Standard Operating Procedure

For

Site Characterization and Analysis Penetrometer System/Laser Induced Fluorescence (SCAPS/LIF)

SOP No: M-0003-SWT-03

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1.0 Scope and Application

1.1 Introduction

This standard operating procedure (SOP) is based on several technical reports and methods, which are referenced at the end of this document. This SOP describes the procedures used to conduct a subsurface in-situ petroleum hydrocarbon investigation with the Site Characterization and Analysis Penetrometer System and Laser Induced Fluorescence technique (SCAPS/LIF) currently deployed by the US Army Corps of Engineers Tulsa District.

1.2 Application

This SOP is applicable to the rapid investigation of subsurface petroleum hydrocarbon contamination at hazardous waste sites.

1.3 Personnel and Training

Implementation of this SOP is restricted to use by, or under the supervision of, field technicians experienced in the use of SCAPS technology and familiar with cone penetrometer testing, soil boring installation, grouting techniques, and laser-induced fluorescence.

The SCAPS manager will ensure all personnel are qualified and have received training relevant to the equipment and instruments currently possessed by the Investigations Section and used to support the District's SCAPS program. Additional District technical resources (chemists, industrial hygienists, geologists, etc.) will be used to support and enhance SCAPS operations whenever required.

2.0 Method Summary

2.1 Introduction

This SOP describes the process by which a subsurface in-situ petroleum hydrocarbon investigation will be conducted with SCAPS/LIF system.

The SCAPS system incorporates surface geophysical methods, surveying and mapping methods, special penetrometers with sensors for contaminant detection, and subsurface sampling equipment to map soil characteristics and contaminant distribution.

2.2 Cone Penetrometer System

Cone penetrometer testing (CPT) and standard penetrometer testing have been widely used in the geotechnical industry for determining soil strength and soil type from measurements of tip resistance and sleeve friction on an instrumented probe. The SCAPS uses a truck-mounted CPT platform to advance its chemical and geotechnical-sensing probe. The CPT platform provides a 20-ton static reaction force associated with the weight of the truck. The forward portion of the truck-mounted laboratory is the push room. It contains the rods, hydraulic rams, and associated system controllers. Underneath the SCAPS CPT push room is the high-pressure hot water equipment for the rod and probe decontamination system. The rear portion of the truck-mounted laboratory is the isolatable data collection room in which components of the CPT, onboard computers, and related support instruments are located.

2.3 Initial Site Survey

The site will be visually surveyed to locate underground utilities and underground obstacles to prevent damage to the SCAPS, ensure crew safety, and to prevent damage to utilities. Many sites contain a variety of underground anomalies, such as telephone cables, gas lines, electrical power cables, water pipes, sanitary sewer lines, drainage pipes, and steam lines. Utility clearances can be obtained if requested by the customer.

Once the survey has been completed, approximate locations for each planned penetration are determined based on such factors as proximity to suspected contaminant sources, anticipated groundwater flow patterns, suspected underground obstacles, cultural features, topography variations, and mobility limitations.

Dependent upon site conditions and field results, the customer, the SCAPS manager, and the technical manager will modify penetrometer locations when appropriate.

2.4 "Dummy" Exploration

At the discretion of the SCAPS manager, a "dummy" tip will be advanced into the subsurface soil to probe for any unanticipated anomalies or advance through surface obstructions (asphalt, gravel, or similar material), that may hinder the intrusive exploration of the location. The "Dummy" tip contains no sensors or sampling tools that may be damaged.

2.5 Soil Classification by Cone Penetrometer Test

A series of locations will be selected to conduct soil classifications in conjunction with the LIF method. Soil strength and type is determined by monitoring tip resistance and sleeve friction when the CPT probe is advanced through the subsurface soil.

The combination of the SCAPS's reaction mass and hydraulics can advance the probe into the ground at a rate of 1m/min in accordance with ASTM

Methods D3441 and D5778. The tip resistance is measured by means of a system of strain gauges that form an internal load cell as the cone tip is advanced. Friction developed along a floating cylindrical sleeve, just behind the cone tip, is measured similarly as the device passes through the soil. Tip penetration resistance and sleeve frictions are measured independently and continuously. The point and sleeve friction load cells are independently calibrated in the field prior to cone penetrometer operation.

Soil classification is conducted on-board the SCAPS during field operations using a computer-based routine that references the strain gauge readings, the calibration curves and an empirical relationship between cone resistance and friction. The SCAPS instruments are capable of discriminating porous sands from tighter, finer-grade silts and clays.

2.6 Laser-Induced Fluorescence (LIF)

A series of locations will be selected to conduct an in-situ analysis for petroleum hydrocarbon contamination in conjunction with the CPT soil classification method. The District's SCAPS supports a Laser-Induced Fluorescence (LIF) Sensor and Support System operated in accordance with ASTM Method D6187, except when noted otherwise within this SOP.

The SCAPS/LIF method provides data on the in-situ distribution of petroleum hydrocarbons based on the fluorescence response induced in the polycyclic aromatic hydrocarbon (PAH) compounds that are components of petroleum hydrocarbons. PAHs in petroleum products are induced to fluorescence by excitation with ultra-violet (UV) light. The method provides a "detect/non-detect" field screening capability relative to a detection limit derived for a specific fuel product on a site-specific soil matrix. The SCAPS LIF is primarily used, as a field screening, qualitative method but can be semi-quantitative at concentrations within two orders of magnitude of its detection limit for fluorescent petroleum hydrocarbons.

The LIF system uses a pulsed nitrogen laser (*PTI ™ 2300*) with an optical multichannel analyzer (*EG&G™ Model 1460*) and photodiode array detector (*EG&G™ Model 1421*) to make fluorescence measurements via optical fibers. These fibers are integrated with the penetrometer probe and umbilical of the SCAPS. The laser is fired and a response is received through a sapphire window on the probe.

Fluorescence emission spectra are collected once per second as the probe is advanced into the subsurface soil. An on-board computer is used to generate real-time depth plots of fluorescent intensity at the spectral peak, wavelength of spectral peak, sleeve friction and tip resistance, and soil type characteristics as interpreted from the strain gauge data. The fluorescent intensity in the spectral window is plotted as a function of depth in real time as the probe is pushed into the soil.

The SCAPS LIF sensor response is validated using an aqueous solution of Rhodamine 6G before and after each penetration event to monitor LIF system responses and document any system drift.

2.7 Borehole Abandonment and Grouting

Grouting will be performed to ensure that vertical cross contamination does not occur in the penetration and borehole locations. To accomplish this a bentonite-cement mixture or a mixture specified by the customer will be placed into the open borehole as the penetrometer probe/sensor is retracted.

2.8 Decontamination

Dependent upon push depth and number of locations, a small volume of decontamination fluid is generated at each location. As the penetrometer/probe is retracted, a high-pressure hot water cleaning system is used to wash each rod section and remove possible contamination. The decontamination fluid is collected in a five-gallon bucket from under the truck and transferred to a DOT certified steel drum or other approved container.

3.0 Method Limitations

3.1 Truck-Mounted Cone Penetrometer Access Limit

The SCAPS CPT support platform is a 20-ton Kenworth diesel powered truck. The dimensions of the truck require a minimum access width of 10 feet and a height clearance of 16 feet. Some sites, or areas of sites, might not be accessible to a vehicle the size of the SCAPS CPT truck. The access limits of the SCAPS CPT truck are similar to those for conventional drill rigs and heavy excavation equipment.

3.2 Cone Penetrometer Advancement Limits

The CPT sensors and sampling tools may be difficult to advance in subsurface lithologies containing cemented sands and clays, buried debris, gravel units, cobbles, boulders, and shallow bedrock. As with all intrusive site characterization methods, it is extremely important that all underground utilities and structures is located using reliable geophysical equipment operated by trained professionals before undertaking activities at a site. Utility clearances can be obtained if requested by the customer.

3.3 Response to Different Petroleum Hydrocarbons

The relative response of SCAPS LIF sensor depends on the specific analyte being measured. The instrument's sensitivity to different hydrocarbon compounds can vary by as much as two orders of magnitude.

3.4 Matrix Effects

The in-situ fluorescence response of the LIF sensor to hydrocarbon compounds is also sensitive to variations in the soil matrix. Matrix properties that affect LIF sensitivity include soil grain size, mineralogy, moisture content, and surface area. Each of these factors influences the relative amount of analyte that is adsorbed on or absorbed into the soil. Only the relative fraction of analyte that is optically accessible at the window of the probe can contribute to the fluorescence signal.

3.5 Spectral Interferences

The SCAPS LIF sensor is sensitive to any material that fluoresces when excited with ultraviolet wavelengths of light. Although intended to specifically target petroleum hydrocarbons, the excitation energy produced by the LIF system's laser may cause other naturally occurring substances to fluoresce as well.

4.0 Quality Assurance/Quality Control

4.1 Overview

Geotechnical and chemical data generated by field crews during the SCAPS investigation will be reviewed by personnel possessing the required skills necessary to evaluate and validate the results. A quality assurance officer will be assigned to the project to ensure that the data quality objectives for the project are adequately being met.

4.2 SCAPS CPT QA/QC

Initial system setup will require the calibration of a few components including, but not limited to, the point and sleeve friction load cells, strain gauges. Calibrations will occur whenever a different probe assembly is used.

4.3 SCAPS LIF QA/QC

Initial system setup will require the calibration of a number of components including, but not limited to, the laser, the detector, strain gauges.

An evaluation of the sensitivity of the LIF sensor and contamination encountered at the site is completed by collecting a number of confirmation soil samples from various depths, and either analyzing these samples on-site or at an analytical laboratory. The field or laboratory analytical tests should adequately characterize the soil sample for the presence of petroleum hydrocarbon contaminants, especially polyaromatic hydrocarbons. Acceptable methods include, but are not limited to, EPA method 418.1, modified 8015, modified 8270.

Due to the nature of the in-situ measurement, duplicate samples cannot be measured by LIF. Soil heterogeneity and variation in contaminant distribution can be significant over short distances both horizontally and vertically. A number of soil samples will be collected at various depths and locations to allow a range of contamination levels to be analyzed and evaluated. Select soil samples will be homogenized. One portion of the homogenized sample will be containerized and submitted for laboratory analysis. Another portion will be containerized and stored until the LIF probe has been retracted into the push room. At that point, the sample will be place upon the LIF tool's sapphire window and fired upon. The spectral data collected from that shot may then be compared to the laboratory analytical results.

5.0 Waste Disposal

Decontamination fluids and other investigative derived wastes (IDW) generated during SCAPS activities will be properly containerized, staged, labeled, and managed in accordance with the project work plan. The volume of waste will be minimized whenever applicable. Soil, liquid, and personal protective equipment (PPE) IDW will be separately containerized and segregated. The PPE will be disposed of as nonhazardous waste unless it has been grossly contaminated or is determined to be contaminated by on-site field data.

6.0 Health and Safety

A site-specific safety and health plan will be developed for SCAPS and related SCAPS activities. All field personnel will attend safety meetings scheduled by SCAPS field manager and industrial hygiene officer.

All field personnel will follow current OSHA standards and regulations documented within USACE's EM385-1-1.

7.0 References

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American Society for Testing and Materials (ASTM). (1998). “Standard Test Method for Mechanical Cone Penetrometer Tests in Soil”. Designation D3441-98. Philadelphia, PA