an emission-excitation multi-dimensional analysis. Initial testing of JP-4 indicates that light PAHs have a maximum fluorescent intensity which is about 10 times greater than the BTEX portion of the emission spectra. The merits of optimizing the BTEX intensity versus the PAH intensity will be addressed.

Comparison of BTEX and PAH concentrations to the fluorescent signal will be evaluated via High Performance Liquid Chromatography (HPLC). A chart showing concentrations of fluorescent BTEX and PAH compounds in JP-4, JP-5 and fuel oil will be produced. These will be correlated to LIF spectral and lifetime information in a qualitative manner only, due to the limited time available for the laboratory testing.

A calibration method for the LIF-ECPT probe will be developed using the soil laboratory testing results. A simulant with a similar fluorescent response to jet fuel will be sought as an alternative to using actual fuels as the calibrant. NDSU has determined p-terphenyl is a fluorophore which meets this criteria. The P-Terphenyl will be contained in a cuvette glass cell and placed in direct contact with the sapphire window. The required p-terphenyl concentration to match the intensity level of each fuel (using the same excitation energy) will be noted. Free solution of P-Terphenyl will also be used in the soil mold to simulate conditions to be used in the local field testing experiment (Section 7.0). The table below summarizes the test matrix for series A. An alternative hydrocarbon mixture may be chosen and tested as the calibrant.

SERIES A: LIF CALIBRATION OF ANALYTE IN SOLUTION

| Analyte                         | Pure Compound      | Concentration                        |                                     |                                   |                                  |                                 |
|---------------------------------|--------------------|--------------------------------------|-------------------------------------|-----------------------------------|----------------------------------|---------------------------------|
|                                 |                    | mg/l                                 |                                     |                                   |                                  |                                 |
| A1: Water                       | N/A                |                                      |                                     |                                   |                                  |                                 |
| A2: JP-4                        | yes                | 10,000                               | 1,000                               | 100                               | 10                               | 1                               |
| A3: JP-5                        | yes                | 10,000                               | 1,000                               | 100                               | 10                               | 1                               |
| A4: NTA Fuel Oil                | yes                | 10,000                               | 1,000                               | 100                               | 10                               | 1                               |
| A5: P-Terphenyl (free solution) | match to each fuel | 10,000 mg/l equivalent for each fuel | 1,000 mg/l equivalent for each fuel | 100 mg/l equivalent for each fuel | 10 mg/l equivalent for each fuel | 1 mg/l equivalent for each fuel |
| A6: P-Terphenyl (in cuvette)    | "                  | "                                    | "                                   | "                                 | "                                | "                               |

The effects of moisture levels and density on LIF will be evaluated as part of the final calibration procedure. If bending loss is significant, then additional corrections will be assessed as well.

## 6.2 Series B: Instrumental Error Evaluation

Assess the pertinent instrumental uncertainties due to the fiber optic train. The following parameters will be systematically evaluated: bending effect of single and multiple bends, length of fiber, distance of fiber tip end to the window, loss of 1 to 5 of the 6 collection fibers, and angle of delivery at the window relative to the normal. Use calibrant from Series A for the evaluation. Additionally, the variability across the window will be assessed for the NTA soil.

Two long-term bend classes are anticipated for the LIF-ECPT probe. A 1.0-inch radius will occur in the cone mandrel when the fiber turns to meet the sapphire window. Additional 6- to 12-inch bends will occur for cable looped through the 1-meter rod sections as they are stacked in the CPT vehicle. The effects of these bends on the fiber durability and transmission are to be quantified. Also, as the rods are inserted into the ground the fiber optic cable is straightened out. If the number of bends influences the signal, this would require change in the LIF calibration factor during the push. The following test matrix for bending is presented below:

SERIES B: INSTRUMENTATION ERROR (ATTENUATION DUE TO BENDING)

| Parameter       | Test Description                                                                                         | Analyte                   |
|-----------------|----------------------------------------------------------------------------------------------------------|---------------------------|
| 90 degree bend  | Bend 7-fiber cable through a 1-inch bend radius                                                          | 100 mg/l solution of JP-4 |
| 180 degree bend | Bend 20-m, 7-fiber cable with 20 bends with 6-inch radius. Measure difference to when cable is straight. | 100 mg/l solution of JP-4 |

The net attenuation intensity of UV light launched through the sapphire window will be assessed for both the laboratory setup and the expected LIF-ECPT system setup.

The effect of distance between the fiber optic cable tip and the sapphire window will be assessed by noting the change in LIF readings with increasing distance from the window. The values will be normalized to readings obtained with the probe tip flush with the window. Effects of the relative geometry of the delivery and collection fibers (e.g., Apitz et. al., 1992) are not expected to be large due to the large diameter fibers used and concentric arrangement of the collection fibers around the delivery fiber at the probe tip. This is to be confirmed by additional LIF measurements.

If collection fibers are removed from operation due to breakage or other causes, the LIF intensity is expected to decrease in a proportional manner. The removal of 1 to 5 collection fibers from the optical system will be assessed to quantify this effect. Additionally, replicate measurements across each window will be made to assess variability in soil LIF response. The inclusion of 3 sapphire windows will incorporate this variability in the calibration curves.

### 6.3 Series C: Background Soil Measurements

Background LIF measurements of "clean" NTA soil will be made for a suite of soil batch samples with different initial water contents: dry, 15 percent (natural), 15 percent (rehydrated), and 30 percent. All samples will be prepared according to Section 5.0, excluding step 5. The natural sample which will only be sieved, while the other 3 batch samples will be dried, crushed, sieved, wetted, cured, and mixed.

The porosity range for these background samples will be examined as well. An initial porosity of 50 percent, corresponding to a 2.95 cm sample height, will be measured. Each batch sample will be tested at reduced porosity values of 40, 30 and 20 percent, corresponding to sample heights of 2.46, 2.11 and 1.84 cm, respectively. Each sample will be compressed to its effective saturation state. Complete saturation will not occur due to the entrapment of air in the pore spaces. Testing of Batch Sample C3 will illustrate the effects of porosity reduction under saturated conditions. For this sample, pore pressure will be monitored as described in Step 10 of Section 5.0.

The following test matrix will be performed (see attachment 1 for explanation of symbols):

SERIES C: SOIL BACKGROUND MEASUREMENTS

| Batch | w       | Ww   | Wt    | H for measurement |      |      |      | Hsat |
|-------|---------|------|-------|-------------------|------|------|------|------|
|       |         | g    | g     | cm                |      |      |      |      |
| C1    | 0%      | 0    | 80.0  | 2.95              | 2.46 | 2.11 | 1.84 | —    |
| C2    | 15%     | 12.0 | 92.0  | 2.95              | 2.46 | 2.11 | 1.84 | 2.06 |
| C3    | natural | —    | 92.0  | 2.95              | 2.46 | 2.11 | 1.84 | 2.06 |
| C4    | 30%     | 24.0 | 104.0 | 2.95              | 2.46 | 2.11 | 1.84 | 2.66 |

A total of 16 moisture-density configurations are indicated with 3 LIF measurements for each state. Pore pressure cycling (step 10) will be performed for saturated cases. Intermediate heights will also be tested if significant variation is observed. If significant signal is obtained a representative WTM dataset will be obtained, using an excitation wavelength appropriate for the three analytes.

### 6.4 Series D: Effect of Sample Preparation and Handling

Assess the loss of contaminant due to volatilization or evaporation. The percent recovery is measured by treating a standard batch sample at 10 percent moisture content and 30 percent porosity (2.11 cm sample height) with 10,000 mg/kg of JP-4. Concentration will be determined as [contaminant weight]/[dry soil weight]. Measure LIF intensity at each of the sapphire windows using the optimum excitation wavelength. The sample will be reprocessed using Steps 6, 7, 8 and of Section 5.0. The reprocessing and measurement will be repeated until no

significant change in LIF intensity is detected. The percent recovery will be projected from these measurements.

#### 6.5 Series E: Effect of Contaminant Loading on Soils at Various Densities

In order to examine LIF intensity versus concentration, NTA soils will be prepared to a moisture content of 10 percent and spiked with progressive loadings of analyte. Three fuels are to be assessed: JP-4, JP-5 and NTA fuel oil. The optimal excitation wavelength for each fuel will be used for total intensity measurements. All samples will be compressed to similar density states using the soil mold apparatus. The four density states selected have 50, 40, 30 and 20 percent porosity, respectively. The analyte loadings will begin at 100,000 mg/kg and decrease in concentration in a logarithmic fashion (1 loading per log cycle) until background level measurements are obtained. Three (3) additional batch samples with concentrations in areas of linear response will be measured. A linear plot of log (analyte concentration) versus log (LIF Intensity) will provide a basis to quantify the detection limits.

WTM measurements for each analyte will be made at a chosen concentration (1,000 ppm suggested) for a sample height of 2.11 cm (30 percent porosity). The relative contributions of the various BTEX and PAH components to the LIF response will be qualified for each analyte using the HPLC-derived fuel characterization data and the LIF data. Optimization of the LIF excitation wavelength derived from the solution calibration testing will be confirmed during the soil testing. This will enable the Tinker AFB field demonstration to implement a work plan to specify instrument calibration settings for the particular fuel type present.

This series has the following test matrix:

SERIES E: CONTAMINANT LOADING FOR JP-4, JP-5 AND NTA FUEL OIL

| Batch | Contaminant Load | Ws   | Ww  | Wfuel    | H for measurement |      |      |      |
|-------|------------------|------|-----|----------|-------------------|------|------|------|
|       | mg/kg            | g    | g   | g        | cm                |      |      |      |
| E1    | 100,000          | 80.0 | 8.0 | 8        | 2.95              | 2.46 | 2.11 | 1.84 |
| E2    | 10,000           | 80.0 | 8.0 | 0.8      | 2.95              | 2.46 | 2.11 | 1.84 |
| E3    | 1,000            | 80.0 | 8.0 | 0.08     | 2.95              | 2.46 | 2.11 | 1.84 |
| E4    | 100              | 80.0 | 8.0 | 0.008    | 2.95              | 2.46 | 2.11 | 1.84 |
| E5    | 10               | 80.0 | 8.0 | 0.0008   | 2.95              | 2.46 | 2.11 | 1.84 |
| E6    | 1                | 80.0 | 8.0 | 0.0001   | 2.95              | 2.46 | 2.11 | 1.84 |
| E7-F9 | variable         | 80.0 | 8.0 | variable | 2.95              | 2.46 | 2.11 | 1.84 |

The above test matrix consists of 27 batch samples with a total of 108 density states and 333 LIF measurements. The concentration range will be altered based on the LIF response, i.e., the lower concentrations will be eliminated depending on the results of Series C. The most fluorescent analyte will be run first. Since saturation for these samples will be achieved at 1.87 cm (21.1 percent porosity), pore pressure cycling may be performed for the 1.84 cm sample height (20 percent porosity). Additional density states may be added if a significant dependence is found.

#### 6.6 Series F: Effect of Saturation Level at Various Density States

Based on the results of Series E, the effect of moisture content and soil density cycling on LIF measurements will be assessed. Each batch sample will have the same analyte type and concentration (e.g., 1,000 mg/kg of JP-4 equivalent to 0.08 g for 80 g dry soil plus water). Batch samples will consist of 5 water content states and a dry case, each cycled at 4 densities. The following test matrix is applicable:

SERIES F: EFFECT OF SATURATION AND POROSITY VARIABILITY

| Batch | W   | Ww   | Wt(-fuel) | H for measurement |      |      |      | Hsat |
|-------|-----|------|-----------|-------------------|------|------|------|------|
|       |     | g    | g         | cm                |      |      |      |      |
| F1    | 0%  | 0    | 80.00     | 2.95              | 2.46 | 2.11 | 1.84 | —    |
| F2    | 5%  | 4.0  | 84.00     | 2.95              | 2.46 | 2.11 | 1.84 | 1.67 |
| F3    | 10% | 8.0  | 88.00     | 2.95              | 2.46 | 2.11 | —    | 1.87 |
| F4    | 15% | 12.0 | 92.00     | 2.95              | 2.46 | 2.11 | —    | 2.06 |
| F5    | 20% | 16.0 | 96.00     | 2.95              | 2.46 | —    | —    | 2.26 |
| F6    | 30% | 24.0 | 104.00    | 2.95              | 2.46 | 2.11 | 1.84 | 2.66 |

According to Section 5.0, each density state will have 3 measurements for total LIF intensity. Batch F6 serves to isolate the effect of porosity reduction as each density state is saturated. Pore pressure cycling will be performed for this batch. A total of 6 batch samples and 63 LIF measurements are required to complete this final series.

### 7.0 CONTROLLED FIELD TEST

ARA, with NDSU assistance, will perform controlled field tests in a secured pit or barrel, using layered soils with variable soil density, contamination, and water content. The pilot test will examine possible bias due to 1) smearing of soil along rod and the probe window, and 2) development of a strain field about the cone tip. ARA testing will use a non-hazardous JP-4 substitute (e.g., p-tertphenyl) if possible.

## 8.0 DATA ANALYSIS

A total of 35 to 40 batch samples will be required to complete the test plan. With 3 replicate measurements per density state, about 280 total LIF intensity measurements will be required. Additionally, one WTM for an aqueous solution and soil matrix will be performed for each fuel, and possibly an additional WTM for background conditions, for a total of 7 WTM datasets. The total intensity and WTM data will be processed and included in summary tables and graphs, respectively.

Log-log plots of contaminant concentration and LIF intensity will be used for determination of detection limits and evaluation of the LIF response for NTA soils. A family of curves appropriate for different excitation wavelengths or fuel types may also be developed. Error bars showing the variability in replicate measurements will be plotted for each concentration. Appropriate linear regression techniques will be used to fit the data. The calibration curves for the 3 fuels will be compared.

A straight-line portion for calibration curve is expected for aqueous solution samples, but not necessarily for soils. Soils with a small percentage of clay tend to have an overall higher detection limit and also have an S-shaped curve when intensity and concentration are plotted in a linear-linear sense (Apitz and others, 1992). The NOSC group attributes the high detection limit for clays to be a result of a higher specific surface area for clays, i.e., high specific area limits the amount of contaminant available at the soil-window interface. Since they sieve their dried clay samples into uniform aggregate sizes prior to mixing, they have also observed that coarser clay aggregate samples have a larger LIF response. The S-shaped curve is hypothesized to be an effect of the "available surface area" resulting from the degree of aggregation or "lumpiness" of the sieved clay aggregate. Although this study will not address different soil types, the effects of sample preparation for clayey soils will be compared to the NOSC group results. It appears that the NOSC study did not address the specific surface area of clays from a soil mechanics perspective (e.g., Lambe and Whitman, 1969).

Plots of LIF intensity versus water content, LIF intensity versus percent saturation, and LIF intensity versus saturated porosity will be made for the standard concentration tested. The plots will illustrate the variability of LIF data due to soil conditions. Possible corrections to LIF-ECPT measurements due to the influence of cone penetration on soil porosity and percent saturation will be evaluated.

## 9.0 QUALITY ASSURANCE REVIEW

This test plan is prepared to address quality assurance within the validation and demonstration program. Procedures are outlined for conducting experimentation and assessing the accuracy of the measurements. Appropriate logs will document the conditions and results of the tests. Data reduction and presentation of this laboratory testing program will incorporate procedures which check the data for correctness and that insure unambiguous knowledge of the origin and history of the data.

# LIF CALIBRATION CHAMBER - PHASE RELATIONSHIPS (metric version)

## PARAMETERS:

|                               |                        |
|-------------------------------|------------------------|
| H = Height, soil              | Wt = Weight, total     |
| A = Area, soil                | Ws = Weight, solid     |
| x = Displacement              | Ww = Weight, water     |
| Gs = Specific Density, solid  | Vt = Volume, total     |
| gw = Density, water           | Vs = Volume, solids    |
| w = Water Content (% Dry Wt.) | Vw = Volume, water     |
| e = Void Ratio                | Va = Volume, air       |
| n = Porosity (%)              | Vv = Volume, voids     |
| S = Saturation (%)            | gt = Bulk Soil Density |
|                               | gd = Dry Soil Density  |

## Assumed Constants:

|                            | Max   | Min      |
|----------------------------|-------|----------|
| H = Short Cylinder         | 3.693 | 1.598 cm |
| Long Cylinder              | 6.241 | 4.145 cm |
| A = 20.268 cm <sup>2</sup> |       |          |
| Gs = 2.68                  |       |          |
| gw = 1.00 g                |       |          |

## INITIAL CONDITIONS:

|                            |                    |
|----------------------------|--------------------|
| Enter: H = 2.95 cm         | w = 15.0%          |
|                            | Ws = 80.00 g       |
| Output: Wt = 92.00 g       | n = 50.0%          |
| Ww = 12.00 g               | e = 1.00           |
| Vt = 59.69 cm <sup>3</sup> | S = 40.2%          |
| Vs = 29.85 cm <sup>3</sup> | gt = 1.54 g/cc     |
| Vw = 12.00 cm <sup>3</sup> | gd = 1.34 g/cc     |
| Va = 17.84 cm <sup>3</sup> | H for saturation = |
| Vv = 29.84 cm <sup>3</sup> | 2.06 cm            |

## FINAL CONDITIONS:

|                            |                |
|----------------------------|----------------|
| Enter: H = 2.06 cm         |                |
| Output: Ww = 12.00 g       | n = 28.7%      |
| Vt = 41.85 cm <sup>3</sup> | e = 0.402      |
| Vw = 12.00 cm <sup>3</sup> | w = 15.0%      |
| Va = 0.00 cm <sup>3</sup>  | S = 100.0%     |
| Vv = 12.00 cm <sup>3</sup> | gt = 2.20 g/cc |
| x = 0.88 cm                | gd = 1.91 g/cc |

## CHAPTER 3

### *Description of an Assemblage of Particles*

This chapter considers the description of an assemblage of particles. It presents relationships among the different phases in the assemblage, and discusses particle size distribution and degree of plasticity of the assemblage. The phase relationships are used considerably in soil mechanics to compute stresses. The phase relationships, particle size characteristics, and Atterberg limits are employed to group soils and thus facilitate their study.

#### 3.1 PHASE RELATIONSHIPS

By being a particulate system, an element of soil is inherently "multiphase." Figure 3.1 shows a typical element of soil containing three distinct phases: *solid* (mineral particles), *gas*, and *liquid* (usually water). Figure 3.1a represents the three phases as they would typically exist in an element of natural soil. In Part (b) the phases have been separated one from the others in order to facilitate the development of the phase relationships. The phases are dimensioned with volumes on the left and weights on the right side of the sketch.

Below the soil elements in Fig. 3.1 are given expressions that relate the various phases. There are three important relationships of volume: *porosity*, *void ratio*, and *degree of saturation*. *Porosity* is the ratio of void volume to total volume and *void ratio* is the ratio of void volume to solid volume. Porosity is usually multiplied by 100% and thus the values are given in percent. Void ratio is expressed in a decimal value, such as a void ratio of 0.55, and can run to values greater than unity. Both porosity and void ratio indicate the relative portion of void volume in a soil sample. This void volume is filled with fluid, either gas or liquid, usually water. Although both terms are employed in soil mechanics, void ratio is the more useful<sup>1</sup>

<sup>1</sup> During a typical compression of a soil element, both the numerator and the denominator of the porosity decrease, whereas only the numerator of the void ratio decreases. This fact results in void ratio being more useful than porosity for studying soil compression.

of the two. Two relationships between porosity  $n$  and void ratio  $e$  are

$$n = \frac{e}{1 + e} \quad \text{and} \quad e = \frac{n}{1 - n}$$

The degree of saturation indicates the percentage of the void volume which is filled with water. Thus a value of  $S = 0$  indicates a dry soil,  $S = 100\%$  indicates a saturated soil, and a value between 0 and 100% indicates a partially saturated soil.

The most useful relationship between phase weights is *water content*, which is the weight of water divided by the weight of solid in a soil element. The water content of a soil sample is readily obtained by: weighing the natural soil; drying it in an oven; weighing the dry soil; and, finally, computing the water content as the difference in initial and dry weights divided by the dry weight. This procedure assumes that all of the volatiles are water, an acceptable assumption except when working with organic soils or soils containing additives such as asphalt. For a saturated soil the water content and void ratio are uniquely related, as one can see by examining the expressions for the two terms. Since it is much easier to obtain weights than to obtain volumes, the soil engineer makes considerable use of changes in water content of a saturated soil to measure volumetric strain.

The lower part of Fig. 3.1 gives expressions for various unit weights, i.e., the weight of a given volume. The *total unit weight*  $\gamma$ , is, for example, the weight of the entire soil element divided by the volume of the entire element.<sup>2</sup> The *dry unit weight*, often called *dry density*, is the weight of mineral matter divided by the volume of the entire element. Unit weights appear in units of weight per volume such as pounds per cubic foot, grams per cubic centimeter, and tons per cubic meter.

315 The symbol  $\gamma$  is also used for total unit weight.

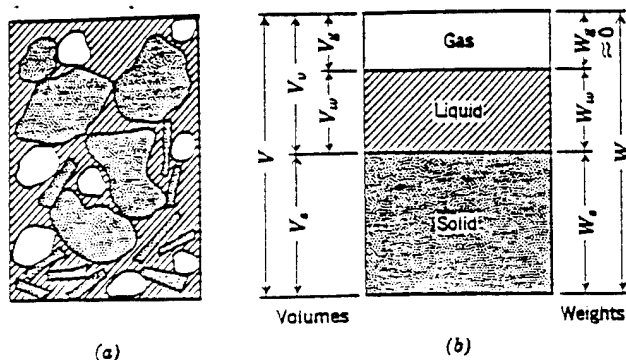


Fig. 3.1 Relationships among soil phases. (a) Element of natural soil. (b) Element separated into phases.

Volume

Porosity:

$$n = \frac{V_v}{V}$$

Void ratio:

$$e = \frac{V_v}{V_s}$$

Degree of saturation:

$$S = \frac{V_w}{V_v}$$

$$n = \frac{e}{1 + e}; \quad e = \frac{n}{1 - n}$$

Weight

Water content:

$$w = \frac{W_w}{W_s}$$

Specific Gravity

Mass:

$$G_m = \frac{\gamma_t}{\gamma_w}$$

Water:

$$G_w = \frac{\gamma_w}{\gamma_0}$$

Solids:

$$G = \frac{\gamma_s}{\gamma_0}$$

$\gamma_0$  = Unit weight of water at 4°C  $\approx \gamma_w$

Note that  $Gw = Se$

Unit Weight

Total:

$$\gamma_t = \frac{W}{V} = \frac{G + Se}{1 + e} \gamma_w = \frac{1 + w}{1 + e} G \gamma_w$$

Solids:

$$\gamma_s = \frac{W_s}{V_s}$$

Water:

$$\gamma_w = \frac{W_w}{V_w}$$

Dry:

$$\gamma_d = \frac{W_s}{V} = \frac{G}{1 + e} \gamma_w = \frac{G \gamma_w}{1 + wG/S} = \frac{\gamma_t}{1 + w}$$

Submerged (buoyant):

$$\gamma_b = \gamma_t - \gamma_w = \frac{G - 1 - e(1 - S)}{1 + e} \gamma_w$$

Submerged (saturated soil):

$$\gamma_b = \gamma_t - \gamma_w = \frac{G - 1}{1 + e} \gamma_w$$

Specific gravity is the unit weight divided by the unit weight of water. Values of specific gravity of solids  $G$  for a selected group of minerals<sup>3</sup> are given in Table 3.1.

Table 3.1 Specific Gravities of Minerals

|                                 |                   |
|---------------------------------|-------------------|
| Quartz                          | 2.65              |
| K-Feldspars                     | 2.54-2.57         |
| Na-Ca-Feldspars                 | 2.62-2.76         |
| Calcite                         | 2.72              |
| Dolomite                        | 2.85              |
| Muscovite                       | 2.7-3.1           |
| Biotite                         | 2.8-3.2           |
| Chlorite                        | 2.6-2.9           |
| Pyrophyllite                    | 2.84              |
| Serpentine                      | 2.2-2.7           |
| Kaolinite                       | 2.61 <sup>a</sup> |
|                                 | 2.64 $\pm$ 0.02   |
| Halloysite (2 H <sub>2</sub> O) | 2.55              |
| Illite                          | 2.84 <sup>a</sup> |
|                                 | 2.60-2.86         |
| Montmorillonite                 | 2.74 <sup>a</sup> |
|                                 | 2.75-2.78         |
| Attapulgite                     | 2.30              |

<sup>a</sup> Calculated from crystal structure.

The expression  $Gw = Se$  is useful to check computations of the various relationships.

The student in soil mechanics must understand the meanings of the relationships in Fig. 3.1, convince himself once and for all that they are correct, and add these terms to his active vocabulary. These relationships are basic to most computations in soil mechanics and thus are an essential part of soil mechanics.

#### Typical Values of Phase Relationships for Granular Soils

Figure 3.2 shows two of the many possible ways that a system of equal-sized spheres can be packed. The dense packings represent the densest possible state for such a system. Looser systems than the simple cubic packing can be obtained by carefully constructing arches within the packing, but the simple cubic packing is the loosest of the stable arrangements. The void ratio and porosity of

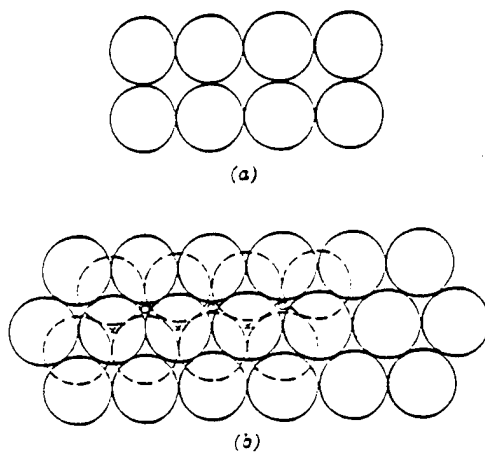


Fig. 3.2 Arrangements of uniform spheres. (a) Plan and elevation view: simple cubic packing. (b) Plan view: dense packing. Solid circles, first layer; dashed circles, second layer:  $\triangleright$ , location of sphere centers in third layer: face-centered cubic array;  $\times$ , location of sphere centers in third layer: close-packed hexagonal array. (From Deresiewicz, 1958.)

these simple packings can be computed from the geometry of the packings, and the results are given in Table 3.2.

This table also gives densities for some typical granular soils in both the "dense" and "loose" states. A variety of tests have been proposed to measure the maximum and

Table 3.2 Maximum and Minimum Densities for Granular Soils

| Description            | Void Ratio |            | Porosity (%) |            | Dry Unit Weight (pcf) |                  |
|------------------------|------------|------------|--------------|------------|-----------------------|------------------|
|                        | $e_{\max}$ | $e_{\min}$ | $n_{\max}$   | $n_{\min}$ | $\gamma_{d\min}$      | $\gamma_{d\max}$ |
| Uniform spheres        | 0.92       | 0.35       | 47.6         | 26.0       | —                     | —                |
| Standard Ottawa sand   | 0.80       | 0.50       | 44           | 33         | 92                    | 110              |
| Clean uniform sand     | 1.0        | 0.40       | 50           | 29         | 83                    | 118              |
| Uniform inorganic silt | 1.1        | 0.40       | 52           | 29         | 80                    | 118              |
| Silty sand             | 0.90       | 0.30       | 47           | 23         | 87                    | 127              |
| Fine to coarse sand    | 0.95       | 0.20       | 49           | 17         | 85                    | 138              |
| Micaceous sand         | 1.2        | 0.40       | 55           | 29         | 76                    | 120              |
| Silty sand and gravel  | 0.85       | 0.14       | 46           | 12         | 89                    | 146              |

B. K. Hough, *Basic Soils Engineering*. Copyright © 1957, The Ronald Press Company, New York.

minimum void ratios (Kolbuszewski, 1948). The test to determine the maximum density usually involves some form of vibration. The test to determine minimum density usually involves pouring oven-dried soil into a

not been entirely standardized, and values of the maximum density and minimum density for a given granular soil depend on the procedure used to determine them. By using special measures, one can obtain densities greater than the so-called maximum density. Densities considerably less than the so-called minimum density can be obtained, especially with very fine sands and silts, by slowly sedimenting the soil into water or by fluffing the soil with just a little moisture present.

The smaller the range of particle sizes present (i.e., the more nearly uniform the soil), the smaller the particles, and the more angular the particles, the smaller the minimum density (i.e., the greater the opportunity for building a loose arrangement of particles). The greater the range of particle sizes present, the greater the maximum density (i.e., the voids among the larger particles can be filled with smaller particles).

A useful way to characterize the density of a natural granular soil is with *relative density*  $D_r$ , defined as

$$D_r = \frac{e_{\max} - e}{e_{\max} - e_{\min}} \times 100\% \\ = \frac{\gamma_{d\max}}{\gamma_d} \times \frac{\gamma_d - \gamma_{d\min}}{\gamma_{d\max} - \gamma_{d\min}} \times 100\% \quad (3.1)$$

where

$e_{\min}$  = void ratio of soil in densest condition

$e_{\max}$  = void ratio of soil in loosest condition

$e$  = in-place void ratio

$\gamma_{d\max}$  = dry unit weight of soil in densest condition

$\gamma_{d\min}$  = dry unit weight of soil in loosest condition

$\gamma_d$  = in-place dry unit weight

Table 3.3 characterizes the density of granular soils on the basis of relative density.

Table 3.3 Density Description

| Relative Density (%) | Descriptive Term |
|----------------------|------------------|
| 0-15                 | Very loose       |
| 15-35                | Loose            |
| 35-65                | Medium           |
| 65-85                | Dense            |
| 85-100               | Very dense       |

Values of water content for natural granular soils vary from less than 0.1% for air-dry sands to more than 40% for saturated, loose sand.

#### Typical Values of Phase Relationships for Cohesive Soils

The range of values of phase relationships for cohesive soils is much larger than for granular soils. Saturated sodium montmorillonite at low confining pressure can exist at a void ratio of more than 25; saturated clays

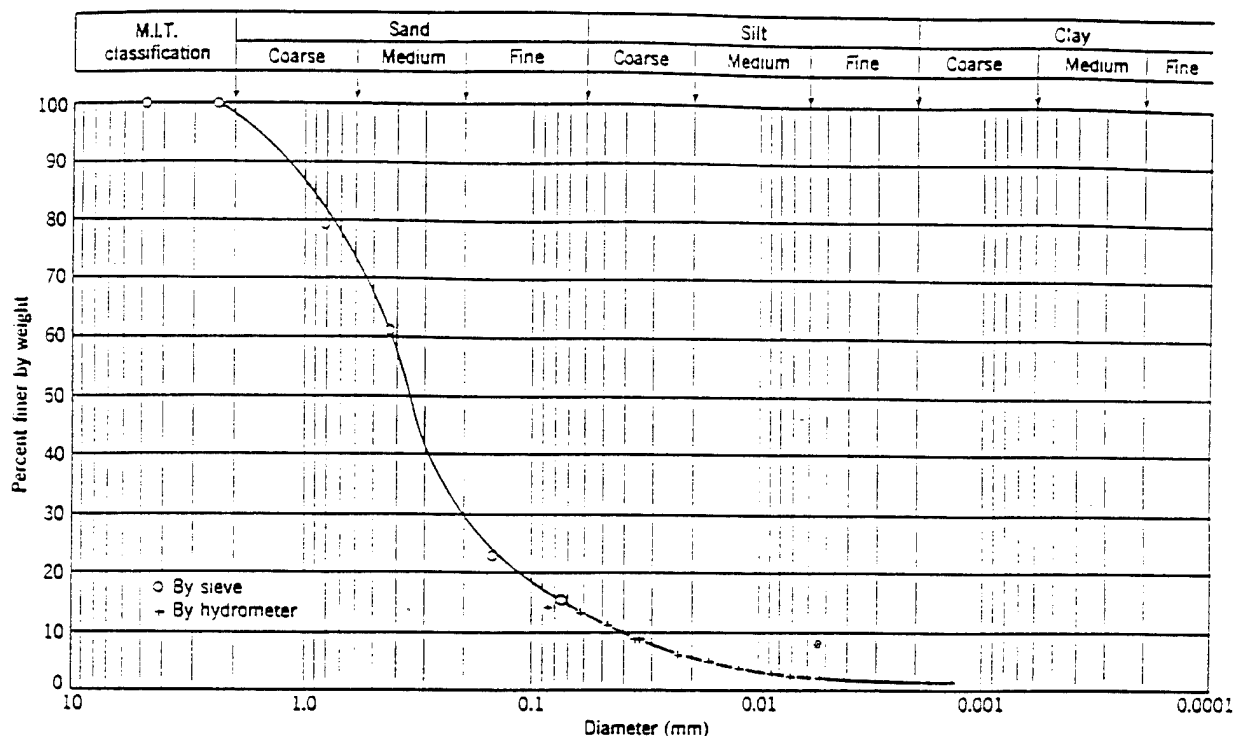


Fig. 3.3 Particle size distribution curve (From Lambe, 1951).

compressed under the high stresses (e.g., 10,000 psi) that exist at great depths in the ground can have void ratios less than 0.2.

Using the expression  $G_w = Se$  (Fig. 3.1), we can compute the water contents corresponding to these quoted values of void ratio:

|                          |      |
|--------------------------|------|
| Sodium montmorillonite   | 900% |
| Clay under high pressure | 7%   |

If a sample of oven-dry Mexico City clay sits in the laboratory (temperature = 70°F, relative humidity = 50%), it will absorb enough moisture from the atmosphere for its water content to rise to 2½% or more. Under similar conditions, montmorillonite can get to a water content of 20%.

### 3.2 PARTICLE SIZE CHARACTERISTICS

The particle size distribution of an assemblage of soil particles is expressed by a plot of percent finer by weight versus diameter in millimeters, as shown in Fig. 3.3. Using the definition for sand, silt, and clay noted at the top of this figure<sup>4</sup> we can estimate the make-up of the soil sample as:

|        |     |
|--------|-----|
| Gravel | 2%  |
| Sand   | 85% |
| Silt   | 12% |
| Clay   | 1%  |

<sup>4</sup> This set of particle size definitions is convenient and widely used. A slightly different set is given in Tables 3.5 and 3.6.

The uniformity of a soil can be expressed by the *uniformity coefficient*, which is the ratio of  $D_{60}$  to  $D_{10}$ , where  $D_{60}$  is the soil diameter at which 60% of the soil weight is finer and  $D_{10}$  is the corresponding value at 10% finer. A soil having a uniformity coefficient smaller than about 2 is considered "uniform." The uniformity of the soil whose distribution curve is shown in Fig. 3.3 is 10. This soil would be termed a "well-graded silty sand."

There are many reasons, both practical and theoretical, why the particle size distribution curve of a soil is only approximate. As discussed in Chapter 4, the definition of particle size is different for the coarse particles and the fine particles.

The accuracy of the distribution curves for fine-grained soils is more questionable than the accuracy of the curves for coarse soils. The chemical and mechanical treatments given natural soils prior to the performance of a particle size analysis—especially for a hydrometer analysis—usually result in effective particle sizes that are quite different from those existing in the natural soil. Even if an exact particle size curve were obtained, it would be of only limited value. Although the behavior of a cohesionless soil can often be related to particle size distribution, the behavior of a cohesive soil usually depends much more on geological history and structure than on particle size.

In spite of their serious limitations, particle size curves, particularly those of sands and silts, do have practical value. Both theory and laboratory experiments show

## **APPENDIX L**

### **WORK PLAN FOR THE AFSCAPS DEMONSTRATION, TEST AND EVALUATION PROGRAM AT TINKER AFB**

**WORK PLAN  
FOR THE  
AFSCAPS DEMONSTRATION, TEST AND EVALUATION PROGRAM  
AT  
TINKER AIR FORCE BASE**

**Submitted to:**

**OKLAHOMA CITY AIR LOGISTICS COMMAND  
DIRECTORATE OF ENVIRONMENTAL MANAGEMENT  
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**Revised**

**August 17, 1992**

## DEMONSTRATION WORK PLAN

### Table of Contents

| <u>Section</u>                                                           | <u>Page</u> |
|--------------------------------------------------------------------------|-------------|
| 1.0 PURPOSE AND ORGANIZATION . . . . .                                   | 1           |
| 1.1 Objective . . . . .                                                  | 1           |
| 1.2 DT&E Plan Organization . . . . .                                     | 2           |
| 2.0 BACKGROUND . . . . .                                                 | 3           |
| 2.1 Cone Penetrometer Technology and Environmental Assessments . . . . . | 3           |
| 2.2 LIF-ECPT for Environmental Analyses . . . . .                        | 5           |
| 3.0 FIELD PROGRAM . . . . .                                              | 8           |
| 3.1 Anticipated Subsurface Conditions . . . . .                          | 8           |
| 3.2 Technical Approach . . . . .                                         | 11          |
| 4.0 DATA EVALUATION . . . . .                                            | 13          |
| 5.0 WASTE MANAGEMENT . . . . .                                           | 14          |
| 6.0 SCHEDULE . . . . .                                                   | 15          |

### Appendix A Overview of Electronic Cone Penetrometer Testing

### LIST OF TABLES AND FIGURES

|                                                                               |    |
|-------------------------------------------------------------------------------|----|
| Table 1. Summary of Tinker AFB Subsurface Contaminants by Test Area . . . . . | 8  |
| Table 2. Tinker AFB Average Site Subsurface Conditions . . . . .              | 10 |
| Table 3. Summary of Site Testing and Field Activities . . . . .               | 12 |
| Figure 1. Site Plan . . . . .                                                 | 9  |
| Figure 2. Schedule (GANTT) . . . . .                                          | 16 |
| Figure 3a. Schedule (Calendar) . . . . .                                      | 17 |
| Figure 3b. Schedule (Calendar) . . . . .                                      | 18 |

## 1.0 PURPOSE AND ORGANIZATION

### 1.1 Objective

The purpose of the Air Force Site Characterization and Analysis Penetrometer System (AFSCAPS) Demonstration, Testing and Evaluation (DT&E) Program at Tinker Air Force Base (AFB) is two-fold: 1) develop, test and demonstrate the feasibility of using an situ Laser-Induced Fluorescence (LIF) - Electric Cone Penetrometer Test (ECPT) probe to detect petroleum-contaminated soils, and 2) perform soil and ground water sampling and analyses to delineate the nature and extent of volatile organic compounds (VOCs) and other contaminants.

The statement of work, prepared by the Air Force Civil Engineering Support Agency (AFCESA) and the Directorate of Environmental Management at Tinker AFB, outlines the project as being within the advanced development phase (6.3 effort) of the Air Force research and development program. Research and development supported by the Air Force has included the advancement of 1) tunable LIF spectroscopy and fiber optics at North Dakota State University (NDSU), and 2) ECPT systems equipped with fiber optic sensors at the Army Waterways Experiment Station (WES). The combination of the cone penetrometer with the tunable (excitation wavelength selectable) laser spectrometer will enable the Air Force to address site characterization, remediation and post-remedial monitoring of Air Force Base petroleum, oil and lubricant (POL) contaminated sites, particularly jet fuel-contaminated subsurface soils, in a rapid and efficient manner.

Applied Research Associates, Inc. (ARA), the prime contractor for this DT&E program, is integrating NDSU's laser spectrometer and WES's fiber optic probe into ARA's existing ECPT and real-time data analysis system. NDSU will serve as a subcontractor to ARA in assisting in the acquisition, installation and bench-testing of hardware and software components, performing laboratory LIF calibration testing of POL-contaminated soils, and performing on-site LIF analyses and follow-up assessment.

As part of the AFSCAPS project, ARA has been specifically tasked to execute the following:

1. Develop a prototype LIF-ECPT probe by integrating NDSU's fiber optic, laser-induced fluorescence (LIF) spectrometer and WES's optical cone technology,
2. Validate the prototype LIF-ECPT probe as an environmental screening device for detecting POL-contamination in soils by performing calibration tests in the laboratory and pilot tests in the field,
3. Perform operational tests of the prototype penetrometer-spectrometer system at Tinker AFB, and evaluate the technology for characterization of subsurface POL-contamination and site hydrogeology,
4. Collect and present subsurface environmental data obtained with the cone penetrometer at designated contaminated sites at Tinker AFB, and
5. Assist in transferring the recommended AFSCAPS technology for engineering development within the Air Force.

Successful completion of tasks 3 and 4 are the essential concerns of this DT&E plan.

## **1.2 DT&E Plan Organization**

The DT&E Plan for the Tinker AFB demonstration is organized into 3 separate plans. This document, the Work Plan, presents the background and scope of work, including technical approach, site background information, data analysis and management, waste management, and schedule for the AFSCAPS project. Detailed presentations of field procedures and analytical methods are found in the accompanying Sampling and Analysis Plan. The third plan, the Health and Safety Plan, provides safety and QA/QC policies and procedures which will be followed during standard field operations and in response to emergency situations.

## 2.0 BACKGROUND

### 2.1 Cone Penetrometer Technology and Environmental Assessments

ARA has developed a site characterization methodology which integrates the minimally invasive ECPT techniques with on-site environmental analyses. The overall purpose of ARA's site characterization approach is to identify and characterize subsurface contamination. Surface geophysics, such as seismic refraction/reflection, electrical/electromagnetic methods or ground penetrating radar, have also been incorporated in this approach.

The ECPT system has been adapted to include various in situ geophysical and environmental sensors to complement standard in situ geotechnical ECPT measurements. Sampling of soil, ground water and soil gas is also an attribute of the ECPT system. ARA's probe capabilities are summarized below:

- Tip and Sleeve Stress - used to identify materials and their mechanical properties. Detects very thin layers and other details such as potential contaminant pathways not easily found with drilling and sampling.
- Pore Pressure - used to identify the water table surface and hydraulic gradients. Additionally, information on soil type and hydraulic conductivity is provided by changes in pore pressure during penetration and by dissipation to ambient piezometric conditions.
- Vertical Seismic Profiling - used to determine downhole seismic velocities. Triaxial geophones located in the probe record P-wave and S-wave generated by surface sources beneath the penetrometer vehicle. P-wave and S-wave velocities can be used as control for surface seismic refraction and reflection surveys. Detailed velocity-depth profiles may also be used to substantiate soil type and moisture content.
- Electrical Resistivity - used to measure conductivity/resistivity profiles of geological materials and pore fluids. The measurements are used to identify materials and contaminants which produce a resistivity contrast, and to support the interpretation of surface resistivity/electromagnetic surveys.
- Gamma Radiation - used to locate buried radioactive waste canisters or to determine the natural gamma radiation background. Three specific energy levels and total energy are monitored.

- Grouting - Once a penetration or conductivity test is complete, the ECPT hole can be grouted by pumping a low viscosity grout down the probe and out through the sides of the module. Grout is pumped continually as the probe is withdrawn. The pressure and volume of grout pumped are monitored to insure that the penetration hole is properly sealed.
- Soil Sampling - 1 to 1.8-foot soil samples may be retrieved at specified depths using several commercially available cone penetrometer soil samplers.
- Ground Water Sampling - Several cone penetrometer water samplers and sample retrieval methods are used depending on the sampling objectives. The sampler is pushed to the desired depth and retracted to expose the filtered-intake section of the probe. Ground water is retrieved by using a bailer or by direct infiltration to a sample vial.
- Soil Gas Sampling - Soil vapors in unsaturated zones are extracted using the vadose monitoring system in the ECPT. Soil gas may be analyzed using field-compatible vapor detectors or gas chromatography.
- Decontamination - using a self-contained steam cleaning system located at the base of the CPT vehicle, the exterior of the rods and probe are decontaminated as they are withdrawn from the penetrometer hole.

Soil, water and gas samples are analyzed using a gas chromatography (GC) instrumentation installed in ARA's trailer-mounted environmental laboratory. Gas samples are directly injected into the GC unit, whereas the volatile organic compounds from water or soil samples are stripped and concentrated through the use of a O/I 4460A Sample Concentrator System (purge and trap system). This unit complies with U.S. EPA-recommended analysis protocols. The GC analysis is performed on a Hewlett Packard 5890 Series II GC unit equipped with dual detectors. A Flame Ionization Detector (FID) and an Electron Capture Detector (ECD) are used. These two units combine to allow detection levels down to 1 ppb for many common volatile organic compounds. The GC unit is controlled by, and the data recorded and reduced, on a 80486-based computer running HP ChemStation Software.

Environmental site characterization is greatly enhanced by the ability to perform real-time, on-site analysis of test data. In this way the ongoing exploration can be immediately guided by information as it becomes available, thereby improving the effectiveness of the site characterization. ARA's ECPT systems have on-board data processing and graphics hardware.

ARA proprietary software is used to acquire, analyze and present the data as it is being acquired in the field.

A major site characterization program produces large amounts of data from various sources and in various forms. Convenient and flexible storage, retrieval and manipulation of the data are required to provide optimal and timely analysis. In parallel with the database problem is the need for multi-dimensional graphical display of data to aid in analysis and decision-making. ARA is implementing state-of-the-art software to achieve these objectives.

The TECHBASE<sup>®</sup> system is being used for database management, statistical processing and part of the graphic display. The system incorporates a relational database, a wide range of tools for analysis of stored data, geostatistical modeling, and graphics capability to display contours, cross-sections, perspectives, and vector drawings.

For ease of data interpretation and on-site presentation purposes, ARA is using Advanced Visualization Systems, Inc.'s three-dimensional volume rendering package to display subsurface conditions. A personal/Iris Silicon Graphics workstation, installed in the Mobile Environmental Laboratory, is used to perform database management and scientific visualization routines.

## **2.2 LIF-ECPT for Environmental Analyses**

As was first shown by the WES geotechnical group, incorporation of fiber optic spectroscopy into a cone penetrometer opens up new possibilities for field screening. The essence of the WES idea was to incorporate a sapphire window in the side of the cone to perform LIF measurements. Ultraviolet (UV) light at 337 nm is generated by a pulsed nitrogen gas laser and launched down a 0.3-mm diameter fiber optic. The UV light is essentially directed from inside the cone onto soil moving past the sapphire window as the cone is pushed into the ground. For particular compounds within POL-contaminated soil, the 337 nm excitation wavelength produces LIF. Fluorescence back scattered into the cone is collected by a second fiber optic, which returns the light to the surface for analysis. Both the delivery and collection fibers are bundled into the instrumentation cable with the other conventional geotechnical sensors.

While the WES system has had success in detecting Diesel Fuel Marine in various subsurface settings, it has inherent drawbacks in addressing particular fuel types. In response to the problems of delineating POLs at Air Force Installations, NDSU has developed an innovative laser spectrometer system which is field-operable and has been used for ground water monitoring of aromatic hydrocarbons. The main components of the NDSU laser spectrometer system are the following: a Nd:YAG laser (pulsed pump laser) and dye laser cell, transfer optics from the pump laser to the dye laser, filters, single strand delivery fiber optic (0.6 mm diameter plastic-clad silica core), 6-strand fiber optic collection, detection system (photomultiplier tube and signal averaging digital oscilloscope), and 80486-based control computer with custom software. As part of this project, the NDSU system is being adapted for analysis of soils with ARA's ECPT system.

Various aromatic hydrocarbons commonly associated with fuels, such as BTEX compounds (Benzene, Toluene, Ethylbenzene, and Total Xylene) and polycyclic aromatic hydrocarbon (PAH) compounds (e.g., naphthalene), are detected using excitation wavelengths in the near ultraviolet (250-350 nm) range. BTEX compounds tend to have maximum fluorescence intensity for excitation wavelengths near 266 nm, producing emission maxima near 290 nm. PAHs fluoresce over a broader range of UV excitation wavelengths and generally have a higher fluorescent response than the BTEX. Naphthalene has maximum emission intensity at 335 nm produced with an 280 nm excitation wavelength. The tunability of NDSU's laser system allows detection of these POL compounds, whereas a fixed wavelength excitation system cannot induce the optimal fluorescence in both BTEX and PAH compounds.

Using a tunable Nd:YAG laser spectrometer system, speciation of BTEX and PAH compounds, as well as POL-types, is possible by characterizing the fluorescent signature from the combination of excitation spectra, emission spectra and lifetime profiles. Wavelength time matrices (WTM), consisting of LIF intensity-time decay profiles for a series of emission wavelengths, have been used by NDSU to differentiate single component aromatics in aqueous solution (e.g., Gillispie and Germain, 1992). Alternatively, Excitation-Emission Matrices (EEM) have been used to "fingerprint" POL solutions using a spectral fluorimeter. Advanced processing of these multi-dimensional data potentially enables the analyst to specify the types and

concentrations of various aromatic hydrocarbons or fuel types.

Prior LIF studies for environmental analysis have mainly dealt with aqueous media (e.g., Gillispie and St. Germain, 1992). The NOSC group (Apitz, Theriault, and Lieberman, 1992), in collaboration with WES, have shown that LIF results of soils are dependent on a larger set of variables compared to LIF measurements of aqueous solutions.

Environmental uncertainties for ground water measurements arise if 1) unknown fluorescent compounds exist in solution, 2) turbidity (suspended solids content) is high, thereby decreasing the effective excitation energy due to scattering (producing a lower measured intensity), or 3) dissolved oxygen levels are variable. Corrections for these effects may be made, depending on the development of LIF signal processing and analysis techniques or synergistic sensor technologies.

For soil media, environmental uncertainties in fluorescent response are more complex. Generally, the sensitivity appears to be dependent on soil type (e.g., surface area, grain size, mineralogy, and degree of soil aggregation), porosity, moisture content, saturation level and LIF response of natural fluorophores (e.g., humic acid). The presence of solids increases the amount of backscattering and decreases the effective penetration depth of the excitation energy. For a given fiber optic spectrometer system, the effective signal attenuation increase by over 1 to 3 orders of magnitude for soil versus aqueous media.

As part of the AFSCAPS project, NDSU's wavelength-tunable laser spectrometer system is being used to measure LIF of the Tinker AFB soil samples. The preliminary results confirm the prototype applicability to petroleum-contaminated site investigations.

LIF measurements using the LIF-ECPT system are made with the probe in "push" and "static" modes. The push mode features constant wavelength spectral analysis of LIF data collected at regular depth intervals (e.g., 6 cm). Similar to the ECPT pore pressure dissipation tests (Appendix A), static mode LIF profiles are obtained when the probe is stationary (typically at 1-meter depth intervals or at particular points of interest). The static mode allows generation

of multi-dimensional matrices, such as WTM's. Using appropriate excitation wavelengths, WTM data potentially provide essential information for specification of aromatic hydrocarbons.

### 3.0 FIELD PROGRAM

#### 3.1 Anticipated Subsurface Conditions

Tinker AFB has 8 contaminated areas which will be addressed during the 30-day field program (Figure 1). A variety of contaminants are suspected at the site, including Jet Fuel (JP-4 and JP-5), fuel oil No. 2, chlorinated solvents (e.g., TCE), and metals. These contaminants have been released as surface spills, leakage from Underground Storage Tanks (USTs) or piping, and leachate from wastewater and solid waste management facilities. Suspected contaminants and chemical test parameters are provided in Table 1 below.

Table 1. SUMMARY OF TINKER AFB SUBSURFACE CONTAMINANTS BY TEST AREA

| Test Area          | Contaminants Known or Suspected | Parameters of Concern                                             |
|--------------------|---------------------------------|-------------------------------------------------------------------|
| North Tank         | Fuel Oil, Diesel, TCE           | BTEX, TPH, VOC                                                    |
| Fuel Purge         | JP-4 and JP-5 Jet Fuel          | BTEX, TPH, VOC                                                    |
| Fire Training      | Jet Fuel                        | BTEX, TPH, VOC                                                    |
| USTs (4 Fuel)      | Fuel, Solvents, Metals          | BTEX, VOC, Metals, Semi-VOCs                                      |
| IWTP               | Solvents, Metals                | Metals, VOCs, Semi-Vocs                                           |
| Bldg. 3001 Outfall | Solvents?, Metals?              | Metals, VOCs, Semi-Vocs                                           |
| Offbase            | Solvents?                       | Metals, VOCs, Semi-Vocs                                           |
| Landfill 2&4       | Solvents, Metals, Rads, Gas     | Metals, VOCs, Semi-Vocs, $\alpha$ & $\beta$ Rads, CH <sub>4</sub> |

Note: BTEX = Benzene, Toluene, Ethyl Benzene, and Xylene  
 VOCs = Volatile Organic Compounds  
 TPH = Total Petroleum Hydrocarbon  
 Semi-VOCs = Semivolatile Organic Compounds

A thick red-bed, sandstone and shale sequence underlies Tinker AFB. The Garber-Wellington formation, a thick water-bearing sandstone formation with interbedded shale, is located about 50 to 100 feet below the site. This semi-confined aquifer is essentially confined

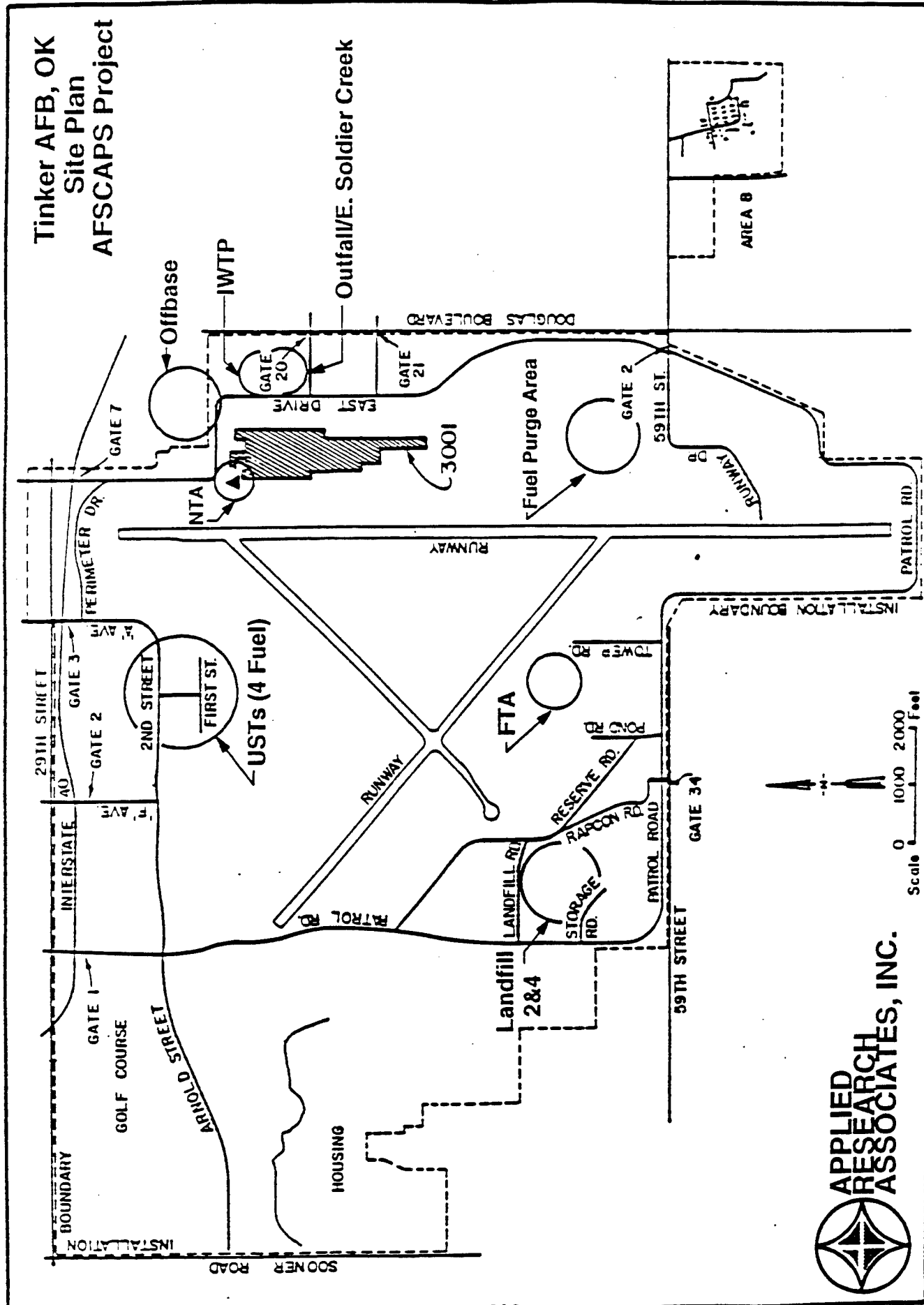


Figure 1. Site plan.

○ Sites to be Investigated

by the Hennessey Formation, a shale formation with interbedded sandstone. The Hennessey outcrops over most of the base, and is weathered to about 40 feet below ground surface. The predominant soil type at Tinker is sandy clay, a by-product of the outcropping shale.

Thin sandstone lenses or discontinuous layers are found at shallow depths (5 to 20 feet) within the Hennessey Shale. These sandstone lenses are relatively unweathered and consolidated compared to the weathered shale; the sandstone layer behaves as competent rock in that the layer is resistant to standard geotechnical drilling and cone penetrometer testing. In most cases, the perched water layer lies below the sandstone lens. Thus, to sample below the sandstone, alternative drilling methods must be used. Table 2 lists the approximate perched water level and depth to competent rock at each of the test areas. Some test areas have been altered in places by excavation and fill; in these cases, the depth to refusal will be deeper.

Table 2. TINKER AFB AVERAGE SITE SUBSURFACE CONDITIONS

| Test Area          | Est. Field Time (d) | Total Locations | Ave. Final Depth (ft) | Ave. Depth to Bedrock <sup>a</sup> (ft) | Ave. Depth to GW <sup>a</sup> (ft) |
|--------------------|---------------------|-----------------|-----------------------|-----------------------------------------|------------------------------------|
| North Tank         | 4                   | 12              | 20                    | 10                                      | 15                                 |
| Fuel Purge         | 6                   | 35              | 20                    | 12                                      | 15                                 |
| Fire Training      | 2                   | 8               | 20                    | 12                                      | 15                                 |
| USTs (4 Fuel)      | 4                   | 15              | 15                    | 12                                      | 9                                  |
| IWTP               | 3                   | 10              | 18                    | 6                                       | 13                                 |
| Bldg. 3001 Outfall | 1                   | 10              | 10                    | 5                                       | 2                                  |
| Offbase            | 1                   | 8               | 7                     | 7                                       | 15                                 |
| Landfill 2&4       | 9                   | 32              | 15                    | —                                       | 10                                 |
| Total/Est. Range   | 30                  | 130             | 7-25                  | 5-12                                    | 2-20                               |

Note: <sup>a</sup> From existing data, the estimated uncertainties for the average depths to the perched ground water table (GW) and hard sandstone formations (bedrock) is  $\pm 5$  feet. GW level is also estimated to have a maximum seasonal variation of 8 feet.

Due to the heterogeneous presence of sand units and the effects of weathering on the shale, a perched water table system exists beneath most of Tinker AFB. The Garber-Wellington

aquifer, having potential well yields of 400 gallons per minute, is a public and private drinking water supply for the region. Although the perched water table is most directly affected by anthropogenic activity, both the deep semi-confined aquifers and shallow perched ground water system have instances of contamination.

### 3.2 Technical Approach

This DT&E program addresses the nature of subsurface contamination in the shallow unsaturated zone and in the perched water table system through the use of ECPT and by drilling with augers. ARA's minimally-invasive ECPT system offers a good platform for hazardous waste site operations in that it allows in situ geotechnical analyses, adequate protection of the work crew, efficient decontamination of equipment, and on-site assessment of subsurface contamination. ECPT logs, generated from geotechnical or chemical sensor-based data acquisition systems, allow for real-time data evaluation. Further on-site analyses are made using a Silicon Graphics workstation running a 3-D relational database (TECHBASE) and scientific visualization software. On-screen displays and hardcopies of graphics permit on-site interpretation of data and aid in decision-making. Planned LIF profiling and field GC characterization of contaminants complement the AFSCAPS objectives of rapid and accurate on-site environmental analysis.

The major elements of the field program activities are presented in Table 3. ARA's ECPT profiling consists of in situ geotechnical measurements of tip stress, sleeve stress and pore pressure. These three parameters are combined with published or site-specific data to yield real-time automatic stratigraphic profiles after each push. A detailed overview of the ECPT measurement (neglecting additional geophysical or environmental modules such as LIF, resistivity, vertical seismics, Ground Penetrating Radar, etc.) is provided in Appendix A. LIF and the standard ECPT parameters will be collected simultaneously using the prototype LIF-ECPT probe.

Table 3. SUMMARY OF SITE TESTING AND FIELD ACTIVITIES

|                                               |                                           |
|-----------------------------------------------|-------------------------------------------|
| Geophysical Profiling in Overburden with ECPT | LIF Screening and Real-Time Analysis      |
| Soil Sampling                                 | Water Sampling/Water Level Determinations |
| Rock Drilling/Coring                          | Grouting                                  |
| Decontamination                               | Waste Management                          |
| Field GC/MS                                   | Analytical Lab                            |
| On-Site Analysis with 3-D Graphics            | Survey                                    |

Soil sampling, water sampling, rock drilling, grouting and decontamination procedures are discussed in the Sampling & Analysis Plan. Details of the chemical test parameters, analysis procedures and QA/QC are provided in Sampling & Analysis Plan as well. Regulatory compliance issues will be addressed through Beverly Allen, the Tinker AFB Directorate of Environmental Management on-site coordinator for the project. Surveys of push/boring locations will be made by ARA engineers at agreed upon sites. Digging permits for Tinker AFB require that a 2-week notification be made prior to any subsurface explorations. Waste management and pavement repair procedures will be coordinated with Beverly Allen as well.

Tinker AFB has outlined test locations within each study area. Table 2 sets up the site field program with anticipated field days at each test area, total locations at each test area, and various depths of interest. A summary table of cone penetrometer footage and drilling footage is also provided in the Sampling and Analysis Plan. The layout and depths are in basic agreement with the scope of work. In Table 2, the field time has been determined by assessing the anticipated site conditions. Actual site investigation work is dependent on the field conditions encountered. The total number of locations (130) are as suggested in the preliminary site location plans enclosed with the statement of work. The average depth to ground water and to competent sandstone are estimated from various available site information. The total depth has been assumed to be about 5 feet into the water table for most locations.

Most locations or stations will consist of several proximal push sites and/or a drill site. For example, a LIF-ECPT profiling push site and a cone penetrometer soil sampler push site may be horizontally offset from each other by 1 to 3 feet, but comprise one station location with

the test area. Alternatively, an LIF-ECPT profiling push may have a complementary drill hole. The locations of these sites have been recommended in the statement of work and reviewed by ARA personnel. Final locations, to be staked during preliminary survey work, will be solidified during the application of the Tinker AFB digging permits.

#### 4.0 DATA EVALUATION

Numerous types of data will be produced during the scope of this project, therefore data management will be important. The data is to be used to effectively make decisions in the field. For this reason both computing power and data management resources are necessary for this project. To satisfy these needs, a Silicon Graphics workstation, with a color monitor along with a color printer will be used to display the data produced. To handle the data, TECHBASE, a database program by Minesoft, Inc., will be used to store and organize the data. This program was selected because it has been developed to store geologic type data sets. TECHBASE offers some graphic capabilities, but to display the data with surface or volume rendering, Application Visualization Software scientific visualization software will be used. All software is designed to read data files from other sources, therefore reducing the amount of manual input required.

One of the objectives of this project is to demonstrate the ability to present data visually in the field so that better decisions are made regarding remedial or monitoring objectives. This will require various levels of analysis to be present in the field. Standard ECPT information (Tip, Sleeve, Pore Pressure measurements) will be plotted following each penetration test. This data will be further analyzed in the field to determine engineering properties, prior to entry into the database. The LIF intensity profiles and WTM information collected during the penetration process will be entered into the database system as well as on-site GC data and off-site laboratory data. Comparison between the LIF data and aromatic hydrocarbon analytical results will be made. The database and graphics system will be used to present all the data, including hardcopy of data and plots.

Results from the entire field demonstration program will be available in the final report which will be submitted prior to November 30, 1992. These data include volume renderings of LIF data, GC and other environmental data, soil stratigraphy, ground water table configuration, and site features. Two-dimensional contour plots, cross-sections and individual site plans for each test area will be produced as well.

## 5.0 WASTE MANAGEMENT

Three types of waste will be generated during the DT&E program:

1. Soil generated from auger drilling. Conventional drilling generates a substantial volume of cuttings compared to the sample volume. Being a minimally-invasive method, cone penetrometer testing does not produce drill cuttings.
2. Fluids resulting from the decontamination process and water sampling.
3. Decontamination and personnel protection equipment. Nearly all this equipment will be decontaminated and reused.

Solid waste management policy at Tinker AFB treats drill cuttings as potential hazardous material. Consequently, all drilling waste will be containerized in barrels, palletized as needed, and transported to a staging area for ultimate disposal. Representative solid waste samples for each area will be obtained by compositing the containerized waste. These samples will be chemically tested for toxicity using the Total Characteristic Leaching Procedure (TCLP). Grab samples from each site will also be composited and tested using TCLP. Based on the TCLP results, a qualified subcontractor will transport and dispose of the waste in accordance with local, state, EPA and Air Force regulations. Tinker AFB will be identified as the waste generator on the disposal manifest. The manifest will be signed with appropriate records maintained by Tinker AFB personnel.

Depending on the depth, waste generated from each drill hole will amount to about one 55-gallon barrel for the 7-5/8-inch diameter hollow-stem auger method or about 30 gallons using a 3-inch solid-stem auger. Most drilling will require the hollow-stem auger due to its preferred soil sampling capabilities. Therefore, approximately 50 barrels of solid waste are anticipated to be generated during the DT&E program.

Liquid wastes generated by water sampling and decontamination will also be collected in barrels, and stored in roll-off containers (mobile holding tanks) and transported to a staging area. This liquid waste will be treated as a single waste stream for characterization and disposal. Depending on the waste characterization results, USPCI's Lone Mountain facility in Oklahoma will be used for ultimate disposal and treatment.

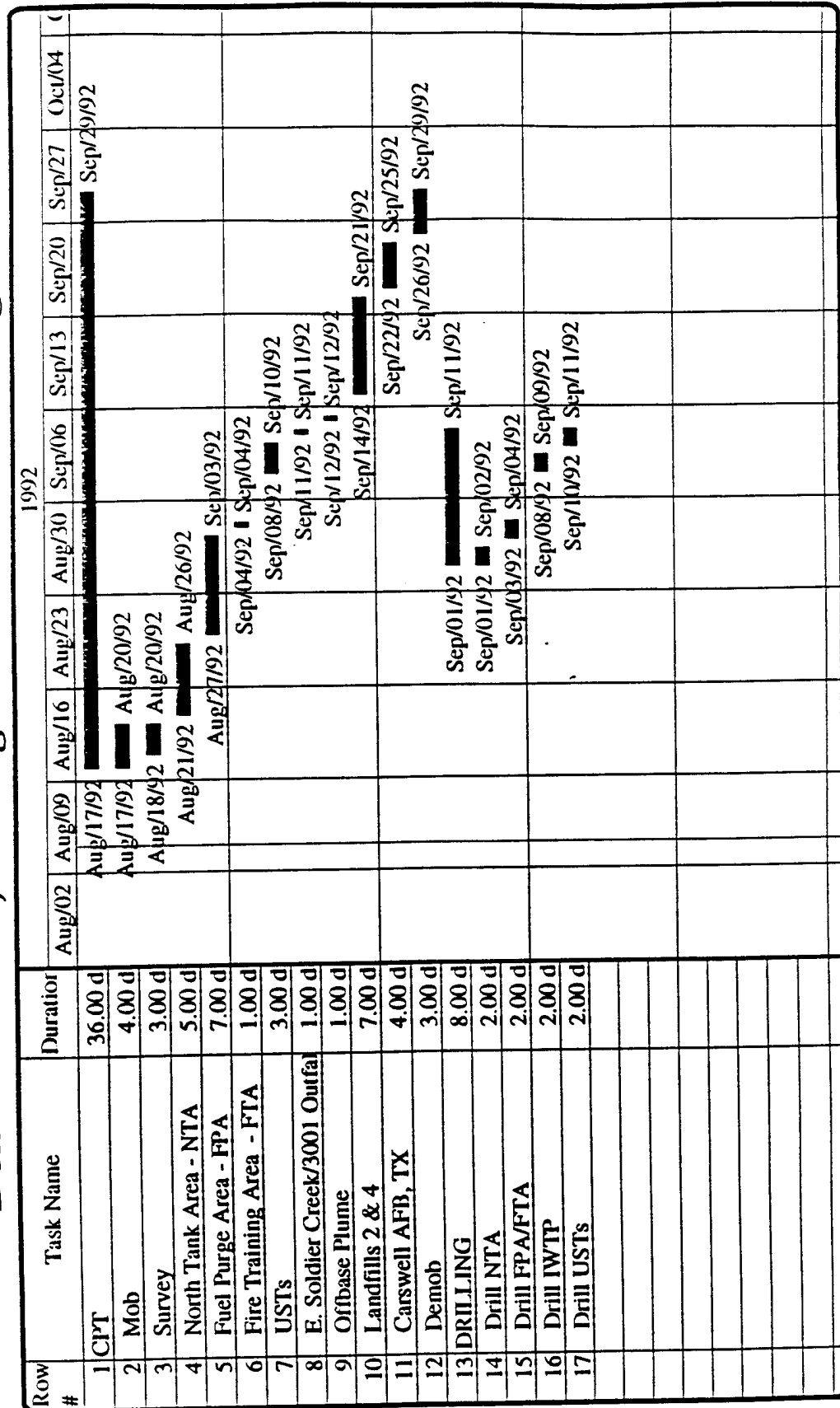
## 6.0 SCHEDULE

As shown in the cone penetrometer testing schedule (Figures 2 and 3), petroleum-contaminated sites will be addressed earlier in the field program to make efficient use of scheduled staff, including the NDSU group. The petroleum-contaminated sites, the Fuel Purge Area, North Tank Area, Fire Training Area, and the Underground Storage Tank Area (Four Fuel Site), comprise about half of the field time allotted for the DT&E. The baseline schedule is shown as shaded bars in the gantt chart (Figure 2). Summary tasks are (black bars), subtasks (indented), and milestones (triangles) for the entire project are also shown. Start and end dates for each task are illustrated at either end of the horizontal bars. The duration of each task, given in working days, is shown as well. A 60-hour work week has been assumed for the field program, excluding Labor Day weekend.

The drilling schedule has been broken out into a separate schedule with an estimated start date of September 1. The schedule will be modified on an as-needed basis in order to account for weather, equipment maintenance, and the subsurface conditions encountered.

# AFSCAPS SCHEDULE - TINKER AFB

## Demonstration, Testing and Evaluation Program



Printed: Aug/11/92  
Page 1

Figure 2. Schedule (GANTT chart).

Milestone Δ Summary

# AFSCAPS SCHEDULE - TINKER AFB

## Demonstration, Testing and Evaluation Program

August 1992

| Sun                   | Mon | Tue                   | Wed | Thu                   | Fri | Sat                   |
|-----------------------|-----|-----------------------|-----|-----------------------|-----|-----------------------|
|                       |     |                       |     |                       |     | 1                     |
| 2                     | 3   | 4                     | 5   | 6                     | 7   | 8                     |
| 9                     | 10  | 11                    | 12  | 13                    | 14  | 15                    |
| 16                    | 17  | 18                    | 19  | 20                    | 21  | 22                    |
|                       |     | Mob                   |     | Survey                |     | North Tank Area - NTA |
| 23                    | 24  | 25                    | 26  | 27                    | 28  | 29                    |
|                       |     | North Tank Area - NTA |     | Fuel Purge Area - FPA |     |                       |
| 30                    | 31  |                       |     |                       |     |                       |
| Fuel Purge Area - FPA |     |                       |     |                       |     |                       |

Printed: Aug/11/92  
Page 1

Figure 3a. Schedule (calendar).

## September 1992

Printed: Aug/11/92  
Page 2

Figure 3b. Schedule (calendar).

**APPENDIX A**  
**OVERVIEW**  
**OF THE**  
**ELECTRONIC CONE PENETROMETER TECHNIQUE**

## OVERVIEW OF ARA ELECTRIC CONE PENETROMETER TESTING

The electric cone penetrometer test (ECPT) was originally developed for use in soft soil. Over the years, cone and push system designs have evolved to the point where they can now be used in strong cemented soils and even soft rock. ARA's penetrometer consists of an instrumented probe which is forced into the ground using a hydraulic load frame mounted on a heavy truck with the weight of the truck providing the necessary reaction mass. The probe has a conical tip and a friction sleeve which measure vertical resistance beneath the tip and frictional resistance on the side of the probe, respectively. A schematic view of ARA's penetrometer probe is shown in Figure 1. A pressure transducer and porous filter are installed in the cone to measure pore water pressure as the probe is pushed into the ground (Piezo-ECPT).

### Electric Cone Penetrometer Test Equipment

Cone penetrometer tests are conducted inside a van. The penetrometer equipment is mounted inside the van body attached to a truck chassis. Ballast in the form of a tank, which can hold 4,000 lbs of water, are added to the truck to achieve an overall push capability in excess of 45,000 lbs. Penetration force is supplied by a pair of large hydraulic cylinders bolted to the truck frame.

The penetrometer probe has standard dimensions consisting of a 1.405-in diameter, 60° conical tip, and a 1.405-in diameter by 5.27 in long friction sleeve. The shoulder between the base of the tip and the porous filter is 0.08 in long. A 1.5 in expander, located 5.25 in behind the top of the friction sleeve and shown in Figure 3.1, pushes the penetration hole open and reduces the frictional drag on the push tubes behind the probe. The penetrometer is normally advanced vertically into the soil at a constant rate of 48 in/min, although this rate must sometimes be reduced as hard layers are encountered. The electric cone penetrometer test is conducted in accordance with ASTM D3441.

## AFSCAPS for Fuel-Contaminated Sites

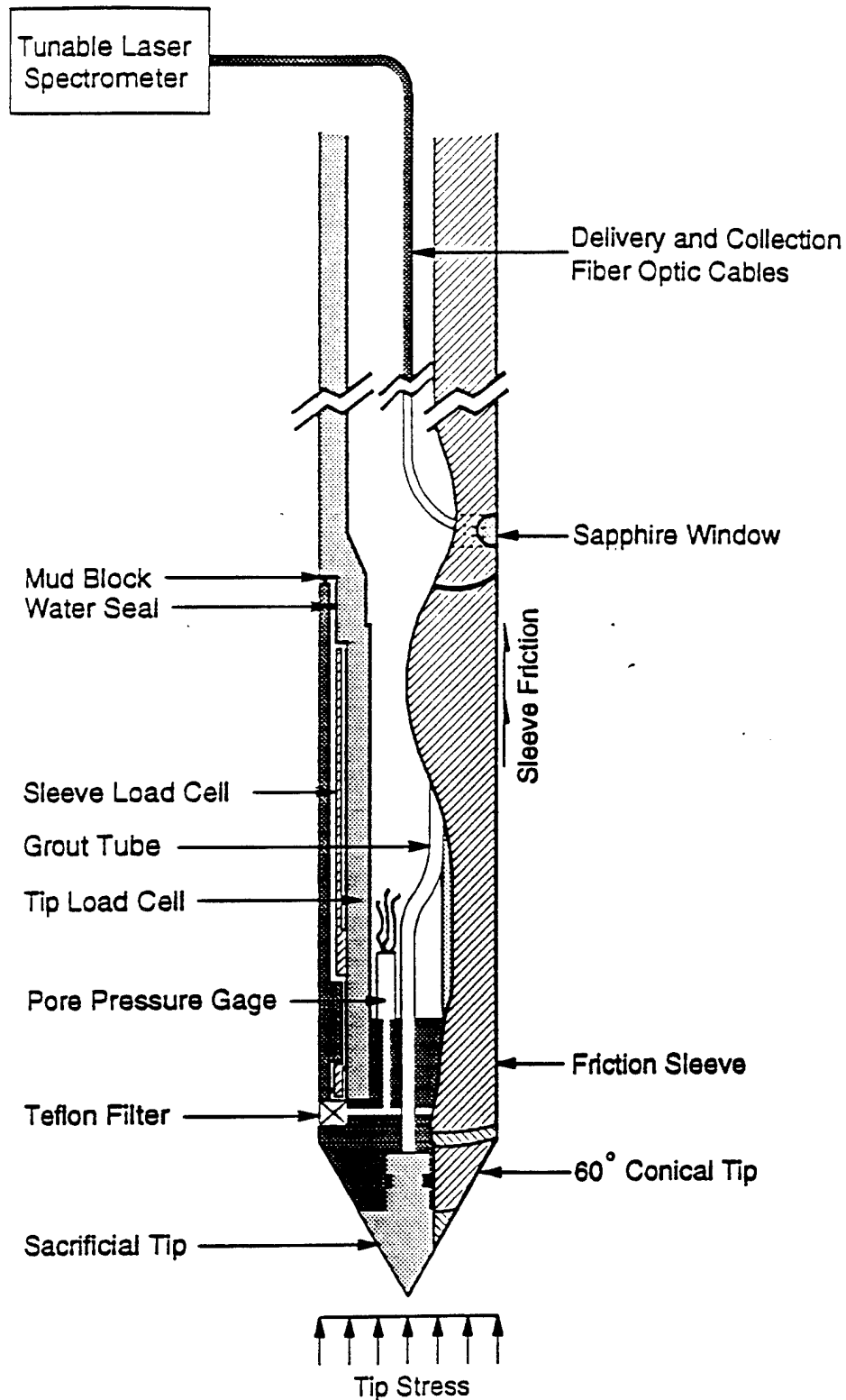


Figure 1. Schematic of LIF-ECPT Probe

Inside the probe, two load cells independently measure the vertical resistance against the conical tip and the side friction along the sleeve. Each load cell is a cylinder of uniform cross section inside the probe which is instrumented with four strain gages in a full-bridge circuit. Loads are measured with the load cells and the data are transmitted from the probe assembly via a cable running through the push tubes. The analog data are digitized, recorded, and plotted by computer in the penetrometer truck. A set of data is normally recorded each second, for a minimum resolution of about one data point every 0.8 in of cone advancement. The depth of penetration is measured using either a string potentiometer mounted on the push frame or a Tempsonic gage mounted inside one of the two push cylinders.

Electronic data acquisition equipment for the cone penetrometer consists of a 80486-based computer with a graphics monitor, an analog to digital converter board, and a rack of eight software programmable signal conditioners. Analog signals are transmitted from the probe to the signal conditioners where the data are amplified and filtered. Once amplified, the analog signals are transmitted to the high speed analog-to-digital converter, where the signals are digitized; usually at the rate of one sample per second. The digital data are then stored in memory and written to a magnetic disk for future processing. During and/or upon completion of the penetration, dissipation and seismic data are plotted.

### **Saturation of the Piezo-Cone**

As shown in Figure 1, penetration pore pressures are measured with a pressure transducer located behind the tip in the lower end of the probe. Water pressures in the soil are sensed through a 250  $\mu$ m porous polyethylene filter which is 0.25 in high and 0.202 in thick. The pressure transducer is connected to the porous filter through a pressure port. The pressure port and the filter are filled with a high viscosity silicone oil.

In order for the pressure transducer to respond rapidly and correctly to changing pore pressures during penetration, the filter and pressure port must be completely saturated with oil upon assembly of the probe. A vacuum pump is used to completely de-air the silicone oil before use and also to completely saturate the porous filters with oil. The probe is assembled with the pressure transducer up and the cavity above the pressure transducer filled with de-aired oil. A

previously saturated filter is then placed on a tip and oil is poured over the threads. When the cone tip is then screwed into place, excess oil is ejected through the pressure port and filter thereby forcing out any trapped air.

Complete saturation of the piezo cone is verified with field calibrations performed before the probe is inserted into the ground. The high viscosity of the silicone oil coupled with the small pore space in the filter prevents the loss of saturation as the cone is pushed through dry soils. Saturation of the cone can be verified with a calibration check at the completion of the penetration. Extensive field experience has proven the reliability of this technique with no known case where saturation of the cone was lost.

### **Penetration Data Format**

A typical penetration profile is shown in Figure 2. Tip resistance, sleeve friction, and pore pressure are plotted as a function of elevation. Friction ratio (sleeve/tip stress) and hydrostatic pore pressure are also displayed. When the surface elevation of the test location is unknown, the penetration data is plotted against depth. Pore pressure dissipation tests, when performed, are indicated on the penetration profile with a small circle at the lowest recorded pressure.

Tip resistance,  $q_t$  (lb/in<sup>2</sup>), is obtained by dividing the vertical force on the conical tip by the effective tip area (1.550 in<sup>2</sup>). The tip resistance is then corrected for pore pressures acting behind the conical tip as discussed in the next section. Corrected tip resistance,  $q_{tr}$  (lb/in<sup>2</sup>), is plotted in the penetration profile. Sleeve friction,  $f_s$  (lb/in<sup>2</sup>), is obtained by dividing the total frictional force on the sleeve by the sleeve's surface area (23.26 in<sup>2</sup>). The offset between the depth at the tip and the depth at the friction sleeve is corrected by shifting the sleeve friction profile downward so that it corresponds to the depth at the centroid of the tip. A friction ratio is simply the sleeve friction expressed as a percentage of the tip resistance. In uncemented soils, the friction ratio can be used to determine soil type.

P-ECPT1 Applied Research Associates, Inc.  
 North 234.75 ft. East 298.87 ft. Elevation 100.00 ft.

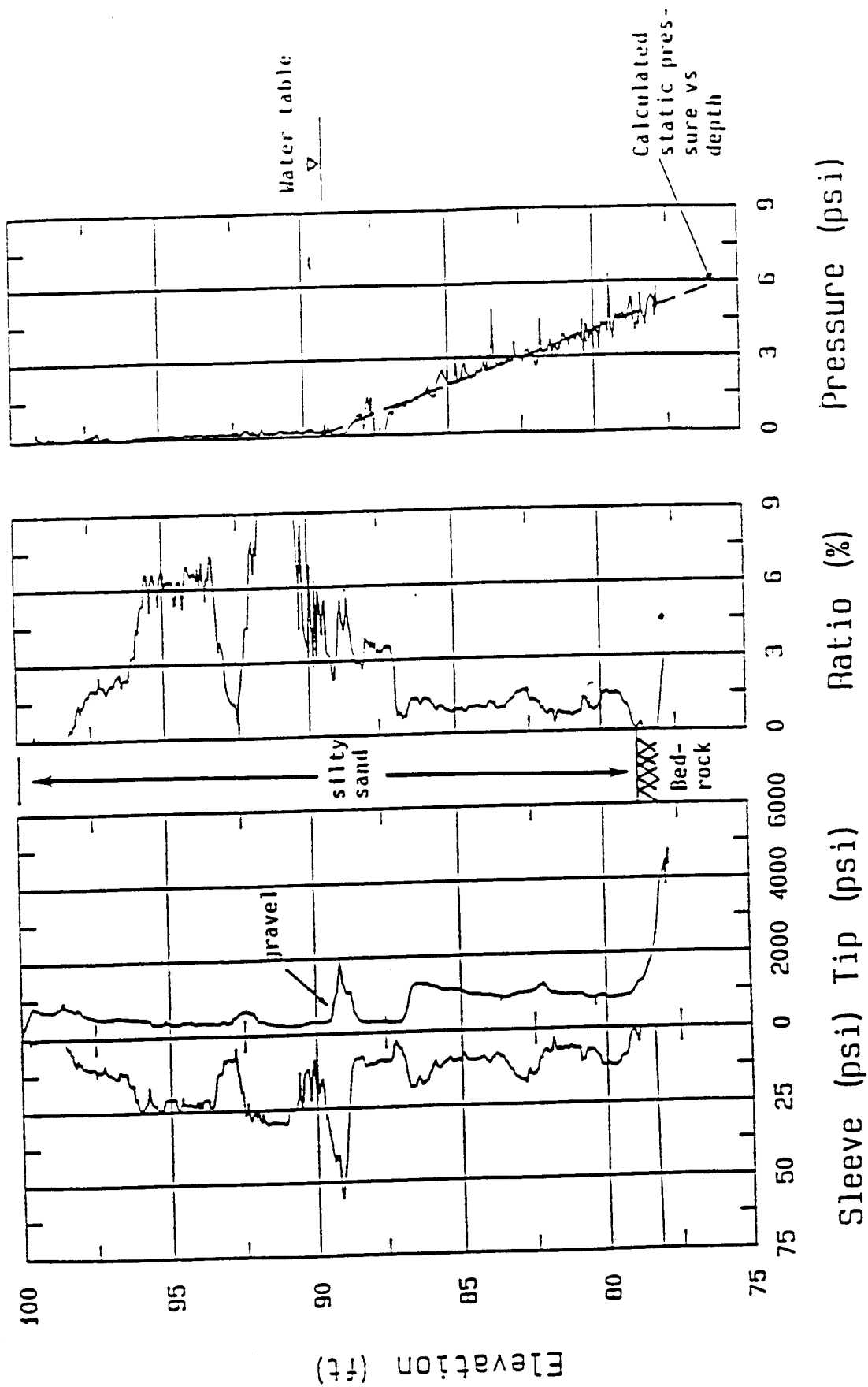


Figure 2. Typical piezocone penetration data for a silty-sand over bedrock site.

Pore pressure is measured as the probe is advanced. ARA has chosen to locate the pore pressure sensor behind the tip as the filter is protected from the direct thrust of the penetrometer. In this position, the measured pore pressure can be used to correct the tip resistance data (see next section). The magnitude of the penetration pore pressure is a function of the soil compressibility and, most importantly, permeability. In freely draining soil layers, the measured pore pressures will be very close to the hydrostatic pressure computed from the elevation of the water table. The hydrostatic pressure line, computed from the water table, is identified on Figure 2. When low permeability soil layers are encountered, excess pore pressures generated by the penetration process can not dissipate rapidly, resulting in measured pore pressures which are significantly higher than the hydrostatic pressures. Whenever penetration is stopped to add another section of push tube, or to run a pore pressure dissipation test, the excess pore pressure dissipates. When the penetration is resumed, the pore pressure normally rises to the level measured before the penetrometer was stopped. This process causes some of the spikes that may appear in the penetration pore pressure data.

### Pore Pressure Correction of Tip Stress

Cone penetrometers, by necessity, must have a joint between the tip and sleeve. Pore pressure acting behind the tip decreases the total tip resistance that would be measured if the penetrometer was without joints. The influence of pore pressure in these joints is compensated for by using the net area concept. The corrected tip resistance is given by:

$$q_T = q_c + u \left[ 1 - \frac{A_n}{A_T} \right] \quad (1)$$

where:

$q_T$  = corrected tip resistance

$q_c$  = measured tip resistance

$u$  = penetration pore pressure measured behind the tip

$A_n$  = net area behind the tip not subjected to the pore pressure (1.257 in<sup>2</sup>)

$A_T$  = projected area (1.550 in<sup>2</sup>).

Tip resistance for the ARA cone design is corrected as:

$$q_T = q_c + u(.1890) \quad (2)$$

Laboratory calibrations have verified Equation 2 for ARA's piezo-cone design.

A joint also exists behind the top of the sleeve (see Figure 1). However, since the sleeve is designed to have the same cross sectional area on both ends, the pore pressures acting on the sleeve cancel out. Thus, no correction for pore pressure is needed for the sleeve friction data. The net effect of applying the pore pressure correction is to increase the tip resistance and to decrease the friction ratio. Generally, this correction is only significant when the measured tip resistance is very low.

### Numerical Editing of the Penetration Data

Any time that the cone penetrometer is stopped or pulled back during a test, misleading data can result. For instance, when the probe is stopped excess pore pressures will dissipate towards the hydrostatic pore pressure. When the penetration is resumed, pore pressure generally rises very quickly to pressures experienced prior to the pause in the test. Additionally, the probe is sometimes pulled back and cycled up and down at intervals to reduce soil friction on the push tubes. This results in erroneous tip stress data when the cone is advanced in the previously penetrated hole.

To eliminate this misleading data from the penetration profile, the data is automatically edited before it is plotted or used in further analysis. Anytime the penetrometer stops or backs up, as apparent from the depth data, the penetration data is not plotted. Plotting of successive data is resumed only after the tip is fully re-engaged in the soil by one tip length (1.22 in) of new penetration. This algorithm also eliminates any data acquired at the ground surface before the tip has been completely inserted into the ground. The sleeve data is similarly treated and this results in the first data point not occurring at the ground surface. Using these procedures, penetration data which is plotted and used for analysis is ensured to have been acquired as the

probe has advanced fully into undisturbed soil.

### Pore Pressure Dissipation Tests

At selected depths, the penetration may be stopped to observe dissipation of excess pore pressure. Pore pressures, as sensed by the pressure transducer, are recorded at regular time intervals (typically 1 sample/second, but the sample rate can be adjusted for local site conditions) and plotted on the graphics monitor. Dissipation tests are usually run until at least 50 percent of the excess pore pressure is dissipated. This length of time,  $t_{50}$ , can be used to determine the lateral coefficient of consolidation and permeability in the given soil layer. Depending on site conditions,  $t_{50}$ , can range from a few minutes to several hours. These tests may also be run to more accurately measure hydrostatic pore pressure.

A classic dissipation profile in a clay soil is shown in Figure 3. Total pore pressure is presented versus time on a semi-log plot. The classic dissipation curve will show a dissipation rate that decreases with time. If the dissipation test is allowed to run long enough, the static pore pressure will eventually be reached. The value of  $P_a$  at the top of Figure 3 is the average of the last ten pore pressure measurements. If the dissipation test is sufficiently long,  $P_a$  will be equal to the static pore pressure. This value can also be determined from the water table elevation at some sites. Knowing the static pore pressure ( $u_o$ ), as well as the peak pressure observed during the test ( $u_p$ ), the pore pressure at 50 percent of dissipation ( $u_{50}$ ) can be determined. As indicated on Figure 6,  $t_{50}$  can then be read directly from the dissipation profile.

Locations of each pore pressure dissipation test are indicated by plotting the  $P_a$  values on the penetration profile as shown in Figure 2.

PC1EP60      Applied Research Associates Inc.      09/23/88  
 Depth 60.00 Ft.      Pn 23.69 psi

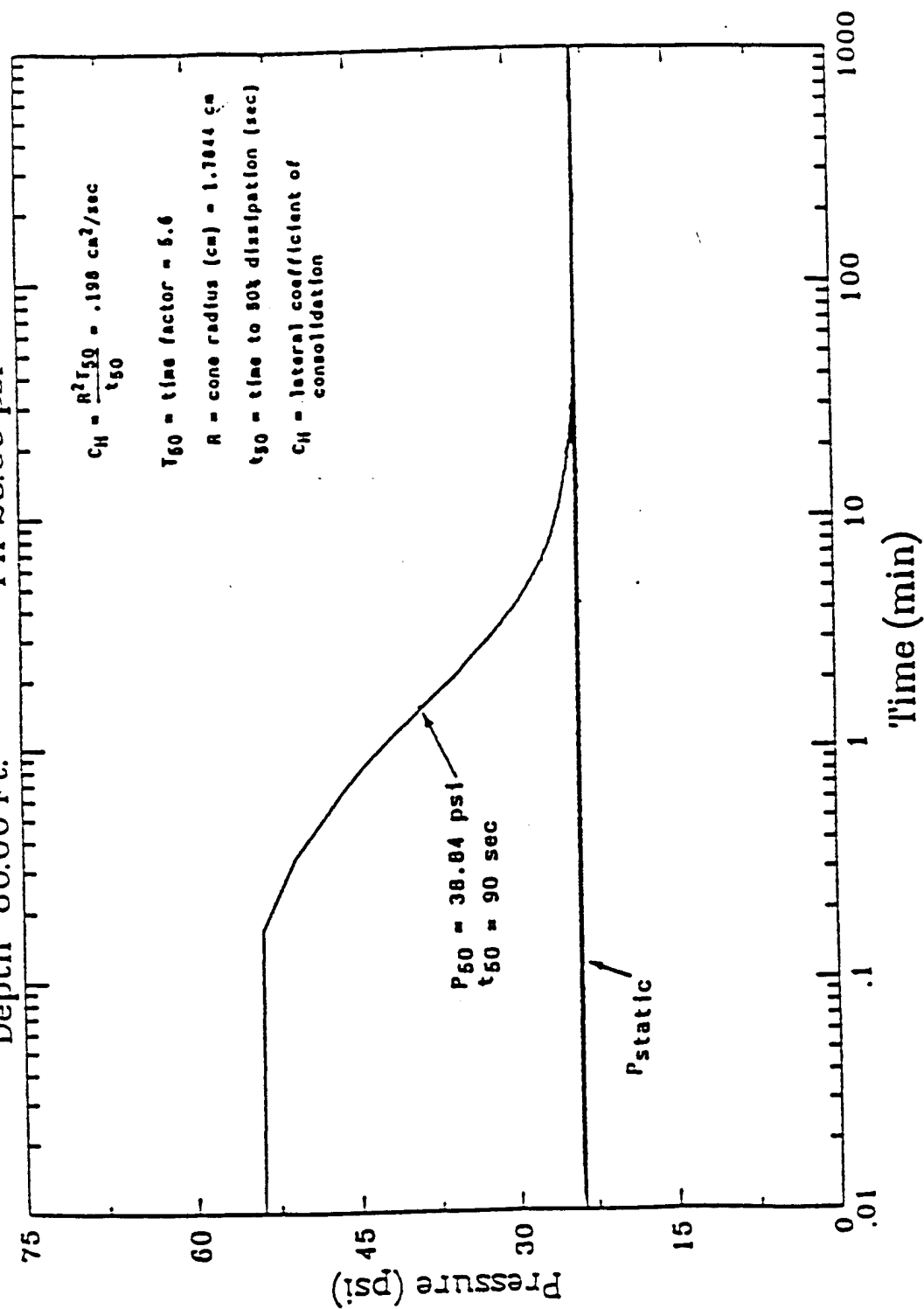


Figure 3. Piezo-cone dissipation test in a silty sand.

## **APPENDIX M**

### **SAMPLING AND ANALYSIS PLAN FOR THE AFSCAPS DEMONSTRATION, TEST AND EVALUATION PROGRAM AT TINKER AFB**

**SAMPLING AND ANALYSIS PLAN  
FOR THE  
AFSCAPS DEMONSTRATION, TEST AND EVALUATION PROGRAM  
AT  
TINKER AIR FORCE BASE**

**Submitted to:**

**OKLAHOMA CITY AIR LOGISTICS COMMAND  
DIRECTORATE OF ENVIRONMENTAL MANAGEMENT  
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**ARA Project Number 5735**

**July 20, 1992**

**Revised  
August 17, 1992**

# SAMPLING AND ANALYSIS PLAN

## Table of Contents

| Section                                                     | Page |
|-------------------------------------------------------------|------|
| 1.0 PURPOSE . . . . .                                       | 1    |
| 2.0 INTRODUCTION . . . . .                                  | 1    |
| 3.0 GENERAL SAMPLING METHODS AND FIELD PROCEDURES . . . . . | 4    |
| 3.1 Cone Penetrometer Profiles and Sampling . . . . .       | 4    |
| 3.2 Hollow-Stem Auger Drilling . . . . .                    | 4    |
| 3.3 Field QC Soil Samples . . . . .                         | 5    |
| 3.4 Ground Water Sample Collection Procedure . . . . .      | 6    |
| 3.5 Sample Containers and Sample Preservation . . . . .     | 7    |
| 3.6 Sample Identification and Transport Custody . . . . .   | 8    |
| 3.6.1 Sample Identification . . . . .                       | 8    |
| 3.6.2 Sample Custody . . . . .                              | 9    |
| 3.6.3 Sample Transport . . . . .                            | 10   |
| 3.7 Equipment Decontamination . . . . .                     | 10   |
| 4.0 ON-SITE GAS CHROMATOGRAPH ANALYSIS . . . . .            | 11   |
| 4.1 Sample Preparation and Handling . . . . .               | 12   |
| 4.2 Aromatic Hydrocarbon Analysis . . . . .                 | 13   |
| 4.3 Chlorinated Hydrocarbon Analysis . . . . .              | 14   |
| 4.4 QA/QC . . . . .                                         | 14   |
| 5.0 OFF-SITE ANALYTICAL PROCEDURES . . . . .                | 15   |

## Appendices

|            |                                       |
|------------|---------------------------------------|
| Appendix A | Standard Operating Procedures         |
| Appendix B | Off-Site Laboratory QA/QC Information |

## SAMPLING AND ANALYSIS PLAN

### List of Tables

|                                                              | Page |
|--------------------------------------------------------------|------|
| Table 1. Tinker AFB cone push/boring test matrix . . . . .   | 2    |
| Table 2. Tinker AFB chemical analysis matrix . . . . .       | 3    |
| Table 3. Contained types for analytical procedures . . . . . | 7    |
| Table 4. Tinker AFB field chemical testing matrix . . . . .  | 12   |

## 1.0 PURPOSE

The purpose of this Sampling and Analysis Plan is to define appropriate field procedures and quality control measures to be implemented during the Air Force Site Characterization and Analysis Penetrometer System (AFSCAPS) Demonstration, Testing and Evaluation (DT&E) Program at Tinker Air Force Base (AFB). As discussed in the companion Work Plan, the DT&E program has two main objectives. One is to test and demonstrate the feasibility of using the in situ Laser-Induced Fluorescence (LIF) probe to detect the nature and extent of petroleum-contaminated soils. The second is to perform subsurface investigations and soil and ground water sampling to analyze volatile organic compounds (VOCs) and other contaminants.

This document provides guidance for sampling and associated activities which are required to meet the second program objective. Included in the Sampling and Analysis Plan are details regarding sample collection and handling methods, field procedures, and analytical methods to be implemented for on-site and off-site chemical testing. General procedures for operation of the LIF-Electronic Cone Penetrometer Test LIF-ECPT are also provided.

## 2.0 INTRODUCTION

The DT&E program addresses subsurface conditions and contamination at 8 sites located at Tinker AFB. As discussed in the Work Plan, the sites, designated as areas, are located along the perimeter of the airfield in the vicinity of various fuel storage, waste management facilities, or suspected contaminant sources. The North Tank Area is located adjacent to the northern end of Building 3001. The Four Fuels Area is located in a highly-developed area north of the airfield. Landfills 2 & 4 Area and the current Fire Training Area are sites located in undeveloped areas to the southwest of the airfield. The Fuel Purge Area is a 5-acre area located at the southeast corner of the airfield. The Industrial Wastewater Treatment Plant (IWTP) Area and the Building 3001 Outfall/E. Soldier Creek Area are located east of Building 3001. The Offbase Area, which lies north of Building 3001 and the IWTP, consists of several abandoned residential lots.

The sampling objectives and effort at each site have been outlined within the project statement of work (SOW) prepared by the Directorate of Environmental Management at Tinker AFB and the Air Force Civil Engineering Support Agency (AFCESA). The test areas have from 8 to 35 test locations planned, with recommended individual locations provided in the SOW. Most locations involve subsurface profiling using the LIF-ECPT probe, soil sampling, or ground water sampling, or a combination thereof. Table 1 presents a summary of the subsurface activities for the AFSCAPS project.

Table 1. TINKER AFB CONE PUSH/BORING TEST MATRIX

| Test Area          | ECPT Push Sites |        | Soil Sample Locations |        | Drilling Sites* |        | Water Sampling Sites |
|--------------------|-----------------|--------|-----------------------|--------|-----------------|--------|----------------------|
|                    | No.             | T. Ft. | No.                   | T. Ft. | No.             | T. Ft. | No.                  |
| North Tank         | 12              | 120    | 12                    | 180    | 6               | 120    | 12                   |
| Fuel Purge         | 35              | 420    | 14                    | 210    | 6               | 120    | 6                    |
| Fire Training      | 8               | 96     | 4                     | 60     | 1               | 20     | 1                    |
| USTs (4 Fuel)      | 15              | 180    | 8                     | 120    | 8               | 120    | 15                   |
| IWTP               | 10              | 60     | 0                     | 0      | 10              | 180    | 10                   |
| Bldg. 3001 Outfall | 8               | 60     | 8                     | 60     | 0               | 0      | 2                    |
| Offbase            | 2               | 20     | 8                     | 80     | 0               | 0      | 0                    |
| Landfill 2&4       | 32              | 480    | 26                    | 780    | 0               | 0      | 32                   |
| Totals             | 122             | 1,436  | 80                    | 1,490  | 31              | 560    | 78                   |

\* Drilling sites contingent on subsurface conditions.

Both on-site and off-site analytical testing will define contaminant levels due to POLs, halogenated VOCs, metals and other compounds. Table 2 provides a summary of chemical testing to be performed at Tinker AFB.

ARA's mobile environmental laboratory will use gas chromatography to assess the level of targeted VOCs at each site. Over 300 samples will be analyzed using the on-site laboratory. A certified laboratory will perform confirmatory VOCs, using EPA GC/MS methods, in addition to Total Petroleum Hydrocarbon (TPH) testing, semi-volatiles analyses, and metals analyses. TCLP testing will be conducted for waste management purposes.

Table 2. TINKER AFB CHEMICAL ANALYSIS MATRIX

| Test Area          | Water VOA Samples <sup>a</sup> | Soil VOA Samples <sup>b</sup> | Soil Suite A <sup>c</sup> | Soil Suite B <sup>d</sup> | TCLP <sup>e</sup> | LIF Profiles |
|--------------------|--------------------------------|-------------------------------|---------------------------|---------------------------|-------------------|--------------|
| North Tank         | 12                             | 3/12                          | 12                        | —                         | 2                 | 12           |
| Fuel Purge         | 6                              | 42/8                          | 14                        | —                         | 2                 | 35           |
| Fire Training      | 1                              | 13/3                          | 4                         | —                         | 2                 | 8            |
| USTs (4 Fuel)      | 15                             | 24/5                          | 5                         | 3 <sup>41</sup>           | 2                 | 15           |
| IWTP               | 10                             | 10/2                          | —                         | 10                        | 2                 | 10           |
| Bldg. 3001 Outfall | 2                              | 8/2                           | —                         | 8 <sup>42</sup>           | 2                 | 8            |
| Offbase            | 0                              | 17/3                          | —                         | 8                         | 2                 | 2            |
| Landfill 2&4       | 32 <sup>41</sup>               | 84/17                         | —                         | 22 <sup>43</sup>          | 4                 | 32           |
| Total              | 78                             | 201/52                        | 35                        | 51                        | 18                | 122          |

Notes: <sup>a</sup> Volatile organic analyses (VOA) are performed in the field using GC and modified EPA methods 601/602 to scan the site-specific target compounds. Twenty percent of the water samples (19 samples) will be duplicate samples analyzed at a certified laboratory using GC/MS and EPA Method 8240.

<sup>41</sup> Eight methane samples to be analyzed by EPA RSKERL.

<sup>b</sup> X/Y - X: Soil VOA performed in the field using modified EPA method 601/602 to scan the site-specific target compounds. Y: Soil VOA analyses by a certified laboratory using EPA method 8240. Lab and field VOA include 20 percent splits.

<sup>c</sup> Suite A Parameters: TPH (EPA method 418.1), T. Phenols, and PAHs (HPLC method for selected compounds). Several splits for PAHs/Phenols will be performed using EPA method 8270 for the GC/MS.

<sup>d</sup> Suite B Parameters: T. Metals (Cd, Cr, Ba, Pb, Zn, As, Hg, Ni), T. Phenols, and PAHs (GC/MS method with Base/Neutral extraction).

<sup>41</sup> Bldg. 201 sites only.

<sup>42</sup> No PAHs tested.

<sup>43</sup> Two analyses for  $\alpha$  and  $\beta$  radiation to be performed.

<sup>e</sup> TCLP tests for metals, volatiles and semi-volatiles performed on both grab and composite soil samples.

### **3.0 GENERAL SAMPLING METHODS AND FIELD PROCEDURES**

#### **3.1 Cone Penetrometer Profiles and Sampling**

The LIF-ECPT probe will essentially measure LIF intensity with depth and serves as in situ screening device for petroleum contaminants. The LIF-ECPT probe will obtain standard tip stress, sleeve stress, and pore pressure data profiles and allow automatic generation of subsurface stratigraphic sections. Seismic and resistivity modules for ECPT are also available but are not particularly applicable for this DT&E. The LIF-ECPT probe is self-grouting and seals the small diameter (1.75-inch) penetrometer hole with cement grout as the probe is withdrawn from the hole (see Appendix A).

Cone penetrometry will serve as the main platform for sampling and analysis. General procedures for operation of the LIF-ECPT probe, soil sampling, water sampling and grouting are provided in Appendix A. For cone penetrometer locations, soil samples will generally be collected every 5 feet using cone samplers. Two similar cone samplers are used: 1) a Gouda sampler and a MOSTAP-36® sampler. The MOSTAP-36® or AP sampler is capable of obtaining 20-inch samplers yielding 500 grams of relatively undisturbed soil samples. The Gouda sampler, as described in Appendix A, obtains a 1-foot sample.

#### **3.2 Hollow-Stem Auger Drilling**

Cone penetrometer sampling will be supplemented by drilling methods in order to obtain deeper required subsurface samples. Although the cone penetrometer has "soft rock" penetration capability, a thin but resistant sandstone layer offers refusal to the cone penetrometer as well as traditional auger drilling techniques. The depth to this layer is estimated to be 5 to 12 feet across Tinker AFB. For sites where high quality soil samples are required, a modified hollow-stem auger with a bearing-head sample tube system will be used to sample below the sandstone to depths of 20 to 25 feet. The hollow-stem auger drilling protocol is as follows:

- An experienced drilling subcontractor with knowledge of local geologic conditions will be selected.

- The rig and the hollow-stem augers will be decontaminated using a steam cleaner prior to drilling each borehole. Steam cleaning will be performed at a location designated by the base Point of Contact.
- A hydraulically or mechanically powered drill rig which simultaneously rotates and axially advances a hollow-stem auger column will be used. Each of the joints between auger sections will be properly connected to prevent contaminants from entering the auger.
- A continuous sampler consisting of a 5-foot split barrel contained within the drilling auger will be used to collect soil samples for lithologic and chemical analyses. During drilling, the sampler advances with the head of the auger and will be retrieved at 5-foot intervals, allowing the collection of 5-foot sections of continuous soil cores.
- After retrieval, the sampler will be opened and the soil core scanned to obtain an organic vapor measurement using an HNu instrument. This enables the sampler to collect a sample as quickly as possible in order to minimize volatilization. The contents of the sampler will be logged by the on-site geologist and lithologic observations recorded on the Boring Log Form. When a soil sample is to be taken, logging will be done following sample collection.
- In addition to completing the Boring Log Form for each boring, the on-site geologist will maintain a Field Logbook which will document the following: day, date, time entered site, temperature, weather conditions, names and titles of personnel present, names and titles of any visitors on site; arrival time of driller and other subcontractors, feet drilled, materials used, equipment used, calibration, date, references to the Boring Logs, decontamination iterations, and any potential problem areas or incidents. The entries into the logbook will be signed by the on-site geologist.
- After water samples are retrieved (see below), each borehole will be grouted to the surface with cement, and the horizontal and vertical location of each borehole will be surveyed using a local control point or baseline.

For sites where only water samples are needed, a 4.5-inch diameter solid stem auger will be used. Decontamination and grouting procedures for solid-stem auguring will be as described above for THE hollow-stem augering.

### 3.3 Field QC Soil Samples

Field Duplicate Samples: Twenty (20) percent of the soil samples collected for volatile organic analyses (VOA) shall be field duplicate samples. Duplicate samples will consist of submitting

adjacent samples from the same soil core to both the mobile GC and the certified laboratory. The two samples shall be recorded in the logbook as a sample and a duplicate sample.

Trip Blanks: One field trip blank will be submitted with every cooler shipment of regular samples. A trip blank is a VOC sample bottle filled in the laboratory with distilled water, transported to the site, handled like a sample, and returned to the laboratory for analysis. Trip blanks shall not be opened in the field. Trip blanks to the certified laboratory will be analyzed by EPA Method 8240. Since trip blanks are used to analyze sample handling and shipping methods for contamination sources, the same type of trip blank is used for all sample types.

Rinsate Blanks: One rinsate or equipment blank will be submitted for every twenty regular samples collected. A rinsate blank will be prepared by pouring distilled water through a decontaminated sampling device, in this case a cone soil sampler or a CME continuous sampler. Rinsate blanks will be analyzed for the same analyses required for regular samples.

### **3.4 Ground Water Sample Collection Procedure**

Ground water sampling using the cone penetrometer is performed with ARA's water sampler and bailer. Alternatively, CPT and auger holes may have temporary PVC wells installed so that bailed samples may be retrieved. Only clean, decontaminated PVC screen and riser will be used. CPT and auger holes may be allowed to recharge overnight in situations where low permeability water-table formations are encountered. Since no long-term monitoring wells are to be installed, all holes will have any PVC material removed and will be grouted with a cement mixture using a tremmie pipe.

Before a hole is sampled the water level of the well will be measured and recorded. The measurement reference point will be the approximate undisturbed ground surface. These measurements will assist in evaluating the ground-water flow patterns in the site area and in estimating the volume of water that needs to be purged from the borehole prior to sampling. Using the water level data and known dimensions of each well, an estimate of the volume of standing water in each well will be calculated. At a minimum, one well volume will be purged

from each borehole prior to sampling.

Samples will be withdrawn by use of thoroughly decontaminated Teflon or PVC bailers. Where appropriate, samples will be placed directly into pre-labeled sample containers. Sampling at Landfills 2 and 4 will be coordinated with Don Kampbell of EPA-RSKER2, Ada, OK for analysis of dissolved methane.

Upon completion of sampling at each monitoring location, the chain-of-custody document will be completed (see below).

### 3.5 Sample Containers and Sample Preservation

All containers will be acquired from a vendor(s) that use decontamination procedures consistent with EPA protocols. Table 3 contains minimum volume requirements and bottle types required for each sample type. One quart containers with teflon liners will be sufficient for most soil samples.

Table 3. Container types for analytical procedures.

| Parameter      | Liquids       | Solids     |
|----------------|---------------|------------|
| Semi-Volatiles | N/A           | 1 L (G)    |
| Volatiles      | (2) 40 ml (G) | 5 g (G)    |
| Metals         | N/A           | 10 g (P)   |
| TCLP           | N/A           | 200 g (G)  |
| Phenols        | N/A           | 500 ml (G) |

All samples will be cooled to 4°C  
(G) Glass Container  
(P) Polyethylene Container

After samples are containerized, they will be cooled to 4°C. Chemical preservation will be performed upon acceptance by the laboratory as required. For most soil situations involving VOA, the soil sampling tube will be delivered directly to the lab. This will minimize loss of volatiles due to sample handling.

## 3.6 Sample Identification and Transport Custody

### 3.6.1 Sample Identification

At a minimum, the following information will be included on each sample label and on the chain of custody:

- Site Name (e.g., North Tank Area, Tinker AFB)
- Field sample identification number (see below)
- Date and time of sample collection
- Desired methods of analysis
- Sampler's initials

Sample labels will be waterproof, written with indelible ink, and secured to the sample container with clear acetate tape. QC samples will only be logged in the field notebooks and not on the sample labels. This will ensure that the laboratory does not know which of the samples are QC samples.

Each sample will be identified by a unique field sample identification number which indicates the site name, sampling station, sample type, and sequence number. An example of the sample identification number is as follows:

NTA-C01-SS-01

The three place alpha-numeric code NTA, is used to identify samples collected from the North Tank Area. The field chemical testing matrix summary table (Table 4) lists codes for the other sites.

The next alpha-numeric code, C01, is used to identify the station location where a sample was collected. Samples collected from the cone penetrometer sample and boring sample are identified by a C and B code, respectively. Note that a location may have more than one station, as a station may consist of several push or boring sites offset 1-foot from each other.

The two-letter designation SS will be used to identify the specific type of sample collected. The sample types to be collected include:

- GW - Ground water samples
- SS - Subsurface soil sample

The final sample identification code, 01, is used to distinguish separate samples collected at the same station, such as at different depth intervals (for soil samples), time intervals, or duplicate samples.

The sampling station, sample type, and sample sequence codes will be established prior to field activities. The sample identification code for each sample will be recorded in a field logbook, along with other appropriate information, at the time the sample is collected.

### 3.6.2 Sample Custody

Sample custody will begin, in all cases, at the time of sample collection. The sampler will complete the sample chain-of-custody as follows:

1. Enter the complete ARA project number.
2. Enter the project name: AFSCAPS - Tinker AFB.
3. Identify the person(s) who participated in the collection of the samples (signature and printed).
4. Enter the date of sample collection. If sample is a composite, list both start and finish dates.
5. Enter actual time of sample collection. If sample is a composite, list start and finish times.
6. Indicate with a check mark whether the sample is a composite or a grab.
7. Enter a description of the sample location.
8. Enter the actual number of sample bottles to be submitted to the laboratory.
9. List the parameters to be analyzed for the particular sample.

Upon completion of all line items, the field sample custodian will sign, date, list time, and confirm completeness of all descriptive information contained on the form. A copy of the chain-of-custody form will be retained by the field sample custodian for the project files. All samples will be accompanied by a chain-of-custody form. Each individual who subsequently assumes responsibility for the samples will sign, and note the time and date on the chain-of-custody form. The field chain-of-custody terminates upon laboratory receipt of the samples.

### **3.6.3 Sample Transport**

Samples will be placed in a cooler with bagged ice for transfer to the certified laboratory or on-site GC lab.

For the off-site lab, one cooler in each shipment will contain the chain-of-custody forms for that shipment. All coolers will have custody seals to indicate unauthorized opening prior to official receipt of the samples. Packing materials (styrofoam, cardboard) plus a common sense arrangement of plastic and glass will be used to prevent glass breakage during shipment. All coolers are sealed using fiberglass packing tape. Samples will be shipped at least every other day by priority one (next day) delivery or pick-up directly by the lab.

### **3.7 Equipment Decontamination**

In order to minimize the risk of exposure to hazardous substances and ensure the collection of representative samples, all sampling and drilling equipment will be decontaminated prior to the field activities at a designated decon pad. The decon pad will consist of plastic sheeting.

All non-disposable equipment such as samplers, bailers, scoops, reusable PVC casing, wash buckets, etc. will be decontaminated using the following sequence:

1. Rinse with tap water
2. Wash in non-phosphate soap
3. Rinse with tap water
4. Rinse with a 1:1 mix of reagent-grade methanol and distilled water
5. Rinse twice with distilled water

6. Air dry for at least 5-10 minutes before reuse.

Decontamination of equipment will not be necessary between locations when collecting individual and grab samples for a composite.

Gross contamination on the drilling equipment will be removed at the work site prior to its transfer to the decontamination pad. Equipment will be decontaminated by steam-cleaning with a solution of hot water and approved detergent, rinsing with clear water, and allowing to air dry for not less than 10 minutes. Additional cleaning will be performed if the equipment appears to have residual contamination.

The cone penetrometer rods and probes are decontaminated by pressurized washing with a steam cleaner. Cleaning is to be performed as the rods are extracted from the ground with steam nozzles located beneath the CPT vehicle. Spray from the rod steam cleaner is collected within a self-contained unit and drains to a container via a hose. All rinsate will be disposed of as contaminated liquid waste (see Work Plan).

#### **4.0 ON-SITE GAS CHROMATOGRAPH ANALYSIS**

The on-site gas chromatograph analysis will consist of two separate types of purge and trap analyses. At the fuel contaminated sites, aromatic hydrocarbons will be analyzed. All water and soil samples from these sites will be analyzed for Benzene, Toluene, Ethylbenzene, and Total Xylenes (BTEX) and for Naphthalene and 2- Methylnaphthalene (representative polynuclear aromatic hydrocarbons, PAHs). At the other locations, samples will be analyzed for Methylene Chloride, Trichloroethylene (TCE), and TCE's biodegradation by-products: 1,1,1 Trichloroethane, 1,2 Dichloroethane, and 1,1 Dichloroethene. The North Tank Area and Four Fuels Site (USTs) will have both hydrocarbon suites tested, as shown in Table 4.

**Table 4. TINKER AFB FIELD CHEMICAL TESTING MATRIX**

| Test Area          | Label   | Aromatic Hydrocarbon Analysis | Chlorinated Hydrocarbon Analysis |
|--------------------|---------|-------------------------------|----------------------------------|
| North Tank         | NTA     | X                             | X                                |
| Fuel Purge         | FPA     | X                             |                                  |
| Fire Training      | FT3     | X                             |                                  |
| USTs (4 Fuel)      | FFA     | X                             | X                                |
| IWTP               | WTP     |                               | X                                |
| Bldg. 3001 Outfall | OSC     |                               | X                                |
| Offbase            | OFB     |                               | X                                |
| Landfill 2&4       | LF2/LF4 |                               | X                                |

Note: Aromatics Scan: BTEX, Naphthalene, 2-Methylnaphthalene

Halocarbon Scan: Trichloroethylene, 1,1,1 Trichloroethane, 1,2 Dichloroethane, 1,1 Dichloroethene, and Methylene Chloride

The specifics of each gas chromatograph analysis method is discussed below. Analysis will be made within ARA's mobile environmental laboratory equipped with an HP-5890 Series II GC unit, dual detectors (Flame Ionization Detector, FID and Electron Capture Detector, ECD), IO 4460A Sample Concentrator system (purge and trap system), and a 486 computer running HP Chemstation software.

#### **4.1 Sample Preparation and Handling**

The following sample handling and sample preparation protocols will be followed to satisfy quality control requirements. All samples received in the on-site GC trailer will be assigned a number and recorded in the laboratory log book. The soil samples will be split into duplicate samples with unique numbers. All samples including duplicates will be stored at a temperature of 4°C in the GC Trailer. Analysis will occur within 14 days after sample collection.

One of the duplicate vials will be analyzed using a purge and trap method. For the water samples the sample will be poured into a gas tight 5 ml syringe for injection into the purge and trap unit. Excess air and water will be expelled from the syringe to bring the sample volume

to exactly 5 ml. For soil samples, 1 gram of soil will be combined with 4 ml of reagent water in a sparging vessel. The sparging vessel will be connected to the purge and trap unit as specified by the manufacturer.

## 4.2 Aromatic Hydrocarbon Analysis

### Purge and Trap Operation:

The trap will consist of methyl silicone and 2,6-diphenylene oxide polymer or similar materials. The sample will be purged for 12 minutes at ambient temperature followed by a dry purge for 6 minutes at ambient temperature. Following the dry purge, the trap will be baked at 180°C for a period of 4 minutes onto the GC column using a heated transfer line. The trap will be baked an additional 7 minutes to remove any other materials in the trap. The purging vessel will be rinsed twice using reagent water during this time.

### GC Operation:

Once the purge and trap begins to bake the sample components onto the column a temperature program will automatically begin. The GC operating specifications will consist of an injection temperature of 250°C, a 30-m, 0.533-mm diameter capillary column with a 1.2- $\mu$ m film of AT-5 from Alltech Associates. The detector will be an FID operating at a temperature of 300°C.

GC analysis will be performed using an external standard method. Each of the selected compounds will be identified and quantified if present in the sample. A three point calibration curve will be used to establish method detection limits and calibration factors. Both a spiked sample (prepared independently of the calibration solutions) and a blank sample will be processed each day to confirm proper operation of the GC. If results are beyond control limits during the analysis, the sample will be diluted and reanalyzed as necessary.

Chromatograms will be developed showing all recorded peaks, however only the 6 compounds of interest will be quantified and presented in the tabular test report.

### 4.3 Chlorinated Hydrocarbon Analysis

#### Purge and Trap Operation:

The trap will consist of methyl silicone, 2,6-diphenylene oxide polymer, silica gel, charcoal or similar materials. The sample will be purged for 11 minutes at ambient temperature. Subsequently, the trap will be baked at 180 °C for a period 4 minutes onto the GC column using a heated transfer line. The trap will be baked an additional 7 minutes to remove any other materials in the trap.

#### GC Operation:

Once the Purge and Trap begins to bake the sample components onto the column, a temperature program will be run. The GC operating specifications consist of an injection temperature of 250 °C, a 30-m, 0.533-mm diameter capillary column with a 3- $\mu$ m film of AT-624 from Alltech Associates. The detector will be an ECD operating at a temperature of 300 °C.

GC analysis will be performed using an external standard method. Each of the selected compounds will be identified and quantified if present in the sample. A three point calibration curve will be used to establish method detection limits and calibration factors. Both a spiked sample (prepared independently of the calibration solutions) and a blank sample will be processed each day to confirm proper operation of the GC. If results are beyond control limits during the analysis, the sample will be diluted and reanalyzed as necessary.

Chromatograms will be developed showing all recorded peaks, however only the 5 compounds of interest will be quantified and presented in the tabular test report.

### 4.4 QA/QC

QA/QC data obtained from the spiked and blank samples will be recorded throughout the field program. A spiked recovery control chart and relative percent error calculations will be performed. Duplicates for 20 percent of the samples will be tested using Ana-Lab Corporation,

a state-certified laboratory. The laboratory will perform EPA methods 8024 on both water and soil samples (see below).

## **5.0 OFF-SITE ANALYTICAL PROCEDURES**

A certified laboratory, such as Ana-Lab Corporation, will be used for the off-site analyses. These analyses, as shown in Table 2, will include EPA methods 8240 (VOA), 8270 (Base/Neutral) for PAHs, 1311 (TCLP), and 418.1 (TPH). Laboratory QA/QC procedures will be in accordance with EPA methods or appropriate specifications. These test methods will be reported along with the samples on the laboratory report. Pertinent certifications and operating procedures for Ana-Lab are enclosed in Appendix B.

## **APPENDIX A**

### **STANDARD OPERATING PROCEDURES**

## **LIF-ELECTRIC CONE PENETROMETER TEST (LIF-ECPT) PROCEDURES**

Step-by-step procedures are provided below to ensure LIF-ECPT field tests are properly conducted. Procedures specifically covered include: system setup, computer assembly, cone calibration, standard ECPT sounding, pore pressure dissipation tests and LIF testing.

### **Setup Procedures**

1. Park the truck with the cone over the test location and engage the PTOs to supply hydraulic and electric power.
2. Level the truck using the four hydraulic cylinders and bubble levels. Make sure the weight of the truck is fully on the pads (i.e., all wheels are off the ground and all 4 pads are touching the ground).
3. Attach the guide tube extension under the truck.

### **Computer Assembly**

1. Turn the inverter on.
2. Turn the CPT computer and peripheral on.
3. Turn the Laser computer and peripherals on.

### **Field Calibrations**

Many factors can effectively change the calibration factors used to convert the raw instrument readouts, measured in volts, to units of force or pressure. As a quality control measure, as well as a check for instrument damage, the load cells and the pressure transducer should be routinely calibrated in the field. Calibrations are completed with the probe ready to insert into the ground so that any factor affecting any component of the instrumentation system will be included and detected during the calibration.

### **CPT Calibration**

The tip and sleeve load cells are calibrated with the conical tip and friction sleeve in place on the probe. For each calibration, the probe is placed in the push frame and loaded onto a

precision reference load cell. The reference load cell is periodically calibrated against a NIST traceable standards. To calibrate the pore pressure transducer, the saturated probe is inserted into a pressure chamber with air pressure supplied by the compressor on the truck. The reference transducer in the pressure chamber is also periodically calibrated against an NIST traceable instrument. Additionally, the string potentiometer, used to measure the depth of penetration, is periodically checked against a tape measure.

Each instrument is calibrated using a specially-written computer code, CALDAS, that displays the output from the reference device and the probe instrument in graphical form. During the calibration procedure, the operator checks for linearity and repeatability in the instrument output. At the completion of each calibration, this code computes the needed calibration factors using a linear regression algorithm. At a minimum, the probe instrument is calibrated at the beginning of each day of field testing. Furthermore, the pressure transducer is recalibrated each time the porous filter is changed and the cone is resaturated. Calibrations are also performed to verify the operation of any instrument if any damage is suspected.

Procedures:

1. Clamp the cone in the head clamp.
2. Connect reference load cell to junction box.
3. Remove tip and seal ring.
4. Apply loads to the cone and save data points.
5. Calculate and update calibration factors if correlation is good.
6. Repeat Steps 1 through 6 for tip and pore pressure if included after reassembling cone.
7. Exit calibration program.

LIF Calibration

The LIF module will be calibrated by placing soil or water with a known amount of Analyte in a mold which is held up to the sapphire window located in the cone assembly. Three (3) concentrations of the analyte will be used for the initial calibration. A calibration factor will be determined from the reading. This initial calibration will be performed only once on instrument start-up. For subsequent locations, the calibration factor will be checked by placing a single spiked sample matrix and taking a reading. If the computer returns a reading within

10 percent of the actual reading, then the calibration will be considered to be valid, otherwise a complete calibration using three concentrations will be performed.

**Initial Calibration Procedure:**

1. With cone clamped in the head clamp and the laser calibration program running on the laser computer, place prepared soil mold next to window and make reading of measured intensity.
2. Repeat step 1, with soil molds 2 and 3.
3. Use laser calibration program to determine the calibration factor.
4. Exit Laser calibration program.

**Routine Calibration Procedure:**

1. With cone clamped in the head clamp and the laser calibration program running on the laser computer, place prepared calibration mold next to window and make reading of measured intensity.
2. If measured concentration is within 10 percent of the actual concentration of the calibration mold then stop, otherwise perform an initial calibration.

## Testing

Cone procedures can be subdivided into LIF-ECPT profiling, pore pressure dissipation testing, and LIF-generated wavelength time matrix (WTM) testing. Pore pressure dissipation tests and WTM tests are conducted at preselected depth increments during pauses in the LIF-ECPT sounding.

### Procedures:

The following sections describe the sequence of each test.

1. Run ARA's Penetration Data Acquisition System Software and select the appropriate function key.
2. Ensure that the cone tip is slightly above ground level.
3. Complete the header information and select the variables requested by the computer.
4. Start penetration test.
5. Advance the cone at 2 cm/sec.
6. Connect the next rod while the cone is advancing (if practical).
7. Stop at desired depths to run pore pressure dissipation tests (see pore pressure dissipation tests for details).
8. Stop at desired depths to run WTM tests (see WTM tests for details).
9. When rod penetration is complete, pause the data acquisition system, raise the ram and clamp on the next rod.
10. Repeat the test-advance-test sequence, adding additional rods as required, until reaching cone refusal or beyond the depth of interest.
11. After reaching maximum depth, withdraw the rods from the ground, and end data acquisition.
12. Plot or print data if necessary.

## Pore Pressure Dissipation Test Procedures

If you are conducting dissipation tests select the appropriate option when starting the data acquisition program. The pore pressure dissipation test begins automatically every time the cone stops.

### Procedures:

1. Stop penetration at desired depth.
2. Pause the penetration acquisition (the acquisition system should automatically begin acquiring dissipation data).
3. Unclamp the head from the push tube.
4. Allow the excess pore pressure to dissipate to the desired level ( $P_{50} - P_{100}$ ).
5. Pause the dissipation acquisition system.
6. Save the dissipation data.
7. Print the dissipation plot if immediate hardcopy is desired.
8. Exit the dissipation acquisition system.

## WTM Test Procedures

When the desired depth has been reached for a WTM test, then pause the push data acquisition system running on the laser computer. Start the WTM data acquisition system and adjust the frequency as required. After all the necessary data has been acquired, save the file and return the computer system to the push data acquisition system.

### Procedures:

- 1) Pause the push data acquisition system.
- 2) Start the WTM data acquisition system.
- 3) Record LIF Intensity-time data for the various emission frequencies.
- 4) Save the WTM file under a unique name.
- 5) Return to the push data acquisition system.

## SELF-GROUTING MODULE

### 1.0 APPLICABILITY

Cone penetration tests leave holes which represent potential contamination pathways into groundwater supplies. To prevent any contamination, the test holes can be grouted to seal the hole and eliminate the contaminant pathway. This procedure applies to the methods to be used to grout and seal these test holes.

### 2.0 DEFINITIONS

N/A

### 3.0 RESPONSIBLE STAFF

Cone Operator(s)

### 4.0 PROCEDURE

#### 4.1 Prerequisites

##### 4.1.1 Equipment

The following equipment will be needed to perform this procedure:

- Cone Grouting Module with attached tubing
- 5 gal buckets (2)
- ARA Grout Pump - 130 psi
- Extra tubing - 150 psi, .550 in o.d., 30 in i.d.

##### 4.1.2 Safety Precautions

The following safety equipment is recommended as a minimum. Additional safety equipment may also be required as specified in the project's Health and Safety Plan and/or by the Project manager:

- Gloves
- Steel-toed boots
- Hard Hat
- Safety glasses
- Dust Mask

#### 4.2 Step-by-Step Instructions

#### 4.2.1 Grouting the Test Hole

Position responsible: Cone Operator

1. Thread 1.75 in rods with cable and grout tubing. Attach hose coming out of the 1.75 in o.d. rods to the out flow side of the pump.
2. Mix 6 gallons of grout using the ratio of 1 bag Portland cement, 2 lbs bentonite, and 5.5 gallons of water. Mix until a uniform consistency is obtained.
3. If steam cleaning is required, connect the steam cleaning spider to the steam cleaner. Start the steam cleaner and follow steam cleaning operating procedures.
4. Retrieve the cone probe approximately 3 inches to create a void for the grout to flow into.
5. Turn on the pump and ensure that grout begins to flow. Begin retrieving the cone rods according to standard operating procedures, while monitoring the grout pump to ensure grout is flowing, and the volume of grout being pumped. If an excessive volume of grout is being pumped, reduce pressure on the pump, but ensure that the grout remains flowing. When the press is stopped for the second operator to remove the rod, turn the pump off.
6. Repeat Step 5 until either all the rods have been retrieved and the cone tip is exposed outside the guide tube under the truck, or additional grout is needed. If additional grout is needed, then proceed to step 2 and resume procedure.
7. Once all the cone rods have been retrieved and the cone tip is exposed outside the guide tube under the truck, turn off the pump. Record the remaining volume of unused grout in the log book and calculate the total volume of grout used. Write this value in the log book along with the depth of penetration and the rod diameter used.
8. Clean out the grout mixer and fill with clean water. Turn pump back on and pump water through the cone into a collection bucket until clean water is obtained from the cone tip. The water bucket may have to be filled several times during this procedure.
9. Once clean water has been obtained from the cone tip, install new sleeve over the grout ports to prevent clogging during the next penetration. Note completion time in logbook and proceed to next test location.

## TREMMIE GROUTING METHOD

### 1.0 APPLICABILITY

Cone penetration tests leave holes which represent potential contamination pathways into groundwater supplies. To prevent any contamination, the test holes can be grouted to seal the hole and eliminate the contaminant pathway. This procedure applies to the methods to be used to grout and seal these test holes.

### 2.0 DEFINITIONS

N/A

### 3.0 RESPONSIBLE STAFF

Cone Operator(s)

### 4.0 PROCEDURE

#### 4.1 Prerequisites

##### 4.1.1 Equipment

The following equipment will be needed to perform this procedure:

- Disposable Tip with O-ring
- Air Compressor connector
- 5 gal buckets (2)
- ARA Grout Pump - 130 psi
- Extra tubing - 150 psi, .55 in o.d., 30 in i.d.

##### 4.1.2 Safety Precautions

The following safety equipment is recommended as a minimum. Additional safety equipment may also be required as specified in the project's Health and Safety Plan and/or by the Project manager:

- Gloves
- Steel-toed boots
- Hard Hat
- Safety glasses
- Dust Mask

#### 4.2 Step-by-Step Instructions

#### 4.2.1 Grouting the Test Hole

Position responsible: Cone Operator

1. Once the instrumented cone assembly has been completely removed from the penetration hole, insert a disposable tip with O-ring into the male end of an empty 1.75 inch o.d. push rod pre-threaded with a grout hose. Also install the steam cleaning spider to the guide tube.
2. Push the rods to the bottom of the penetration hole or refusal using standard push procedure at the maximum rate possible. The operator should monitor the pressure in the two push cylinders to ensure that the pressures are approximately 1/3 of penetration pressures. This ensures that the grout rods travel down the same hole as the penetration test. Depth measurement can be obtained by either using the computer electronics or counting rods (1 rod  $\approx$  3.5 ft).
3. Install the air compressor connector on top of the rods along with the pressure regulator. Apply an air pressure of above 80 psi to the rods and note the pressure value. Pull up on rods approximately 6 inches and not if pressure drops. If pressure drops, proceed with step 4, else retrieve all rods. Inspect tip to determine why it was plugged. Return to step one.
4. Attach the free end of grout hose to the out-flow side of the grout pump.
5. Mix 6 gallons of grout using one of the mix designs from the grout mixture operating procedures. Mix until a uniform consistency is obtained.
6. Turn on the pump and increase the pressure until grout begins to flow. When pump pressures increase, begin extracting rods. When one rod is fully extracted, shut down pump and remove the rod.
7. Repeat Step 6 until either all rods have been retrieved and the grout rods are exposed outside the guide tube under the truck, or additional grout is needed. If additional grout is needed, then proceed to Step 5 and resume procedure.
8. Once all the cone rods have been retrieved, turn off the pump. Record the remaining volume of unused grout in the log book and calculate the total volume of grout used. Write this value in the log book along with the depth of penetration and the rod diameter used.
9. Clean out the grout mixture and fill with clean water. Turn pump back on and pump water through the cone into a collection bucket until clean water is obtained from the grout hose. The water bucket may have to be filled several times during this procedure.

## CPT SOIL SAMPLER

### 1.0 APPLICABILITY

Obtaining soil samples for analysis can easily be accomplished using the CPT. The major advantage is that a physical sample is obtained that can be analyzed for numerous different properties and also contaminant concentration. This procedure applies to the methods used to obtain soil samples from a specified depth.

### 2.0 DEFINITIONS

N/A

### 3.0 RESPONSIBLE STAFF

Cone Operator(s)

### 4.0 PROCEDURE

#### 4.1 Prerequisites

##### 4.1.1 Equipment

The following equipment will be needed to perform this procedure:

Gouda OR MOSTAP-36® Soil Sampler  
Cooler  
Aluminum Foil  
Masking Tape  
Permanent Marker

##### 4.1.2 Safety Precautions

The following safety equipment is recommended as a minimum. Additional safety equipment may also be required as specified in the project's Health and Safety Plan and/or by the Project manager:

Gloves  
Steel-toed boots  
Hard Hat  
Safety glasses  
Dust Mask

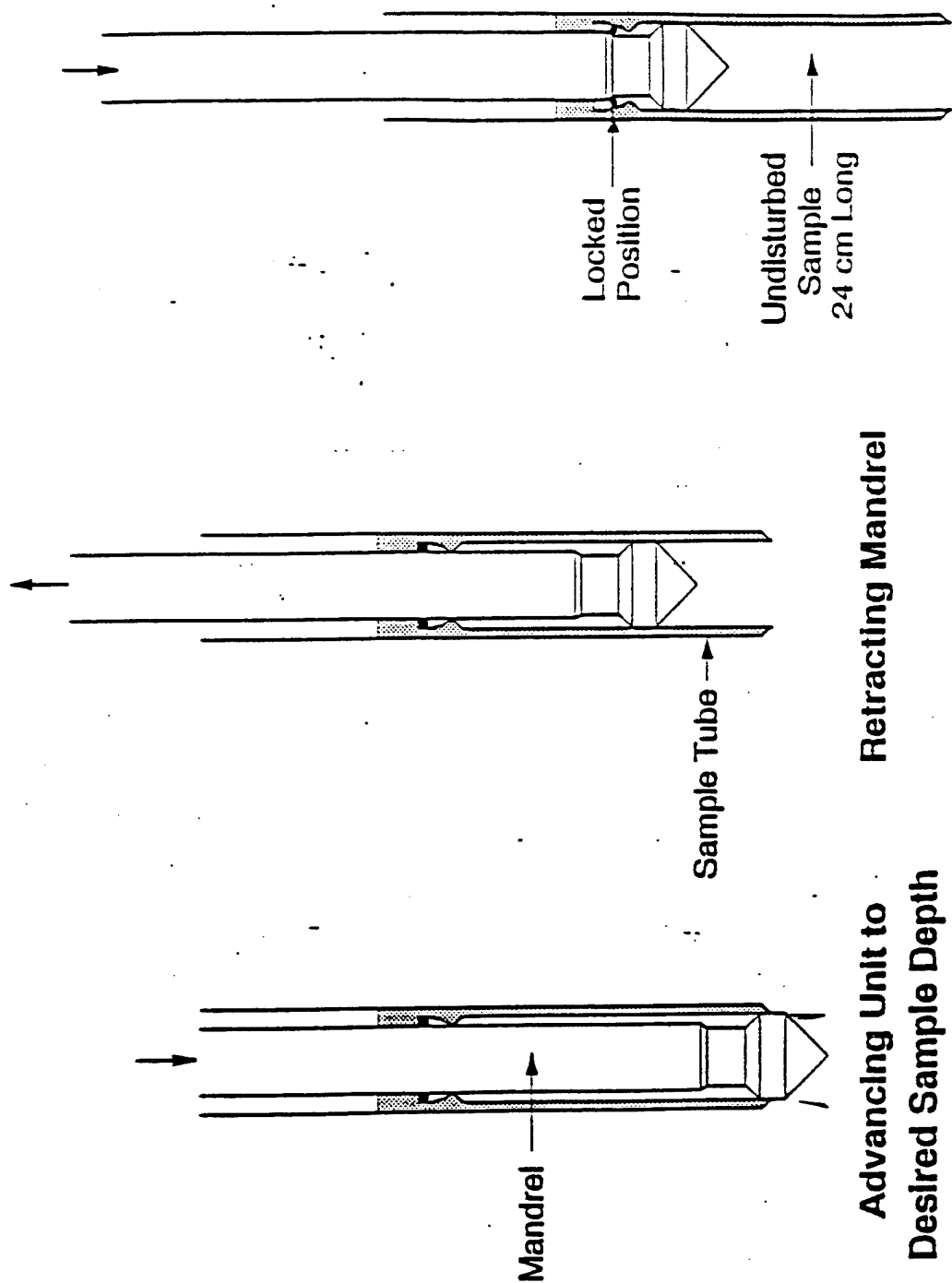
##### 4.2 Step-by-Step Instructions

#### 4.2.1 Obtaining Soil Samples

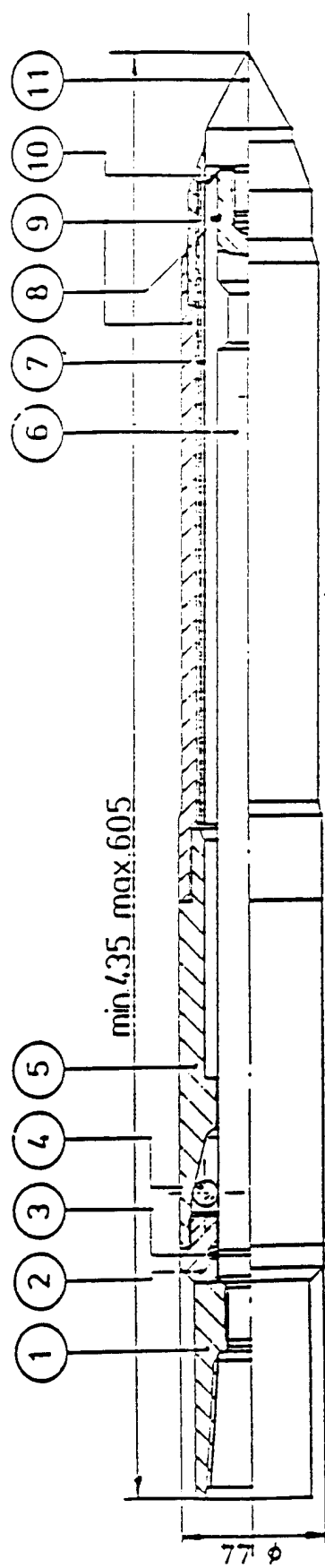
Position responsible: Cone Operator

1. Follow the assembly instructions provided on the attached sheet.
2. Attach the soil sampler to the push rods and push to the desired depth.
3. Pull up on the rods approximately 12 or 20 inches to open the Gouda or MOSTAP soil samplers, respectively.
4. Push the rods back down 24 or 40 inches to obtain a soil sample with the Gouda or MOSTAP samplers, respectively.
5. Retrieve all push rods and the soil sampler with a soil sample.
6. Carefully wrap the soil sample in foil, and label with job number, hole identifier, date, time, depth, and sample number. Place soil sample in a zip-lock freezer bag and place in a cooler.
7. If grouting is required, follow the tremmie grouting operating procedures.
8. Deliver soil samples to the client at the end of each day.

# SCHEMATIC OF SOIL SAMPLING PROBE



Advancing Sampler



- a) Put the cupped washer (10) over the cone tip (11) threads and screw the cone tip into the cone rod (6). Tighten securely.
- b) Put the locking piece (5) onto the cone rod while holding vertically. Put the balls (4) on their spots and screw the nut (2) into the locking piece. Screw the connecting piece (1) onto the cone rod and tighten securely.
- c) Put the PVC sampling container (7) into the sampling sleeve (9) and push it over the cone tip. Screw the sampling sleeve onto the locking piece.
- d) Check the assembly by pulling out the connection piece (1) while holding the assembly in a vertical position, cone tip downwards. If the assembly has been done correctly the balls will have locked the cone rod.
- e) By turning the apparatus upside down and pulling the connection piece, the balls will fall from the locking piece and the connection piece can be pushed upwards into it's pre-test position.

## ARA WATER SAMPLER

### 1.0 APPLICABILITY

Obtaining water samples for analysis can easily be accomplished using the CPT. The major advantage is that expenses are significantly reduced due to the fact that an entire monitoring well does not have to be installed and monitored as required by regulation. This procedure applies to the methods used to obtain ground water samples from a specified depth.

### 2.0 DEFINITIONS

N/A

### 3.0 RESPONSIBLE STAFF

Cone Operator(s)

### 4.0 PROCEDURE

#### 4.1 Prerequisites

##### 4.1.1 Equipment

The following equipment will be needed to perform this procedure:

- ARA Water Sampler
- Distilled Water
- Liquinox
- Brushes
- Precleaned 40 ml vials
- Cooler with ice
- Bailer
- Fishing line (30 lb test)
- Weights
- 14 gal bucket
- 4 gal bucket

##### 4.1.2 Safety Precautions

The following safety equipment is recommended as a minimum. Additional safety equipment may also be required as specified in the project's Health and Safety Plan and/or by the Project manager:

- Gloves
- Steel-toed boots
- Hard Hat
- Safety glasses

Dust Mask  
Surgical Gloves

4.2 Step-by-Step Instructions

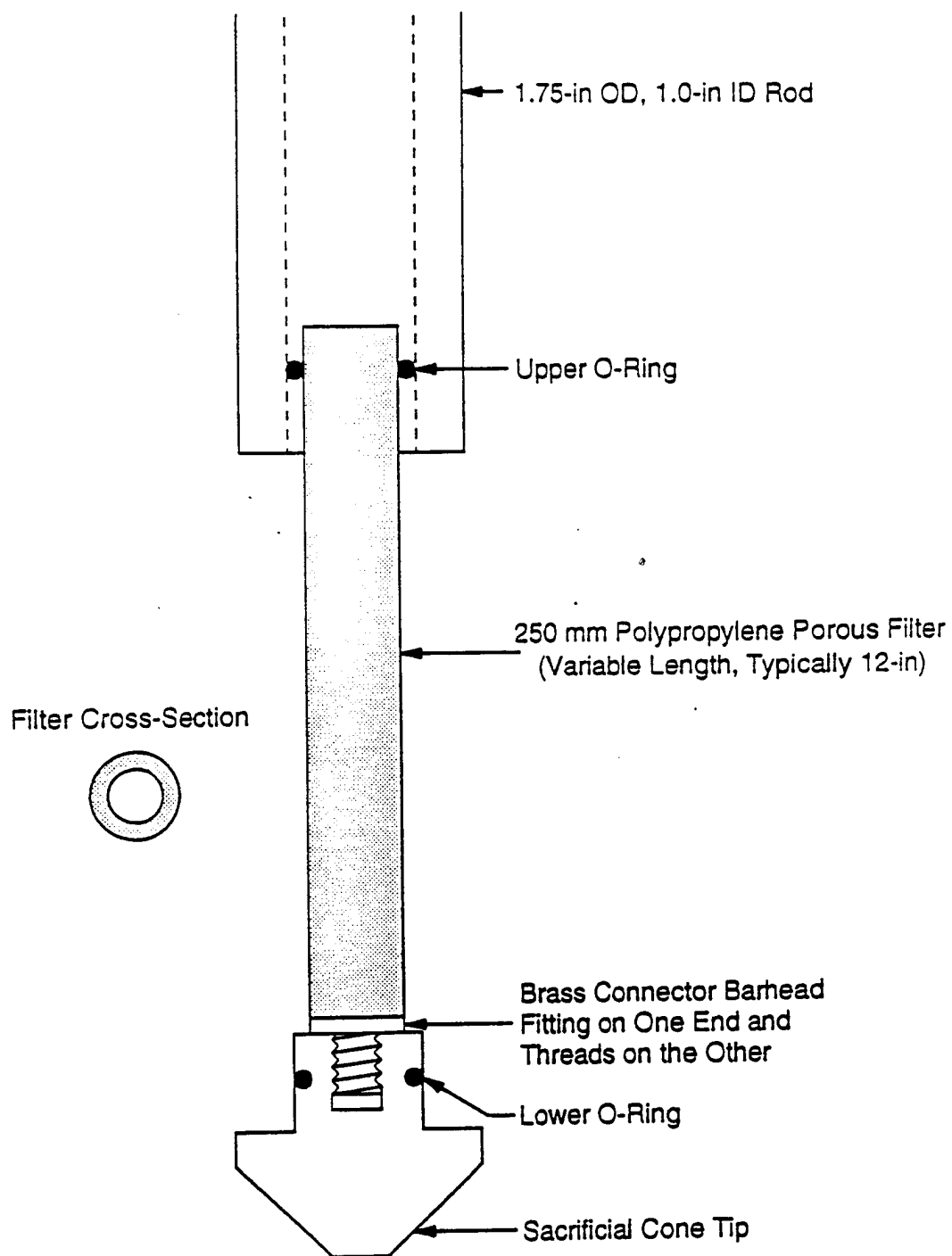
4.2.1 Obtaining Water Samples

Position responsible: Cone Operator

1. Clean the inside of all 1.75 in o.d. rods with Liquinox soapy water and a brush. Steam clean the rods again and set aside. Brush cleaning with Liquinox is only required at the start of each job, then these rods can be set aside and steam cleaned between all samples.
2. One technician should put on the surgical gloves and clean all parts in a 14 gallon bucket with distilled water and the Liquinox soap. Rinse all parts with distilled water and place in a clean 4 gallon bucket. The technician with the surgical gloves must be cautious to keep the gloves clean. For this reason, he should perform all assembly and raise and lower the bailer. He should not operate any of the hydraulics or touch any equipment that has not been cleaned.
3. Assemble the ARA water sampler.
4. Push the water sampler and push rods to the desired sample depth using standard push procedures at the maximum rate possible. Depth measurement can be obtained by either using the computer electronics or counting rods (1 rod = 3.5 ft).
5. Pull back on the rods approximately 6 inches, allowing water to flow into the rods (approximately 5 minutes). Assemble the bailer with weights and fishing line.
6. Lower the bailer into the core of the rods until the bottom is reached. Raise and lower the bailer several times to fill the bailer.
7. Pull the bailer to the surface and inspect to ensure that the bailer is full. If the bailer is not full, then wait 10 minutes before obtaining another bail. After obtaining one full bailer, empty the bailer in a waste water bucket and repeat step 6. This acclimates the bailer to the groundwater.
8. After the bailer has been acclimated, then carefully pour the next bailer into a 40 ml vial. The vial must be filled entirely to the top and from one bailer volume. Carefully install the vial top and label the vial with job number, location information, date, time, depth, and sample number information. Place vial into cooler on ice. Repeat steps 6, 7, and 8 to obtain a duplicate sample.

9. If grouting is required, follow the tremmie grouting operating methods to grout the water sampling hole upon retrieval.
10. Take cooler with samples to the refrigerator in the trailer or turn over samples to client at the end of each day.

# ARA Water Sampler



**APPENDIX B**  
**OFF-SITE LABORATORY QA/QC INFORMATION**

ROBERT S. KERR, JR.

*Chairman*

WILL SECREST

*ice-Chairman*

G. JOHNSON

*Secretary*

ERLAND BORELLI

RANK H. CONDON

MIKE HENSON

CHARL McDONALD

IVIN MITCHELL

CK SEYBOLT



PATRICIA P. EATON

*Executive Director*

MICHAEL R. MELTON

*Assistant Director*

600 N. HARVEY AVE. P.O. BOX 150  
OKLAHOMA CITY, OKLAHOMA 73101-0150

MEMORANDUM

TO: Laboratory Director

FROM: Dave Dillon, Chief, Water Quality Division *[Signature]*

DATE: December 12, 1991

SUBJECT: Validation Decal for January 1, 1992, through May 31, 1992, CWRB Laboratory Certification Program.

---

Enclosed is a validation decal for your laboratory's certificate. Both this decal and the List of Certified Parameters (previously sent to your laboratory June 13, 1991) are necessary to fully demonstrate your laboratory's certification with the Oklahoma Water Resources Board (OWRB).

The enclosed decal must be applied to your certificate. This decal indicates that your laboratory is certified to analyze at least one (1) parameter for the period of January 1, 1992, through May 31, 1992. In each subsequent year, participating laboratories will receive a new validation decal to be applied to the certificate, along with an updated List of Parameters certified for the next year. These mail-outs will most likely be sent in the middle of May each year.

Another condition of a valid certificate is to maintain on file the List of Certified Parameters for which your laboratory is certified to perform analyses. This means that at least one (1) copy of the list should be kept available in the laboratory at all times for review by clients and for OWRB on-site inspectors. In addition, it is the responsibility of each commercial/contract laboratory to provide a copy of this list and its I.D. number to any clients which are permitted under the OWRB's Waste Disposal Permit Program and/or EPA's NPDES Program.

The List of Certified Parameters, dated June 13, 1991, which was previously sent to your laboratory states that your certification expires December 31, 1991. However, as provided in the Oklahoma

Memorandum  
Laboratory Director  
December 12, 1991  
Page 2

Water Resources Board's Rules, Regulations and Modes of Procedure, Chapter X, Rule 1065.14, your present certification will continue in effect until May 31, 1992. This memorandum should be kept with the parameter list to verify that your laboratory is indeed certified.

If you have any questions concerning your certified parameters or validation decal, please do not hesitate to contact Mr. Anthony Bright, Laboratory Certification Coordinator, at (405) 231-2541.

# OKLAHOMA WATER RESOURCES BOARD

Hereby Recognizes That

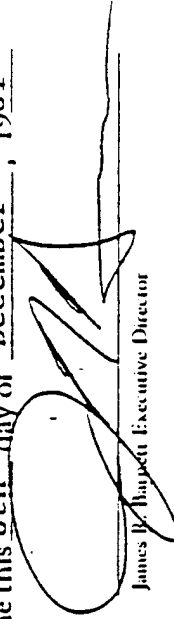
*Ana - Lab Corporation*

Laboratory No. **8125**

is a participant in the Oklahoma Water Resources Board's LABORATORY CERTIFICATION PROGRAM and maintains on file a List of Parameters for which it is certified to perform analyses.



Done this 8th day of December, 1981

  
James D. Harpett Executive Director

This certificate is valid only for

JANUARY 1, 1982  
THROUGH  
MAY 31, 1982

1000 N.E. TENTH STREET, P.O. BOX 53525  
OKLAHOMA CITY, OKLAHOMA 73152

LABORATORY CERTIFICATION PROGRAM  
UPDATED LIST OF PARAMETERS CERTIFIED FOR 1991

CATEGORY I (MINERALS), CATEGORY II (NUTRIENTS),  
CATEGORY III (METALS & TOXIC SUBSTANCES),  
AND CATEGORY IV (MISCELLANEOUS)

Each laboratory shall provide a copy of this list  
to any of their clients that are permitted by the  
Oklahoma Water Resources Board and/or EPA.

June 13, 1991

- + The following parameters are certified for the SECOND HALF of 1991. These are the parameters which were successfully analyzed in the Spring Test of 1991, or successfully analyzed in both the Spring and Fall Tests of 1990.

\* ANA-LAB CORPORATION

ID # 8125

BILL PERRY, JR.  
2500 DUDLEY ROAD  
KILGORE TX 75662

TEL. (214) 984-0551

- + The following parameters are certified from 7-1-91 to 12-31-91

|                   |                  |                  |                 |
|-------------------|------------------|------------------|-----------------|
| Hardness          | Chloride         | Sulfate          | Dis. Solids     |
| Spec. Conductance | Ammonia-Nitrogen | Nitrate-Nitrogen | Tot. Phosphorus |
| pH                | Aluminum         | Arsenic          | Barium          |
| Cadmium           | Calcium          | Chromium         | Copper          |
| Iron              | Lead             | Magnesium        | Manganese       |
| Mercury           | Nickel           | Potassium        | Selenium        |
| Sodium            | Zinc             |                  |                 |

Alkalinity (Total and/or P-), Antimony (Sb), BOD 5-Day, Beryllium (Be), Boron (B), COD, Carbon Dioxide, Carbonate/Hydroxide/Bicarbonate Alkalinity and Carbon Dioxide, Chlorine (Total Residual), Cobalt (Co), Color, Cyanide, DO, EP Toxicity Extraction, Fecal Coliform, Fixed and Volatile Suspended Solids, Fluoride, GC-Acrolein and Acrylonitrile (603), GC-Chlorinated Hydrocarbons (612), GC-Herbicides, GC-Pesticides & PCBS (608), GC-Phenols (604), GC-Phthalate Esters (606), GC-Polynuclear Aromatic Hydrocarbons (PAH) (610), GC-Purgeable Aromatics (602), GC-Purgeable Halocarbons (601), GC/MS-Acid Compounds (625), GC/MS-Base/Neutral Compounds (625), GC/MS-Pesticides (625), GC/MS-Volatile Compounds (Purgeables) (624), Hexavalent Chromium, Metals (only those certified in Part I) in Sediments, Molybdenum (Mo), Nitrite, Oil and Grease, Organic Nitrogen, Orthophosphate, Petroleum Hydrocarbon (Total Recoverable), Phenols, Settleable Solids, Silicon (Si), Silver (Ag), Strontium (Sr), Sulfide, Sulfite, Surfactants (MBAS), TCLP, TOC, Thallium (Tl), Tin (Sn), Titanium (Ti), Total Coliform, Total Fixed and Volatile Solids, Total Kjeldahl Nitrogen, Total Organic Halides (TOX), Total Solids, Total Suspended Solids, Trihalomethanes, Trinitrotoluene (TNT), Turbidity, Vanadium (V),

- \* This commercial/contract laboratory may provide analytical services to the permittees of CWRB or EPA.

STANDARD OPERATING PROCEDURE FOR EPA GC/MS VOLATILE METHODS  
(524,624,8240)

GC/MS Theory

Gas Chromatograph/Mass Spectrometer instrumentation operates by two distinct theories. Primarily, all compounds in a sample are separated by passing the sample through a chromatographic column via a carrier gas, in this case helium. The column is slowly heated, and the temperature change as well as the physical packing of the column tend to separate each compound from another. In general, the larger a molecule is, the slower it will travel through the column. Ideally, by the end of a run (the time from sample introduction until the last compound has eluted from the column end) all compounds will have eluted far enough apart, in terms of time, that one peak will appear for every compound present. This produces a 2-dimensional graph of peak intensity vs. elution time.

However, instead of each peak being detected by a simple recorder, thereby producing a strong signal, the recorder is replaced by the Mass Spectrometer. This instrument is capable of fragmenting each molecule as it is eluted by shooting an electron beam perpendicular to the molecule. Every compound has a distinct fragmentation pattern, much like a fingerprint. In other words, every time a specific compound is subjected to an electron beam, it will fragment exactly in the same way every time. Even isomers will produce slightly different fragmentation patterns.

After fragmentation, each fragment is induced to travel through some method of filter whereby only one molecular weight is allowed through at one time. The filter is set up in a way that it can scan for each molecular weight in the range of 5-550 AMU. In our case, the filter is known as a quadrupole. As each fragment travels through the filter according to its molecular weight, its intensity is recorded by an electron multiplier and stored on a data system. From this information, a mass spectra may be drawn, producing a 2-dimensional graph for one compound of mass intensity vs. mass weight. Mass intensity in this case is set relative to the largest mass peak in the spectra.

Since peak intensity is ambiguous, depending on the multiplier settings and the purge efficiency, as well as numerous other interferences, accurate quantitation of each compound cannot be accomplished by external standards. This is a method of quantitating by injecting a known concentration of the compounds of interest, followed by an injection of the unknown, and quantitating by comparing areas under each corresponding peak. An alternate and much more accurate method is the use of internal standards. These are compounds closely resembling the compounds of interest, usually deuterated (containing heavy hydrogen), which are placed in the sample prior to injection. As unknown areas increase or decrease,

so do the internal standards.

This overcomes the sensitivity ambiguity, as well as decreasing the number of injections required.

#### GC/MS Volatile Methods

The correct concentration for volatile GC/MS work is 50 PPB for most methods. The internal standards are:

Bromochloromethane  
1,4-Difluorobenzene  
Chlorobenzene-d5

#### Initial Calibration Curve

All volatile compounds to be analyzed by any method will require a calibration curve of a minimum of 5 points. These points will be 20, 50, 80, 120, and 160 PPB (Parts Per Billion). All compounds should be mixed together in one solution at a concentration of 5 PPM in methanol. This allows a high enough concentration to guarantee an accurate curve while retaining the precision by requiring a large volume of mix to be injected, thereby minimizing injection to injection ambiguity. The final mix may be prepared from individual solutions or from a purchased mix.

For every PPB concentration you wish to inject, transfer 1 ul of mix to a 5 ml syringe containing 5 ml reagent water and the correct amount of internal standards (50 PPB - 10 ul of 25 PPM standard in 5 ml reagent water).

After all 5 points have been acquired and quantitated, calculate response factors for each compound using the following equation:

$$RF = (Auk/Cuk) * (Cism/Aism)$$

where:     Auk=area of the analyte under the quantitation ion  
              as defined by EPA method 8240.  
              Cuk=concentration of the analyte in PPB.  
              Aism=area of the corresponding internal standard  
                  quantitation ion as defined by EPA Method  
                  8240.  
              Cism=concentration of the corresponding internal  
                  standard.

EPA Method 8240 defines the correct Internal Standard to use for each compound. The standard deviation for each 5 point curve is calculated, as well as the percent relative standard deviation, which should be no more than 30% for each compound.

## 12 Hour Shift Tuning and Calibration

Every 12 hours the analyst must demonstrate that the instrument is operating properly. This is accomplished by two events: tuning the instrument with a tuning compound, and running calibration and performance check standards. These events are performed until minimum criteria are met. The analyst may not under any circumstance proceed with sample injections until this criteria are met.

### BFB (Bromofluorbenzene)

The tuning compound for the volatile instrument is BFB. 2 ul of a 25 PPM standard (the same standard that is used for sample injections if the surrogates are mixed with the internal standards) is directly injected into the Gas Chromatograph. This is equivalent to the required 50-ng injection stated by EPA method 8240.

NOTICE: Do not attempt to tune by purging BFB - this will take much too long.

Each peak in the BFB spectra must pass within certain ranges - refer to EPA method 8240 for specifics. BFB is also used to set the multiplier intensity, as well as check the helium line pressure. BFB should always appear within 25 scans of it's normal retention time. If this is not so, increase or decrease the helium line pressure to compensate. If this does not resolve the problem, maintenance is required on the gas chromatograph. If no peaks or trace of background noise are apparent in the chromatogram, maintenance is required on the mass spectrometer.

After BFB is met according to EPA method 8240, calibration and performance check can continue.

### CCC/SPCC

After passing BFB, a 5 ml reagent blank containing the usual internal standards must be spiked with the CCC's (Calibration Check Compounds) and the SPCC's (System Performance Check Compounds).

These compounds are as follows:

|        |                               |
|--------|-------------------------------|
| CCC's: | 1,1-Dichloroethene            |
|        | Chloroform (Trichloromethane) |
|        | 1,2-Dichloropropane           |
|        | Toluene (Methyl Benzene)      |
|        | Ethylbenzene                  |
|        | Vinyl Chloride                |

SPCC's: 1,1-Dichloroethane  
Bromoform (Tribromomethane)  
1,1,2,2-Tetrachloroethane  
Chlorobenzene  
Chloromethane

All 11 compounds may be spiked into the same reagent blank or run separately. After acquisition and quantitation, response factors for each compound must be calculated using the above equation. The percent RSD for the CCC calculated response factors must be less than 30%. This is done to check the validity of the current 5 point calibration curve on the data system. The minimum response factor for the SPCC's is .3 (.25 for bromoform). If these criteria are not met, the analyst may not proceed with sample injections.

If one or more of the CCC's fail, the current 5 point curve is invalid. Create a new curve as stated above.

If one or more of the SPCC's fail, the system is not operating properly. Check for leaks in the purge and trap unit and the gas chromatograph. Pay particular attention to the column and trap connections and fittings.

#### Surrogate spikes

Every sample must be spiked with surrogates. These compounds are usually deuterated and verify that all extractions and transfers including injections and purging are done efficiently with minimum loss. The surrogates for the volatile methods are:

Toluene-d8  
4-Bromofluorobenzene  
1,2-Dichloroethane-d4

These compounds may be prepared in the same mix as the internal standards at a concentration of 50 PPB, producing an internal standard mix (ISM). Transfer 10 ul of a 25 PPM internal standard/surrogate mix into 5 ml of reagent water to achieve this concentration.

#### Blanks

Every set (defined as every 20 samples injected) a reagent blank containing nothing but the ISM must be acquired. This is to verify that the instrument is not contaminated by carry-over or cross contamination. If contamination is found, subtract the amount quantitated from each injection for that set to produce accurate

results.

#### Duplicates/Spikes

Every set, as defined above, one sample chosen by the analyst must be run in duplicate and spiked with spiking compounds. To run a duplicate, run the same sample sequentially under identical conditions. Calculate the percent difference for each sample.

To produce a spike, run an additional duplicate, but add the following spiking compounds at a concentration of 20 PPB:

- 1,1-Dichloroethene
- Trichloroethene
- Chlorobenzene
- Toluene
- Benzene

The spike mix should be prepared at a concentration of 10 PPM, thereby producing a 20 PPB concentration if 10 ul are added to 5 ML of reagent water. The calculated range for each spike must fall between the spike criteria as stated in Table 6 of EPA method 8240.

#### Maintenance

To produce accurate and precise results, an ongoing maintenance routine must be followed for each instrument. If the analyst finds BFB hard to meet, the mass spectrometer should be cooled down and the stack cleaned. The instrument must then be re-calibrated using the calibration gas, FC43. Afterwards, BFB can be met. Occasionally, exceptionally contaminated samples can cause problems with the gas chromatograph, producing blockage which must be cleared, or contaminating the column which must then be baked out, cleaned or replaced. These samples can also contaminate the trap in the purge and trap unit. Baking the trap for several hours may solve the problem, but often the trap must be replaced. Keep a continuous watch on each acquisition, even after all QC criteria have been met, for possible problems with the system.

## TOTAL PETROLEUM HYDROCARBONS MEASUREMENT

SCOPE: This method is for the measurement of hydrocarbons extracted with Freon 113 from solid or liquid samples. The infrared absorbance at  $2930\text{ cm}^{-1}$  of a sample is compared to the absorbance of a standard for quantitation.

### REAGENTS

1. Freon 113 (1,1,2-trichloro-1,2,2-trifluoroethane).
2. Reference oil,  $10^6\text{ppm}$  - Prepared by pipetting 15.0ml n-Hexadecane, 15.0ml Isooctane and 10.0ml Chlorobenzene into a 50ml glass stoppered bottle. The integrity of this mixture is maintained by storing at  $4^\circ\text{C}$  and keeping stoppered except when removing aliquots from bottle.
3. Stock standard,  $10^4\text{ppm}$  - Prepared by pipetting 1.0ml into a 100ml volumetric flask and diluting to volume with Freon 113. Store at  $4^\circ\text{C}$  in a bottle equipped with a Teflon lined screw cap.
4. Working standards, 50ppm and 150ppm - Prepared by pipetting 1.0ml and 3.0ml of the stock standard into separate 200ml volumetric flasks and diluting to volume with Freon 113. These will have concentrations of 50ppm and 150ppm respectively.

### APPARATUS

1. Infrared spectrometer capable of measuring absorbance at  $2930\text{ cm}^{-1}$ .
2. Liquid cell, 1cm pathlength, sodium chloride windows. (A 1cm quartz cell may be substituted if they are transparent to infrared in the region of interest.)
3. Syringe, 5ml, gasw tight with teflon tipped plunger.
4. Beakers, 150ml Griffin style or equal.
5. Several volumetric flasks (10ml, 25ml, 50ml, etc.) for making dilutions of samples.

## PROCEDURE

1. Turn on the infrared instrument and allow to warm up for at least 30 minutes. The following parameters are to be set while the instrument is warming up.

|                  |                      |
|------------------|----------------------|
| MODE             | %TRANSMITTANCE       |
| SLIT-SCAN TIME   | 3 - 5                |
| NOISE FILTER     | 16                   |
| CHART EXPANSION  | 5                    |
| WAVELENGTH, HIGH | 3000cm <sup>-1</sup> |
| WAVELENGTH, LOW  | 2900cm <sup>-1</sup> |

2. After the instrument is warmed up, fill the measuring cell with Freon 113, seal the filling tubes with the Teflon plugs provided with the cell, and place in the measuring compartment. Adjust the %transmittance of this sample to 96% by keying in 96 and pressing the Pen Set key on the keyboard. Then press the Scan key and allow the instrument to scan the baseline sample over the wavelength region of interest. Use a red ink pen to record the scan.
3. Return the wavelength to 2930cm<sup>-1</sup>, press the pen down momentarily to place a dot on the recording paper. Run out the chart paper so that the region of interest is on the flat portion of the recorder. Using a ruler and a fine pen or pencil, mark a line down the chart paper at the red dot mark indicating the wavelength of interest. Record the absorbance, as read from the chart paper, in the laboratory notebook.
4. Replace the Freon 113 in the cell with a 50ppm standard sample. Trace and record the spectrum of this sample using a green marking pen. Record the absorbance of this sample in the laboratory notebook.
5. Repeat step 4 using a 150ppm standard in the place of the 50ppm standard. The cell must be rinsed with Freon between each sample.
6. Again replace the sample in the cell with a blank sample which has been put through the extraction process along with the samples. Using a black marking pen, trace the spectrum over the region of interest. The value obtained for this blank must be less than 10ppm for solid samples and 1.0ppm for liquid samples.
7. Repeat step 6 using analytical samples and scanning over the region of 2940cm<sup>-1</sup> to 2920cm<sup>-1</sup> only.

## CALCULATIONS

$$\text{TPH in ppm} = \frac{A \times 150 \times \text{dilution factor} \times \text{extraction factor}}{B}$$

where            A is the absorbance of the sample - absorbance  
                     absorbance of the baseline.  
                     B is the absorbance of the 150ppm standard -  
                     absorbance of the baseline.

QUALITY CONTROL

1. Two standards are run before each analysis group. One of these standards is used to establish a standard absorbance and the other is to check that the curve is still valid.
2. Blanks are run at a frequency of one for every batch extracted or for each tenth sample analyzed whichever is the more frequent.
3. Duplicates are run at a frequency of one for every tenth sample extracted or one per batch analyzed whichever is the more frequent.

## REFERENCES

1. EPA 600/4-79-020, revised March, 1983, Method 418.1

TOTAL PETROLEUM HYDROCARBONS  
ANA-LAB's Summarization of EPA Method 418.1  
LIQUID EXTRACTION

SCOPE: This method is for the measurement of Freon 113 extractables from water and wastewater. It is applicable to measurement of light fuels. This method is sensitive to levels of 1 mg/L or less.

REAGENTS

1. Hydrochloric acid (HCl), 1+1 - Carefully add a portion of HCl to an equal portion of water. Mix well.
2. Sodium Sulfate ( $\text{Na}_2\text{SO}_4$ ), anhydrous.
3. Silica Gel, 60-200 mesh, Davidson grade 950 or equal.
4. Freon 113 (1,1,2-trichloro-1,2,2-trifluoroethane).

APPARATUS

1. Separatory funnel, Teflon, 1 liter.
2. Beaker, Griffin, 150 ml.
3. Filter paper, Whatman 40, 11 cm circle.
4. Funnel, glass, 75mm stemless.
5. Vial, 40ml screw cap, previously rinsed with Freon, equipped with Teflon lined cap.

PROCEDURE

1. Pour entire sample into separatory funnel.
2. Rinse sample bottle with 30ml of Freon and add rinsings to separatory funnel.
3. Place stopper in separatory funnel and shake vigorously for 2 minutes. Funnel should be vented about every 15-20 seconds by inverting and opening and closing stopcock.
4. Place separatory funnel on a ring stand and allow layers to separate.
5. Drain bottom solvent layer from separatory funnel through a funnel containing about 2 to 3 grams of Sodium Sulfate and about a teaspoonful of silica gel. Catch the solvent in a 150 ml beaker.
6. Repeat steps 2 through 5 twice more.
7. Rinse the tip of the separatory funnel and the filter with a total of 5-10ml of solvent. Catch these rinsing in the 150ml beaker.
8. Transfer total volume of rinsings to a 40ml vial and cap with a Teflon lined screw cap.
9. Sample is now ready for analysis by Infrared spectroscopy.

#### QUALITY CONTROL

1. One blank should be carried through this extraction procedure with every batch of 10 samples or fraction of 10 samples.
2. One duplicate sample should be extracted for every group of 10 samples or fraction of 10 samples.

#### REFERENCES

1. EPA 600/4-79-020, revised March, 1983, Methods for Chemical Analysis of Water and Wastes.
2. Standard Methods for the Examination of Water and Wastewaters, 16th Edition, APHA/AWWA

TOTAL PETROLEUM HYDROCARBONS  
ANA-LAB's Summarization of EPA SW-846 Method 3550  
SOLID EXTRACTION

SCOPE: This procedure is used to quantitatively remove the Freon extractable petroleum hydrocarbons from soil or solid samples in preparation for subsequent analysis by infrared spectroscopy. It has the disadvantage of being calibrated with a mixture of three different heavy hydrocarbons measured on a infrared spectrometer. It is assumed that all hydrocarbon contamination has the same composition as this calibration mixture.

REAGENTS

1. Freon 113 (1,1,2-trichloro-1,2,2-trifluoroethane)
2. Sodium sulfate, anhydrous powder.
3. Silica gel, 60-100 mesh, Davidson grade 950.

APPARATUS

1. Horn sonicator, Branson 450 Sonifier or equivalent, operated at a Duty cycle of 50, Output at microtip limit setting and Time of 10 minutes.
2. Beaker, 150ml Griffin style.
3. Vial, 40ml, equipped with a Teflon lined screwcap.
4. Glass Funnel, 75mm stemless.
5. Filter paper, Whatman #40, 11cm or equivalent.
6. Beaker, 400ml Griffin style (a one-pint straight side glass Mason jar may be substituted.)

PROCEDURE

1. Weigh 30 grams of well mixed sample into a 400ml beaker.
2. Add to this sample enough powdered Sodium sulfate to yield a mixture which appears to be dry and has a consistency of very dry biscuit dough (i.e. the sample will form very small balls or appear to be a dry granular substance when stirred).
3. Add 100 ml of Freon and stir well.
4. Place in the sonicator and sonicate for 10 minutes. (Determine that the sonicator is rotating and mixing samples well.)
5. While the sample is sonicating, prepare the filter by folding filter paper into quarters, opening to form an inverted cone, and placing in a funnel supported on a 150ml beaker.

6. Add about a teaspoonful of silica gel followed by an equal amount of Sodium sulfate to the filter paper.
7. At the end of the sonication period, decant the Freon layer onto the filter.
8. After all the solvent has run through the filter, pour 5-10ml of Freon through the filter paper to rinse. Collect these rinsing in the beaker with the rest of the sample.
9. Stir the contents of the beaker and transfer the contents to a 40ml vial and cap with a Teflon lined screwcap.
10. Sample is now ready for analysis by infrared spectroscopy.

#### QUALITY CONTROL

1. A duplicate sample is carried through the extraction for every batch of 10 samples or fraction of 10 samples.
2. A blank is extracted for every batch of 10 samples.

#### REFERENCES

1. EPA SW-846 Method 3550

## **APPENDIX N**

### **HEALTH AND SAFETY PLAN FOR THE AFSCAPS DEMONSTRATION, TEST AND EVALUATION PROGRAM AT TINKER AFB**

**HEALTH AND SAFETY PLAN  
FOR THE  
AFSCAPS DEMONSTRATION, TEST AND EVALUATION PROGRAM  
AT  
TINKER AIR FORCE BASE**

**Submitted to:**

**OKLAHOMA CITY AIR LOGISTICS COMMAND  
DIRECTORATE OF ENVIRONMENTAL MANAGEMENT  
OC-ALC/EM  
TINKER AFB, OKLAHOMA 73145**

**Prepared By:**

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**ARA Project Number 5735**

**July 20, 1992  
Revised August 17, 1992**

# HEALTH AND SAFETY PLAN

## Table of Contents

|                                            | <u>Page</u> |
|--------------------------------------------|-------------|
| 1.0 PURPOSE . . . . .                      | 1           |
| 2.0 EMERGENCY INFORMATION . . . . .        | 1           |
| 2.1 Emergency Contacts . . . . .           | 1           |
| 2.2 Emergency Route to Hospital . . . . .  | 2           |
| 2.3 Emergency Procedure . . . . .          | 2           |
| 3.0 APPLICABILITY . . . . .                | 2           |
| 4.0 BACKGROUND INFORMATION . . . . .       | 4           |
| 5.0 HAZARD EVALUATION . . . . .            | 5           |
| 6.0 SITE DELINEATION AND CONTROL . . . . . | 5           |
| 7.0 SITE SAFETY MEASURES . . . . .         | 5           |
| 7.1 Air Monitoring . . . . .               | 5           |
| 7.2 Level of Protection . . . . .          | 6           |
| 7.3 Work Limitations . . . . .             | 6           |
| 7.4 Site Safety Personnel . . . . .        | 6           |
| 7.5 Decontamination Procedures . . . . .   | 7           |
| 7.6 Forms . . . . .                        | 7           |

## LIST OF TABLES AND FIGURES

|                                              | Page |
|----------------------------------------------|------|
| Table 1. Emergency Contacts . . . . .        | 1    |
| Table 2. Basic Emergency Procedure . . . . . | 2    |
| Figure 1. Tinker AFB Site Plan . . . . .     | 3    |

## 1.0 PURPOSE

The purpose of this plan is to assign responsibilities, establish personnel protection standards and mandatory safety practices and procedures, and provide for contingencies that may arise while conducting cone penetrometer testing, sampling and other on-site activities at Tinker Air Force Base. This plan is consistent with Applied Research Associates, Inc. (ARA) general safety policy for site characterization work (Appendix A).

## 2.0 EMERGENCY INFORMATION

### 2.1 Emergency Contacts

Should any situation of unplanned occurrence require outside support services or emergency support contacts listed in Table 1 should be made, as appropriate.

Table 1. EMERGENCY CONTACTS

| CONTACT                                                             | TELEPHONE      | NAME/FACILITY                                       |
|---------------------------------------------------------------------|----------------|-----------------------------------------------------|
| Police                                                              | ext. 43737     | Tinker AFB Security                                 |
| Fire/Spill                                                          | ext. 73117     | Tinker AFB Fire Dept.                               |
| 24-Hr. Ambulance                                                    | ext. 43768     | Tinker AFB Fire Dept.                               |
| Hospital                                                            | ext. 48249     | Tinker AFB Hospital                                 |
| Safety Office                                                       | ext. 93263     | Tinker AFB Health Dept.                             |
| Bio                                                                 | ext. 478844    | Tinker AFB Health Dept.                             |
| Client Contact/TAFB Coordinator                                     |                | Beverly Allen                                       |
| USEPA, Dallas                                                       | (214) 655-6730 | Lydia Boada-Clista (RCRA)<br>Susan Webster (CERCLA) |
| OK State Dept. of Health<br>(OSDH)                                  | (405) 271-7158 | Damon Wingfield (RCRA)<br>Hal Cantwell (CERCLA)     |
| OSDH Spill Hotline                                                  | (405) 521-2481 |                                                     |
| ARA On-Site Project Manager                                         | (802) 763-8348 | Jack Jemsek                                         |
| ARA On-Site Safety Officer                                          | (802) 763-8348 | Robert Wilson                                       |
| ARA Office Project Manager                                          | (802) 763-8348 | Jim Shinn                                           |
| Corporate Operations Officer                                        | (505) 883-3636 | Jim Eddings                                         |
| Nearest Water, Telephone, Radio to be determined for each site area |                |                                                     |

## 2.2 Emergency Route to Hospital

Tinker AFB Hospital is located in the northwest corner of the base. The hospital resides on the south side of Arnold Street, approximately 0.5 mile west of Patrol Road (see Figure 1). Access to the hospital may be gained from 2nd Street or Patrol Road, depending on the point of origination.

## 2.3 Emergency Procedure

In the event that an emergency develops on-site, appropriate procedures should be taken by the field crew. Table 2 lists basic emergency conditions with responses.

Table 2. BASIC EMERGENCY PROCEDURE

| EMERGENCY                                                                                                      | RESPONSE                                                                                                            |
|----------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------|
| Any member of the field crew is involved in an accident or experiences adverse effects or symptoms of exposure | Entire field crew should immediately halt work and act according to the instruction provided by the on-site manager |
| A condition is discovered that suggests the existence of a situation more hazardous than anticipated           | Field crew should evacuate the site and re-evaluate the hazard and level of protection required                     |

Should the situation require outside support services or an increase in the protection level, the client will be notified along with the senior ARA contacts noted in Table 1.

## 3.0 APPLICABILITY

The provisions of the Plan are mandatory for all on-site ARA employees and ARA subcontractors engaged in on-site operations who will be exposed or have the potential to be exposed to on-site hazardous substances.

ARA personnel, subcontractors, and visitors are responsible for operating in accordance with the Occupational Safety and Health Administration (OSHA) rules and regulations, 29 CFR 1910: General Industry Standards; 29 CFR 1926: Construction Industry Standards; and applicable state or local legislation as relevant to their respective site activities.

**Tinker AFB, OK  
Site Plan  
AFSCAPS Project**

Key features and labels on the map include:

- Boundaries:** INSTALLATION BOUNDARY, OUTFALL/E. SOLDIER CREEK
- Streets and Roads:** 29TH STREET, 40TH AVE, INTERSTATE 40, GATE 1, GOLF COURSE, ARNOLD STREET, 1ST AVE, 2ND STREET, 59TH STREET, PATROL ROAD, PATROL RD., RESERVE RD., RAPCON RD., STORAGE RD., LANDFILL RD., DOUGLAS BOULEVARD, EAST DRIVE, PERIMETER DR.
- Facilities:** HOSPITAL, HOUSING, Landfill 2&4, FTA (Fuel Treatment Area), USTs (4 Fuel), Fuel Purge Area, NTA (Non-Hazardous Toxic Area), IWTP (Industrial Wastewater Treatment Plant), Offbase
- Gates:** GATE 1, GATE 2, GATE 3, GATE 20, GATE 21, GATE 34
- Other:** RUNWAY, RUNWAY, RUNWAY, AREA 8, SOONER ROAD

Scale: 0 1000 2000 Feet

APPLIED RESEARCH ASSOCIATES, INC.

Figure 1. Site plan.

### Sites to be Investigated

ARA policy states that ARA subcontractors shall provide a health and safety plan for their employees covering any exposure to hazardous materials and shall complete all work in accordance with that plan. The subcontractor may choose to use ARA's Health and Safety Plan as a guide in developing its own plan or may choose to adopt in full the ARA plan. In either case, the subcontractor shall hold ARA harmless from, and indemnify it against, all liability in case of any injury. ARA reserves the right to review and approve the subcontractor's plan at any time. All subcontractors will, at a minimum, follow all provisions of the ARA Health and Safety Plan.

#### **4.0 BACKGROUND INFORMATION**

As shown in Figure 1, eight site areas within Tinker AFB (North Tank Area (NTA), Fuel Purge Area, Four Fuels Site (USTs), Fire Training Area (FTA), Industrial Wastewater Treatment Plant (IWTP), E. Soldier Creek/Outfall, Offbase, and Landfills 2 & 4) are to be investigated to evaluate the extent of petroleum-contamination in the shallow subsurface using cone penetrometry and drilling. The first 4 sites are contaminated mainly by jet fuel. The latter 4 site areas, in addition to the North Tank Area, has subsurface contamination by solvents or metals. Additionally, alpha and beta radiation and methane will be tested at Landfills 2 & 4. Uncontrolled release of contaminants at each site area may have occurred within the last few years at some of the sites, the most active being the Fuel Purge Area.

A prototype in situ Laser-Induced Fluorescence (LIF) spectrometer and cone penetrometer system is to be demonstrated as part of a comprehensive site characterization and on-site analysis program. Planned activities by ARA include: 1) electronic cone penetrometer testing with ARA cone penetrometer vehicle and probes, 2) soil and water sampling using the cone penetrometer, 3) grouting with a tremmie pipe or self-grouting CPT module, 4) monitoring subcontractor drilling for retrieval of soft rock samples, 5) collecting soil and water samples from open drill holes, and 6) performing on-site volatile organic analysis of sediment and water samples. The proposed period of investigation is August 1992 and September, 1992.

calibrated daily and noted in the project field notebook. Background readings will be taken after each station set-up. The frequency of readings will correspond with the retrieval of soil samples. Action levels for monitoring with the HNu and 10.2 eV lamp are readings greater than 10 ppm. Action levels for the CGI and the oxygen meter are readings greater than 10% of the lower explosive limit (LEL) and less than 21.0% oxygen, respectively.

## **7.2 Level of Protection**

All on-site work will be conducted with OSHA Level D personnel protection or better. For cone penetration testing, this includes, but is not limited to, the use of petroleum chemical-resistant gloves for sampling, steel toe and shank boots, shirt and long pants, and safety eyewear. Hard hats are required in the vicinity of drilling activities.

## **7.3 Work Limitations**

In general, field work will be conducted during daylight hours only. At least two personnel will be in the field at all times. The ARA On-Site Project Manager must grant special permission for any field activities conducted beyond daylight hours. All ARA personnel working in the field will have completed the OSHA-certified hazardous waste site activity training course and yearly refresher course. Additionally, all ARA field personnel have been declared medically fit for duty and, where respiratory protection is necessary, have been properly trained, fit tested and declared fit for respirator use. No drilling shall take place without first confirming the absence of subsurface utility lines or other buried metal objects. Clearance for digging at all sites will be obtained from appropriate Tinker AFB authorities.

## **7.4 Site Safety Personnel**

As indicated in Table 1, the work party will consist of the following persons:

On-Site Project Manager: Jack Jemsek

On-Site Safety Officer: Robert Wilson

Work Party #1: qualified ARA personnel to be assigned

## **5.0 HAZARD EVALUATION**

The overall hazard potential for the proposed site activities is deemed to be low. The cone penetrometer is a minimally-invasive tool which does not bring excess subsurface soil to the surface. The penetrometer vehicle is set up to decontaminate all probing equipment as the penetrometer is extracted. Air monitoring within the CPT vehicle will be performed as deemed necessary. A synopsis of the known hazards, which was taken from recent demonstration work plans prepared for Tinker AFB, is provided in Appendix B. Besides the chemical and flammable hazards associated with fuels, a few physical and biological hazards have also been defined. The physical hazards are related to heavy equipment operation, aircraft movement, proximity to industrial activities (wastewater treatment plant, landfill, fuel purge zone), and noise. Biological hazards are mainly attributed to heat stress.

## **6.0 SITE DELINEATION AND CONTROL**

At each of the 8 study areas, natural barriers are inadequate to prevent access to the site. Therefore, provisions to restrict non-essential personnel from site activities will be utilized. Work zones, i.e., the interior of the CPT vehicle, or within 20 feet of the drilling, will be delineated for restriction of non-authorized personnel. These work zones will be established by flagging around the immediate area during the following activities: cone penetration testing and sampling, drilling and grouting. All work zones will be entered in Level D protection (see below).

## **7.0 SITE SAFETY MEASURES**

### **7.1 Air Monitoring**

Applicable air quality instruments will be employed, depending on the anticipated site conditions. This generally entails the use of an organic vapor measurement device (HNu) with the cone penetrometer and around the drilling area. A combustible gas indicator (CGI) and oxygen meter will be required for cone work at Landfill 2 & 4. These instruments will be

The responsibilities of the On-Site Project Manager, the On-Site Safety Officer and ARA project personnel are listed in Appendix D and must be adhered to at all times. Additional standard safe work practices for cone penetrometer field operations, detailed in Appendix A, will be observed as well.

## **7.5 Decontamination Procedures**

Personnel decontamination will take place at an area upwind of the work zone (cone penetrometer vehicle or drill rig). The decon pad will consist of an appropriate plastic sheeting placed on the ground. A boot/glove wash and rinse bucket and disposal bags will be available for the personnel protection equipment. Decontamination solution will be a non-phosphate detergent with a clear water rinse. Gross contamination will be removed as necessary within the work zone.

The level of equipment decontamination will be determined after inspection of the extent of contamination. Gross contamination will be removed at the work site prior to its transfer to the decontamination pad. Equipment will be decontaminated by steam-cleaning with a solution of hot water and approved detergent, rinsed with clear water, and allowed to air dry for not less than 10 minutes. Additional cleaning will be performed if the equipment appears to have residual contamination.

## **7.6 Forms**

The following forms are located in Appendix E: Plan Acceptance Form, Site Safety Briefing Form and Plan Feedback Form. The Plan Acceptance Form should be filled out by all employees engaged in on-site activities. The Site Safety Briefing Form should be filled out by the On-Site Safety Officer and signed by all employees engaged in on-site activities. The Plan Feedback Form should be filled out by the On-Site Safety Officer and any other on-site employee who wishes to fill one out.

**APPENDIX A**

**SAFETY POLICY FOR CONE PENETROMETER  
FIELD WORKER**

# **SAFETY POLICY FOR PENETROMETER FIELD WORKERS**

## **APPLIED RESEARCH ASSOCIATES, INC.**

### **NEW ENGLAND DIVISION**

#### **PURPOSE**

Applied Research Associates, Inc. (ARA) owns and operates custom-built penetrometer testing rigs to perform geotechnical site investigations. This equipment is operated by ARA staff personnel at sites throughout the country. These testing activities require work around heavy diesel-powered trucks, drill rigs, electrical systems, hydraulic systems, and compressed gases. The opportunity for serious accidents exists with the routine use of this equipment.

Worker safety is a primary concern during all of ARA's testing activities. It is the purpose of this safety policy to ensure a safe working environment during penetrometer testing activities.

#### **RESPONSIBILITIES**

**Management.** ARA management is responsible for setting policy and practice to ensure a safe working environment. Specific responsibilities include:

- developing, reviewing, and updating this policy;
- providing safe equipment in good working order for use during field operations. This includes the safe operating condition of ARA vehicles driven on the highways determined to be unsafe. Equipment will be promptly repaired or replaced;
- providing new worker orientation as well as training on a continuing basis to correct unsafe work habits;
- providing specialized worker training for work on hazardous waste sites.

**Field Workers.** Typically, ARA field workers perform testing services for a project without on-site supervision from ARA management. Hence, the field workers are ultimately responsible for maintaining a safe working environment. Field workers must:

- follow provisions of this safety policy and, specifically, to wear the required

personal safety equipment;

- identify and report any site hazards, broken or defective equipment, or the unsafe conditions to their supervisor;
- report any accidents or injuries that occur during testing activities (this is necessary to identify potentially unsafe conditions);
- report any personal medical conditions that could pose additional risks when performing field work.
- field workers always have the right to suspend specific activities if an undue safety risk is present. Report such conditions immediately.
- site visitors who refuse to abide by the safety rules outline in this policy should be asked to leave.

Everyone should be reminded that safety measures reduce injuries and can save lives, but will be ineffective if each individual does not follow the provisions of this policy. Also, as no policy can cover every situation, workers are expected to use their own judgement to maintain on-site safety.

### **GENERAL SAFETY RULES**

1. The use of illegal drugs or narcotics is strictly forbidden. No person is to be permitted around ARA testing activities while under the influence of alcohol. The use of prescription drugs that could potentially affect a site worker (such as causing drowsiness or susceptibility to heat stroke) should be reported to your supervisor.
2. Minimize heavy lifting. Always lift with your legs to avoid back injuries.
3. Be aware of potential risks due to heat or cold. Always drink plenty of fluids. When needed, take breaks to rest, warm up, or cool down.
4. Use seat belts when driving or riding in any vehicle including penetrometer trucks and rental cars.
5. Certain project sites may require additional safety measures which must be observed. The provisions on this policy are to be considered as minimum requirements that must be followed on any site.
6. Remember the buddy system. Alert your partner to hazardous conditions. Be on the look out for abnormal behavior that may indicate illness, heat or cold stress, or exposure to hazardous materials.

7. Horseplay on site is dangerous and forbidden.

## TESTING EQUIPMENT

All components, instruments, and equipment should be properly maintained. Safety guards on power tools should be used. Damaged power cords and hydraulic lines should be repaired or replaced. Broken handles on hand tools should be replaced. More specifically:

1. Special care should be taken when ascending or descending the stairs leading into the back of the testing trucks. Also, use care when climbing onto the top of the trucks. Muddy and wet conditions can result in very slippery surfaces.
2. When using compressed gas cylinders, special precautions are warranted. Always close the tank valve and place a valve cap on the tank when not in use. Secure cylinders in an upright position using ropes, cables, or chains. Take special care to secure cylinders prior to transport.

## PERSONAL SAFETY EQUIPMENT

Assuming Level D contamination levels, the following personal protection equipment should be used:

1. Shirts and long pants must be worn at all times.
2. Steel toe safety shoes must be worn at all times.
3. Safety glasses, with side shields, must be worn during testing operations.
4. Hearing protection will be used for prolonged work around the penetrometer truck.
5. Hard hats will be worn when working around drill rigs.

Because each individual may have their own preferences for some of this equipment, each field worker will be asked to supply safety glasses, safety shoes, and hearing protection. To offset the cost of this equipment, each field worker will receive an annual stipend of \$150.00. ARA will continue to furnish hard hats and special safety gear for work on hazardous waste sites.

## UTILITIES

Contact with overhead or buried utilities poses a very dangerous situation for the site

worker. Every precaution should be taken, both during project planning stages and field operations, to minimize this risk. Everyone should remember that there is no fool-proof method for locating utilities. Caution and diligence on the part of every employee is the best insurance against such an accident. Be particularly careful of low overhead power lines when moving a rig around a site.

## **ENFORCEMENT**

ARA takes worker safety very seriously and will hold each employee responsible to follow the provisions of this policy. This policy is not only for your personal safety, but for the safety of those you work with. Disciplinary action will be taken against any employee who refuses to abide by measures described in this policy.

**APPENDIX B**  
**HAZARDOUS MATERIAL SUMMARY**  
**AND**  
**HAZARD EVALUATION**

## HAZARDOUS MATERIAL SUMMARY AND HAZARD EVALUATION

The following hazardous materials and safety hazards are either known or suspected to be on site:

### CHEMICAL

Several volatile and semi-volatile organic compounds have been discovered in previous site investigations. These compounds are generally hazardous by inhalation and ingestion and may also be hazardous by contact or skin absorption. The toxicity of these compounds varies, as do the symptoms and effects of exposure. Generally, symptoms of acute exposure result in eye, nose, and throat irritation, headache, nausea, vomiting, etc. The vapors given off by these compounds are in some cases easily detected by smell, but are not in other cases. Most are detectable using an organic vapor monitoring instrument (HNu).

OSHA regulations mandate a Permissible Exposure Limit (PEL) for these compounds. These limits are determined by extensive research and testing and are being constantly re-evaluated. The (OSHA) PEL is considered the highest concentration of a compound that an individual can be exposed to without adverse health effects. The PEL concentration is an average over eight hours (a typical work shift) known as the threshold limiting value (TLV) time weighted average (TWA) by the American Conference of Governmental Industrial Hygienists (ACGIH). The (OSHA) ceiling value is the maximum concentration individuals can be exposed to regardless of the length of exposure time (i.e., not averaged). The action level represents the maximum concentration individuals can be exposed to at each level of personal protection before additional measures must be taken. This level is roughly equivalent to an Immediate Danger to Life and Health (IDLH) Limit or TLV-Ceiling Limit. Action levels are generally much lower than the PEL in order to provide an additional safety margin to the individual.

Organic vapor concentrations are expected to remain below the action levels due to low contamination levels, natural and mechanical ventilation, and minimal (cone penetrometer) or limited (through boreholes and drill cuttings) access to the contamination. Continuous monitoring ambient air with the HNu will alert personnel if organic vapor concentrations are

approaching the action level. The action level for Level D is defined as greater than 10 ppm using an HNu equipped with a 10.2 eV lamp. Respiratory protection using an air-purifying respirator with organic vapor cartridges can extend the PEL concentration and/or the period of exposure in some cases. However, if the action level is reached, personnel shall immediately evacuate the area and consult the site safety officer regarding further action.

In addition to the exposure hazards listed above, organic compounds can be combustible, flammable, or explosive. The concentrations expected at this site should not represent a fire or explosion hazard. However, underground pockets of organic vapors can build up and be released during invasive operations. Cone penetrometry with self-grouting substantially decreases this possibility. Continuous monitoring with a combustible gas meter is necessary to alert personnel when this condition exists. The instrument alarm will sound at a level well below any dangerous level.

Due to the low concentrations of contaminants expected compared to the chemical PELs, the ventilation provided, and continuous monitoring, hazards are evaluated as being low.

#### **PHYSICAL:**

In addition to the above outlined chemical hazards, physical hazards exist. They primarily arise from the use of heavy equipment, aircraft movement, proximity to industrial activities, noise, and biological hazards.

Personnel working around heavy equipment should be constantly aware of the location, position, or movement of the equipment and avoid contact with any part of the moving equipment. Work is not planned for areas with aircraft movement and personnel should avoid such areas. Aircraft may be moving adjacent to the work areas, however, and will create a noise hazard in addition to that of the heavy equipment used onsite. Appropriate ear protection will minimize this hazard.

All work sites will require minimally intrusive (cone penetrometer testing) or intrusive

(drilling) activities which will require that an excavation permit be issued by the appropriate Tinker AFB authority. This will require verification of overhead and underground utility locations. Personnel should be aware of the possibility of undiscovered utilities and use caution when excavating or drilling onsite. Other permits may be required (such as hot work permits) and must be obtained before work of this type may proceed.

The primary biological hazard onsite during this phase is heat stress. Lyme disease and poison oak may be potential hazards, depending on the specific site area conditions. Information and procedures concerning heat stress is contained elsewhere in this plan. The site safety officer will be responsible to see that the procedures are strictly followed by all onsite personnel in order to maintain a hazard evaluation of low for the above mentioned physical hazards.

## **APPENDIX C**

### **HEAT STRESS**

## HEAT STRESS

Since site work is to be conducted during the summer in a possibly hot environment, heat stress is a concern in the health and safety of personnel. For workers wearing permeable clothing, recommendations for monitoring requirements and suggested work/rest schedules are taken from the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values for Heat Stress. For workers wearing semipermeable or impermeable clothing, the ACGIH standard cannot be used (for these situations, workers should be monitored when the temperature in the work area is above 70°F).

To monitor workers, measure:

- Heart rate. Count the radial pulse during a 30-second period as early as possible in the rest period. If the heart rate exceeds 110 beats per minute at the beginning of the rest period, shorten the next work cycle by one-third and keep the rest period the same. If the heart rate still exceeds 110 beats per minute at the next rest period, shorten the following work cycle by one-third.
- Oral temperature. Use a clinical thermometer (3 minutes under the tongue) or similar device to measure the oral temperature at the end of the work period (before drinking). If the oral temperature exceeds 99.6°F (37.6°C), shorten the next work cycle by one-third without changing the rest period. Do not permit a worker to wear a semipermeable or impermeable garment when his/her oral temperature exceeds 100.6°F (38.1°C).
- Body water loss, if possible. Measure weight on a scale accurate to  $\pm 0.25$  lb at the beginning and end of each work day to see if enough fluids are being taken to prevent dehydration. Weights should be taken while the employee wears similar clothing, or, ideally, is nude. The body water loss should not exceed 1.5 percent total body weight loss in a work day.

Initially, the frequency of physiological monitoring depends on the air temperature adjusted for solar radiation and the level of physical work (see following Table). The length of the work cycle will be governed by the frequency of the required physiological monitoring.

SUGGESTED FREQUENCY OF PHYSIOLOGICAL MONITORING  
FOR FIT AND ACCLIMATED WORKERS

| ADJUSTED TEMPERATURE (1)    | NORMAL WORK ENSEMBLE       | IMPERMEABLE ENSEMBLE       |
|-----------------------------|----------------------------|----------------------------|
| 90°F (32.2°C) or above      | After each 45 min of work  | After each 15 min of work  |
| 87.5°-90°F (30.8°-32.2°C)   | After each 60 min of work  | After each 30 min of work  |
| 82.5°-87.5°F (28.1°-30.8°C) | After each 90 min of work  | After each 60 min of work  |
| 77.5°-82.5°F (25.3°-28.1°C) | After each 120 min of work | After each 90 min of work  |
| 72.5°-77.5°F (22.5°-25.3°C) | After each 150 min of work | After each 120 min of work |

- (1) Calculate the adjusted air temperature ( $t_{adj}$ ) by using this equation:  $t_{adj}^{\circ}F = t_a^{\circ}F + (13 \times \% \text{ sunshine})$ . Measure air temperature ( $t_a$ ) with a standard mercury-in-glass thermometer, with the bulb shielded from radiant heat. Estimate percent sunshine by judging what percent time the sun is not covered by clouds that are thick enough to produce a shadow. (100 percent sunshine = no cloud cover and a sharp, distinct shadow; 0 percent sunshine = no shadows.)

If workers are not monitored for heat stress, work activities in hot environments can result in dehydration, heat exhaustion, heat stress or even heat stroke.

#### Signs and Symptoms of Heat Stress

- Heat rash of the skin may result from continuous exposure to heat or humid air.
- Heat cramps are caused by heavy sweating with inadequate electrolyte replacement. Signs and symptoms include:
  - muscle spasms
  - pain in the hands, feet and abdomen.
- Heat exhaustion occurs from increased stress on various body organs including inadequate blood circulation due to cardiovascular insufficiency or dehydration. Signs and symptoms include: pale, cool, moist skin, heavy sweating, dizziness, nausea, and fainting.
- Heat stroke is the most serious form of heat stress. Temperature regulation fails and the body temperature rises to critical levels. Immediate action must be taken to cool the body before serious injury and death occur. Competent medical help must be obtained. Signs and symptoms are:
  - red, hot, usually dry skin
  - lack of or reduced perspiration
  - nausea
  - dizziness and confusion
  - strong, rapid pulse
  - coma

## **APPENDIX D**

### **RESPONSIBILITIES OF SITE SAFETY PERSONNEL**

## RESPONSIBILITIES OF SITE SAFETY PERSONNEL

### PROJECT MANAGER

The On-Site Project Manager shall direct daily field investigations and operational efforts. The PM, assisted by the On-Site Safety Officer, has primary responsibility for:

1. Making certain that appropriate personnel protective equipment and monitoring equipment are available and properly utilized by all on-site personnel;
2. Making certain that personnel receive this plan and are aware of the provisions of this plan, are instructed in the work practices necessary to ensure safety, and are familiar with planned procedures for dealing with emergencies;
3. Confirm that personnel working on-site have the proper medical-surveillance program and Health & Safety training which qualifies them to work at a hazardous waste site. Also responsible for identifying all ARA site personnel with special medical problems (i.e. allergies).
4. Making certain that personnel are aware of the potential hazards associated with site operations;
5. Monitoring the safety performance of all personnel to ensure that proper work practices are maintained;
6. Correcting any work practices or conditions that may result in injury or exposure to hazardous substances;
7. Preparing any accident/incident reports and exposure records;
8. Assuring the completion of Plan Acceptance and Feedback Forms attached hereto.

### ON-SITE SAFETY OFFICER

The On-Site Safety Officer shall:

1. Implement project Health & Safety Plans;
2. Report to the Project Manager or designated site safety coordinators within ARA if any deviations from the anticipated conditions described in the plan;
3. Calibrate all monitoring equipment on a daily basis and record results in a field log

notebook.

4. Make certain that all monitoring equipment is operating correctly according to manufacturer's instructions and provide maintenance if it is not;

## PROJECT PERSONNEL

Project personnel involved in on-site investigations and operations are responsible for:

1. Taking all reasonable precautions to prevent injury to themselves and to their fellow employees;
2. Performing only those tasks that they believe they can do safely, and immediately reporting any accidents and/or unsafe conditions to the On-Site Safety Officer;
3. Notifying the Project Manager and On-Site Safety Officer of any special medical problems (i.e. allergies) and making certain that all on-site personnel are aware of any such problems.

## **APPENDIX E**

### **FORMS**

**PLAN ACCEPTANCE FORM**  
**PROJECT HEALTH AND SAFETY PLAN**

**INSTRUCTIONS:** This form is to be completed by each person to work on the subject project work site and returned to the Office Safety Coordinator.

Job No.: \_\_\_\_\_

Client/  
Project: \_\_\_\_\_

Date: \_\_\_\_\_

I represent that I have read and understand the contents of the above Plan and agree to perform my work in accordance with it.

\_\_\_\_\_  
Signed

\_\_\_\_\_  
Print Name

\_\_\_\_\_  
Company/Office

\_\_\_\_\_  
Date

## Site Safety Briefing Forms

### ON-SITE SAFETY MEETING

Project \_\_\_\_\_  
Date \_\_\_\_\_ Time \_\_\_\_\_ Job No. \_\_\_\_\_  
Address \_\_\_\_\_  
Specific Location \_\_\_\_\_  
Type of Work \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

### SAFETY TOPICS PRESENTED

Protective Clothing/Equipment \_\_\_\_\_  
\_\_\_\_\_  
Chemical Hazards \_\_\_\_\_  
\_\_\_\_\_  
Emergency Procedures \_\_\_\_\_  
\_\_\_\_\_  
Hospital/Clinic \_\_\_\_\_ Phone \_\_\_\_\_  
Hospital Address \_\_\_\_\_  
Special Equipment \_\_\_\_\_  
\_\_\_\_\_  
Other \_\_\_\_\_

### ATTENDEES

Name (Printed)

Signature

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Meeting Conducted By: \_\_\_\_\_  
Name (Printed)

\_\_\_\_\_  
Signature

Site Safety Officer \_\_\_\_\_ Team Leader \_\_\_\_\_

## PLAN FEEDBACK FORM

b Number: \_\_\_\_\_

b Name: \_\_\_\_\_

ate: \_\_\_\_\_

blems with plan requirements:

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unexpected situations encountered:

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commendations for future revisions:

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