**DOE/LX/07-1276&D1**
**Primary Document**

# 90% Remedial Design Report *In Situ* Source Treatment Using Deep Soil Mixing for the Southwest Groundwater Plume Volatile Organic Compound Source at the C-747-C Oil Landfarm (Solid Waste Management Unit 1) at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky

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Date Issued—February 2013

U.S. DEPARTMENT OF ENERGY
Office of Environmental Management

Prepared by
LATA ENVIRONMENTAL SERVICES OF KENTUCKY, LLC
managing the
Environmental Remediation Activities at the
Paducah Gaseous Diffusion Plant
under contract DE-AC30-10CC40020

**CLEARED FOR PUBLIC RELEASE**

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# ACRONYMS

| | |
|---|---|
| ARAR | applicable or relevant and appropriate requirement |
| bgs | below ground surface |
| DNAPL | dense nonaqueous-phase liquid |
| DOE | U.S. Department of Energy |
| E/PP | excavation/penetration permit |
| EVS-ES | Environmental Visualization Systems Expert System |
| FFS | focused feasibility study |
| FID | flame ionization detector |
| GAC | granular activated carbon |
| GC | gas chromatograph |
| HU | hydrogeologic unit |
| KO | knock-out tank |
| LDA | large diameter auger |
| LUC | land use control |
| MDL | method detection limit |
| NAL | no action level |
| OU | operable unit |
| PAH | polycyclic aromatic hydrocarbon |
| PGDP | Paducah Gaseous Diffusion Plant |
| PID | photoionization detector |
| RA | remedial action |
| RAO | remedial action objective |
| RAWP | remedial action work plan |
| RDR | remedial design report |
| RDSI | remedial design support investigation |
| RDWP | remedial design work plan |
| RGA | Regional Gravel Aquifer |
| RI | remedial investigation |
| ROD | record of decision |
| SI | site investigation |
| SPT | standard penetration test |
| SWMU | solid waste management unit |
| UCRS | Upper Continental Recharge System |
| VCS | vapor conditioning system |
| VOC | volatile organic compound |
| WAG | waste area grouping |
| ZVI | zero-valent iron |

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# EXECUTIVE SUMMARY

This Remedial Design Report has been prepared for the *In Situ* Source Treatment Using Deep Soil Mixing with Interim Land Use Controls (LUCs) Remedial Action (RA) for the Southwest Plume volatile organic compound (VOC) source area, Solid Waste Management Unit 1 at the Paducah Gaseous Diffusion Plant (PGDP) in Paducah, Kentucky. This remedial design report was prepared in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act and is the response action selected in the *Record of Decision for Solid Waste Management Units 1, 211-A, 211-B, and Part of 102 Volatile Organic Compound Sources for the Southwest Groundwater Plume at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* DOE/LX/07-0365&D2/R1 (ROD) (DOE 2012a).

The response action for VOCs selected in the ROD is required to address the release of hazardous substances into the environment that are sources of groundwater contamination and present unacceptable risk from direct exposure to residual VOCs and non-VOCs. Removal of VOCs, like trichloroethene, from the soils in the Southwest Plume source areas will contribute to the final cleanup of the Groundwater Operable Unit at PGDP.

The ROD specified an *in situ* source treatment using deep soil mixing with interim LUCs. The RA also will include the implementation of interim LUCs consisting of the Excavation/Penetration Permit Program and the posting of warning signs at the source area(s).

This report contains information regarding the design of the *in situ* source treatment using deep soil mixing remediation system, including discussions of the following:

- Mixing soil using large diameter augers;
- Injecting hot air and steam to volatize targeted contaminants;
- Injecting zero-valent iron as a polishing step for treating residual VOCs;
- Treating recovered vapor through a vapor conditioning/treatment system;
- Treating condensate via localized air stripping and/or granular activated carbon;
- Excavating 2 ft of surface soil, stockpiling, and respreading after the completion of mixing; and
- Collecting data and monitoring.

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# 1. INTRODUCTION

This Remedial Design Report (RDR) presents the 90% design for the remedial action (RA) to be implemented at the Southwest Groundwater Plume source area at Paducah Gaseous Diffusion Plant (PGDP) at Solid Waste Management Unit (SWMU) 1. The remedy planned for SWMU 1 is documented in the *Record of Decision for Solid Waste Management Units 1, 211-A, 211-B, and Part of 102 Volatile Organic Compound Sources for the Southwest Groundwater Plume at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* DOE/LX/07-0365&D2 (ROD) (DOE 2012a). The overall design process is described in the *Remedial Design Work Plan for Solid Waste Management Units 1, 211-A, and 211-B Volatile Organic Compound Sources for the Southwest Groundwater Plume at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-1268&D2/R1 (RDWP) (DOE 2012b).

The Southwest Plume Sources Record of Decision (ROD) requiring development of this remedial design document was signed March 20, 2012 (DOE 2012a). Based upon the assumption of a trichloroethene (TCE) mass/volume estimate of 49 gal and the corresponding cost estimates, Deep Soil Mixing at Solid Waste Management Unit (SWMU) 1 was determined to be cost-effective and to represent a reasonable value for the money to be spent at the time the ROD was signed. A Remedial Design Support Investigation (RDSI) subsequently was conducted to identify the extent of volatile organic compound contamination. Based on data evaluation from the RDSI, the U.S. Department of Energy (DOE) has developed a revised estimate of TCE mass/volume of 8 gal. The U.S. Environmental Protection Agency (EPA) has indicated its belief that the TCE volume could be as high as 70 gal based on its interpretation of the RDSI data. Based on the revised TCE mass/volume estimate of 8 gal, the estimated cost per unit gal would represent a significant potential increase in cost per gal for the selected remedy. The revised mass/volume estimates currently are under review by the Federal Facility Agreement (FFA) parties. Based on the revised TCE mass of about 8 gal, DOE is concerned that proceeding with the remedy as selected may not be cost-effective.

DOE requested an FFA extension of time for the submittal of the Remedial Design Report (RDR) to allow the parties time to determine what, if any, implications the changes in TCE mass/volume might have on the remedial design. EPA and the Kentucky Department for Environmental Protection (KDEP) indicated their expectation that DOE submit the RDR by the current February 19, 2013, milestone. DOE is submitting the report to comply with EPA's and KDEP's stated expectation. Due to the lack of time to engage in meaningful discussions regarding this most recent data to reconcile the estimated volume of TCE in question, DOE requests EPA and KDEP withhold approval of the design reflected in this document.

Conceptual design information provided in this report includes the following:

- Site description
- Technology description
- Remedial action objectives
- Design requirements
- Construction requirements

PGDP, located approximately 10 miles west of Paducah, Kentucky, and 3.5 miles south of the Ohio River in the western part of McCracken County, is an active uranium enrichment facility owned by the U.S. Department of Energy (DOE) (Figure 1). Bordering PGDP to the northeast, between the plant and the Ohio River, is the Tennessee Valley Authority Shawnee Fossil Plant.

The Southwest Groundwater Plume refers to an area of groundwater contamination at PGDP in the Regional Gravel Aquifer (RGA), which is south of the Northwest Groundwater Plume and west of the C-400 Cleaning Building (also known as the C-400 Building). The plume was identified during the Waste Area Grouping (WAG) 27 Remedial Investigation (RI) in 1998 (DOE 1999). Additional work to characterize the plume was performed as part of the WAG 3 RI (DOE 2000a) and Data Gaps Investigation (DOE 2000b). As discussed in these reports, the primary groundwater contaminant of concern for the Southwest Groundwater Plume (hereinafter referred to as the Southwest Plume) is trichloroethene (TCE). Other contaminants found in the plume include additional volatile organic compounds (VOCs), metals, and the radionuclide technetium-99 (Tc-99).

DOE conducted a site investigation (SI) in 2004 to address the uncertainties associated with potential source areas to the Southwest Plume that remained after previous investigations. The SI further profiled the current level and distribution of VOCs in the dissolved-phase plume along the west plant boundary. Results of the SI were reported in the *Site Investigation Report for the Southwest Groundwater Plume at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-2180&D2/R1 (DOE 2007). The Focused Feasibility Study (FFS) (DOE 2010a) is based on the SI (DOE 2007), as well as previous investigations. A Remedial Design Support Investigation (RDSI) was performed in 2012 consistent with the RDWP (DOE 2012b). Existing analytical data from the SWMU 1 source area is included on a CD as Appendix A.

The RA includes the implementation of *in situ* soil mixing with large diameter augers (LDAs) combined with the introduction of hot air and/or steam for thermal volatilization and stripping of VOCs in the soil and groundwater in the target treatment zone and injection of zero-valent iron (ZVI). The RA also includes the implementation of interim land use controls (LUCs) consisting of the Excavation/Penetration Permit Program (E/PP) and the posting of warning signs at the source areas.

An RDSI is included in the RA that was completed during July, August, and September 2012. The data collected while implementing the RDSI was used to further delineate areas of TCE impacts in the Upper Continental Recharge System (UCRS) soils and in the upper RGA [hydrogeologic unit (HU4)]. The additional data was used to refine the area to be treated by the soil mixing process. Refer to Section 1.3 for more detailed information regarding the RDSI.

This 90% design report provides information regarding the remediation system, based on unit processes and activities to be included in the *in situ* source treatment. These processes and activities will include the following:

- Mixing soil using LDAs;
- Heating soil *in situ* by application of hot air/steam;
- Removing VOCs and steam from heated subsurface zones by vacuum extraction;
- Treating recovered vapor off-gas via vapor conditioning/treatment systems;
- Injecting a ZVI slurry mixture;
- Treating condensate via localized air stripping and/or granular activated carbon; and
- Collecting real-time data and monitoring contaminant concentrations in vapor phase during extraction and treatment.

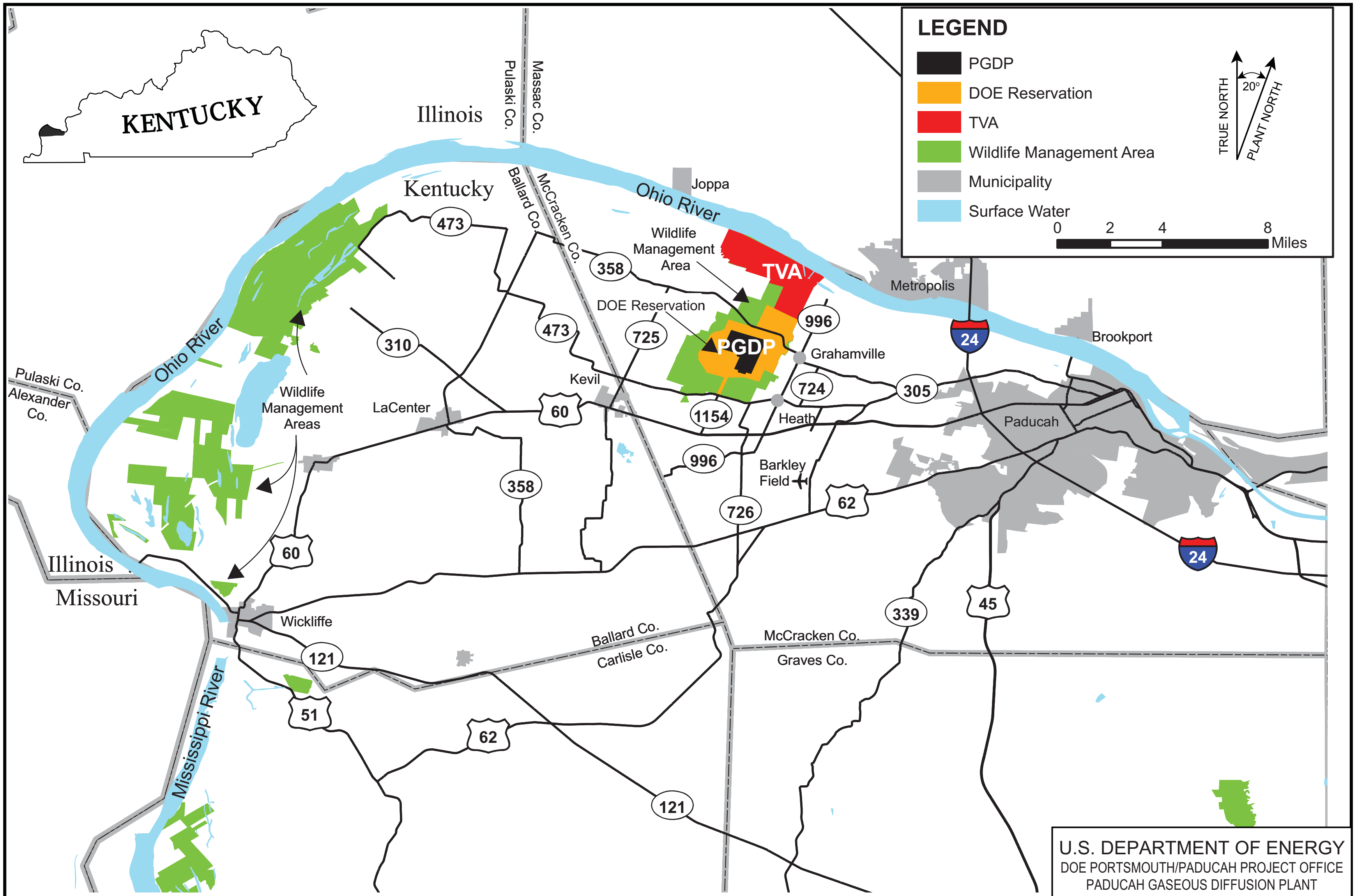


Figure 1. PGDP Site Location

U.S. DEPARTMENT OF ENERGY
DOE PORTSMOUTH/PADUCAH PROJECT OFFICE
PADUCAH GASEOUS DIFFUSION PLANT

LATA Environmental Services of Kentucky, LLC

## 1.1 REGIONAL GEOLOGY AND HYDROGEOLOGY

PGDP is underlain by a sequence of clay, silt, sand, and gravel layers deposited on limestone bedrock. The sediments above the limestone bedrock are grouped into three major stratigraphic units: (1) loess, (2) continental deposits, and (3) McNairy Formation. The continental deposits are further divided into the subunits of upper continental deposits and lower continental deposits. Hydrogeologically, there are three major units: (1) UCRS, upper continental deposits; (2) RGA, lower continental deposits; and (3) McNairy Flow System.

The upper-most stratigraphic unit consists of fill and a layer of wind-deposited, silty clay, or loess, extending from the surface to a depth of approximately 20 ft below ground surface (bgs). Beneath the loess, the upper continental deposits, a subunit of the continental deposits consisting of discontinuous sand and gravel layers interbedded with silt and clay, extend to an average depth of approximately 55 ft bgs. These deposits comprise the local hydrostratigraphic unit known as the UCRS. The lower continental deposits, also a subunit of the continental deposits, is a highly permeable layer of gravelly sand and chert gravel, typically extending from approximately 55 to 92 ft bgs. These deposits comprise the local hydrostratigraphic unit known as the RGA. Below the continental deposits is the McNairy Formation, a sequence of marine silts, clays, and fine sands that extends from approximately 92 to 350 ft bgs. These deposits comprise the local hydrostratigraphic unit known as the McNairy Flow System.

The UCRS is subdivided into the HU1, HU2, and HU3 units and consists of the loess (HU1) and the underlying upper continental deposits (HU2 and HU3). The sand and gravel lenses of the HU2 unit are separated from the underlying RGA by a 12- to 18-ft thick silty or sandy clay interval designated as the HU3 aquitard. The aquitard reduces the vertical flow of groundwater from the sands and gravels of the HU2 unit to the gravels of the RGA. The RGA is the uppermost aquifer in the Southwest Plume source areas. The RGA consists of an upper thin sand unit (HU4), which is the basal unit of the Upper Continental Deposits, and a 30-ft thick sandy gravel unit (HU5), which comprises the Lower Continental Deposits beneath most of PGDP. Below the RGA is the McNairy Flow System, which corresponds to the McNairy Formation. The uppermost portion of the McNairy Flow System typically is a clay or silty clay, which restricts groundwater flow between the RGA and McNairy Flow System.

The depth of the water table within the UCRS varies considerably across PGDP. Monitoring wells MW161 and MW162 are directly adjacent to the northern edge of SWMU 1 and are screened in the RGA from 78 to 83 ft (bgs) and the UCRS from 18 to 24 ft (bgs), respectively. Both monitoring wells were installed in 1991 and have had periodic water levels measured from 1991 to the present. MW162 (UCRS) has an average water level of 12.6 ft, while MW161 (RGA) has had an average water level over the same time period of 45.8 ft. Water within the UCRS tends to flow downward to the RGA. Groundwater flow in the RGA generally is to the northwest, although there is evidence for some divergent flow to the east and to the west as part of the Northeast and Southwest Plumes, respectively. Flow direction for RGA groundwater in the area of SWMU 1 is northwest. Divergent flow is limited primarily to the area of the PGDP site and is influenced mainly by anthropogenic recharge due to loss of water from plant piping systems for raw, sanitary, cooling, and fire water and focused infiltration from engineered runoff controls, such as paved areas, building roofs, lagoons, and ditches most of which are predominantly north and east of the SWMU 1 area.

## 1.2 TREATMENT SITE LOCATION

The treatment location for this RA is SWMU 1, C-747-C Oil Landfarm (Oil Landfarm), which is located near the western edge of the PGDP. The location of the SWMU 1 source area (Oil Landfarm) is shown in Figure 2 and is the focus of this RDR. The SWMU 1 area has been investigated several times in support of remedy selection and development of this remedial design including the Phase II SI (1991); WAG 27 RI (1997); Southwest Plume SI (2004); and the RDSI (2012). The potential Southwest Plume source areas investigated in the Southwest SI included the C-747-C Oil Landfarm (Oil Landfarm) (SWMU 1); C-720 Building Area near the northeast and southeast corners of the building [C-720 Northeast Site (SWMU 211A) and C-720 Southeast Site (SWMU 211B)]; and the storm sewer system between the south side of Building C-400 and Outfall 008 (Storm Sewer) (part of SWMU 102) (DOE 2007). As a result of the Southwest Plume SI sampling, the storm sewer subsequently was excluded as a potential VOC source to the Southwest Plume.

## 1.3 REMEDIAL DESIGN SUPPORT INVESTIGATION

The RDSI was conducted in 2012 to gather supplemental data necessary for the design and implementation of the *in situ* source treatment deep soil mixing remedial action selected for SWMU 1. Furthermore, this RDSI field effort involved the collection of contaminant characterization and engineering design-related data at the C-720 SWMUs. This data will be used to support the Federal Facility Agreement parties' decision regarding selection and implementation of either enhanced *in situ* bioremediation or long-term monitoring strategies and the subsequent remedial design efforts. The design and implementation of either the enhanced *in situ* bioremediation or long-term monitoring RA for the C-720 Building will follow the remedial action at SWMU 1 by an estimated two years.
An RDSI Characterization Plan was developed as part of the RDWP to support the implementation of the selected alternatives for remediation at the Southwest Plume and to resolve data gaps identified through a data quality objectives process (DOE 2010b). Data collected during the RDSI, coupled with data from previous investigations, has allowed for a more refined delineation of TCE concentrations in the UCRS soils and in the upper RGA (HU4) to better define the size and shape of the overall treatment area for this remedial action. The RDSI consisted of 18 primary borings and 4 contingency borings. The contingency borings were drilled and incorporated consistent with decision rules contained in the RDSI work plan and to allow refinement of the lateral extent of the source treatment area. Results of the RDSI sampling efforts collected in support of the 90% RDR are included in Table 1 and are based on analytical results received from the fixed-base laboratory. A total of 13 boreholes contained an average TCE result that exceeded the soil cleanup level of 73 micrograms per kilogram (µg/kg) (see Draft-Final Average column in Table 1). There were 11 boreholes that exceeded the TCE soil cleanup level in samples collected below the interval beginning at 55 ft bgs. Five boreholes had average concentrations that exceed the cleanup levels for TCE degradation compounds and 1,1-dichloroethene.

Specifically, there is one borehole that exceeded cleanup levels for *cis*-1,2-dichloroethene, vinyl chloride, and 1,1-dichloroethene accounting of three of the four instances. The other instance of cleanup level exceedance was for *cis*-1,2-dichloroethene. All exceedances of the TCE breakdown products and 1,1-dichloroethene also coincided with the exceedances of TCE, as would be expected. As such, it will not be necessary to conduct mixing and treatment of other VOC areas located outside of the overall TCE treatment area footprint.

Soil sampling results from RDSI sampling efforts at SWMU 1 are presented on Figure 3. For each RDSI soil boring location (001-301 through 001-322) the depth-specific data has been presented for each detected VOC and an arithmetic average has been calculated for each detected VOC at each soil boring location. Arithmetic average concentrations have not been calculated in instances where the VOC was not detected above the sample-specific method detection limit (MDL) at all depth intervals within the boring.

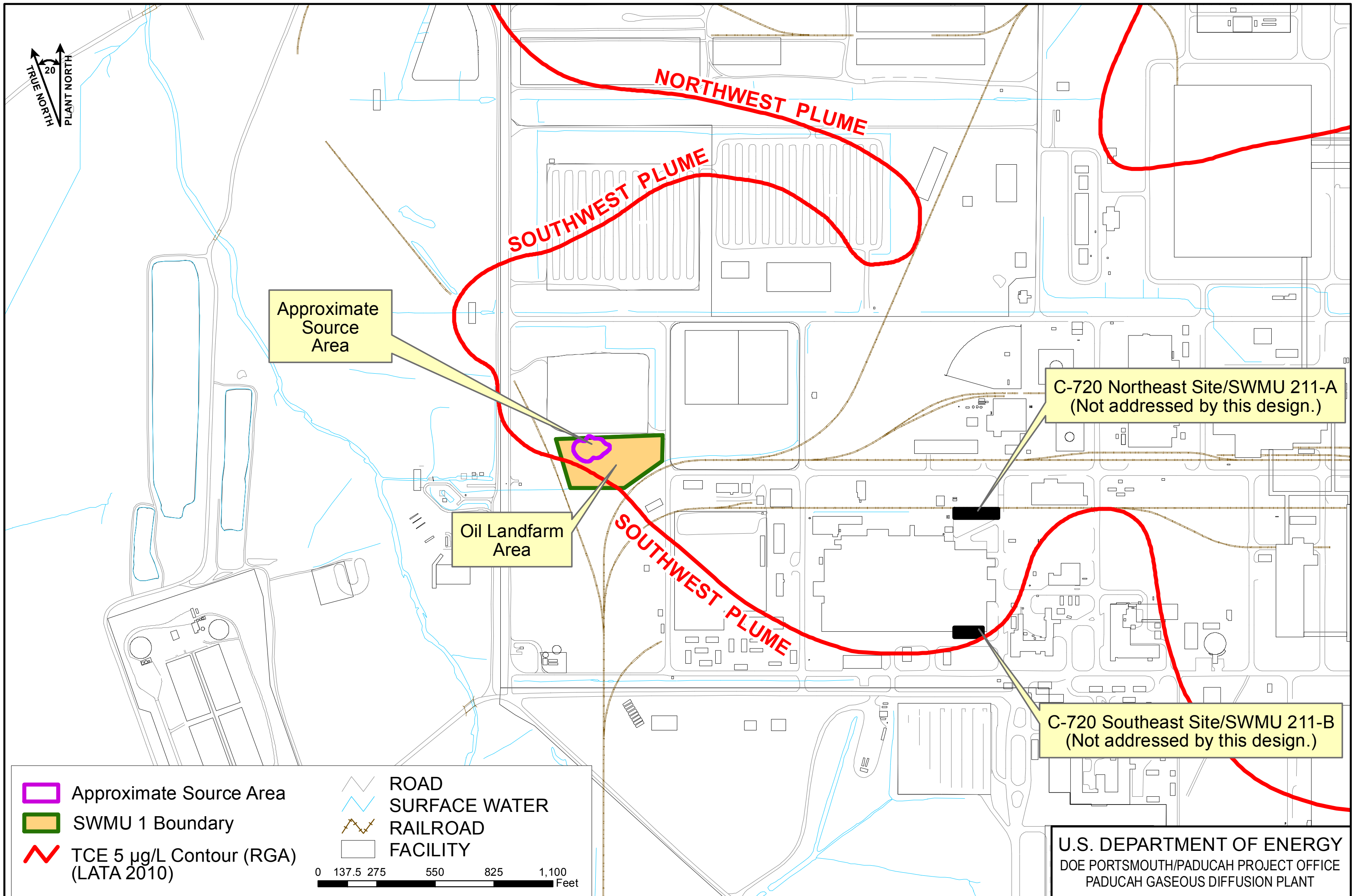


**Figure 2. Southwest Plume Source Area Addressed by the Remedial Design**

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# Table 1. Southwest Plume RDSI Characterization Data

SOUTHWEST PLUME RDSI CHARACTERIZATION DATA
DRAFT Final and Preliminary Soil Analytical Data (SWMU - 1 C-747-C Oil Landfarm)

| Boring ID | Date of (collection) | Depth bgs | Actual Sample Depth bgs (ft) | PID (ppb) | TCE (µg/Kg) Preliminary Reported | TCE Preliminary Average[1,2] | TCE Draft Final Reported | TCE Qual[8] | TCE Draft Final Average[9] | cis-1,2-DCE (µg/Kg) Reported | cis-1,2-DCE Preliminary Average[1,2] | cis-1,2-DCE Draft Final Reported | cis-1,2-DCE Qual[8] | cis-1,2-DCE Draft Final Average[9] | trans-1,2-DCE (µg/Kg) Reported | trans-1,2-DCE Preliminary Average[1,2] | trans-1,2-DCE Draft Final Reported | trans-1,2-DCE Qual[8] | trans-1,2-DCE Draft Final Average[9] | VC (µg/Kg) Reported | VC Preliminary Average[1,2] | VC Draft Final Reported | VC Qual[8] | VC Draft Final Average[9] | 1,1 DCE (µg/Kg) Reported | 1,1 DCE Preliminary Average[1,2] | 1,1 DCE Draft Final Reported | 1,1 DCE Qual[8] | 1,1 DCE Draft Final Average[9] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Oil Landfarm UCRS Soil Cleanup Level (µg/Kg)** | | | | | **73** | | | | | **600** | | | | | **1080** | | | | | **34** | | | | | **130** | | | | |
| 001-311 | 7/20/2012 | 5 | NA | 0 | 120 | 120 | 140 | | 140 | ND | 0.24 | 0.56 | U | 0.28 | ND | 0.375 | 0.44 | U | 0.22 | ND | 0.17 | 0.4 | U | 0.2 | ND | 0.65 | 1.5 | U | 0.75 |
| | | 10 | 8.0 | 200 | 290 | 290 | 350 | | 350 | ND | 4.3 | 10 | U | 5 | ND | 3.35 | 8.2 | U | 4.1 | ND | 11.5 | 28 | U | 14 | ND | 10 | 24 | U | 12 |
| | | 15 | 13.0 | 437 | 1100 | 1100 | 1300 | | 1300 | ND | 4.3 | 10 | U | 5 | ND | 3.35 | 7.8 | U | 3.9 | ND | 11.5 | 27 | U | 13.5 | ND | 10 | 23 | U | 11.5 |
| | | 20 | 15.5 | 399 | 670 | 670 | 770 | | 770 | ND | 3.9 | 8.9 | U | 4.45 | ND | 3.05 | 7 | U | 3.5 | ND | 10.5 | 24 | U | 12 | ND | 9 | 21 | U | 10.5 |
| | | 25 | 20.5 | 56 | 540 | 540 | 590 | | 590 | ND | 3.8 | 8.3 | U | 4.15 | ND | 3 | 6.5 | U | 3.25 | ND | 10 | 22 | U | 11 | ND | 9 | 19 | U | 9.5 |
| | | 30 | 27.0 | 1,717 | 5300 | 5300 | 6300 | | 6300 | 360 | 360 | 430 | | 430 | ND | 3.4 | 8.1 | U | 4.05 | ND | 11.5 | 28 | U | 14 | ND | 10 | 24 | U | 12 |
| | | 35 | 34.9 | 19,820 | 6900 | 6900 | 8300 | | 8300 | 420 | 420 | 510 | | 510 | ND | 6.5 | 7.9 | U | 39.5 | ND | 11 | 27 | U | 13.5 | ND | 9.5 | 23 | U | 11.5 |
| | | 40 | 35.1 | 2,650 | 4600 | 4600 | 5500 | | 5500 | 310 | 310 | 370 | | 370 | ND | 3.05 | 7.4 | U | 3.7 | ND | 10.5 | 25 | U | 12.5 | ND | 9 | 22 | U | 11 |
| | 7/23/2012 | 45 | 40.5 | 9,280 | 2100 | 2100 | 2400 | | 2400 | 130 | 130 | 160 | J | 160 | ND | 3.2 | 7.5 | U | 3.75 | ND | 11 | 25 | U | 12.5 | ND | 9.5 | 22 | U | 11 |
| | | 45D[3] | 40.5 | 9,280 | 1000 | | 1200 | | | 78 | | 91 | J | | ND | | 7.4 | U | | ND | | 25 | U | | ND | | 22 | U | |
| | | 50 | 47.0 | 676 | 1200 | 1200 | 1400 | | 1400 | 31 | 31 | 36 | J | 36 | ND | 3.05 | 7.2 | U | 3.6 | ND | 10.5 | 25 | U | 12.5 | ND | 9 | 22 | U | 11 |
| | | 55 | 54.0 | 899 | 950 | 950 | 1100 | | 1100 | 42 | 42 | 50 | J | 50 | ND | 3.45 | 8.4 | U | 4.2 | ND | 12 | 28 | U | 14 | ND | 10.5 | 25 | U | 12.5 |
| | | 60 | 57.5 | 982 | 1300 | 1300 | 1500 | | 1500 | 72 | 72 | 85 | J | 85 | ND | 3.3 | 7.8 | U | 3.9 | ND | 11.5 | 27 | U | 13.5 | ND | 10 | 23 | U | 11.5 |
| | | Prelim. Borehole Average Analytical Value (0-60') | | | | 2089 | | | 2471 | | 115 | | | 138 | | 3 | | | 6 | | 10 | | | 12 | | 9 | | | 10 |
| 001-310 | 7/23/2012 | 5 | 3.5 | 0 | 5.8 | 5.8 | 6.3 | J | 6.3 | ND | 0.2505 | 0.56 | U | 0.28 | ND | 0.4 | 0.87 | U | 0.435 | ND | 0.18 | 0.4 | U | 0.2 | ND | 0.7 | 1.5 | U | 0.75 |
| | | 10 | 9.9 | 1,556 | 840 | 840 | 1000 | | 1000 | 460 | 460 | 540 | | 540 | ND | 3.4 | 8 | U | 4 | ND | 11.5 | 27 | U | 13.5 | ND | 10 | 24 | U | 12 |
| | | 15 | 12.0 | 3,408 | 7100 | 7100 | 8300 | | 8300 | 2600 | 2600 | 3000 | | 3000 | ND | 3.25 | 7.7 | U | 3.85 | 58 | 58 | 26 | U | 13 | 21 | 21 | 23 | U | 11.5 |
| | | 20 | 16.0 | 312,000 | 890000 | 890000 | 960000 | | 960000 | ND | 1300 | 2900 | U | 1450 | ND | 1050 | 2200 | U | 1100 | ND | 3500 | 7600 | U | 3800 | ND | 3050 | 6700 | U | 3350 |
| | | 25 | 20.1 | 2,415 | 2900 | 2900 | 3300 | | 3300 | 250 | 250 | 280 | | 280 | ND | 3.5 | 7.8 | U | 3.8 | ND | 12 | 27 | U | 13.5 | ND | 10.5 | 23 | U | 11.5 |
| | 7/24/2012 | 30 | 29.5 | 41,290 | 380000 | 380000 | 440000 | | 440000 | ND | 200 | 460 | U | 230 | ND | 155 | 360 | U | 180 | ND | 500 | 1200 | U | 600 | ND | 460 | 1100 | U | 550 |
| | | 35 | 31.5 | 8,271 | 20000 | 20000 | 24000 | | 24000 | 810 | 810 | 960 | J | 960 | ND | 23.5 | 32 | U | 16 | ND | 45.5 | 110 | U | 55 | ND | 40 | 94 | U | 47 |
| | | 40 | 37.0 | 29,230 | 23000 | 23000 | 28000 | | 28000 | 1300 | 1300 | 1500 | J | 1500 | ND | 33.5 | 81 | U | 40.5 | ND | 115 | 280 | U | 140 | ND | 100 | 240 | U | 120 |
| | | 45 | 44.5 | 28,180 | 33000 | 33000 | 40000 | | 40000 | 1500 | 1500 | 1800 | | 1800 | ND | 18 | 42 | U | 21 | ND | 60 | 140 | U | 70 | ND | 55 | 130 | U | 65 |
| | | 50 | 47.5 | 21,170 | 37000 | 37000 | 45000 | | 45000 | 1300 | 1300 | 1600 | | 1600 | ND | 17 | 41 | U | 20.5 | ND | 55 | 140 | U | 70 | ND | 50 | 120 | U | 60 |
| | | 55 | 50.1 | 24,140 | 37000 | 37000 | 44000 | | 44000 | 1500 | 1500 | 1800 | | 1800 | ND | 17 | 40 | U | 20 | ND | 55 | 140 | U | 70 | ND | 50 | 120 | U | 60 |
| | | 60 | 55.1 | 36,120 | 2400 | 2400 | 2800 | | 2800 | ND | 4.85 | 11 | U | 5.5 | ND | 3.75 | 8.6 | U | 4.3 | ND | 13 | 29 | U | 24.5 | ND | 11 | 26 | U | 13 |
| | | Prelim. Borehole Average Analytical Value (0-60') | | | | 119437 | | | 133034 | | 935 | | | 1097 | | 111 | | | 118 | | 369 | | | 406 | | 322 | | | 358 |
| 001-309 | 7/24/2012 | 5 | 4.0 | 0 | 19 | 19 | 22 | | 22 | ND | 0.25 | 0.59 | U | 0.295 | ND | 0.395 | 0.92 | U | 0.455 | ND | 0.18 | 0.42 | U | 0.21 | ND | 0.7 | 1.6 | U | 0.8 |
| | | 10 | 7.5 | 0 | 28 | 28 | 34 | | 34 | 11 | 11 | 14 | | 14 | ND | 0.38 | 0.92 | U | 0.455 | ND | 0.175 | 0.42 | U | 0.21 | ND | 0.65 | 1.6 | U | 0.8 |
| | | 15 | 12.5 | 0 | 16 | 16 | 19 | | 19 | 4.9 | 4.9 | 5.9 | J | 5.9 | ND | 0.18 | 0.91 | U | 0.455 | ND | 0.175 | 0.42 | U | 0.21 | ND | 0.65 | 1.6 | U | 0.8 |
| | | 15D[3] | 17.0 | 0 | 14 | | 17 | | | 4.7 | | 5.7 | J | | ND | | 0.92 | U | | ND | | 0.42 | U | | ND | | 1.6 | U | |
| | | 20 | 17.0 | 28,100 | 2.6 | 2.6 | 2.9 | J | 2.9 | 0.6 | 0.6 | 0.67 | J | 0.67 | ND | 0.47 | 1 | U | 0.5 | ND | 0.215 | 0.48 | U | 0.24 | ND | 0.8 | 1.8 | U | 0.9 |
| | | 25 | 22.5 | 2,402 | 3600 | 3600 | 4100 | | 4100 | 1700 | 1700 | 1900 | | 1900 | ND | 3.3 | 7.5 | U | 3.75 | ND | 11 | 26 | U | 13 | ND | 10 | 22 | U | 11 |
| | 7/25/2012 | 30 | 25.1 | 161 | 3800 | 3800 | 3800 | | 3800 | 1700 | 1700 | 1700 | | 1700 | ND | 3.35 | 6.7 | U | 3.35 | ND | 11.5 | 23 | U | 11.5 | ND | 10 | 20 | U | 10 |
| | | 35 | 31.5 | 2,407 | 3700 | 3700 | 3700 | | 3700 | 1300 | 1300 | 1300 | | 1300 | ND | 3.25 | 6.5 | U | 3.25 | ND | 11 | 22 | U | 11 | ND | 10 | 20 | U | 10 |
| | | 40 | 35.1 | 1,452 | 2600 | 2600 | 2600 | | 2600 | 820 | 820 | 820 | | 820 | ND | 3.05 | 6.1 | U | 3.5 | ND | 10.5 | 21 | U | 10.5 | ND | 9 | 18 | U | 9 |
| | | 45 | 40.5 | 6,070 | 2100 | 2100 | 2100 | | 2100 | 950 | 950 | 950 | | 950 | ND | 3.15 | 6.3 | U | 3.15 | ND | 10.5 | 21 | U | 10.5 | ND | 9.5 | 19 | U | 9.5 |
| | | 50 | 45.5 | 1,670 | 2500 | 2500 | 2500 | | 2500 | 860 | 860 | 860 | | 860 | ND | 3.15 | 6.3 | U | 3.15 | ND | 11 | 22 | U | 11 | ND | 9.5 | 19 | U | 9.5 |
| | | 55 | 52.5 | 1,838 | 2500 | 2500 | 2500 | | 2500 | 440 | 440 | 440 | | 440 | ND | 3.3 | 6.6 | U | 3.3 | ND | 11 | 22 | U | 11 | ND | 10 | 20 | U | 10 |
| | | 60 | 59.5 | 4,340 | 2000 | 2000 | 2000 | | 2000 | 670 | 670 | 670 | | 670 | ND | 3.4 | 6.8 | U | 3.4 | ND | 11.5 | 23 | U | 11.5 | ND | 10 | 20 | U | 10 |
| | | Prelim. Borehole Average Analytical Value (0-60') | | | | 1905 | | | 1948 | | 705 | | | 722 | | 2 | | | 2 | | 7 | | | 8 | | 7 | | | 7 |
| 001-304 | 7/26/2012 | 5 | 3.5 | 0 | ND | 0.18 | 0.4 | U | 0.2 | ND | 0.275 | 0.61 | U | 0.305 | ND | 0.43 | 0.96 | U | 0.48 | ND | 0.195 | 0.44 | U | 0.22 | ND | 0.75 | 1.6 | U | 0.8 |
| | | 10 | 9.5 | 292 | 0.52 | 0.52 | 0.61 | J | 0.61 | 30 | 30 | 35 | | 35 | ND | 0.38 | 0.89 | U | 0.445 | 3.2 | 3.2 | 3.8 | J | 3.8 | ND | 0.65 | 1.5 | U | 0.75 |
| | | 15 | 14.9 | 9,209 | 1900 | 1900 | 2300 | | 2300 | 360 | 360 | 440 | | 440 | ND | 3.7 | 8.9 | U | 4.45 | ND | 12.5 | 30 | U,* | 15 | ND | 11 | 27 | U | 13.5 |
| | | 20[10] | 15.1 | 1,508 | 2300 | 2300 | 780 | | 780 | 350 | 350 | 190 | J | 190 | ND | 0.41 | 0.92 | U | 0.46 | 9.4 | 9.4 | 11 | | 11 | 2.7 | 2.7 | 3 | J | 3 |
| | | 25 | 21.0 | 473 | 3.7 | 3.7 | 4.2 | J | 4.2 | 3 | 3 | 3.5 | J | 3.5 | ND | 0.37 | 0.84 | U | 0.42 | ND | 0.17 | 0.38 | U | 0.19 | ND | 0.65 | 1.4 | U | 0.7 |
| | | 30 | 26.5 | 0 | 62 | 62 | 64 | | 64 | 53 | 53 | 58 | | 58 | ND | 0.355 | 1.1 | U | 0.55 | 3.7 | 3.7 | 4.7 | J | 4.7 | ND | 0.6 | 1.9 | U | 0.95 |
| | | 35 | 30.5 | 527 | 50 | 50 | 130 | | 130 | 44 | 44 | 110 | | 110 | ND | 0.365 | 1.1 | U | 0.55 | 2.3 | 2.3 | 7.4 | J | 7.4 | ND | 0.65 | 1.9 | U | 0.95 |
| | | 35D[3] | 30.5 | 527 | 51 | | 60 | | | 47 | | 55 | | | ND | | 0.84 | U | | 2.3 | | 2.7 | J | | ND | | 1.4 | U | |
| | | 40 | 36.5 | 22 | 210 | 210 | 240 | | 240 | 110 | 110 | 9.3 | U | 4.65 | ND | 0.36 | 7.2 | U | 3.6 | ND | 11 | 25 | U,* | 12.5 | ND | 9.5 | 22 | U | 11 |
| | | 45 | 42.5 | 0 | ND | | 15 | U | 7.5 | ND | 3.95 | 9.1 | U | 0.455 | ND | 3.1 | 7.1 | U | 3.55 | ND | 10.5 | 24 | U,* | 12 | ND | 9 | 21 | U | 10.5 |
| | | 50 | 46.5 | 611 | 390 | 390 | 240 | | 240 | 170 | 170 | 190 | J | 190 | ND | 4 | 8.7 | U | 4.35 | ND | 13.5 | 30 | U,* | 15 | ND | 12 | 26 | U | 13 |
| | | 55 | 50.1 | 1,250 | 680 | 680 | 770 | | 770 | 280 | 280 | 320 | | 320 | ND | 3.4 | 7.8 | U | 3.9 | ND | 11.5 | 26 | U,* | 13 | ND | 10 | 23 | U | 11.5 |
| | | 60 | 55.1 | 246 | 680 | 680 | 820 | | 820 | 260 | 260 | 310 | | 310 | ND | 3.7 | 8.9 | U | 4.45 | ND | 12.5 | 30 | U,* | 15 | ND | 11 | 26 | U | 13 |
| | | Prelim. Borehole Average Analytical Value (0-60') | | | | 571 | | | 446 | | 139 | | | 138 | | 2 | | | 2 | | 8 | | | 9 | | 6 | | | 7 |

**Table 1. Southwest Plume RDSI Characterization Data (Continued)**

SOUTHWEST PLUME RDSI CHARACTERIZATION DATA
DRAFT Final and Preliminary Soil Analytical Data (SWMU - 1 C-747-C Oil Landfarm)

| Boring ID | Date of (collection) | Depth bgs | Actual Sample Depth bgs (ft) | PID (ppb) | TCE (µg/Kg) Preliminary Reported | TCE Preliminary Average[1,2] | TCE Draft Final Reported | TCE Qual[8] | TCE Draft Final Average[9] | cis-1,2-DCE (µg/Kg) Reported | cis-1,2-DCE Preliminary Average[1,2] | cis-1,2-DCE Draft Final Reported | cis-1,2-DCE Qual[8] | cis-1,2-DCE Draft Final Average[9] | trans-1,2-DCE (µg/Kg) Reported | trans-1,2-DCE Preliminary Average[1,2] | trans-1,2-DCE Draft Final Reported | trans-1,2-DCE Qual[8] | trans-1,2-DCE Draft Final Average[9] | VC (µg/Kg) Reported | VC Preliminary Average[1,2] | VC Draft Final Reported | VC Qual[8] | VC Draft Final Average[9] | 1,1 DCE (µg/Kg) Reported | 1,1 DCE Preliminary Average[1,2] | 1,1 DCE Draft Final Reported | 1,1 DCE Qual[8] | 1,1 DCE Draft Final Average[9] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Oil Landfarm UCRS Soil Cleanup Level (µg/Kg) | | | 73 | | | | | 600 | | | | | 1080 | | | | | 34 | | | | | 130 | | | | |
| 001-312 | 7/26/2012 | 5 | 3.5 | 0 | ND | 0.205 | 0.45 | U | 0.225 | ND | 0.31 | 0.7 | U | 0.35 | ND | 0.49 | 1.1 | U | 0.55 | ND | 0.225 | 0.5 | U | 0.25 | ND | 0.85 | 1.9 | U | 0.95 |
| | | 10 | 9.5 | 0 | ND | 0.165 | 0.39 | U | 0.195 | ND | 0.25 | 0.6 | U | 0.3 | ND | 0.395 | 0.93 | U | 0.465 | ND | 0.18 | 0.43 | U | 0.215 | ND | 0.65 | 1.6 | U | 0.8 |
| | | 15 | 12.5 | 0 | 0.78 | 0.78 | 0.94 | U | 0.47 | ND | 0.255 | 0.61 | U | 0.305 | ND | 0.4 | 0.96 | U | 0.49 | ND | 0.185 | 0.44 | U | 0.22 | ND | 0.7 | 1.6 | U | 0.8 |
| | | 20 | 17.0 | 0 | 5.6 | 5.6 | 6.2 | J | 6.2 | 0.79 | 0.79 | 0.88 | J | 0.88 | ND | 0.4 | 0.89 | U | 0.445 | ND | 0.185 | 0.41 | U | 0.205 | ND | 0.7 | 1.5 | U | 0.75 |
| | | 25 | 21.5 | 0 | ND | 0.19 | 0.41 | U | 0.205 | ND | 0.29 | 0.63 | U | 0.315 | ND | 0.455 | 0.98 | U | 0.49 | ND | 0.41 | 0.45 | U | 0.225 | ND | 0.8 | 1.7 | U | 0.85 |
| | | 30 | 26.5 | 0 | 9.4 | 9.4 | 11 | | 11 | 1.8 | 1.8 | 2.1 | J | 2.1 | ND | 0.365 | 0.84 | U | 0.42 | ND | 0.165 | 0.38 | U | 0.19 | ND | 0.65 | 1.4 | U | 0.7 |
| | | 35 | 31.5 | 0 | 67 | 67 | 80 | | 80 | 12 | 12 | 15 | | 15 | ND | 0.38 | 0.91 | U | 0.455 | ND | 0.175 | 0.41 | U | 0.205 | 3.7 | 3.7 | 4.4 | J | 4.4 |
| | | 40 | 39.0 | 0 | 80 | 80 | 95 | | 95 | 14 | 14 | 16 | | 16 | ND | 0.395 | 0.94 | U | 0.47 | ND | 0.18 | 0.43 | U | 0.215 | 4.7 | 4.7 | 5.6 | J | 5.6 |
| | | 45 | 43.0 | 0 | 32 | 32 | 38 | | 38 | 6.4 | 6.4 | 7.6 | J | 7.6 | ND | 0.415 | 0.98 | U | 0.49 | ND | 0.19 | 0.45 | U | 0.225 | 1.9 | 1.9 | 2.3 | J | 2.3 |
| | | 50 | 49.9 | 0 | 4.5 | 4.5 | 5.3 | J | 5.3 | 1 | 1 | 1.2 | J | 1.2 | ND | 0.36 | 0.84 | U | 0.42 | ND | 0.165 | 0.38 | U | 0.19 | ND | 0.6 | 1.4 | U | 0.7 |
| | | 55 | 54.5 | 0 | 58 | 58 | 69 | | 69 | 11 | 11 | 13 | | 13 | ND | 0.37 | 0.87 | U | 0.435 | ND | 0.17 | 0.4 | U | 0.2 | 3.2 | 3.2 | 3.8 | J | 3.8 |
| | | 60 | 55.5 | 0 | 56 | 56 | 65 | | 65 | 10 | 10 | 12 | | 12 | ND | 0.38 | 0.89 | U | 0.445 | ND | 0.175 | 0.41 | U | 0.205 | 2.7 | 2.7 | 3.1 | J | 3.1 |
| | | Prelim. Borehole Average Analytical Value (0-60') | | | | 26 | | | 31 | | 5 | | | 6 | | 0 | | | 0 | | 0 | | | 0 | | 2 | | | 2 |
| 001-315 | 7/27/2012 | 5 | 4.0 | 0 | ND | 0.195 | 0.42 | U | 0.21 | ND | 0.3 | 0.65 | U | 0.325 | ND | 0.47 | 1 | U | 0.5 | ND | 0.215 | 0.46 | U | 0.23 | ND | 0.8 | 1.7 | U | 0.85 |
| | | 10 | 7.5 | 0 | ND | 0.175 | 0.42 | U | 0.21 | ND | 0.265 | 0.64 | U | 0.32 | ND | 0.415 | 1 | U | 0.5 | ND | 0.19 | 0.46 | U | 0.23 | ND | 0.7 | 1.7 | U | 0.85 |
| | | 15 | 14.5 | 0 | 1.9 | 1.9 | 2.2 | J | 2.2 | ND | 0.255 | 0.56 | U | 0.28 | ND | 0.385 | 0.87 | U | 0.435 | ND | 0.175 | 0.4 | U | 0.2 | ND | 0.65 | 1.5 | U | 0.75 |
| | | 20 | 16.5 | 0 | 11 | 11 | 12 | | 12 | 0.66 | 0.66 | 0.74 | J | 0.74 | ND | 0.35 | 0.78 | U | 0.39 | ND | 0.16 | 0.36 | U | 0.18 | ND | 0.6 | 1.3 | U | 0.65 |
| | | 20D[3] | 16.5 | 0 | 11 | | 12 | | | 0.69 | | 0.87 | J | | ND | | 0.81 | U | | | | 0.37 | U | | U | | 1.4 | U | |
| | | 25 | 23.0 | 92 | 4100 | 4100 | 5000 | | 5000 | 260 | 260 | 310 | | 310 | ND | 3.4 | 8.3 | U | 4.15 | ND | 11.5 | 28 | U | 14 | ND | 10 | 25 | U | 12.5 |
| | | 30 | 25.1 | 1,978 | 3400 | 3400 | 4100 | | 4100 | 220 | 220 | 260 | | 260 | ND | 0.325 | 7.9 | U | 3.95 | ND | 11 | 27 | U | 13.5 | ND | 10 | 23 | U | 11.5 |
| | | 35 | 33.5 | 15,018 | 3500 | 3500 | 4300 | | 4300 | 300 | 300 | 370 | | 370 | ND | 3.5 | 8.5 | U | 4.25 | ND | 12 | 29 | U | 14.5 | ND | 10.5 | 25 | U | 12.5 |
| | | 40 | 35.5 | 9,630 | 2100 | 2100 | 2400 | | 2400 | 200 | 200 | 230 | | 230 | ND | 3.15 | 7.3 | U | 0.365 | ND | 10.5 | 25 | U | 12.5 | ND | 9.5 | 22 | U | 11 |
| | | 45 | 40.1 | 15,100 | 4200 | 4200 | 5100 | | 5100 | 370 | 370 | 440 | | 440 | ND | 3.45 | 8.3 | U | 4.15 | ND | 12 | 28 | U | 14 | ND | 10.5 | 25 | U | 12.5 |
| | | 50 | 45.1 | 4,920 | 4000 | 4000 | 4900 | | 4900 | 360 | 360 | 440 | | 440 | ND | 3.4 | 8.3 | U | 4.15 | ND | 11.5 | 28 | U | 14 | ND | 10 | 25 | U | 12.5 |
| | | 55 | 50.1 | 10,700 | 2800 | 2800 | 3200 | | 3200 | 250 | 250 | 290 | | 290 | ND | 4.05 | 9.4 | U | 4.95 | ND | 13.5 | 32 | U | 16 | ND | 12 | 28 | U | 14 |
| | | 60 | 59.5 | 4,708 | 400 | 400 | 4600 | | 460 | ND | 4.8 | 11 | U | 5.5 | ND | 3.75 | 8.5 | U | 4.2 | ND | 12.5 | 29 | U | 14.5 | ND | 11 | 25 | U | 12.5 |
| | | 65 | 62.5 | 3,487 | 2500 | 2500 | 2900 | | 2900 | 120 | 120 | 130 | J | 130 | ND | 4.05 | 9.2 | U | 4.6 | ND | 14 | 31 | U | 15.5 | ND | 12 | 28 | U | 14 |
| | | Prelim. Borehole Average Analytical Value (0-60') | | | | 2078 | | | 2490 | | 160 | | | 191 | | 2 | | | 3 | | 8 | | | 10 | | 8 | | | 9 |
| 001-318 | 7/30/2012 | 5 | 3.0 | 0 | ND | 0.195 | 0.36 | U | 0.18 | ND | 0.3 | 0.56 | U | 0.28 | ND | 0.47 | 0.87 | U | 0.435 | ND | 0.225 | 0.4 | U | 0.2 | ND | 0.8 | 1.5 | U | 0.75 |
| | | 10 | 9.0 | 0 | ND | 0.195 | 0.41 | U | 0.205 | ND | 0.3 | 0.63 | U | 0.315 | ND | 0.47 | 0.99 | U | 0.495 | ND | 0.215 | 0.45 | U | 0.225 | ND | 0.8 | 1.7 | U | 0.85 |
| | | 15 | 13.0 | 0 | ND | 0.195 | 0.36 | U | 0.18 | ND | 0.3 | 0.55 | U | 0.275 | ND | 0.47 | 0.86 | U | 0.43 | ND | 0.415 | 0.39 | U | 0.195 | ND | 0.8 | 1.5 | U | 0.75 |
| | | 20 | 19.0 | 0 | ND | 0.195 | 0.34 | U | 0.17 | ND | 0.3 | 0.53 | U | 0.265 | ND | 0.47 | 0.82 | U | 0.41 | ND | 0.215 | 0.38 | U | 0.19 | ND | 0.8 | 1.4 | U | 0.7 |
| | | 20D[3] | 19.0 | 0 | ND | | 0.34 | U | | ND | | 0.52 | U | | ND | | 0.81 | U | | ND | | 0.37 | U | | ND | | 1.4 | U | |
| | | 25 | 20.5 | 553 | 0.55 | 0.55 | 0.33 | U | 0.165 | 0.66 | 0.66 | 0.51 | U | 0.255 | ND | 0.47 | 0.8 | U | 0.4 | ND | 0.215 | 0.37 | U | 0.185 | ND | 0.8 | 1.4 | U | 0.7 |
| | | 30 | 29.0 | 0 | 110 | 110 | 65 | | 65 | 67 | 67 | 47 | | 47 | ND | 0.47 | 0.86 | U | 0.43 | ND | 0.215 | 0.39 | U | 0.195 | 3.3 | 3.3 | 2.4 | J | 2.4 |
| | | 35 | 34.0 | 24 | 170 | 170 | 200 | J | 200 | 160 | 160 | 190 | J | 190 | ND | 3.4 | 8.2 | U | 4.1 | ND | 11.5 | 28 | U,* | 14 | ND | 10 | 24 | U | 12 |
| | | 40[5] | 35.5 | 58 | 170 | 170 | 190 | J | 190 | 160 | 160 | 190 | J | 190 | ND | 3.4 | 8.4 | U | 4.2 | ND | 11.5 | 29 | U | 1.45 | ND | 10 | 25 | U | 12.5 |
| | | 45 | 41.0 | 4 | 110 | 110 | 61 | | 61 | 64 | 64 | 44 | | 44 | ND | 0.47 | 1 | U | 0.5 | 0.94 | 0.94 | 0.46 | U | 0.23 | 5.5 | 5.5 | 3.5 | J | 3.5 |
| | | 50 | 46.0 | 16 | 29 | 29 | 19 | | 19 | 8.2 | 8.2 | 5.9 | J | 5.9 | ND | 0.47 | 0.95 | U | 0.475 | ND | 0.215 | 0.43 | U | 0.215 | 2.3 | 2.3 | 1.9 | J | 1.9 |
| | | 55 | 50.5 | 0 | 7.4 | 7.4 | 6.4 | J | 6.4 | 1.8 | 1.8 | 1.6 | J | 1.6 | ND | 0.47 | 0.82 | U | 0.41 | ND | 0.215 | 0.37 | U | 0.185 | ND | 0.8 | 1.4 | U | 0.7 |
| | | 60 | 56.5 | 0 | 24 | 24 | 22 | | 22 | 24 | 24 | 22 | | 22 | ND | 0.47 | 0.89 | U | 0.445 | ND | 0.215 | 0.41 | U | 0.205 | ND | 0.8 | 1.5 | U | 0.75 |
| | | Prelim. Borehole Average Analytical Value (0-60') | | | | 52 | | | 47 | | 41 | | | 42 | | 1 | | | 1 | | 2 | | | 1 | | 3 | | | 3 |
| 001-317 | 7/30/2012 | 5 | 3.7 | 0 | ND | 0.195 | 0.41 | U | 0.205 | ND | 0.3 | 0.63 | U | 0.315 | ND | 0.47 | 0.99 | U | 0.495 | ND | 0.215 | 0.45 | U | 0.225 | ND | 0.8 | 1.7 | U | 0.85 |
| | | 10 | 8.5 | 0 | 4.5 | 4.5 | 4.6 | J | 4.6 | 2.3 | 2.3 | 2.3 | J | 2.3 | ND | 0.47 | 0.94 | U | 0.47 | ND | 0.215 | 0.43 | U | 0.215 | ND | 0.8 | 1.6 | U | 0.8 |
| | | 15 | 12.0 | 0 | 7.9 | 7.9 | 7.8 | J | 7.8 | 6.2 | 6.2 | 6.1 | J | 6.1 | ND | 0.47 | 0.93 | U | 0.465 | ND | 0.215 | 0.43 | U | 0.215 | ND | 0.8 | 1.6 | U | 0.8 |
| | | 20 | 15.5 | 0 | 9 | 9 | 7.9 | J | 7.9 | 11 | 11 | 9.7 | | 9.7 | ND | 0.47 | 0.83 | U | 0.415 | ND | 0.215 | 0.38 | U | 0.19 | ND | 0.8 | 1.4 | U | 0.7 |
| | | 25 | 21.0 | 2,176 | 11 | 11 | 6.6 | J | 6.6 | 27 | 27 | 17 | | 17 | ND | 0.47 | 0.93 | U | 0.465 | ND | 0.215 | 0.42 | U | 0.21 | ND | 0.8 | 1.6 | U | 0.8 |
| | | 30 | 29.9 | 506 | 190 | 190 | 240 | J | 240 | 350 | 350 | 420 | | 420 | ND | 0.47 | 8.2 | U | 4.1 | 10 | 10 | 28 | U | 14 | 3.4 | 3.4 | 24 | U | 12 |
| | | 35 | 30.5 | 895 | 140 | 140 | 230 | J | 230 | 250 | 250 | 440 | | 440 | ND | 0.47 | 8 | U | 4 | 7 | 7 | 27 | U | 13.5 | 2.7 | 2.7 | 24 | U | 12 |
| | | 40 | 38.5 | 2,607 | 3.5 | 3.5 | 3.4 | J | 3.4 | 2.4 | 2.4 | 2.3 | J | 2.3 | ND | 0.47 | 0.91 | U | 0.455 | ND | 0.215 | 0.42 | U | 0.21 | 2.7 | 2.7 | 1.6 | U | 0.8 |
| | | 45 | 40.5 | 450 | 92 | 92 | 150 | | 150 | 100 | 100 | 180 | | 180 | ND | 0.47 | 0.99 | U | 0.495 | ND | 0.215 | 0.45 | U | 0.225 | 4.3 | 4.3 | 8.2 | J | 4.1 |
| | | 50 | 47.0 | 4,926 | 87 | 87 | 93 | | 93 | 37 | 37 | 40 | | 40 | ND | 0.47 | 1 | U | 0.5 | ND | 0.215 | 0.46 | U | 0.23 | 5.1 | 5.1 | 5.5 | J | 5.5 |
| | | 55 | 50.1 | 328 | ND | 0.195 | 0.36 | U | 0.18 | ND | 0.3 | 0.55 | U | 0.275 | ND | 0.47 | 0.86 | U | 0.43 | ND | 0.215 | 0.4 | U | 0.2 | ND | 0.8 | 1.5 | U | 0.75 |
| | | 60 | 56.0 | 0 | 29 | 29 | 28 | | 28 | 8.1 | 8.1 | 7.8 | J | 7.8 | ND | 0.47 | 0.9 | U | 0.45 | ND | 0.215 | 0.41 | U | 0.205 | ND | 0.8 | 1.5 | U | 0.75 |
| | | Prelim. Borehole Average Analytical Value (0-60') | | | | 48 | | | 64 | | 66 | | | 94 | | 0 | | | 1 | | 2 | | | 2 | | 2 | | | 3 |

## Table 1. Southwest Plume RDSI Characterization Data (Continued)

SOUTHWEST PLUME RDSI CHARACTERIZATION DATA
DRAFT Final and Preliminary Soil Analytical Data (SWMU - 1 C-747-C Oil Landfarm)

| Boring ID | Date of (collection) | Depth bgs | Actual Sample Depth bgs (ft) | PID (ppb) | TCE (µg/Kg) Preliminary Reported | Preliminary Average[1,2] | Draft Final Reported | Qual[8] | Draft Final Average[9] | cis-1,2-DCE (µg/Kg) Reported | Preliminary Average[1,2] | Draft Final Reported | Qual[8] | Draft Final Average[9] | trans-1,2-DCE (µg/Kg) Reported | Preliminary Average[1,2] | Draft Final Reported | Qual[8] | Draft Final Average[9] | VC (µg/Kg) Reported | Preliminary Average[1,2] | Draft Final Reported | Qual[8] | Draft Final Average[9] | 1,1 DCE (µg/Kg) Reported | Preliminary Average[1,2] | Draft Final Reported | Qual[8] | Draft Final Average[9] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Oil Landfarm UCRS Soil Cleanup Level (µg/Kg) | | | 73 | | | | | 600 | | | | | 1080 | | | | | 34 | | | | | 130 | | | | |
| 001-316 | 7/31/2012 | 5 | 4.9 | 1,196 | ND | 0.165 | 0.33 | U | 0.165 | ND | 0.255 | 0.51 | U | 0.255 | ND | 0.4 | 0.8 | U | 0.4 | ND | 0.185 | 0.37 | U | 0.185 | ND | 0.7 | 1.4 | U | 0.7 |
| | | 10 | 6.0 | 4,003 | ND | 0.165 | 0.33 | U | 0.165 | ND | 0.25 | 0.5 | U | 0.25 | ND | 0.395 | 0.79 | U | 0.395 | ND | 0.18 | 0.36 | U | 0.18 | ND | 0.65 | 1.3 | U | 0.65 |
| | | 10D[3] | 6.0 | 4,003 | ND | | 0.38 | U | | ND | 0.255 | 0.58 | U | | ND | 0.4 | 0.91 | U | | ND | 0.85 | 0.42 | U | | ND | 0.7 | 1.6 | U | |
| | | 15 | 10.1 | 6,571 | ND | 0.155 | 0.33 | U | 0.165 | | | 0.51 | U | 0.255 | | | 0.8 | U | 0.4 | | | 0.37 | U | 0.185 | | | 1.4 | U | 0.7 |
| | | 20 | 17.0 | 0 | ND | 0.155 | 0.31 | U | 0.155 | 4.8 | 4.8 | 4.8 | J | 4.8 | ND | 0.37 | 0.74 | U | 0.37 | 1.3 | 1.3 | 1.3 | J | 1.3 | ND | 0.65 | 1.3 | U | 0.65 |
| | | 25 | 23.0 | 9,091 | 320 | 320 | 320 | | 320 | 430 | 430 | 430 | | 430 | ND | 3.85 | 7.7 | U | 0.385 | ND | 13 | 26 | U | 13 | ND | 11.5 | 23 | U | 11.5 |
| | | 30 | 29.9 | 6,875 | 2400 | 2400 | 2400 | | 2400 | 1200 | 1200 | 1200 | | 1200 | ND | 3.3 | 6.6 | U | 3.3 | ND | 11.5 | 23 | U | 11.5 | ND | 10 | 20 | U | 10 |
| | | 35 | 31.5 | 4,443 | 2900 | 2900 | 2900 | | 2900 | 1300 | 1300 | 1300 | | 1300 | ND | 3.5 | 7 | U | 3.5 | ND | 12 | 24 | U | 12 | ND | 10.5 | 21 | U | 10.5 |
| | | 40 | 35.5 | 8,915 | 1500 | 1500 | 1500 | | 1500 | 410 | 410 | 410 | | 410 | ND | 3.3 | 6.6 | U | 3.3 | ND | 11 | 22 | U | 11 | ND | 10 | 20 | U | 10 |
| | | 45 | 41.0 | 2,242 | 12 | 12 | 12 | | 12 | 3.6 | 3.6 | 3.6 | J | 3.6 | ND | 0.41 | 0.82 | U | 0.41 | ND | 0.185 | 0.37 | U | 0.185 | ND | 0.7 | 1.4 | U | 0.7 |
| | | 50 | 46.5 | 14 | 52 | 52 | 52 | | 52 | 7.7 | 7.7 | 7.7 | J | 7.7 | ND | 0.415 | 0.83 | U | 0.415 | ND | 0.19 | 0.38 | U | 0.19 | 2.1 | 2.1 | 2.1 | J | 2.1 |
| | | 55 | 54.0 | 0 | 6 | 6 | 6 | J | 6 | 0.59 | 0.59 | 0.59 | J | 0.59 | ND | 0.39 | 0.78 | U | 0.39 | ND | 0.18 | 0.36 | U | 0.18 | ND | 0.65 | 1.3 | U | 0.65 |
| | | 60 | 57.0 | 0 | 14 | 14 | 14 | | 14 | 1.4 | 1.4 | 1.4 | J | 1.4 | ND | 0.415 | 0.83 | U | 0.415 | ND | 0.19 | 0.38 | U | 0.19 | ND | 0.7 | 1.4 | U | 0.7 |
| | | Prelim. Borehole Average Analytical Value (0-60') | | | | 600 | | | 600 | | 280 | | | 280 | | 1 | | | 1 | | 4 | | | 4 | | 4 | | | 4 |
| 001-314 | 7/31/2012 | 5 | 3.0 | 0 | ND | 0.175 | 0.35 | U | 0.175 | ND | 0.27 | 0.54 | U | 0.27 | ND | 0.42 | 0.84 | U | 0.42 | ND | 0.19 | 0.38 | U | 0.19 | ND | 0.7 | 1.4 | U | 0.7 |
| | | 10 | 7.0 | 0 | 1.3 | 1.3 | 1.3 | J | 1.3 | ND | 0.265 | 0.53 | U | 0.265 | ND | 0.41 | 0.82 | U | 0.41 | ND | 0.19 | 0.38 | U | 0.19 | ND | 0.7 | 1.4 | U | 0.7 |
| | | 15 | 14.0 | 0 | 1.8 | 1.8 | 1.8 | J | 1.8 | ND | 0.245 | 0.49 | U | 0.245 | ND | 0.38 | 0.76 | U | 0.38 | ND | 0.175 | 0.35 | U | 0.175 | ND | 0.65 | 1.3 | U | 0.65 |
| | | 20 | 19.0 | 0 | ND | 0.18 | 0.36 | U | 0.18 | ND | 0.275 | 0.55 | U | 0.275 | ND | 0.435 | 0.87 | U | 0.435 | ND | 0.2 | 0.4 | U | 0.2 | ND | 0.75 | 1.5 | U | 0.75 |
| | | 25 | 21.5 | 0 | 13 | 13 | 13 | | 13 | 8.4 | 8.4 | 8.4 | | 8.4 | ND | 0.375 | 0.75 | U | 0.375 | ND | 0.17 | 0.34 | U | 0.17 | ND | 0.65 | 1.3 | U | 0.65 |
| | | 30 | 28.5 | 5,709 | ND | 0.75 | 200 | J | 200 | 81 | 81 | 110 | J | 110 | ND | 3.55 | 8.3 | U | 4.15 | ND | 12 | 28 | U | 14 | ND | 10.5 | 25 | U | 12.5 |
| | | 35 | 32.0 | 695 | 220 | 220 | 220 | | 220 | 120 | 120 | 120 | J | 120 | ND | 3.2 | 6.4 | U | 3.2 | ND | 11 | 22 | U | 11 | ND | 9.5 | 19 | U | 9.5 |
| | | 40 | 36.5 | 511 | 240 | 240 | 270 | | 270 | ND | 4.3 | 9.7 | U | 4.85 | ND | 3.35 | 7.6 | U | 3.8 | ND | 11.5 | 26 | U | 13 | ND | 10 | 23 | U | 11.5 |
| | | 45 | 44.0 | 883 | 790 | 790 | 950 | | 950 | 540 | 540 | 640 | | 640 | ND | 3.45 | 8.2 | U | 4.1 | ND | 11.5 | 28 | U | 14 | ND | 10 | 24 | U | 12 |
| | | 50 | 49.0 | 732 | 850 | 850 | 1000 | | 1000 | 570 | 570 | 700 | | 700 | ND | 3.5 | 8.4 | U | 4.2 | ND | 12 | 29 | U | 14.5 | ND | 10.5 | 25 | U | 12.5 |
| | | 55 | 50.1 | 2,451 | 440 | 440 | 510 | | 510 | 230 | 230 | 270 | | 270 | ND | 3.35 | 7.8 | U | 0.39 | ND | 11.5 | 27 | U | 13.5 | ND | 10 | 23 | U | 11.5 |
| | | 60 | 57.5 | 1,846 | 180 | 180 | 210 | J | 210 | ND | 4.4 | 10 | U | 5 | ND | 3.4 | 7.9 | U | 3.95 | ND | 11.5 | 27 | U | 13.5 | ND | 10 | 24 | U | 12 |
| | | 65 | 60.5 | 137 | 350 | 350 | 410 | | 410 | 170 | 170 | 200 | J | 200 | ND | 3.45 | 8 | U | 4 | ND | 11.5 | 27 | U | 13.5 | ND | 10.5 | 24 | U | 12 |
| | | Prelim. Borehole Average Analytical Value (0-60') | | | | 237 | | | 291 | | 133 | | | 158 | | 2 | | | 2 | | 7 | | | 8 | | 6 | | | 7 |
| 001-307 | 8/1/2012 | 5 | 4.5 | 0 | ND | 0.155 | 0.36 | U | 0.18 | ND | 0.24 | 0.56 | U | 0.28 | ND | 0.375 | 0.87 | U | 0.435 | ND | 0.17 | 0.4 | U | 0.2 | ND | 0.65 | 1.5 | U | 0.75 |
| | | 10 | 8.0 | 0 | ND | 0.16 | 0.39 | U | 0.195 | ND | 0.245 | 0.6 | U | 0.3 | ND | 0.385 | 0.94 | U | 0.47 | ND | 0.175 | 0.43 | U | 0.215 | ND | 0.65 | 1.6 | U | 0.75 |
| | | 10D[3] | 8.0 | 0 | ND | | 0.42 | U | | ND | | 0.64 | U | | ND | | 1 | U | | ND | | 0.46 | U | | ND | | 1.7 | U | |
| | | 15 | 12.5 | 0 | ND | 0.17 | 0.41 | U | 0.205 | ND | 0.26 | 0.63 | U | 0.315 | ND | 0.41 | 0.98 | U | 0.49 | ND | 0.19 | 0.45 | U | 0.225 | ND | 0.7 | 1.7 | U | 0.85 |
| | | 20 | 18.0 | 0 | ND | 0.16 | 0.37 | U | 0.185 | ND | 0.25 | 0.57 | U | 0.285 | ND | 0.39 | 0.9 | U | 0.45 | ND | 0.18 | 0.41 | U | 0.205 | ND | 0.65 | 1.5 | U | 0.75 |
| | | 25 | 23.5 | 0 | ND | 0.16 | 0.34 | U | 0.17 | ND | 0.24 | 0.53 | U | 0.265 | ND | 0.38 | 0.83 | U | 0.415 | ND | 0.175 | 0.38 | U | 0.19 | ND | 0.65 | 1.4 | U | 0.7 |
| | | 30 | 26.0 | 0 | 0.98 | 0.98 | 1.2 | J | 1.2 | 1.8 | 1.8 | 2.1 | J | 2.1 | ND | 0.395 | 0.93 | U | 0.465 | ND | 0.18 | 0.43 | U | 0.215 | 8.4 | 8.4 | 2.7 | J | 2.7 |
| | | 35 | 33.0 | 0 | 0.83 | 0.83 | 0.97 | J | 0.97 | 1.4 | 1.4 | 1.7 | J | 1.7 | ND | 0.395 | 0.93 | U | 0.465 | ND | 0.18 | 0.43 | U | 0.215 | 1.9 | 1.9 | 2.3 | J | 2.3 |
| | | 40 | 37.0 | 0 | ND | 0.175 | 0.4 | U | 0.2 | ND | 0.275 | 0.61 | U | 0.305 | ND | 0.435 | 0.95 | U | 0.475 | ND | 0.195 | 0.44 | U | 0.22 | ND | 0.75 | 1.6 | U | 0.8 |
| | | 45 | 43.0 | 0 | 7.2 | 7.2 | 8.4 | J | 8.4 | 3 | 3 | 3.5 | J | 3.5 | ND | 0.37 | 0.86 | U | 0.43 | ND | 0.17 | 0.39 | U | 0.195 | 2.1 | 2.1 | 2.4 | J | 2.4 |
| | | 50 | 48.5 | 0 | 5.8 | 5.8 | 6.9 | J | 6.9 | 4.2 | 4.2 | 4.9 | J | 4.9 | ND | 0.39 | 0.91 | U | 0.455 | ND | 0.175 | 0.42 | U | 0.21 | 2.7 | 2.7 | 3.2 | J | 3.2 |
| | | 55 | 52.5 | 0 | 7.1 | 7.1 | 8.3 | J | 8.3 | 4.4 | 4.4 | 5.1 | J | 5.1 | ND | 0.38 | 0.89 | U | 0.445 | ND | 0.175 | 0.41 | U | 0.205 | 3.5 | 3.5 | 4.1 | J | 4.1 |
| | | 60 | 57.5 | 0 | 7.2 | 7.2 | 8.5 | J | 8.5 | 4.1 | 4.1 | 4.8 | J | 2.4 | ND | 0.385 | 0.91 | U | 0.455 | ND | 0.175 | 0.42 | U | 0.21 | 2.9 | 2.9 | 3.4 | J | 1.7 |
| | | Prelim. Borehole Average Analytical Value (0-60') | | | | 3 | | | 3 | | 2 | | | 2 | | 0 | | | 0 | | 0 | | | 0 | | 2 | | | 2 |
| 001-308 | 8/1/2012 | 5 | 4.9 | 0 | ND | 0.165 | 0.41 | U | 0.205 | ND | 0.155 | 0.62 | U | 0.31 | ND | 0.4 | 0.98 | U | 0.49 | ND | 0.185 | 0.45 | U | 0.225 | ND | 0.7 | 1.7 | U | 0.85 |
| | | 10 | 9.0 | 0 | 2.3 | 2.3 | 2.7 | J | 2.7 | ND | 0.26 | 0.63 | U | 0.315 | ND | 0.41 | 0.99 | U | 0.495 | ND | 0.185 | 0.45 | U | 0.225 | ND | 0.7 | 1.7 | U | 0.85 |
| | | 15 | 12.5 | 0 | 2.4 | 2.4 | 2.8 | J | 2.8 | ND | 0.24 | 0.56 | U | 0.28 | ND | 0.38 | 0.87 | U | 0.435 | ND | 0.175 | 0.4 | U | 0.2 | ND | 0.65 | 1.5 | U | 0.75 |
| | | 20 | 16.0 | 0 | 5.1 | 5.1 | 5.8 | J | 5.8 | 1 | 1 | 1.2 | J | 1.2 | ND | 0.34 | 0.78 | U | 0.39 | ND | 0.155 | 0.36 | U | 0.19 | ND | 0.6 | 1.3 | U | 0.65 |
| | | 20D[3] | 16.0 | 0 | 2.2 | | 2.6 | J | | ND | | 0.58 | U | | ND | | 0.9 | U | | ND | | 0.41 | U | | ND | | 1.5 | U | |
| | | 25 | 23.5 | 0 | 38 | 38 | 45 | | 45 | 15 | 15 | 18 | | 18 | ND | 0.34 | 0.93 | U | 0.465 | ND | 0.18 | 0.43 | U | 0.215 | ND | 0.65 | 1.6 | U | 0.8 |
| | | 30 | 29.5 | 659 | 270 | 270 | 310 | | 310 | 66 | 66 | 76 | J | 76 | ND | 3.4 | 7.7 | U | 3.65 | ND | 11.5 | 26 | U | 13 | ND | 10 | 23 | U | 11.5 |
| | | 35 | 34.0 | 5,998 | 0.66 | 0.66 | 0.74 | J | 0.74 | ND | 0.245 | 0.56 | U | 0.28 | ND | 0.385 | 0.87 | U | 0.435 | ND | 0.175 | 0.4 | U | 0.2 | ND | 0.65 | 1.5 | U | 0.75 |
| | | 40 | 37.0 | 1,192 | ND | 0.4 | 0.44 | U | 0.22 | ND | 0.31 | 0.68 | U | 0.34 | ND | 0.485 | 1.1 | U | 0.55 | ND | 0.22 | 0.49 | U | 0.245 | ND | 0.85 | 1.8 | U | 0.9 |
| | | 45 | 44.9 | 69 | 410 | 410 | 490 | | 490 | 120 | 120 | 150 | J | 150 | ND | 3.55 | 8.4 | U | 4.2 | ND | 12 | 29 | U | 14.5 | ND | 10.5 | 25 | U | 12.5 |
| | | 50 | 48.5 | 0 | 190 | 190 | 230 | J | 230 | 49 | 49 | 59 | J | 59 | ND | 3.35 | 8.1 | U | 4.05 | ND | 11.5 | 28 | U | 14 | ND | 10 | 24 | U | 12 |
| | | 55 | 54.9 | 150 | 210 | 210 | 250 | | 250 | 58 | 58 | 68 | J | 68 | ND | 3.2 | 7.6 | U | 3.8 | ND | 11 | 26 | U | 13 | ND | 9.5 | 23 | U | 11.5 |
| | | 60 | 58.5 | 500 | 180 | 180 | 200 | | 200 | 38 | 38 | 42 | | 42 | ND | 0.4 | 0.88 | U | 0.44 | ND | 0.18 | 0.4 | U | 0.2 | ND | 4.25 | 2.4 | J | 2.4 |
| | | Prelim. Borehole Average Analytical Value (0-60') | | | | 109 | | | 128 | | 29 | | | 35 | | 1 | | | 2 | | 4 | | | 5 | | 4 | | | 5 |

## Table 1. Southwest Plume RDSI Characterization Data (Continued)

SOUTHWEST PLUME RDSI CHARACTERIZATION DATA

DRAFT Final and Preliminary Soil Analytical Data (SWMU - 1 C-747-C Oil Landfarm)

| Boring ID | Date of (collection) | Depth bgs | Actual Sample Depth bgs (ft) | PID (ppb) | TCE (µg/Kg) Preliminary Reported | TCE Preliminary Average[1,2] | TCE Draft Final Reported | TCE Qual[8] | TCE Draft Final Average[9] | cis-1,2-DCE (µg/Kg) Reported | cis-1,2-DCE Preliminary Average[1,2] | cis-1,2-DCE Draft Final Reported | cis-1,2-DCE Qual[8] | cis-1,2-DCE Draft Final Average[9] | trans-1,2-DCE (µg/Kg) Reported | trans-1,2-DCE Preliminary Average[1,2] | trans-1,2-DCE Draft Final Reported | trans-1,2-DCE Qual[8] | trans-1,2-DCE Draft Final Average[9] | VC (µg/Kg) Reported | VC Preliminary Average[1,2] | VC Draft Final Reported | VC Qual[8] | VC Draft Final Average[9] | 1,1 DCE (µg/Kg) Reported | 1,1 DCE Preliminary Average[1,2] | 1,1 DCE Draft Final Reported | 1,1 DCE Qual[8] | 1,1 DCE Draft Final Average[9] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Oil Landfarm UCRS Soil Cleanup Level (µg/Kg) | | | | | 73 | | | | | 600 | | | | | 1080 | | | | | 34 | | | | | 130 | | | | |
| 001-303 | 8/2/2012 | 5 | 4.0 | 0 | ND | 0.165 | 0.4 | U | 0.2 | ND | 0.255 | 0.62 | U | 0.31 | ND | 0.395 | 0.97 | U | 0.485 | ND | 0.18 | 0.44 | U | 0.22 | ND | 0.7 | 1.7 | U | 0.85 |
| | | 10 | 9.0 | 0 | 4.3 | 4.3 | 5.2 | J | 5.2 | ND | 0.25 | 0.59 | U | 0.295 | ND | 0.39 | 0.92 | U | 0.46 | ND | 0.175 | 0.42 | U | 0.21 | ND | 0.65 | 1.6 | U | 0.8 |
| | | 15 | 14.5 | 0 | 15 | 15 | 17 | | 17 | 6.5 | 6.5 | 7.5 | J | 7.5 | ND | 0.365 | 0.84 | U | 0.42 | ND | 0.165 | 0.38 | U | 0.19 | ND | 0.6 | 1.4 | U | 0.7 |
| | | 20 | 19.5 | 0 | 0.38 | 0.38 | 0.43 | J | 0.43 | ND | 0.255 | 0.57 | U | 0.285 | ND | 0.4 | 0.9 | U | 0.45 | ND | 0.18 | 0.41 | U | 0.205 | ND | 0.7 | 1.5 | U | 0.75 |
| | | 25 | 21.0 | 0 | ND | 0.16 | 0.36 | U | 0.18 | ND | 0.295 | 0.55 | U | 0.275 | ND | 0.385 | 0.87 | U | 0.435 | ND | 0.175 | 0.4 | U | 0.2 | ND | 0.65 | 1.5 | U | 0.75 |
| | | 30 | 27.5 | 0 | 2.5 | 2.5 | 3 | J | 3 | 1.3 | 1.3 | 1.6 | J | 1.6 | ND | 0.39 | 0.93 | U | 0.465 | ND | 0.18 | 0.43 | U | 0.215 | ND | 0.65 | 1.6 | U | 0.8 |
| | | 35 | 34.5 | 12 | 0.36 | 0.36 | 0.41 | J | 0.41 | 0.93 | 0.93 | 1.1 | J | 1.1 | ND | 0.42 | 0.96 | U | 0.48 | ND | 0.19 | 0.44 | U | 0.22 | ND | 0.7 | 1.6 | U | 0.8 |
| | | 40 | 39.9 | 281 | 290 | 290 | 340 | | 340 | 180 | 180 | 210 | J | 210 | ND | 3.45 | 8.2 | U | 4.1 | ND | 12 | 28 | U | 14 | ND | 0.7 | 25 | U | 12.5 |
| | | 45 | 43.5 | 2,016 | 290 | 290 | 340 | | 340 | 190 | 190 | 220 | J | 220 | ND | 3.45 | 8.1 | U | 4.05 | ND | 12 | 28 | U | 14 | ND | 10.5 | 24 | U | 12 |
| | | 50 | 49.5 | 530 | 430 | 430 | 510 | | 510 | 240 | 240 | 280 | | 280 | ND | 3.4 | 8 | U | 4 | ND | 11.5 | 27 | U | 13.5 | ND | 10 | 24 | U | 12 |
| | | 55 | 50.1 | 5,530 | 25 | 25 | 29 | | 29 | 20 | 20 | 23 | | 23 | ND | 0.405 | 0.93 | U | 0.465 | ND | 0.185 | 0.43 | U | 0.215 | ND | 0.7 | 1.6 | U | 0.8 |
| | | 60 | 58.5 | 8,551 | 680 | 680 | 19 | U | 9.5 | 320 | 320 | 11 | U | 5.5 | ND | 0.395 | 8.6 | U | 4.3 | 13 | 13 | 29 | U | 14.5 | 6.6 | 6.6 | 26 | U | 13 |
| | | Prelim. Borehole Average Analytical Value (0-60') | | | | 145 | | | 105 | | 80 | | | 62 | | 1 | | | 2 | | 4 | | | 5 | | 3 | | | 5 |
| 001-305 | 8/2/2012 | 5 | 4.5 | 0 | 2.9 | 2.9 | 3.6 | J | 3.6 | ND | 0.265 | 0.65 | U | 0.325 | ND | 0.425 | 1 | U | 0.5 | ND | 0.19 | 0.46 | U | 0.23 | ND | 0.7 | 1.7 | U | 0.755 |
| | | 10 | 8.5 | 0 | 29 | 29 | 35 | | 35 | ND | 0.24 | 0.57 | U | 0.285 | ND | 0.375 | 0.89 | U | 0.445 | ND | 0.175 | 0.41 | U | 0.205 | ND | 0.65 | 1.5 | U | 0.75 |
| | | 15 | 14.0 | 0 | 45 | 45 | 54 | | 54 | 2 | 2 | 2.4 | J | 2.4 | ND | 0.365 | 0.91 | U | 0.455 | ND | 0.175 | 0.42 | U | 0.21 | ND | 0.65 | 1.6 | U | 0.8 |
| | | 20 | 18.5 | 0 | 13 | 13 | 14 | | 14 | 5.6 | 5.6 | 6.2 | J | 6.2 | ND | 0.365 | 0.81 | U | 0.405 | ND | 0.165 | 0.37 | U | 0.185 | ND | 0.65 | 1.4 | U | 0.7 |
| | | 25 | 24.5 | 0 | 530 | 530 | 640 | | 640 | ND | 4.45 | 11 | U | 5.5 | ND | 3.45 | 8.4 | U | 4.2 | ND | 12 | 28 | U | 14 | ND | 10.5 | 25 | U | 12.5 |
| | | 30 | 25.1 | 246 | 130 | 130 | 160 | J | 160 | ND | 4.6 | 11 | U | 5.5 | ND | 3.6 | 8.6 | U | 4.3 | ND | 12 | 29 | U | 14.5 | ND | 10.5 | 26 | U | 13 |
| | | 35 | 30.5 | 1,826 | 330 | 30 | 380 | | 380 | ND | 4.2 | 9.8 | U | 4.9 | ND | 3.3 | 7.6 | U | 3.8 | ND | 11 | 26 | U | 13 | ND | 10 | 23 | U | 11.5 |
| | | 40 | 39.9 | 870 | 1500 | 1500 | 1800 | | 1800 | ND | 4.15 | 9.7 | U | 4.85 | ND | 3.25 | 7.6 | U | 3.8 | ND | 11 | 26 | U | 13 | ND | 9.5 | 23 | U | 11.5 |
| | | 45 | 43.5 | 2,344 | 390 | 390 | 470 | | 470 | ND | 4.3 | 10 | U | 5 | ND | 3.35 | 8.1 | U | 4.05 | ND | 11.5 | 27 | U | 13.5 | ND | 10 | 24 | U | 12 |
| | | 50 | 45.5 | 28,514 | 3.5 | 3.5 | 4.1 | J | 4.1 | ND | 0.25 | 0.6 | U | 0.3 | ND | 0.395 | 0.94 | U | 0.47 | ND | 0.18 | 0.43 | U | 0.215 | ND | 0.7 | 1.6 | U | 0.8 |
| | | 55 | 53.0 | 2,330 | 11 | 11 | 13 | | 13 | ND | 0.26 | 0.61 | U | 0.305 | ND | 0.41 | 0.95 | U | 475 | ND | 0.19 | 0.44 | U | 0.22 | ND | 0.7 | 1.6 | U | 0.8 |
| | | 60 | 55.1 | 224 | 160 | 160 | 190 | | 190 | 3.5 | 3.5 | 4.1 | U | 2.05 | ND | 0.41 | 0.98 | U | 0.49 | ND | 0.19 | 0.45 | U | 0.225 | ND | 0.7 | 1.7 | U | 0.85 |
| | | Prelim. Borehole Average Analytical Value (0-60') | | | | 237 | | | 314 | | 3 | | | 3 | | 2 | | | 41 | | 5 | | | 6 | | 5 | | | 5 |
| 001-306 | 8/3/2012 | 5 | 3.5 | 0 | ND | 0.155 | 0.37 | U | 0.185 | ND | 0.24 | 0.56 | U | 0.28 | ND | 0.375 | 0.88 | U | 0.44 | ND | 0.17 | 0.4 | U | 0.2 | ND | 0.65 | 1.5 | U | 0.75 |
| | | 5D[3] | 3.5 | 0 | ND | | 0.39 | U | | ND | | 0.6 | U | | ND | | 0.94 | U | | ND | | 0.43 | U | | ND | | 1.6 | U | |
| | | 10 | 8.0 | 0 | ND | 0.165 | 0.4 | U | 0.2 | ND | 0.25 | 0.62 | U | 0.31 | ND | 0.39 | 0.96 | U | 0.48 | ND | 0.18 | 0.44 | U | 0.22 | ND | 0.65 | 1.7 | U | 0.85 |
| | | 15 | 13.5 | 0 | ND | 0.155 | 0.37 | U | 0.185 | ND | 0.24 | 0.57 | U | 0.285 | ND | 0.375 | 0.89 | U | 0.445 | ND | 0.17 | 0.41 | U | 0.205 | ND | 0.65 | 1.5 | U | 0.75 |
| | | 20 | 17.0 | 0 | ND | 0.16 | 0.35 | U | 0.175 | ND | 0.245 | 0.55 | U | 0.275 | ND | 0.38 | 0.85 | U | 0.425 | ND | 0.175 | 0.39 | U | 0.195 | ND | 0.65 | 1.5 | U | 0.75 |
| | | 25 | 22.0 | 45 | 1.1 | 1.1 | 1.2 | J | 1.2 | ND | 0.23 | 0.5 | U | 0.25 | ND | 0.355 | 0.79 | U | 0.395 | ND | 0.165 | 0.36 | U | 0.18 | ND | 0.6 | 1.3 | U | 0.65 |
| | | 30 | 25.1 | 1 | 30 | 30 | 36 | | 36 | 1.5 | 1.5 | 1.8 | J | 1.8 | ND | 0.38 | 0.91 | U | 0.455 | ND | 0.175 | 0.42 | U | 0.21 | ND | 0.65 | 1.6 | U | 0.8 |
| | | 35 | 32.0 | 0 | 27 | 27 | 32 | | 32 | 1.5 | 1.5 | 1.7 | J | 0.85 | ND | 0.405 | 0.96 | U | 0.48 | ND | 0.185 | 0.44 | U | 0.22 | ND | 0.7 | 1.6 | U | 0.8 |
| | | 40 | 39.0 | 50 | 58 | 58 | 67 | | 67 | 3.8 | 3.8 | 4.4 | J | 2.2 | ND | 0.385 | 0.88 | U | 0.44 | ND | 0.175 | 0.4 | U | 0.2 | ND | 0.65 | 1.5 | U | 0.75 |
| | | 45 | 40.5 | 0 | 75 | 75 | 86 | | 86 | 5.1 | 5.1 | 5.9 | J | 2.95 | ND | 0.365 | 0.84 | U | 0.42 | ND | 0.165 | 0.38 | U | 0.19 | ND | 0.65 | 1.4 | U | 0.7 |
| | | 50 | 49.5 | 0 | 64 | 64 | 74 | J | 74 | ND | 4.35 | 10 | U | 5 | ND | 3.4 | 7.9 | U | 3.95 | ND | 11.5 | 27 | U | 13.5 | ND | 10 | 23 | U | 11.5 |
| | | 55 | 53.0 | 1,215 | 37 | 37 | 43 | | 43 | 3.1 | 3.1 | 3.6 | J | 1.8 | ND | 0.385 | 0.89 | U | 0.445 | ND | 0.175 | 0.41 | U | 0.205 | ND | 0.65 | 1.5 | U | 0.75 |
| | | 60 | 56.0 | 39 | 110 | 110 | 130 | | 130 | 7.9 | 7.9 | 9.4 | J | 4.7 | ND | 0.39 | 0.93 | U | 0.465 | ND | 0.18 | 0.43 | U | 0.215 | ND | 0.65 | 1.6 | U | 0.8 |
| | | Prelim. Borehole Average Analytical Value (0-60') | | | | 34 | | | 39 | | 2 | | | 2 | | 1 | | | 1 | | 1 | | | 1 | | 1 | | | 2 |
| 001-313 | 8/6/2012 | 5 | 3.5 | 227 | 21 | 21 | 24 | | 24 | ND | 0.28 | 0.61 | U | 0.305 | ND | 0.44 | 0.96 | U | 0.48 | ND | 0.2 | 0.44 | U | 0.22 | ND | 0.75 | 1.6 | U | 0.8 |
| | | 10 | 7.5 | 599 | 83 | 83 | 100 | | 100 | 1.4 | 1.4 | 1.8 | J | 1.8 | ND | 0.385 | 0.94 | U | 0.47 | ND | 0.175 | 0.43 | U | 0.215 | ND | 0.65 | 1.6 | U | 0.8 |
| | | 15 | 10.5 | 1,419 | 46 | 46 | 55 | | 55 | 3.1 | 3.1 | 3.7 | J | 3.7 | ND | 0.385 | 0.92 | U | 0.46 | ND | 0.175 | 0.42 | U | 0.21 | ND | 0.65 | 1.6 | U | 0.817 |
| | | 20 | 19.5 | 22,230 | 150 | 150 | 170 | | 170 | 7.3 | 7.3 | 8.1 | J | 8.1 | ND | 0.38 | 0.85 | U | 0.425 | ND | 0.175 | 0.39 | U | 0.195 | ND | 0.65 | 1.4 | U | 0.7 |
| | | 25 | 21.5 | 54,270 | ND | 7 | 15 | U | 7.5 | ND | 4.45 | 9.1 | U | 4.55 | ND | 3.3 | 7.1 | U | 3.55 | ND | 11.5 | 24 | U | 12 | ND | 10 | 21 | U | 21 |
| | | 25D[3] | 21.5 | 54,270 | 120 | | | | | 14 | | | | | ND | | | | | ND | | | | | ND | | | | |
| | | 30 | 28.0 | 31,310 | 12000 | 12000 | 14000 | | 14000 | 950 | 950 | 1100 | | 1100 | ND | 6.5 | 16 | U | 16 | ND | 22.5 | 53 | U | 53 | ND | 19.5 | 46 | U | 23 |
| | | 35 | 33.5 | 58,714 | 15000 | 15000 | 18000 | | 18000 | 1000 | 1000 | 1200 | | 1200 | ND | 17 | 41 | U | 20.5 | ND | 60 | 140 | U | 70 | ND | 50 | 120 | U | 60 |
| | | 40 | 35.1 | 70,550 | 12000 | 12000 | 14000 | | 14000 | 770 | 770 | 900 | | 900 | ND | 7 | 16 | U | 8 | ND | 23 | 54 | U | 27 | ND | 20.5 | 48 | U | 24 |
| | | 45 | 40.1 | 17,730 | 900 | 900 | 1100 | | 1100 | ND | 4.3 | 10 | U | 5 | ND | 3.35 | 8 | U | 4 | ND | 11.5 | 27 | U | 13.5 | ND | 10 | 24 | U | 12 |
| | | 50 | 45.5 | 5,745 | 220 | 220 | 260 | | 260 | ND | 4.25 | 9.9 | U | 4.95 | ND | 3.3 | 7.8 | U | 3.9 | ND | 11.5 | 26 | U | 13 | ND | 10 | 23 | U | 11.5 |
| | | 55 | 52.0 | 4,187 | ND | 7.5 | 17 | U | 8.5 | ND | 4.3 | 9.8 | U | 4.9 | nd | 3.35 | 7.6 | U | 3.8 | nd | 11.5 | 26 | U | 13 | ND | 10 | 23 | U | 11.5 |
| | | 60 | 55.1 | 2,749 | 12 | 12 | 14 | | 14 | ND | 0.26 | 0.6 | U | 0.3 | ND | 0.405 | 0.93 | U | 0.465 | ND | 0.185 | 0.43 | U | 0.215 | ND | 0.7 | 1.6 | U | 0.8 |
| | | 62.5 | 60.5 | 2796 | 640 | 640 | 760 | | 760 | ND | 4.25 | 10 | U | 5 | ND | 3.3 | 7.9 | U | 3.95 | ND | 11 | 27 | U | 13.5 | ND | 10 | 23 | U | 11.5 |
| | | Prelim. Borehole Average Analytical Value (0-60') | | | | 3161 | | | 3731 | | 212 | | | 249 | | 4 | | | 5 | | 13 | | | 17 | | 11 | | | 14 |
| 001-319[4] | 8/6/2012 | 5 | 4.5 | 0 | ND | 0.18 | 0.4 | U | 0.2 | | | 0.62 | U | 0.31 | | | 0.97 | U | 0.495 | | | 0.44 | U | 0.22 | | | 1.7 | U | 0.85 |
| | | 10 | 9 | 0 | ND | 0.165 | 0.4 | U | 0.2 | ND | 0.255 | 0.61 | U | 0.305 | ND | 0.405 | 0.96 | U | 0.49 | ND | 0.185 | 0.44 | U | 0.22 | ND | 0.7 | 1.6 | U | 0.8 |
| | | 15 | 11 | 0 | 0.98 | 0.98 | 1.2 | J | 1.2 | ND | 0.26 | 0.62 | U | 0.31 | ND | 0.41 | 0.98 | U | 0.49 | ND | 0.185 | 0.45 | U | 0.225 | ND | 0.7 | 1.7 | U | 0.85 |
| | | 20 | 17.5 | 0 | 42 | 42 | 48 | | 48 | 7.9 | 7.9 | 9 | J | 9 | ND | 0.405 | 0.93 | U | 0.465 | ND | 0.185 | 0.43 | U | 0.215 | ND | 0.7 | 1.6 | U | 0.8 |
| | | 25 | 23 | 0 | 2.3 | 2.3 | 2.7 | J | 2.7 | ND | 0.24 | 0.56 | U | 0.28 | ND | 0.345 | 0.87 | U | 0.435 | ND | 0.17 | 0.4 | U | 0.2 | ND | 0.65 | 1.5 | U | 0.75 |
| | | 30 | 29 | 0 | 1.7 | 1.7 | 2 | J | 2 | ND | 0.26 | 0.62 | U | 0.31 | ND | 0.41 | 0.98 | U | 0.49 | ND | 0.19 | 0.45 | U | 0.225 | ND | 0.7 | 1.7 | U | 0.85 |
| | | 30D[3] | 29 | 0 | 1.6 | | | | | ND | | | | | ND | | | | | ND | | | | | ND | | | | |
| | | 35 | 32 | 0 | 2.3 | 2.3 | 2.7 | J | 2.7 | ND | 0.23 | 0.54 | U | 0.27 | ND | 0.365 | 0.85 | U | 0.425 | ND | 0.165 | 0.39 | U | 0.195 | ND | 0.6 | 1.5 | U | 0.75 |
| | | 40 | 39 | 0 | 45 | 45 | 55 | | 55 | 1.5 | 1.2 | 1.5 | J | 0.75 | | | 1.3 | U | 0.65 | | | 0.58 | U | 0.29 | | | 2.2 | U | 1.1 |
| | | 45 | 44.5 | 0 | 3.2 | 3.2 | 3.9 | J | 3.9 | ND | 0.23 | 0.56 | U | 0.28 | ND | 0.365 | 0.88 | U | 0.44 | ND | 0.165 | 0.4 | U | 0.2 | ND | 0.6 | 1.5 | U | 0.75 |
| | 8/7/2012 | 50 | 49.5 | 115 | 21 | 21 | 24 | | 24 | 0.92 | 0.92 | 1.1 | J | 1.1 | ND | 0.365 | 0.85 | U | 0.425 | ND | 0.165 | 0.39 | U | 0.195 | ND | 0.6 | 1.5 | U | 0.75 |
| | | 55 | 53.5 | 1,712 | 110 | 110 | 130 | | 130 | 7.9 | 7.9 | 9 | J | 9 | ND | 0.415 | 0.94 | U | 0.47 | ND | 0.19 | 0.43 | U | 0.215 | ND | 0.7 | 1.6 | U | 0.8 |
| | | 60 | 59.0 | 1,373 | 9.2 | 9.2 | 10 | | 10 | 0.83 | 0.83 | 0.92 | J | 0.92 | ND | 0.39 | 0.87 | U | 0.435 | ND | 0.18 | 0.4 | U | 0.2 | ND | 0.65 | 1.5 | U | 0.75 |
| | | 65 | 64.1 | 593 | 5.2 | 5.2 | 5.7 | J | 5.7 | | | 0.52 | J | 0.52 | | | 0.79 | U | 0.395 | | | 0.36 | U | 0.18 | ND | 0.6 | 1.3 | U | 0.65 |
| | | Prelim. Borehole Average Analytical Value (0-60') | | | | 19 | | | 22 | | 2 | | | 2 | | 0 | | | 0 | | 0 | | | 0 | | 1 | | | 1 |

## Table 1. Southwest Plume RDSI Characterization Data (Continued)

SOUTHWEST PLUME RDSI CHARACTERIZATION DATA
DRAFT Final and Preliminary Soil Analytical Data (SWMU - 1 C-747-C Oil Landfarm)

| Boring ID | Date of (collection) | Depth bgs | Actual Sample Depth bgs (ft) | PID (ppb) | TCE (µg/Kg) Preliminary Reported | TCE Preliminary Average[1,2] | TCE Draft Final Reported | TCE Qual[8] | TCE Draft Final Average[9] | cis-1,2-DCE (µg/Kg) Reported | cis-1,2-DCE Preliminary Average[1,2] | cis-1,2-DCE Draft Final Reported | cis-1,2-DCE Qual[8] | cis-1,2-DCE Draft Final Average[9] | trans-1,2-DCE (µg/Kg) Reported | trans-1,2-DCE Preliminary Average[1,2] | trans-1,2-DCE Draft Final Reported | trans-1,2-DCE Qual[8] | trans-1,2-DCE Draft Final Average[9] | VC (µg/Kg) Reported | VC Preliminary Average[1,2] | VC Draft Final Reported | VC Qual[8] | VC Draft Final Average[9] | 1,1 DCE (µg/Kg) Reported | 1,1 DCE Preliminary Average[1,2] | 1,1 DCE Draft Final Reported | 1,1 DCE Qual[8] | 1,1 DCE Draft Final Average[9] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Oil Landfarm UCRS Soil Cleanup Level (µg/Kg) | | | | | 73 | | | | | 600 | | | | | 1080 | | | | | 34 | | | | | 130 | | | | |
| 001-320[4] | 8/7/2012 | 5 | 4.0 | 0 | ND | 0.16 | 0.39 | U | 0.195 | ND | 0.25 | 0.59 | U | 0.295 | ND | 0.39 | 0.93 | U | 465 | ND | 0.18 | 0.43 | U | 0.215 | ND | 0.65 | 1.6 | U | 0.8 |
| | | 10 | 6.5 | 43 | ND | 0.155 | 0.37 | U | 0.185 | ND | 0.2 | 0.58 | U | 0.29 | ND | 0.37 | 0.9 | U | 0.45 | ND | 0.17 | 0.41 | U | 0.205 | ND | 0.65 | 1.5 | U | 0.75 |
| | | 15 | 14.9 | 1,175 | 160 | 160 | 180 | | 180 | 8.2 | 8.2 | 9.6 | | 9.6 | ND | 0.365 | 0.89 | U | 0.445 | ND | 0.175 | 0.41 | U | 0.205 | ND | 0.65 | 1.5 | U | 0.75 |
| | | 20 | 17 | 1,074 | 5.9 | 5.9 | 7 | J | 7 | ND | 0.235 | 0.55 | U | 0.275 | ND | 0.365 | 0.86 | U | 0.43 | ND | 0.165 | 0.39 | U | 0.195 | ND | 0.65 | 1.5 | U | 0.75 |
| | | 25 | 23 | 198 | 110 | 110 | 130 | | 130 | 5 | 5 | 6.1 | J | 6.1 | ND | 0.4 | 0.97 | U | 0.485 | ND | 0.185 | 0.44 | U | 0.22 | ND | 0.7 | 1.7 | U | 0.85 |
| | | 30 | 28 | 5,007 | 610 | 610 | 720 | | 720 | 42 | 42 | 49 | J | 49 | ND | 3.3 | 7.8 | U | 0.39 | ND | 11.5 | 27 | U | 23.5 | ND | 10 | 23 | U | 11.5 |
| | | 35 | 32 | 2,548 | 950 | 950 | 1100 | | 1100 | 70 | 70 | 83 | J | 83 | ND | 3.35 | 7.9 | U | 3.95 | ND | 11.5 | 27 | U | 13.5 | ND | 10 | 23 | U | 11.5 |
| | | 40 | 38.5 | 2,275 | 910 | 910 | 1100 | | 1100 | 63 | 63 | 74 | J | 74 | ND | 3.45 | 8 | U | 4 | ND | 11.5 | 27 | U | 13.5 | ND | 10 | 24 | U | 12 |
| | | 45 | 44 | 3,601 | 1200 | 1200 | 1500 | | 1500 | 91 | 91 | 110 | J | 110 | ND | 3.45 | 8.4 | U | 4.2 | ND | 12 | 28 | U | 14 | ND | 10.5 | 25 | U | 12.5 |
| | | 50 | 49.5 | 448 | 210 | 210 | 250 | | 250 | 16 | 16 | 19 | J | 19 | ND | 3.2 | 7.7 | U | 3.65 | ND | 11 | 26 | U | 13 | ND | 9.5 | 23 | U | 11.5 |
| | | 55 | 52.0 | 507 | 400 | 400 | 480 | | 480 | 27 | 27 | 32 | J | 32 | ND | 3.4 | 8 | U | 4 | ND | 11.5 | 27 | U | 13.5 | ND | 10 | 24 | U | 12 |
| | | 60 | 56.5 | 937 | 1.2 | 1.2 | 1.3 | J | 1.3 | ND | 0.3 | 0.69 | U | 0.385 | ND | 0.47 | 1.1 | U | 0.55 | ND | 0.215 | 0.49 | U | 0.245 | ND | 0.8 | 1.8 | U | 0.9 |
| | | Prelim. Borehole Average Analytical Value (0-60') | | | | 380 | | | 456 | | 27 | | | 32 | | 2 | | | 41 | | 6 | | | 8 | | 5 | | | 6 |
| 001-321[4] | 8/8/2012 | 5 | 4.0 | 335 | 1.3 | 1.3 | 1.5 | J | 1.5 | ND | 0.24 | 0.57 | U | 0.285 | ND | 0.38 | 0.9 | U | 0.45 | ND | 0.175 | 0.41 | U | 0.205 | ND | 0.65 | 1.5 | U | 0.75 |
| | | 10 | 7.5 | 16 | 2.7 | 2.7 | 3.3 | J | 3.3 | 4.3 | 4.3 | 5.2 | J | 5.2 | ND | 0.375 | 0.92 | U | 0.46 | ND | 0.17 | 0.42 | U,* | 0.21 | ND | 0.65 | 1.6 | U | 0.8 |
| | | 15 | 13.5 | 0 | 2.5 | 2.5 | 3.1 | J | 3.1 | 7 | 7 | 8.5 | J | 8.5 | ND | 0.355 | 0.86 | U | 0.43 | ND | 0.165 | 0.39 | U,* | 0.195 | ND | 0.6 | 1.5 | U | 0.75 |
| | | 20 | 17.5 | 107 | ND | 0.165 | 0.36 | U | 0.18 | ND | 0.25 | 0.56 | U | 0.29 | ND | 0.395 | 0.87 | U | 0.445 | ND | 0.18 | 0.4 | U | 0.2 | ND | 0.7 | 1.5 | U | 0.75 |
| | | 25 | 20.5 | 23 | ND | 0.155 | 0.34 | U | 0.17 | ND | 0.24 | 0.52 | U | 0.26 | ND | 0.375 | 0.82 | U | 0.41 | ND | 0.175 | 0.37 | U | 0.185 | ND | 0.65 | 1.4 | U | 0.7 |
| | | 25D[3] | 20.5 | 23 | 1.1 | | | | | 1.6 | | | | | ND | | | | | ND | | | | | ND | | | | |
| | | 30 | 28.5 | 3,315 | 28 | 28 | 35 | | 35 | 68 | 68 | 83 | | 83 | ND | 0.4 | 0.98 | U | 0.49 | ND | 0.185 | 0.45 | U,* | 0.225 | 5.3 | 5.3 | 6.5 | J | 6.5 |
| | | 35 | 32 | 312 | 8.4 | 8.4 | 9.5 | | 9.5 | 17 | 17 | 19 | | 19 | | | 0.83 | U | 0.415 | U | 0.415 | 0.38 | U,* | 0.19 | 2 | 2 | 2.2 | J | 2.2 |
| | | 40 | 38 | 136 | ND | 0.175 | 0.41 | U | 0.205 | ND | 0.27 | 0.63 | U | 0.315 | ND | 0.42 | 0.99 | U | 0.495 | ND | 0.195 | 0.45 | U,* | 0.225 | ND | 0.7 | 1.7 | U | 0.85 |
| | | 45 | 40.5 | 113 | 8.4 | 8.4 | 10 | | 10 | 13 | 13 | 15 | | 15 | ND | 0.4 | 0.95 | U | 0.475 | ND | 0.185 | 0.43 | U,* | 0.215 | 3.8 | 3.8 | 4.5 | J | 4.5 |
| | | 50 | 49.5 | 0 | 8 | 8 | 9.3 | J | 9.3 | 15 | 15 | 18 | | 18 | ND | 0.38 | 0.88 | U | 0.44 | ND | 0.175 | 0.4 | U | 0.2 | 1.9 | 1.9 | 2.3 | J | 2.3 |
| | | 55 | 54.0 | 0 | 15 | 15 | 18 | | 18 | 27 | 27 | 32 | | 32 | ND | 0.375 | 0.89 | U | 0.445 | ND | 0.17 | 0.41 | U | 0.205 | 4.4 | 4.4 | 5.2 | J | 5.2 |
| | | 60 | 59.0 | 0 | 14 | 14 | 17 | | 17 | 21 | 21 | 26 | | 26 | ND | 0.38 | 0.92 | U | 0.46 | ND | 0.175 | 0.42 | U,* | 0.21 | 4.1 | 4.1 | 5 | J | 5 |
| | | Prelim. Borehole Average Analytical Value (0-60') | | | | 7 | | | 9 | | 14 | | | 17 | | 0 | | | 0 | | 0 | | | 0 | | 2 | | | 3 |
| 001-322[4] | 8/8/2012 | 5 | 4.0 | 63 | ND | 0.175 | 0.39 | U | 0.195 | ND | 0.275 | 0.61 | U | 0.305 | ND | 0.425 | 0.95 | U | 0.475 | ND | 0.195 | 0.43 | U,* | 0.215 | ND | 0.75 | 1.6 | U | 0.8 |
| | | 10 | 9 | 0 | ND | 0.165 | 0.38 | U | 0.19 | ND | 0.25 | 0.59 | U | 0.295 | ND | 0.39 | 0.92 | U | 0.46 | ND | 0.18 | 0.42 | u,* | 0.21 | ND | 0.65 | 1.6 | u | 0.8 |
| | | 15 | 10.1 | 13 | ND | 0.155 | 0.36 | U | 0.18 | ND | 0.24 | 0.56 | U | 0.28 | ND | 0.38 | 0.87 | U | 0.435 | ND | 0.175 | 0.4 | U | 0.2 | ND | 0.65 | 1.5 | U | 0.75 |
| | | 20[6] | NA | NA | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | 25 | 21.5 | 0 | ND | 0.17 | 0.4 | U | 0.2 | ND | 0.26 | 0.62 | U | 0.31 | ND | 0.41 | 0.97 | U | 0.485 | ND | 0.19 | 0.45 | U,* | 0.225 | ND | 0.7 | 1.7 | U | 0.85 |
| | | 30 | 29 | 54 | 27 | 27 | 32 | | 32 | 18 | 18 | 21 | | 21 | | | 0.96 | U | 0.48 | U | 0.48 | 1.4 | J | 1.4 | ND | 0.7 | 1.7 | U | 0.85 |
| | | 35 | 34.9 | 167 | 5.2 | 5.2 | 5.8 | J | 5.8 | 3.5 | 3.5 | 3.9 | J | 3.9 | ND | 0.405 | 0.91 | U | 0.455 | ND | 0.185 | 0.42 | U,* | 0.21 | ND | 0.7 | 1.6 | U | 0.8 |
| | | 40 | 35.1 | 261 | 3.9 | 3.9 | 4.5 | J | 4.5 | | | 2.3 | J | 2.3 | | | 0.87 | U | 0.435 | ND | 0.175 | 0.4 | U,* | 0.2 | ND | 0.65 | 1.5 | U | 0.75 |
| | | 45 | 44.5 | 4 | 86 | 86 | 100 | | 100 | 42 | 42 | 50 | | 50 | ND | 0.365 | 0.85 | U | 0.425 | ND | 0.165 | 0.39 | U,* | 0.195 | ND | 0.6 | 1.5 | U | 0.75 |
| | | 50 | 48.5 | 51 | 69 | 69 | 80 | | 80 | 40 | 40 | 46 | | 46 | ND | 0.37 | 0.86 | U | 0.43 | ND | 0.17 | 0.39 | U | 0.195 | ND | 0.65 | 1.5 | U | 0.75 |
| | | 55 | 54.9 | 244 | 44 | 44 | 53 | | 53 | 29 | 29 | 34 | | 34 | ND | 0.36 | 0.85 | U | 0.425 | ND | 0.165 | 0.39 | U | 0.195 | ND | 0.6 | 1.5 | U | 0.75 |
| | | 60 | 57.5 | 129 | 2.7 | 2.7 | 3.2 | J | 3.2 | 2.6 | 2.6 | 3.1 | J | 3.1 | ND | 0.44 | 1 | U | 1 | ND | 0.2 | 0.47 | U | 0.235 | ND | 0.75 | 1.8 | U | 0.9 |
| | | Prelim. Borehole Average Analytical Value (0-60') | | | | 22 | | | 25 | | 14 | | | 15 | | 0 | | | 1 | | 0 | | | 0 | | 1 | | | 1 |
| 001-301 | 8/9/2012 | 5 | 4.0 | 0 | ND | 0.16 | 0.38 | U | 0.19 | ND | 0.245 | 0.59 | U | 0.295 | ND | 0.38 | 0.92 | U | 0.46 | ND | 0.175 | 0.42 | U | 0.21 | ND | 0.65 | 1.6 | U | 0.8 |
| | | 10 | 5.1 | 1 | ND | 0.165 | 0.39 | U | 0.195 | ND | 0.25 | 0.6 | U | 0.3 | ND | 0.39 | 0.93 | U | 0.465 | ND | 0.18 | 0.43 | U | 0.215 | ND | 0.65 | 1.6 | U | 0.8 |
| | | 15 | 10.1 | 10 | ND | 0.155 | 0.35 | U | 0.175 | ND | 0.235 | 0.54 | U | 0.27 | ND | 0.37 | 0.84 | U | 0.42 | ND | 0.17 | 0.84 | U | 0.42 | ND | 0.65 | 1.4 | U | 0.7 |
| | | 15D[3] | 10.1 | 10 | ND | | | | | ND | | | | | ND | | | | | ND | | | | | ND | | | | |
| | | 20 | 17 | 0 | ND | 0.185 | 0.41 | U | 0.205 | ND | 0.285 | 0.63 | U | 0.315 | ND | 0.445 | 0.99 | U | 0.495 | ND | 0.205 | 0.45 | U | 0.225 | ND | 0.75 | 1.7 | U | 0.85 |
| | | 25 | 20.5 | 0 | ND | 0.165 | 0.4 | U | 0.2 | ND | 0.25 | 0.61 | U | 0.305 | ND | 0.39 | 0.95 | U | 0.475 | ND | 0.18 | 0.44 | U | 0.22 | ND | 0.65 | 1.6 | U | 0.8 |
| | | 30 | 25.1 | 71 | 6.9 | 6.9 | 7.9 | J | 7.9 | 4.3 | 4.3 | 4.9 | J | 4.9 | ND | 0.355 | 0.81 | U | 0.405 | ND | 0.165 | 0.37 | U | 0.185 | ND | 0.6 | 1.4 | U | 0.7 |
| | | 35 | 31 | 92 | 15 | 15 | 17 | | 17 | 12 | 12 | 13 | | 13 | ND | 0.385 | 0.88 | U | 0.44 | ND | 0.175 | 0.4 | U | 0.2 | ND | 0.65 | 1.5 | U | 0.75 |
| | | 40 | 35.5 | 33 | 25 | 25 | 28 | | 28 | 17 | 17 | 20 | | 20 | ND | 0.38 | 0.87 | U | 0.435 | ND | 0.175 | 0.4 | U | 0.2 | ND | 0.65 | 1.5 | U | 0.75 |
| | | 45 | 44 | 189 | 57 | 57 | 67 | | 67 | 40 | 40 | 47 | | 47 | ND | 0.355 | 0.82 | U | 0.41 | ND | 0.16 | 0.38 | U | 0.19 | ND | 0.6 | 1.4 | U | 0.7 |
| | | 50 | 45.1 | 328 | 83 | 83 | 96 | | 96 | 58 | 58 | 67 | | 67 | ND | 0.36 | 0.83 | U | 0.415 | ND | 0.165 | 0.38 | U | 0.19 | ND | 0.6 | 1.4 | U | 0.7 |
| | | 55 | 50.1 | 510 | 12 | 12 | 13 | | 13 | 19 | 19 | 21 | | 21 | ND | 0.375 | 0.85 | U | 0.425 | ND | 0.17 | 0.39 | U | 0.195 | ND | 0.65 | 1.5 | U | 0.75 |
| | | 60 | 57.5 | 448 | 27 | 27 | 30 | | 30 | 19 | 19 | 21 | | 21 | ND | 0.65 | 1.4 | U | 0.7 | ND | 0.295 | 0.66 | U | 0.33 | ND | 1.1 | 2.5 | U | 1.25 |
| | | Prelim. Borehole Average Analytical Value (0-60') | | | | 19 | | | 22 | | 14 | | | 16 | | 0 | | | 0 | | 0 | | | 0 | | 1 | | | 1 |

# Table 1. Southwest Plume RDSI Characterization Data (Continued)

SOUTHWEST PLUME RDSI CHARACTERIZATION DATA

DRAFT Final and Preliminary Soil Analytical Data (SWMU - 1 C-747-C Oil Landfarm)

| Boring ID | Date of (collection) | Depth bgs | Actual Sample Depth bgs (ft) | PID (ppb) | TCE (µg/Kg) Preliminary Reported | TCE Preliminary Average[1,2] | TCE Draft Final Reported | TCE Qual[8] | TCE Draft Final Average[9] | cis-1,2-DCE (µg/Kg) Reported | cis-1,2-DCE Preliminary Average[1,2] | cis-1,2-DCE Draft Final Reported | cis-1,2-DCE Qual[8] | cis-1,2-DCE Draft Final Average[9] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Oil Landfarm UCRS Soil Cleanup Level (µg/Kg) | | | | | 73 | | | | | 600 | | | | |
| 001-302 | 8/10/2012 | 5 | 2.0 | 0 | ND | 0.17 | 0.4 | U | 0.2 | ND | 0.26 | 0.62 | U | 0.31 |
| | | 10 | 5.5 | 0 | ND | 0.155 | 0.36 | U | 0.18 | ND | 0.235 | 0.56 | U | 0.28 |
| | | 15 | 11 | 45 | ND | 0.16 | 0.37 | U | 0.185 | ND | 0.24 | 0.56 | U | 0.28 |
| | | 20 | 18 | 0 | ND | 0.155 | 0.35 | U | 0.175 | ND | 0.24 | 0.54 | U | 0.27 |
| | | 25 | 24 | 0 | 22 | 22 | 26 | | 26 | | | 15 | | 15 |
| | | 30 | 28.5 | 1,140 | 25 | 25 | 28 | | 28 | 9.5 | 9.5 | 11 | | 11 |
| | | 35 | 31 | 414 | 280 | 280 | 310 | J | 310 | 72 | 72 | 82 | J | 82 |
| | | 40 | 36.5 | 35 | 37 | 37 | 43 | | 43 | 14 | 14 | 16 | | 16 |
| | | 45 [7] | NA | NA | | | | | | | | | | |
| | | 50 | 47.5 | 578 | 21 | 21 | 24 | | 24 | 5.3 | 5.3 | 5.9 | J | 5.9 |
| | | 55 | 53.0 | 278 | 200 | 200 | 230 | J | 230 | 39 | 39 | 46 | J | 46 |
| | | 57.5 | 55.5 | 493 | 150 | 150 | 180 | | 180 | 27 | 27 | 32 | | 32 |
| | | Prelim. Borehole Average Analytical Value (0-60') | | | | 67 | | | 77 | | 17 | | | 19 |

| Depth bgs | trans-1,2-DCE (µg/Kg) Reported | trans-1,2-DCE Preliminary Average[1,2] | trans-1,2-DCE Draft Final Reported | trans-1,2-DCE Qual[8] | trans-1,2-DCE Draft Final Average[9] | VC (µg/Kg) Reported | VC Preliminary Average[1,2] | VC Draft Final Reported | VC Qual[8] | VC Draft Final Average[9] | 1,1 DCE (µg/Kg) Reported | 1,1 DCE Preliminary Average[1,2] | 1,1 DCE Draft Final Reported | 1,1 DCE Qual[8] | 1,1 DCE Draft Final Average[9] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Oil Landfarm UCRS Soil Cleanup Level (µg/Kg) | 1080 | | | | | 34 | | | | | 130 | | | | |
| 5 | ND | 0.405 | 0.97 | U | 0.485 | ND | 0.185 | 0.44 | U | 0.22 | ND | 0.7 | 1.7 | U | 0.85 |
| 10 | ND | 0.37 | 0.88 | U | 0.44 | ND | 0.17 | 0.4 | U | 0.2 | ND | 0.65 | 1.5 | U | 0.75 |
| 15 | ND | 0.38 | 0.88 | U | 0.44 | ND | 0.175 | 0.4 | U | 0.2 | ND | 0.65 | 1.5 | U | 0.75 |
| 20 | ND | 0.375 | 0.85 | U | 0.425 | ND | 0.17 | 0.39 | U | 0.195 | ND | 0.65 | 1.5 | U | 0.75 |
| 25 | | | 0.91 | U | 0.455 | | | 1.8 | J | 1.8 | | | 2.2 | J | 2.2 |
| 30 | ND | 0.415 | 0.93 | U | 0.465 | ND | 0.19 | 0.43 | U | 0.215 | ND | 0.7 | 1.6 | U | 0.8 |
| 35 | ND | 6.5 | 15 | U | 7.5 | ND | 22 | 50 | U | 25 | ND | 19 | 43 | U | 21.5 |
| 40 | ND | 0.455 | 1.1 | U | 0.55 | ND | 0.21 | 0.48 | U | 0.24 | 3.5 | 3.5 | 4.1 | J | 4.1 |
| 45 [7] | | | | | | | | | | | | | | | |
| 50 | ND | 0.435 | 0.97 | U | 0.485 | ND | 0.2 | 0.44 | U | 0.22 | ND | 0.75 | 1.7 | U | 0.85 |
| 55 | ND | 3.8 | 9 | U | 4.5 | ND | 13 | 31 | U | 15.5 | ND | 11.5 | 27 | U | 13.5 |
| 57.5 | ND | 0.45 | 1.1 | U | 0.55 | ND | 0.205 | 0.49 | U | 0.245 | 2.8 | 2.8 | 3.4 | J | 3.4 |
| Prelim. Borehole Average Analytical Value (0-60') | | 1 | | | 1 | | 4 | | | 4 | | 4 | | | 4 |

Notes:

1 For analytical results reported as non-detect (ND), a value equal to one half of the method detection levels (MDLs) was used to calculate the preliminary average borehole soil VOC values.

2 Final average borehole values will be calculated using the sample quantitation limit (SQL). SQLs will be provided from the contract lab as part of the final data package.

3 Denotes duplicate (QA/QC) sample, duplicate samples were not used in the sample VOC averaging calculations.

4 Contingency Boring Locations

5 2 sets of analytical data reported by TA for the 35-40' interval at boring 001-318, SMO determined that reported values should be used. TCE Borehole Average changed from 66 µg/Kg to 52 µg/Kg.

6 Reportedly no 15-20 foot sample collected from 001-322.

7 Reportedly no 40-45 foot sample collected from 001-302.

8 **Qualifier Definitions:** **U** - Non-detect; **J** - Result is less than the RL but greater than or equal to the MDL and the concentration is an approximate value; **X** - Surrogate is outside control limits; **E** - Result exceeds calibration range; **F** - RPD of the MS and MSD exceeds the control limits / MS or MSD exceeds the control limits; **H** - Sample was prepped or analyzed beyond the specified holding time; ***** - RPD of the LCS and LCSD exceeds the control limits.

9 For analytical results identified with a (U) qualifier, a value equal to one half of the sample quantitation limit (SQL ) was used to calculate the Draft Final average borehole soil VOC values.

10 SMO adjusted analytical data for sample 001-304 collected at 20 ft (8-28-2012).

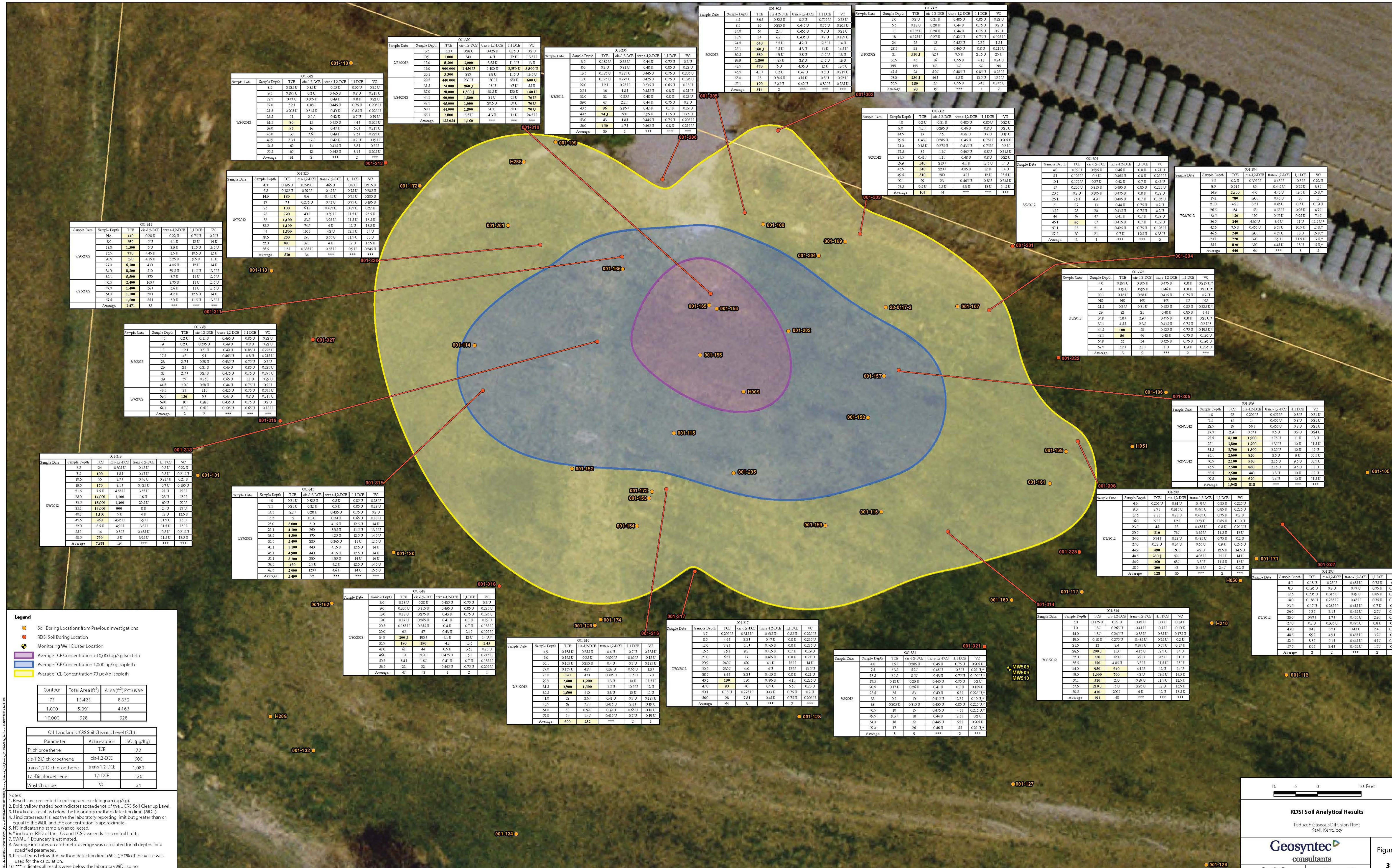


Figure 3. RDSI Soil Sampling Results

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In cases where VOCs were detected in some depth intervals, but were below the MDL in other depth intervals, 50% of the MDL value was utilized in calculation of the arithmetic average. The treatment area/final source area has increased in size based on the collection and utilization of the RDSI data. The mapped area for treatment, as shown in Figure 3 is 13,423 $ft^2$. Isoconcentration contours of TCE in soil were developed using Golden Software's Surfer (Version 7.04) kriging algorithm. Data was preprocessed by using one half of the detection limit for nondetects. The data set was tested for normality and log normality using the Shapiro Wilk Test in the U.S. Environmental Protection Agency's ProUCL statistical software package (Version 4.1.01). Since the data appear log-normal at a 5% significance level, data were log-transformed prior to kriging to develop the 73 µg/kg, 1,000 µg/kg, and 10,000 µg/kg isocontours.

## 1.4 ENVIRONMENTAL VISUALIZATION SOFTWARE EVALUATION AND VOC MASS ESTIMATE

Mass quantity estimates were interpolated using the C Tech Environmental Visualization Systems expert system (EVS-ES) for four target analytes: (1) TCE; (2) *cis*-1,2-dichloroethene; (3) vinyl chloride; and (4) 1,1-dichloroethene. A one-layer geologic model was built focusing on the top 75 ft of soil for modeling soil analyte distribution. Chemical results from the 2012 sampling efforts from the 22 soil boring locations shown in Figure 3 were log processed in the model. The horizontal/vertical anisotropy ratio parameter, which allows the model to take into consideration expected differences in fluid flow through the soil matrix, was set to 1 versus the default of 10. This value was set at 1 to best represent the anticipated distribution of chemicals, as well as resulting in more conservative estimates of chemical mass. The Octant Search method was used to determine which sample points are selected for inclusion in the kriging matrix. This method sets a maximum number of points for each octant, which helps offset bias effects of sampling distribution irregularities. The model used a soil density of 1.5 gram per $cm^3$ and a chemical density of 1.46 gram per $cm^3$. The model's mass calculations then were reviewed and compared to hand calculations of the mass. A compact disc, which includes the EVS-ES output files, is included as Appendix B.

The results of the EVS-ES modeling using the RDSI soil results revealed the following estimated weight of VOCs within the 13,423 $ft^2$ treatment area: TCE (90 lb), *cis*-1,2-dichloroethene (6 lb), vinyl chloride (0.04 lb), and 1,1-dichloroethene (0.1 lb), or approximately 100 lb of total VOC weight. From a mass distribution perspective, approximately 45% of the TCE mass is located within the greater than 10,000 µg/kg isocontour area, representing approximately 7% of the proposed LDA treatment area. The EVS estimated weight calculated is less than the weight estimated in the SI.

## 1.5 SEQUENCING WITH OTHER REMEDIES

This RA will be executed in coordination with the Soils Operable Unit (OU) for remediation of surface soil contaminants, as appropriate. The Soils OU remediation currently is planned for implementation following the SWMU 1 groundwater VOC contaminant source RA. A review of contaminants that exceed the no action level (NAL) as contained in Soils OU RI, DOE/LX/07-0258&D2, (DOE 2012c) was performed. The evaluation contained in the remedial investigation report separated the soils into surface and subsurface. Surface soils are located < 1 ft in depth; while subsurface soils are located > 1 ft in depth and less than 10 ft in depth.

The surface soils in the area to be mixed contain polychlorinated biphenyls (PCBs) and metals above the Industrial NAL (DOE 2012c). The expected maximum PCB and metal contaminant concentrations in the soil mixing area are as follows:

- PCBs 3.4 mg/kg
- Arsenic 6.3 mg/kg
- Beryllium 0.7 mg/kg
- Cadmium 6.4 mg/kg
- Cobalt 13.7 mg/kg
- Vanadium 24 mg/kg

The No VOCs, radioactive compounds or semivolatile organic compound exceeded the NAL in the surface soils in the area to be soil mixed. To protect the aboveground treatment system from potential PCB contamination and to facilitate greater depths in soil mixing, prior to implementing the deep soil mixing RA, the top 2 ft of the treatment/source area soil will be removed, stockpiled adjacent to the mixing area, and respread in the excavation after soil mixing action is complete. The excavation of surface soil supports the soil mixing in the following ways:

1. PCBs contacting the mixing equipment or passing through the vapor of liquid treatment system could contaminate the equipment and prevent the release of the equipment.

2. The presence of the metals could result in their being solubilized and passing through the treatment equipment and resulting in excess metals in the treatment effluent.

3. The soil mixing equipment with the 8-ft augering system, combined and our soil conditions, is limited to a depth of 60 ft, and the excavation will assist in attaining mixing to the bottom of HU4 (see Section 2).

Following completion of the mixing process, the excavated area will be backfilled to bring the ground surface back to grade with the surrounding unmixed area. Due to being disturbed by the mixing process, the soils contained in the mixing area will require recharacterization. DOE intends to recharacterize those soils as part of the Soils OU at the appropriate time in the future. The surface soils located outside of the area to be soil mixed will be addressed, as appropriate, by the Soils OU at a later date.

# 2. TREATMENT TECHNOLOGY

This RA will implement *in situ* source treatment using deep soil mixing with interim LUCs. The selected RA technology involves the utilization of LDAs combined with the introduction of hot air/steam for thermal volatilization and stripping of VOCs in soil and groundwater in the UCRS and upper RGA (hydrogeologically) soils to a depth of 62 ft bgs (takes into consideration the removal of the top 2 ft of soil prior to LDA implementation). To confirm the treatment of the UCRS and upper RGA (HU4) soils, the mapped source treatment area was placed over a kriging-based evaluation of the HU4/HU5 interface (Figure 4). This information, which is based upon the RDSI soil borings, documents that the HU4/HU5 interface is a maximum of 62 ft bgs within the treatment area. Accordingly, the proposed treatment depth of 62 ft bgs matches or exceeds the HU4/HU5 interface within the treatment area.

Granular ZVI in a guar gum solution also will be delivered to the subsurface via LDA injection as a polishing step to provide treatment of residual VOCs within the source area.

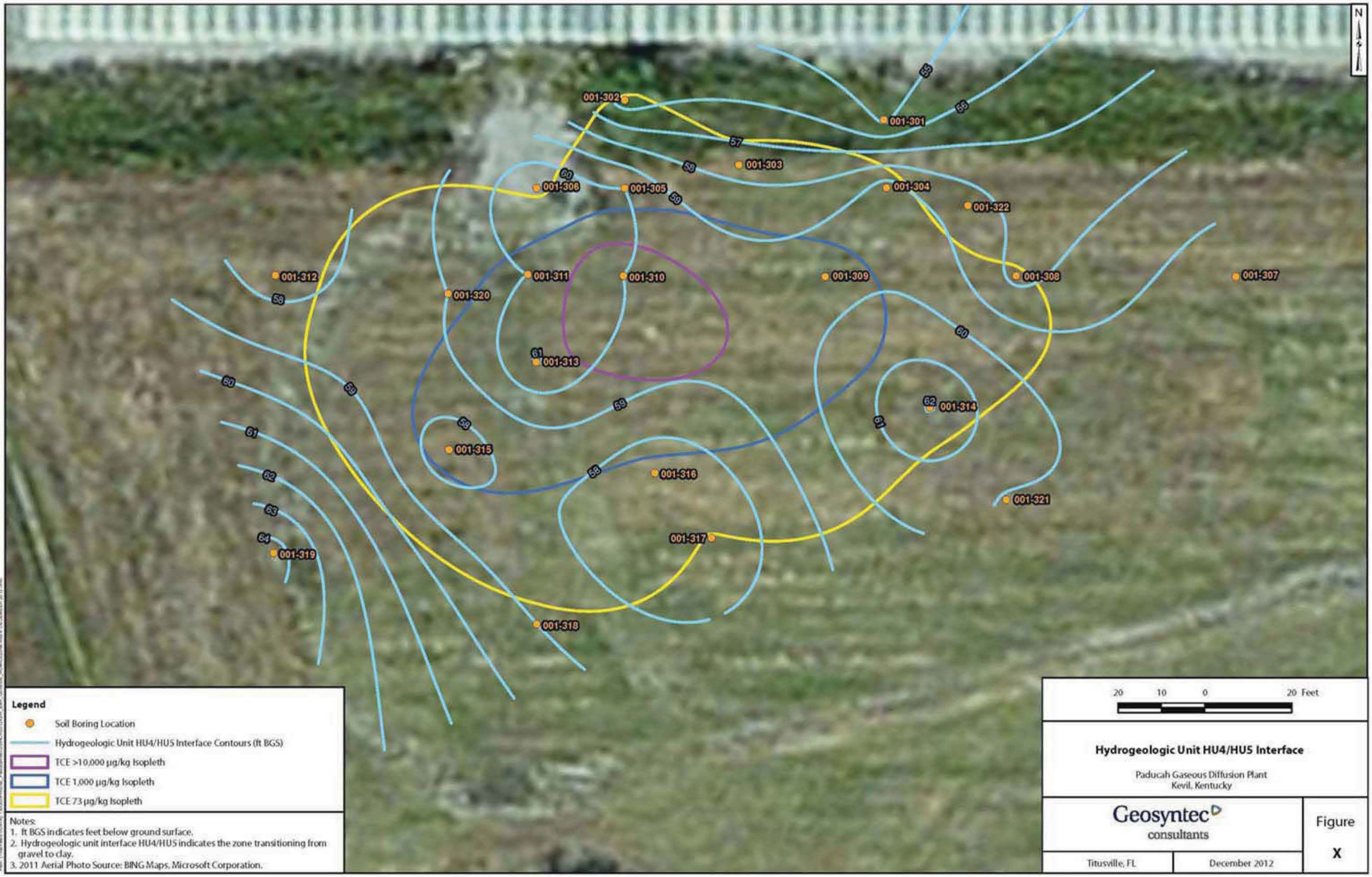


**Figure 4. Hydrogeologic Unit H4/HU5 Interface**

A vapor treatment system will be utilized that includes real-time monitoring and provides a real-time indication of the level of contamination in specific zones being treated. Real-time monitoring will assist in controlling the process parameters to maximize VOC removal, control of operating treatment equipment, and support operation of the LDA and injection systems.

A more detailed description of the treatment technology and process is included in Section 4.

# 3. TREATMENT SYSTEM OBJECTIVES

As discussed in Section 2, design information, including contaminant levels, areas of soil VOC impacts and mass present in the treatment zone, was obtained during the RDSI. The RDSI information regarding the distribution of VOCs in the treatment zone is used in this design to optimize the LDA treatment area layout and auger boring overlap to provide effective VOC treatment and achieve project objectives. The following subsections provide discussions on the remedial action objectives and the key operational parameters of the mixing process to attain the objectives.

## 3.1 RA OBJECTIVES

The following remedial action objectives (RAOs) are defined in the ROD for the Southwest Plume source areas (DOE 2012a).

(1) Treat and/or remove the principal threat waste consistent with the National Contingency Plan;

(2a) Prevent exposure to VOC contamination in the source areas that will cause an unacceptable risk to excavation workers (< 10 ft);

(2b) Prevent exposure to non-VOC contamination and residual VOC contamination through interim LUCs within the Southwest Plume source areas (i.e., SWMU 1, SWMU 211-A, and SWMU 211-B) pending remedy selection as part of the Soils OU and the Groundwater OU; and

(3) Reduce VOC migration from contaminated subsurface soils in the treatment areas at the Oil Landfarm and the C-720 Northeast and Southeast Sites so that contaminants migrating from the treatment areas do not result in the exceedance of maximum contaminant levels in the underlying RGA groundwater.

## 3.2 OPERATIONAL PARAMETERS

The design will allow for operational parameters to be monitored during the treatment period. Operational parameters to be monitored and evaluated will include the following:

- LDA Operational Monitoring for
  - Depth penetration rate
  - Auger rotational rate
  - Applied torque
  - Down-hole temperature

- Temperature, flow rate, and injection pressure for

  - Injected steam
  - Compressed/heated air
  - ZVI slurry mixture

- Vapor recovery flow rate, temperature, and vacuum pressure
- Extracted VOC concentrations
- Treated vapor phase VOC concentrations

# 4. 90% TECHNICAL DESIGN

## 4.1 TECHNICAL JUSTIFICATION FOR SELECTION OF REMEDIAL TECHNOLOGY

The selected RA technology for the Southwest Plume VOC Oil Landfarm source area involves the utilization of *in situ* soil mixing with LDA up to 276 boring locations combined with the introduction of hot air/steam for thermal volatilization and stripping of VOCs in soil and groundwater within the target treatment zone. Additionally, granular ZVI in a guar gum solution will be delivered to the subsurface via LDA injection as a polishing step to provide additional treatment.

Prior to selecting the proposed RA, technology permutations considered included (1) LDA soil mixing with emulsified ZVI delivery, (2) LDA soil mixing with oxidant delivery, and (3) LDA soil mixing with ZVI and clay delivery. Based upon an evaluation of implementation approaches, the *in situ* LDA soil mixing with hot air/steam and ZVI injection offers (1) the highest anticipated level of mass reduction and potential to achieve objectives, (2) an implementation cost that falls within the range of the other technology permutations considered, and (3) demonstrated effectiveness for providing treatment of high levels of VOCs. Unique to the *in situ* LDA soil mixing with hot air/steam and ZVI injection technology, the mixing process and treatment application is adapted real-time based upon the monitoring of off-gas VOC concentrations (discussed in Sections 4.2 and 4.4.2.2). Accordingly, the selected RA has flexibility and can be actively adapted during individual borehole mixing to spend additional time, providing enhanced treatment to specific depth intervals and/or boreholes with higher levels of VOCs, as appropriate (discussed in Section 4.4.2.1).

## 4.2 CRITICAL PARAMETERS

Critical parameters for *in situ* LDA soil mixing with hot air/steam and ZVI injection are those operational parameters of the system and the physical and chemical parameters of the media being treated that have the greatest impact on the ability of the technology to meet the performance goals. These critical parameters are as follows.

**Soil and Groundwater Temperature.** The temperature of soil and groundwater throughout the treated volume must be raised sufficiently to achieve volatilization of the targeted contaminants. The target soil and groundwater temperature to achieve volatilization of identified VOCs in the treatment zone will be 170°F, which has been demonstrated to achieve volatilization of TCE and daughter products at other sites [e.g., Launch Complex 15, Ordnance Support Facility 1381 (USAF 2008), Security Police Confidence Course located at Cape Canaveral Air Force Station (USAF 2007); and Offutt Air Force Base, Nebraska (USACE 2012)] that have employed this remedial technology (the injected hot air/steam contacting the soil will have a temperature exceeding 200°F). A downhole thermocouple data logger, physically mounted to the LDA auger blade, will be used to monitor subsurface temperatures at the end of mixing operations for any given time period. The data logger will be retrieved from the LDA auger blade to download and view the data. The temperature of gas collection will be measured in the surficial shroud in real time. It has been established, based on experience at other sites (identified above) that, by adding a correction factor of 10°F to the shroud gas temperature, the resultant is representative of the downhole temperature. Accordingly, a shroud gas temperature of 160°F will be utilized as a real-time indicator of adequate subsurface temperature for VOC volatilization.

**Percentage of Auger Boring Overlap.** The LDA borings will be established based upon three overlap spacing scenarios: 0% (no overlap); 10% (some overlap for reduction of interstitial space between treatment cells/borings); or 17.5% (representing complete overlap with no interstitial space between treatment cells/borings). The overlap spacing is varied based upon on the average concentration of TCE in the RDSI soil borings. The LDA boring overlap consists of the following overlap scenarios:

- A 17.5% overlap will be provided in the area within the greater than 10,000 µg/kg average TCE isoconcentration contour (928 $ft^2$ area).
- A 10% overlap will be provided in the area within the greater than 1,000 µg/kg and less than 10,000 µg/kg average TCE isoconcentration contours (4,163 $ft^2$ area).
- A 0% overlap (or greater to account for auger boring layout spacing) will be provided in the area within the greater than 73 µg/kg and less than 1,000 µg/kg average TCE isoconcentration contours (8,332 $ft^2$ area).

The LDA boring overlap scenario provided for the effective treatment of the treatment area, with an overlap that exceeds the successful LDA technology implementation at the Security Police Confidence Course (Facility 18003) at Cape Canaveral Air Force Station, which used a 6% overlap throughout (USAF 2007) and the Ordnance Support Facility at Cape Canaveral Air Force Station, which used a 0% overlap throughout (USAF 2008). The referenced sites are located in a fully-saturated sand aquifer, which reflects a heating environment that is more difficult to steam volatilize VOCs than the soils present at SWMU 1. Additionally, the Offutt Air Force Base LDA soil mixing project was performed in a lithology-type (silty clay) similar to SWMU 1 and also achieved project objectives (USACE 2012). Figure 5 presents the LDA boring layout and up to 276 proposed boring locations.

**Soil Properties/Mixing Rate.** Soil properties dictate the rate at which the LDA can penetrate the subsurface, appropriate angle of repose for the mixing blade, and considerations regarding the auger blade terminus. In consideration of the soil characteristics and consistency in the Oil Landfarm source area, which includes a hard layer identified in standard penetration test (SPT) borings in the site vicinity, it is anticipated that "rock teeth" will be required on the auger blades. For the *in situ* LDA soil mixing with hot air/steam and ZVI injection technology to be effective, no large boulders and/or large subsurface concrete structures can be present. No anomalies were identified during the RDSI. Previously, two anomalies were found through geophysical techniques and these were excavated. One was a large concrete pipe that did not appear to be associated with the former operations of the SWMU. The second anomaly was not identified, but was believed to have been a result of the presence of small metal objects such as drum lids, bungs, metal shavings, etc. Appendix C includes SPT blow count data and geotechnical data for soils anticipated to be encountered during LDA soil mixing for determination of penetration rate, angle of repose for the mixing blade/auger blade, and blade type selection by equipment vendors.

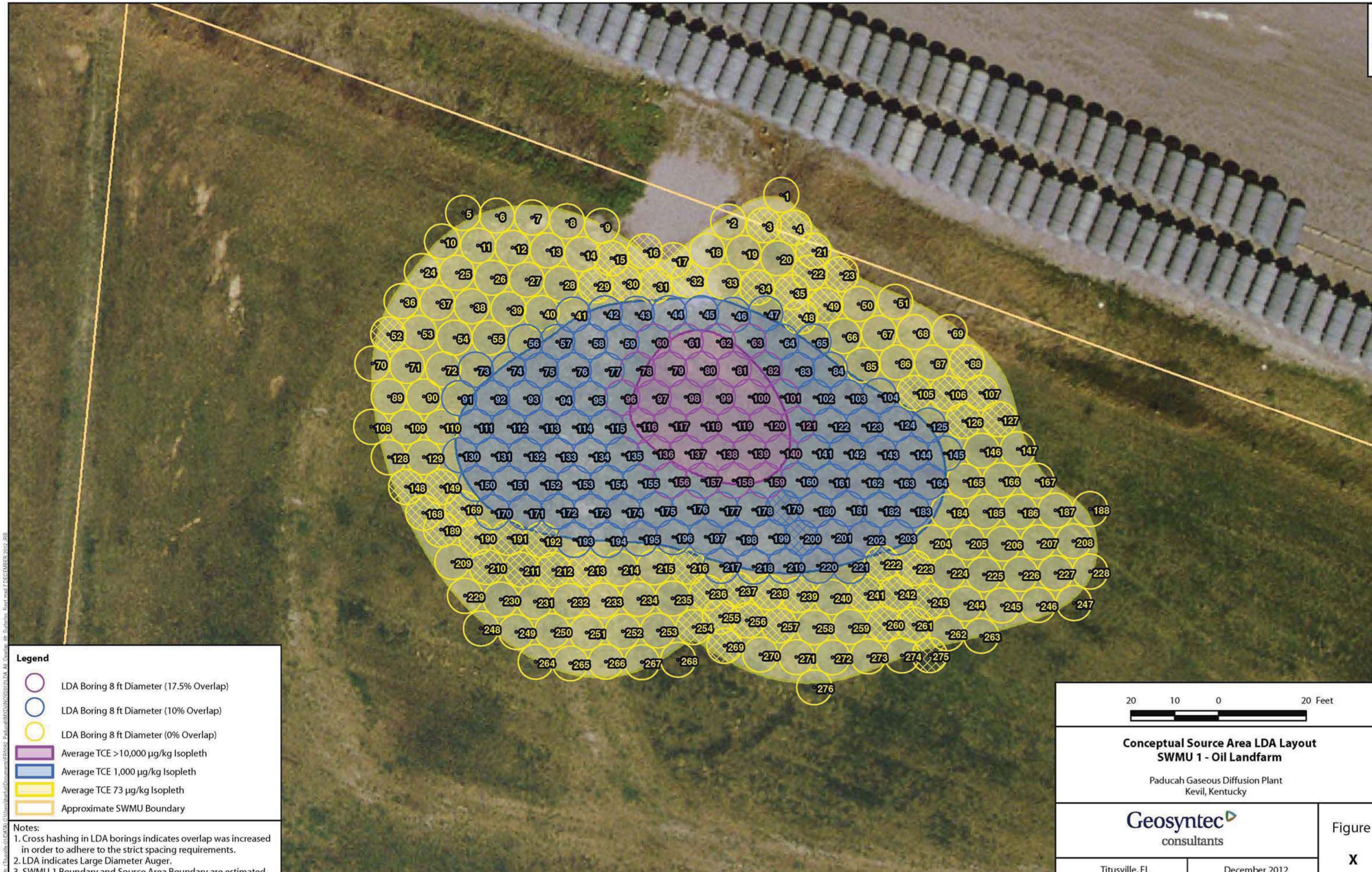


Figure 5. Source Area LDA Layout

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**VOC Vapor Extraction Rate.** The rate of air/vapor extraction from the vadose zone must be greater than the production of contaminant vapors to prevent vaporized contaminants from escaping to the atmosphere or from condensing in the vadose zone. The vapor extraction equipment will be capable of extracting vapors at a flow rate that is twice the maximum flow rate of the hot/air steam injection equipment, and field monitoring will ensure that vapor extraction is occurring at a rate not less than 50% greater than the concurrent hot air/steam injection flow rate.

**Concentration of VOCs in Extracted Vapor.** The concentration of VOCs in the vapor extraction stream must be monitored in real time and balanced with the aboveground treatment system's ability to treat such concentrations. Gas samples from the process streams will be collected from the vapor extraction system for analysis by a photoionization detector (PID)/flame ionization detector (FID) and/or a gas chromatograph (GC). In the unlikely event the LDA soil mixing vendor-specific PID/FID and/or GC data monitoring equipment becomes saturated due to the presence of high VOC concentrations and/or dense nonaqueous-phase liquids (DNAPLs) present in the subsurface, LDA soil mixing will be paused until appropriate adjustments are made (adjustments will vary depending on specific equipment type) to allow resumption of vapor analysis. LDA soil mixing will be restarted when appropriate adjustments are made in the field (based upon vendor specific equipment) to compensate for the elevated concentrations by adjusting the ascent/descent rate of soil mixing, recalibration of the PID/FID equipment to a higher calibration standard to facilitate measurement, and/or introduction of additional bleed air to the system to provide for the adequate real-time monitoring of VOCs. The continuous monitoring of PID/FID and/or GC results in the vapor extraction stream is required at all times to effectively document mass removal rates per LDA soil mixing boring location.

**ZVI Dosing Concentration.** A slurry mixture consisting of granular ZVI, water, and guar gum (to facilitate ZVI injection into the soil) will be delivered based upon a percentage by weight application rate; field-based decisions based upon monitoring data collected during hot air/steam mixing phase will be used to adjust the ZVI dosing concentration. The amount of ZVI delivered to an LDA boring location will be established based on the observed PID/FID response value of VOCs from the first thermal treatment pass according to the following criteria:

- If a maximum PID/FID reading of 1,000 ppm or less (after subtracting the methane value) is observed on the first thermal treatment pass, an application of 0.5% ZVI will be applied.

- If a PID/FID reading of 1,000 to 5,000 ppm (after subtracting the methane value) is observed on the first thermal treatment pass, an application of 1.0% ZVI will be applied.

- If a PID/FID reading exceeding 5,000 ppm (after subtracting the methane value) is observed on the first thermal treatment pass, an application of 1.5% ZVI will be applied.

- Based upon RSDI soil sampling results, the area within the greater than 10,000 µg/kg TCE isoconcentration contour area will be treated with a default 2% ZVI regardless of PID/FID response.

The ZVI dosing concentration will be measured as a percentage by weight of the column of soil being treated. The ZVI dosing strategy is consistent with the LDA soil mixing projects successfully implemented to treat TCE/DNAPL source areas at Cape Canaveral Air Force Station (USAF 2007; USAF 2008) and former Offutt Air Force Base (USACE 2012).

**Impact to Surrounding Structures, Utilities, and Operations.** It must be possible to implement the treatment technology at the Oil Landfarm source area and to operate it with limited interference to site personnel and other facility operations. No obstructions involving utilities, metal, or concrete were identified during the RDSI. Previously, two anomalies were found through geophysical techniques and these were excavated. One was a large concrete pipe that did not appear to be associated with the former operations of the SWMU. The second anomaly was not identified, but was believed to have been a result of the presence of small metal objects such as drum lids, bungs, metal shavings, etc.

**Contaminants of Concern.** The technology is designed specifically for the treatment of VOCs. Unacceptable concentrations of other contaminants will be addressed consistent with the details discussed previously in Section 1.5, Sequencing with Other Remedies. Monitoring of the previous non-target/non-VOC contaminants of concern will be conducted in the collected vapor condensate and the off-gas discharges from the treatment system within a representative subset of the remedial monitoring protocol to establish whether additional condensate treatment measures and/or equipment decontamination procedures will be necessary.

## 4.3 DESIGN REQUIREMENTS

The general input requirements for the *in situ* LDA soil mixing with hot air/steam and ZVI injection remediation design include the following:

- Site location and general site logistics, including nearby structures and site activity;
- Buried underground utilities and obstructions;
- Shape and depth of the treatment area;
- Site geology;
- Site hydrogeology, including depth to groundwater and groundwater flow rate;
- Soil chemical characteristics, including percentage of organic carbon content;
- Contaminant-specific remediation goals, defined in the FFS (DOE 2010a) and listed in Table 2;
- Compliance with applicable or relevant and appropriate requirements (ARARs)(ROD DOE 2012a);
- Absence of low-volatility co-contaminants (at the time of LDA soil mixing within treatment area);
- Desired remediation schedule;
- Options for wastewater disposal; and
- Selection of vapor treatment technology.

**Table 2. Cleanup Levels for the Oil Landfarm Source Area RA**

| Contaminant of Concern | Cleanup Levels for the Oil Landfarm, mg/kg |
|---|---|
| TCE | 7.30E-02 |
| 1,1-DCE | 1.30E-01 |
| *cis*-1,2-DCE | 6.00E-01 |
| *trans*-1,2-DCE | 1.08E+00 |
| Vinyl Chloride | 3.40E-02 |

Note: Also see ROD Tables 17 and 18 for the UCRS Soil Cleanup Levels for VOCs (DOE 2012a).

## 4.4 PROCESS DESCRIPTION FOR *IN SITU* LDA SOIL MIXING WITH HOT AIR/STEAM TREATMENT AND ZVI AMENDMENT

*In situ* LDA soil mixing with hot air/steam and ZVI treatment technology consists of the following major elements: soil mixing, hot air/steam generation and delivery, vapor extraction and conditioning, recovered-liquid treatment and disposal, ZVI mixing and delivery, and vapor treatment. The treatment system includes a monitoring system for real-time data evaluation that assists in controlling the process parameters to maximize VOC removal and supports decision making for operation of the LDA and injection systems.

The mixing system will be equipped with an LDA that shears and mixes the soil as the auger is advanced below the ground surface, while concurrently injecting steam and hot air. This action causes thermal desorption and volatilization of the VOCs from soil particles, groundwater and interstitial spaces. The steam and hot air raises the temperature of the soil mass, increases the vapor pressure of the contaminants, volatilizes the compounds from the soil particles (through heat and air stripping), and allows them to be transported to the surface via the injected hot air/steam where they are collected in a shroud maintained under vacuum, covering the active treatment area. The shroud provides the ability to capture off-gases beyond the auger blades. The vapors then are transported from the shroud through the vapor conditioning system (VCS) to the VOC treatment system by a blower. VOC removal and treatment will then be enhanced via the placement of ZVI in the mixed soil column and aquifer material to enhance abiotic degradation of residual VOCs.

The VOC treatment system consists of a VCS and vapor treatment system. Vapor collected in the LDA shroud contains air, water, VOCs, and particulates. The VCS removes water and particulates from the vapor before being processed by the vapor treatment system. The VCS consists of a knockout tank, chiller, re-heater/heat exchanger, and particulate filter. The vapor from the VCS will then be processed in the vapor treatment system, which will consist of vapor-phase granular activated carbon (GAC) placed in series to remove VOCs. If review of the final RDSI data indicates that greater than anticipated volumes of vapor-phase GAC are required to achieve off-gas treatment, other treatment system components may be incorporated to replace or supplement the GAC units. The liquids from the VCS will be stored in frac tanks and treated on-site via recirculation through the frac tank utilizing liquid-phase GAC and ion exchange resins (Purolite A530E) for removal of VOCs and other contaminants, if present, prior to discharge at a PGDP outfall (e.g., Outfall 008).

Real-time data monitoring is an integral part of the treatment technology because it facilitates real-time decision making to enhance the efficiency of treatment and maximize the results (i.e., additional mixing hot air/steam injection at specific locations and/or discrete depth intervals based upon real-time monitoring results).

### 4.4.1 Equipment Summary

The general process flow diagram for the *in situ* LDA soil mixing with hot air/steam and ZVI injection system for the Oil Landfarm source area is provided in Figure 6. General unit processes shown in Figure 6, including LDA soil mixing; hot air/steam generation and delivery; vapor extraction and conditioning; recovered-liquid storage, treatment, and disposal; ZVI mixing and delivery; and vapor treatment are expected to be part of the final design and are described generally in the following sections.

#### 4.4.1.1 Soil mixing equipment

Major equipment and tools that are to be utilized for soil mixing will include a crane, LDA, kelly bar, and drill platform. The soil mixing rig will be comprised of a crawler-mounted lift crane, with a minimum

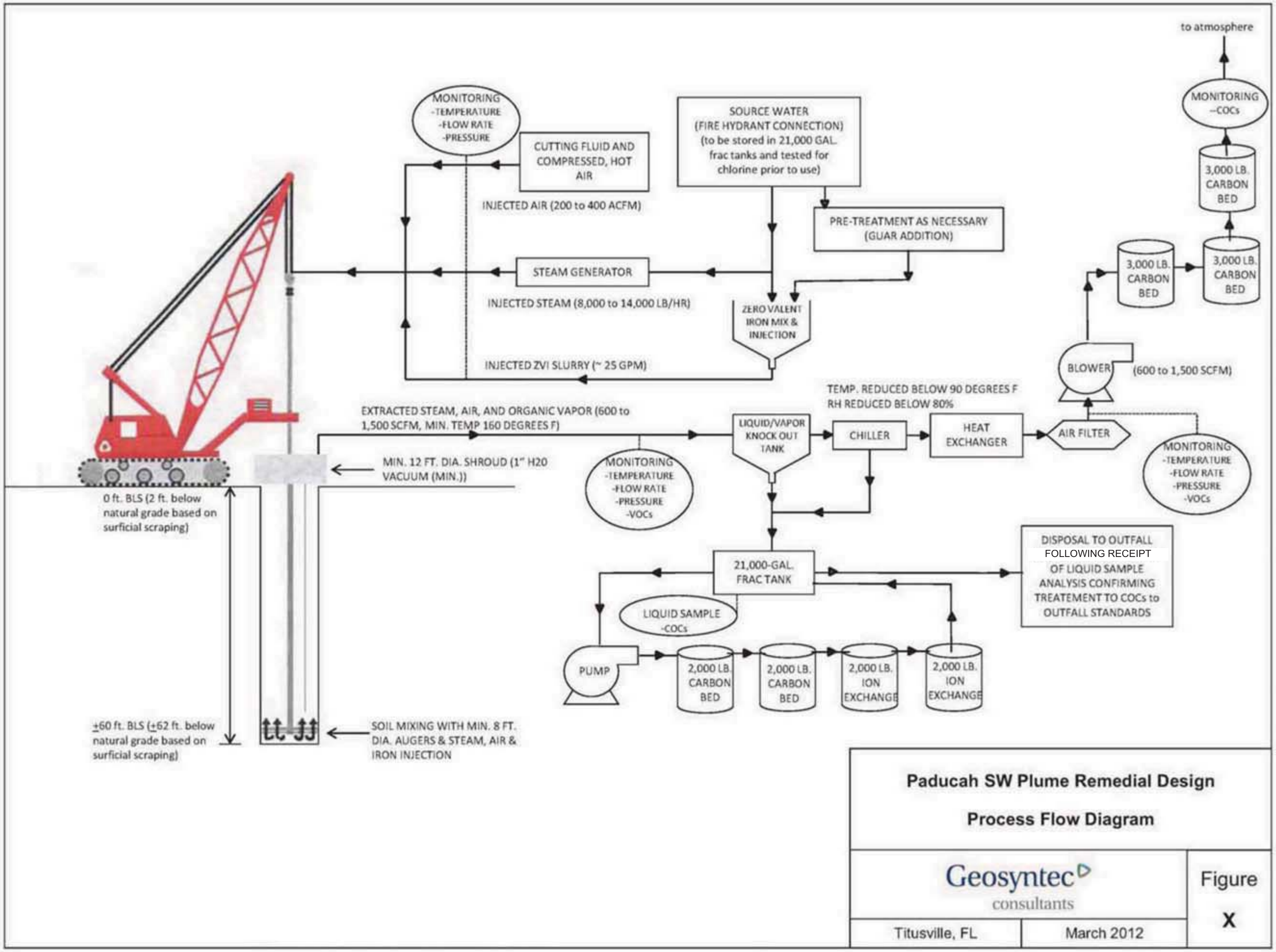


**Figure 6. Process Flow Diagram**

70-ft long hollow drill stem (kelly bar) driven by a high-torque transmission (capable of producing a range of torque of approximately 100,000 to 450,000 ft-lb of torque) and capable of achieving a design soil mix depth of 60 ft bgs (which will be 62 ft below the original land surface elevation based upon the excavation of the upper 2 ft of soil prior to implementation). Alternate heavy equipment (such as excavator-mounted soil mixing equipment) will be considered as an appropriate alternative to a crane if it is capable of meeting the afore-mentioned range of torque and achieving the required target depth. A swivel assembly attached to the end of the crane boom cables serves as the connection point for the kelly bar, allowing the bar to rotate freely while drilling. In addition, the swivel will serve as the injection point of material into the kelly bar from flexible hosing connecting the hot air/steam and ZVI delivery system to the soil mixing equipment. A multi-bladed rotating mixing/injection tool (auger) with a minimum diameter of 8 ft will be located at the base of the kelly bar, which is capable of injecting the hot air, steam, and ZVI slurry into the soil to volatilize and treat VOCs. The mixing tool will include an adequate number of injection ports along the blades to achieve effective distribution of hot air/steam and injected ZVI throughout the mixed soil column. In consideration of the documented soil consistency [hard (greater than 100 blows per ft) at the approximate 20 to 25 ft below grade depth interval], it is anticipated that "rock teeth" will be required on the mixing tool to facilitate penetration. A spare mixing tool of similar diameter also will be maintained on-site. The mixing rig will be capable of reaching outward from the toe of the crawler tracks two rows of overlapped column locations. The mixing rig will operate on mats that will provide stability, maintain vertically plumb mixing, and minimize contamination of drill rig tracks. The soil mixing equipment will be capable of achieving an average LDA ascent/descent rate of 1 to 3 ft per minute and an auger rotational rate of 6 to 10 revolutions per minute within the medium soil consistency range documented in the treatment zone.

#### 4.4.1.2 Hot air/steam generation and delivery system

Hot air will be generated by drawing ambient air though air compressors capable of providing an airflow of 750 actual cubic ft per minute (acfm). A filter bank will be utilized in-line to remove entrained oil from the generated air flow. Injection pressure, temperature, and flow will be monitored and controlled during operations. Hot air will be delivered to the subsurface at flow rates ranging from 200 to 400 actual air compressor capacity (acfm) and minimum temperature of 385ºF at a maximum operating pressure of 150 pounds per square inch gauge (psig), with higher flow rates applied to higher observed VOC concentrations based upon field-based PID/FID VOC measurements after subtracting the methane values.

The steam generating system will be comprised of steam boiler(s) with the capability of producing steam and/or hot air at a minimum temperature of 385°F from a facility-supplied water source that has been staged on-site in a minimum of two 21,000 gal frac tanks to provide time for residual chlorine to dissipate to a concentration of 0.03 mg/L or less (to be evaluated utilizing a Hach field chemistry test or equivalent), prior to utilization as makeup water for steam or ZVI injection. If residual chlorine concentrations remain elevated following a 24-hour stabilization period, an alternative approach to provide removal of residual chlorine may be utilized. At the maximum operating capacity, the boilers are expected to output a minimum of 10 million British thermal units per hour (MBTU/hr). It is anticipated that a minimum of approximately 10,000 gal of water per day will be converted to steam for injection and steam will be injected at flow rates ranging from 8,000 to 14,000 pounds per hour (pph) at a maximum operating pressure of 135 psig, with higher flow rates applied to higher observed VOC concentrations based upon field-based PID/FID VOC measurements. Braided steel and rubber hose will transfer the steam from the boilers to the manifold and rubber hose will be utilized to connect the manifold to the drill stem (kelly bar). Steam injection flow rate, pressure, and temperature will be monitored and controlled during operations.

#### 4.4.1.3 Off-gas extraction and vapor conditioning system

As the mixing blade rotates and hot air and steam are injected in the soils, VOCs will rise to the surface through the annulus created by the soil mixing process and associated pressure gradient. The contaminants will be collected within a minimum 12-ft diameter steel shroud to provide capture of VOCs. The shroud will cover the ground surface around the boring location that is penetrated by the rotating kelly bar providing a minimum 12-ft diameter radius of influence for vapor collection. The shroud provides the ability to capture off-gases beyond the diameter of the 8-ft diameter drilling blades. A blower connected to the shroud will provide a vacuum on the shroud for vapor recovery and transfer to the VCS. The blower connected to the shroud will generate an anticipated air flow rate of 600 to 1,500 standard cubic feet per minute (scfm) at an approximate operating vacuum of 30 inches of water. An applied shroud vacuum of 1 to 5 inches of water will be established prior to soil mixing and maintained throughout soil mixing activities at each boring location. Establishment of the shroud vacuum prior to soil mixing provides a mechanism to confirm that the shroud provides an effective seal around the auger borehole location.

The VCS will consist of a liquid-vapor knock-out (KO)/demister tank, air filter, chiller, and reheater/heat exchanger or equivalent. The vapor entering the shroud from the borehole annulus is expected to be saturated with water; therefore, the vapors initially will flow through a liquid vapor KO tank to remove large dirt particles and moisture. The vapors then will flow from the KO tank into a chiller unit used to cool the gas (typically to a temperature of less than 90°F). Condensate water generated by the KO tank chiller will be transferred and stored in a 21,000-gal frac tank(s) and treated with liquid-phase GAC and ion exchange resins to remove constituents of concern prior to discharge to a PGDP outfall (e.g., Outfall 008), in accordance with ARARs. Additionally, recovered condensate water from each frac tank will be analyzed for VOCs and non-target/non-VOC contaminants, including polycyclic aromatic hydrocarbons (PAHs), PCBs, radionuclides, and heavy metals, consistent with the Memorandum of Agreement for the Southwest Plume FFS (DOE 2010c), to establish whether additional treatment measures will be necessary prior to discharge. Cooled vapor will enter a reheater/heat exchanger to raise the off-gas temperature in order to reduce the off-gas relative humidity to less than 80% (thereby increasing the efficiency of the vapor-phase carbon adsorption system). Vapor then will flow through an air filter to remove fine particulates prior to entering vapor-phase GAC treatment systems. The VCS will be monitored and controlled during operations. Data that will be recorded from monitoring instruments on the VCS include pressure drop over the chiller/heat exchange unit, vapor temperature after chiller, and vapor temperature and relative humidity after the reheater.

#### 4.4.1.4 Liquid treatment system (liquid-phase carbon adsorption and ion exchange)

Condensate water generated by the KO tank chiller will be transferred and stored in a 21,000-gal fractionation tank(s), which will be filled to a capacity not greater than 18,000-gal. It is anticipated that condensate water may contain VOCs and/or some non-target/non-VOC contaminants (such as PAHs, PCBs, radionuclides, and heavy metals), which will require treatment prior to discharge. The collected condensate water will be treated in a closed-loop recirculation treatment system consisting of 2 liquid-phase GAC and 2 ion exchange resin columns connected in series to remove constituents of concern prior to discharge to a PGDP outfall (e.g., Outfall 008) (in accordance with ARARs). The liquid-phase carbon vessels will be utilized primarily for removal of VOCs, PAHs. and PCBs, if present in the condensate water. The ion exchange resin will be utilized for removal/recovery of metals and radionuclides, if present in the condensate water. The GAC vessels will provide a total holding capacity of a maximum of 4,000 lb of virgin, liquid-phase GAC. The ion exchange resin columns will hold a maximum of 4,000 lb of Purolite A530E resin. Each vessel will be capable of treating a flow range of 40 to 60 gpm. Condensate water will be pumped via submersible pump capable of producing a flow rate of 50 gpm placed in the frac tank. Condensate water will be recirculated through the treatment system for a minimum of 24 hours (equal to four treatment volumes of collected condensate water). Following a 24-hour treatment period and prior to discharge, treated condensate water from each frac tank will be analyzed for VOCs and non-target/non-VOC contaminants, including PAHs, PCBs, radionuclides, and heavy metals, by the on-site laboratory facility on a 48-hour turnaround time basis. Laboratory analysis will establish whether additional treatment measures will be necessary or discharge may occur. If the treated condensate water has met the established treatment criteria for a PGDP outfall (e.g., Outfall 008), the treated effluent will be discharged accordingly. While laboratory results are pending, additional condensate water produced by the treatment system will be collected in a separate frac tank. The condensate water treatment system will be utilized for treating condensate water collected within other frac tanks while laboratory results are pending. The effectiveness of the treatment system will be evaluated based on the treatment performance data reported by the laboratory prior to discharge. If necessary, based on the findings of the laboratory data, the treatment system may be amended or modified, and spent media will be changed out to ensure that treatment objectives are being met prior to discharge to a PGDP outfall (e.g., Outfall 008).

#### 4.4.1.5 Vapor treatment system (vapor-phase carbon adsorption)

Conditioned vapors exiting the VCS will be treated on-site utilizing a minimum of three vapor-phase GAC adsorption vessels connected in series. The GAC vessels will provide a total holding capacity of a minimum of 9,000 lb of virgin, vapor-phase GAC and will be capable of treating an airflow range of 600 to 1,500 scfm. To monitor the GAC for breakthrough, the effluent from each GAC vessel will be monitored a minimum of twice daily during active operations using a PID, FID, or Draeger-Tubes®. GAC vessel change out, if required, will occur when GAC breakthrough is documented, as indicated by an increase in initial GAC vessel exhaust concentration to a level that is within 50% of the influent concentration, indicating that breakthrough has occurred in the initial GAC vessel. If an air exhaust measurement of approximately 50% of the influent measurement is detected, planning will begin for carbon replacement.

The results of the EVS-ES modeling using the RDSI soil results revealed the following mass of VOCs within the 13,423 $ft^2$ treatment area: TCE (90 lb), *cis*-1,2-dichloroethene (6 lb), vinyl chloride (0.04 lb), and 1,1-dichloroethene (0.1 lb), or approximately 100 lb of total VOC mass. Based on a conservative range of total VOC contaminant mass in the SWMU 1 area ranging from 100 to up to 1,000 lb, and an assumed carbon adsorptive capacity and usage rate of 20% (20 lb VOCs/100 lb GAC) for an influent GAC relative humidity of 80%, the total mass of vapor-phase carbon to be utilized for off-gas treatment is estimated to be approximately 500 to 5,000 lb (indicating that the 9,000 lb or greater of vapor-phase GAC vessels in series provides adequate capacity).

For design purposes, it is assumed that 100% mass removal will be extracted in the vapor phase. Off-gas from the vapor-phase polishing system will be discharged to the atmosphere through a 20-ft tall by 8-inch diameter stack. Off-gas emissions will be monitored by a photoacoustic analyzer. The analyzer will communicate with a control system to notify operations personnel in the event of an exceedance of discharge criteria. The set point at the stack that will cause the vapor extraction and treatment system to shut down is 20 ppmv of any VOC of concern. This is based on the air dispersion modeling results included in Appendix D. The air dispersion modeling results included in Appendix D indicate that a stack concentration of 20 ppmv results in property boundary concentrations that are significantly lower than the off-site limits; thus, the system will be shut down before emissions reach the quantities that will exceed acceptable risk levels.

#### 4.4.1.6 ZVI mixing and delivery system

A slurry mixture consisting of granular ZVI, water, and guar gum (to facilitate ZVI injection into the soil) will be prepared on-site and delivered on the final pass of the LDA at each boring location. Based upon a review of LDA soil mixing with hot air/steam and ZVI injection applications at Cape Canaveral Air Force Station, Florida, and former Offutt Air Force Base, Nebraska, it is anticipated that granular ZVI particle size will range from approximately 50 micron to 300 micron in diameter. To create this slurry mixture, ZVI will be suspended in the slurry at a rate of approximately 5 to 7 lb of ZVI per gal of water, and guar gum will be mixed at a rate of approximately 60 to 80 lb per 1,000 gal of water. The actual quantity of guar gum and water may be adjusted (within the range provided), during field preparation to create a site-specific mixture, which adequately suspends the ZVI and achieves the optimal pumping viscosity. ZVI preparation and delivery equipment will consist of mixing tanks of a minimum of 500 gal each, a high-shear slurry mixer, a progressive cavity pump and a high viscosity flow meter. It is anticipated that up to approximately 2,000 gal of water per day will be utilized in the preparation of the ZVI/guar slurry.

#### 4.4.1.7 Real-time data collection and monitoring system

The effective application of the *in situ* LDA soil mixing with hot air/steam and ZVI injection system involves real-time data collection and monitoring to allow for field-based decision processes regarding the following:

- Depth penetration rate, auger rotational rate, torque, and down-hole temperature of LDA soil mixing;
- Injection temperature, pressure, and flow rate of hot air and steam;
- Temperature, pressure, flow rate, relative humidity, and VOC concentrations in the vapor extraction and conditioning systems;
- Injection temperature, pressure, and flow rate of the ZVI slurry injection system; and
- VOC concentration of the vapor-phase treatment system effluent.

Operational parameters (frequencies of data collection, monitoring, and associated reporting) of the previously mentioned monitoring protocol are discussed throughout applicable portions of Section 4. Gas samples from the process streams will be collected from the vapor extraction system for analysis by a PID/FID and/or a GC. GCs will be used to detect, speciate, and quantify target analytes from the treatment process off-gas. PIDs/FIDs will be used to continuously monitor the vapors produced by the treatment process. If the PID/FID data monitoring equipment becomes saturated due to the presence of high VOC concentrations and/or DNAPLs present in the subsurface, adjustments will be made in the field to compensate by adjusting the ascent/descent rate of soil mixing, recalibration of the PID/FID equipment to a higher calibration standard to facilitate measurement, and/or introduction of additional bleed air to the system to provide for the adequate real-time monitoring of VOCs. Data from the PIDs/FIDs and GCs will be utilized to evaluate VOC trends in depth, concentration, and location of contamination mass requiring focused treatment (i.e., additional mixing time, higher application of ZVI slurry mixture within a specific interval, etc.).

### 4.4.2 Implementation Sequence

The LDA borings will be established based upon an overlap spacing ranging from 0% to 17.5% (representing complete overlap with no interstitial space) overlap. Figure 5 presents the LDA boring layout. The protocol for establishing overlap spacing is discussed in greater detail in Section 4.2 [generally, reduced overlap spacing will be employed around the periphery of the treatment cell (concurrent with lower VOC concentrations), and increased overlap spacing (concurrent with higher VOC concentrations) will be employed internal to the treatment cell]. The sequencing of soil mixing and treatment locations will be conducted such that the perimeter cells are treated first and subsequent locations will move inward in concentric circles, generally targeting lower concentration areas prior to targeting higher concentration areas and creating a perimeter ZVI slurry enhanced ring, which would provide treatment as a best management practice to potential groundwater displaced outward during implementation.

**4.4.2.1 Description of soil mixing and hot air/steam delivery procedure**

Soil mixing with hot air/steam delivery will be conducted at each cell location in treatment passes (a pass is considered to be one movement of auger through the entire depth of the cell in one direction, up or down). Data collected from off-gas analysis from the PIDs/FIDs and GCs during the first hot air/steam treatment pass will be monitored to aid in the real-time decision making process and to evaluate results against treatment criteria, completion criteria, and iron dosage quantities.

The hot air/steam treatment pass will be initiated when the auger is drilled from the ground surface to the starting thermal treatment depth for the zone of treatment at a typical descent rate of 1 to 3 ft per minute and 6 to 10 revolutions per minute. Additionally, if warranted based on field conditions, a drilling mud may be utilized as a cutting fluid to assist in auger advancement in the formation. The GCs continuously will process samples at a frequency of approximately every 2 to 5 minutes for analysis. The PIDs/FIDs continuously will analyze and process the off-gas total VOC concentration. Once the auger reaches the target starting depth (anticipated to be 5 to 6 ft bgs), the steam valve will be opened, steam will enter the treatment column, and the auger will continue descent to the desired finishing depth, which is anticipated to be 60 ft bgs (62 ft below original land surface because the upper 2 ft will be excavated prior to LDA operations). The protocol for evaluating the number of treatment passes which will be completed at each treatment cell will be based on the peak TCE concentration in UCRS soils and in the upper RGA (HU4) evaluated by the data collection system during the first treatment pass. Once the peak off-gas VOC values are collected from the first treatment pass, the cell treatment protocol will be characterized into one of three categories, which are described as follows.

(1) Low VOC concentration target threshold (less than 100 ppm response)—Requires a minimum of one complete thermal pass; a shroud temperature of 160$^{o}$F maintained throughout the treatment pass; and monitoring of VOC concentrations to ensure that they are below the established low target threshold.

(2) Greater than the low target on the first treatment pass, but less than the low target treatment threshold on second treatment pass—Requires a minimum of two complete thermal passes; a shroud temperature of 160$^{o}$F maintained throughout the complete final pass; and monitoring of VOC concentrations to ensure that they are below the established low target threshold.

(3) Greater than the low target on the first and second treatment passes—Requires a minimum of four complete thermal passes and a shroud temperature of 160$^{o}$F maintained throughout the entire complete final pass. Depth-focused passes could be implemented after the second pass; however, the final pass must have been completed from total treatment depth to top of target treatment interval, and to obtain completion criteria of an FID concentration, after subtracting the methane value, less than 50% of the highest peak FID value obtained during the first pass, or VOC concentrations less than low target threshold, or reach a maximum hot air/steam treatment time of 240 minutes.

If residual VOCs remain following the thermal treatment protocol, they will be addressed further through the introduction of the ZVI slurry mixture, which will be concentration weighted based on PID/FID data, as described in Section 4.4.2.2. The Low VOC concentration target threshold value is based upon the field-screening PID response data from the RDSI boring locations generally corresponding to low VOC concentrations in soil (less than 70 µg/kg TCE).

#### 4.4.2.2 Description of ZVI dosing

A slurry mixture consisting of granular ZVI, water, and guar gum (to facilitate ZVI injection into the soil) will be delivered based upon a percentage mass of ZVI to mass of soil application. Decisions will be based upon monitoring data collected during hot air/steam mixing phase will be used to adjust the ZVI dosing concentration. The amount of ZVI delivered to an LDA boring location will be established based on the observed PID/FID response value of VOCs from the first thermal treatment pass according to the following criteria:

- If a maximum PID/FID reading of 1,000 ppm or less (after subtracting the methane value) is observed on the first thermal treatment pass, an application of 0.5% ZVI will be applied.

- If a PID/FID reading of 1,000 to 5,000 ppm (after subtracting the methane value) is observed on the first thermal treatment pass, an application of 1.0% ZVI will be applied.

- If a PID/FID reading exceeding 5,000 ppm (after subtracting the methane value) is observed on the first thermal treatment pass, an application of 1.5% ZVI will be applied.

- Based upon RSDI soil sampling results, the area within the greater than 10,000 µg/kg TCE isoconcentration contour area will be treated with a default 2% ZVI regardless of PID/FID response.

The ZVI dosing concentration will be measured as a percentage by weight of the column of soil being treated. The ZVI dosing strategy is consistent with the LDA soil mixing projects successfully implemented to treat TCE/DNAPL source areas at Cape Canaveral Air Force Station and former Offutt Air Force Base.

During the LDA ZVI slurry injection pass, the desired quantity of ZVI-guar slurry mixture for each cell will be transferred to the soil mixing auger by a pump. The slurry then will travel down the kelly bar and will be injected into the subsurface at a flow rate of approximately 25 gal per minute (gpm) through the rotating auger to distribute the iron throughout the column. Water will be used to flush the iron-guar slurry from the injection plumbing into the column during the final pass to ensure that the entire quantity of iron required is injected into the column.

# 5. CONSTRUCTION REQUIREMENTS

## 5.1 CONSTRUCTION EQUIPMENT

Construction-type equipment will be required to deliver and stage equipment on-site and to perform *in situ* LDA soil mixing with hot air/steam and ZVI soil mixing and treatment activities. These likely will include, but not be limited to, these items:

- Crawler crane (200-ton crawler crane or equivalent) or heavy equipment capable of delivering required torque and soil mixing requirements to achieve target depth

- Flatbed truck

- Storage units (e.g., Conex boxes/Sealand containers)

- Drill turntable
- Excavator
- Loader
- High reach manlift
- 21,000-gal frac tank(s) for supply water staging and KO vessel water storage
- Telescopic forklift
- Equipment storage trailer

The mixing rig will be mobilized to the site with multiple tractor-trailer components, as necessitated by the vendor-specific equipment. A crane will be required to unload the tractor-trailers and place the component parts of the mixing rig in the site staging area for rig assembly.

## 5.2 *IN SITU* DEEP SOIL MIXING WITH HOT AIR AND STEAM TREATMENT AND ZVI AMENDMENT SYSTEM EQUIPMENT

Following is a list of typical equipment required for the extraction and treatment systems. The equipment required to achieve project objectives shall be based upon vendor-specific components proposed to achieve project objectives. Typical equipment includes the following:

- Mixer
- Liquid mixing tanks
- 400-horsepower (hp), or equivalent boiler generating steam at 385ºF
- Liquid transfer pumps
- Hollow kelly bar (70-ft long) and swivel
- 8 ft auger
- Containment shroud (minimum 12-ft diameter)
- Vapor conditioning system, 70-ton chiller, or equivalent, with blower unit
- Process knockout tank
- Heat exchanger
- SVE Blower capable of 600 to 1,500 scfm at an approximate operating vacuum of 30 inches of water
- Data acquisition system
- Three 3,000-lb or equivalent vapor-phase carbon adsorption vessels
- Power generators

## 5.3 ELECTRICAL REQUIREMENTS

Electrical components needed for the i*n situ* soil mixing and treatment system will require 3-phase power for the operation of air compressor, pumps and blowers, mixing equipment, instrument panels and controls, electronic instruments, and thermocouples, etc. Approximately 750 kilovolt amperes (kVA) will be required to operate the *in situ* LDA soil mixing with hot air/steam and ZVI injection system (this may vary depending on contractor-specific equipment utilized to achieve the site treatment objectives), which will be obtained through an on-site generator to be supplied by the remediation vendor.

### 5.4 WATER REQUIREMENTS

It is anticipated that at least 12,000 gal of water will be utilized by the *in situ* soil mixing and treatment system per day of operation. Water will be utilized for the generation of steam (approximately 10,000 gal per day) and for mixing the ZVI slurry (approximately 2,000 gal per day). Water will be obtained from the fire hydrant located at the southeast intersection of 4$^{th}$ Street and Tennessee St. (see Figure 7) and will be hard piped to the treatment area via culverts that run beneath the streets and railroad tracks. Water will be collected and staged on-site in a minimum of two 21,000-gal frac tanks to provide time for residual chlorine to dissipate to a concentration of 0.03 mg/L or less (to be evaluated utilizing a Hach field chemistry test or equivalent) prior to utilization as makeup water for steam or ZVI injection. If residual chlorine concentrations remain elevated following a 24-hour stabilization period, an alternative approach to provide removal of residual chlorine may be utilized. Additionally, Water entering steam boiler units may require conditioning using water softening ion exchange units to prevent scaling of the units. The need for water softening units will be determined by the LDA soil mixing contractor based upon operations at other sites and experience with the steam boiler units owned and operated by the contractor.

### 5.5 SITE PREPARATION

Site preparation also may include siting of an operations trailer, site surveying, utility locating, clearing and grubbing, grading, and leveling. Additional activities for site preparations will include, but are not limited to, removing the top 2 ft of surface soil to remove potential contaminants that may be present and to facilitate soil mixing to desired depth, stockpiling the excavated soil, and then respreading the excavated soils after mixing is complete. These nonvolatile contaminants will not be treated by the soil mixing technology and will be addressed consistent with the approach discussed previously in Section 1.5, "Sequencing with Other Remedies." Liner material such as polyethylene or Hypalon® will be placed under and over the stockpiled soil until completion of the RA. Figure 7 presents a conceptual LDA equipment layout that includes the stockpiling area.

### 5.6 PERMITTING

Site-specific permits will be required for the implementation of the RA utilizing the selected *in situ* soil mixing and treatment system. Applicable site-specific permits include the following:

- Excavation/penetration permits
- Lockout/tagout permits
- Hot work permits

# 6. SAMPLING AND MONITORING

### 6.1 SAMPLING AND MONITORING DURING SOIL MIXING

During operation, on-site personnel will monitor the soil mixing and treatment system activities to assess the performance and progress of the remedial action. Systems will be designed to accommodate operational sampling and real-time monitoring for parameters, such as the following:

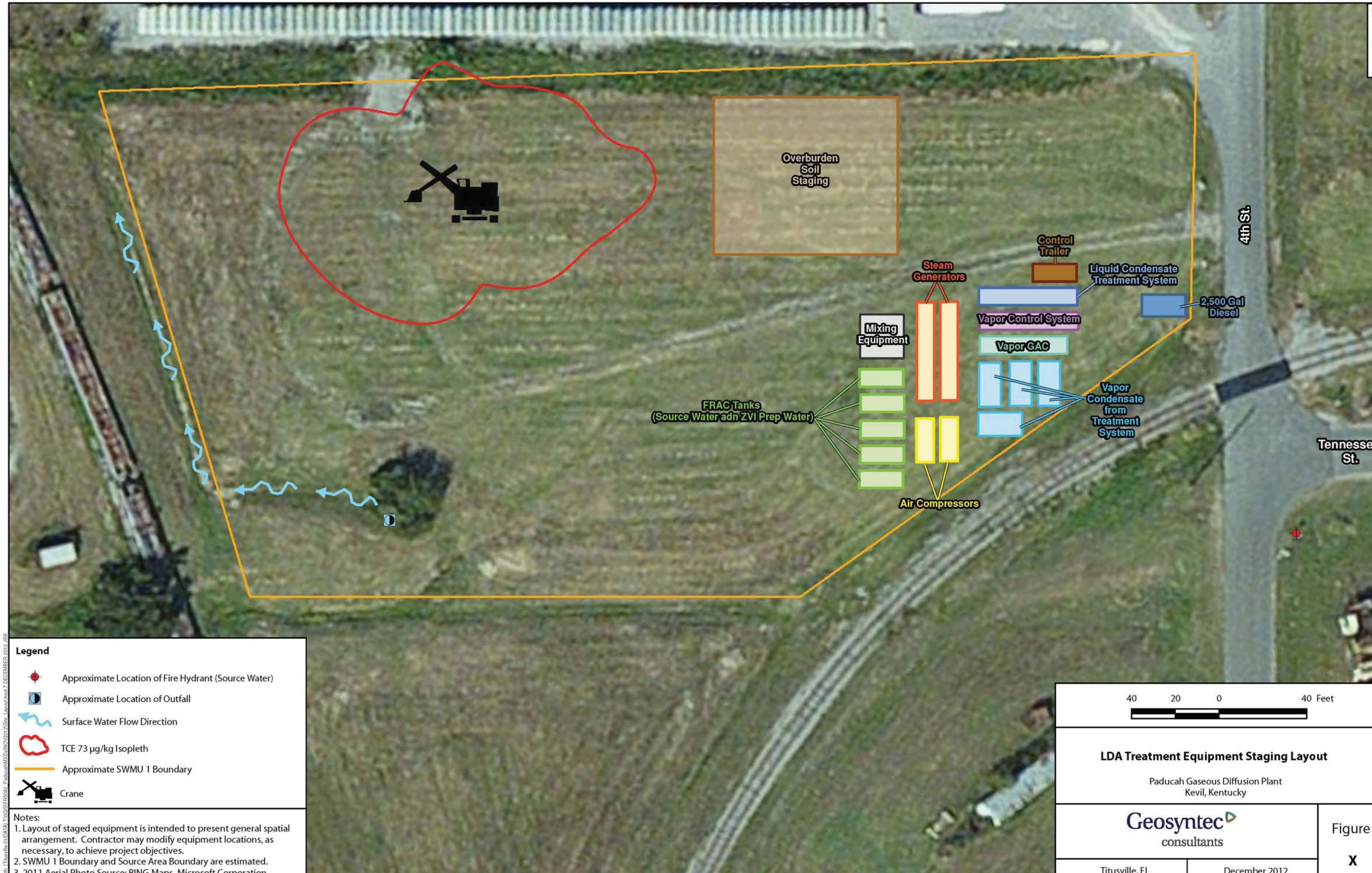


Figure 7. LDA Treatment Equipment Staging Layout

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- **Subsurface Temperatures.** Monitored continuously using a combination of evaluation of vapor shroud off-gas temperature and daily review of auger mixing blade thermocouple data. Subsurface temperatures will be documented for each soil mixing location.

- **VOC Concentrations in Recovered Vapor.** Monitored continuously during soil mixing at each boring location with PID/FID recorded continuously with depth. GCs will continuously process samples at a frequency of approximately every 2 to 5 minutes for analysis during soil mixing activities. Documentation of PID/FID response with depth (per treatment pass) and GC data (every 2 to 5 minutes) will be collected for each soil mixing location.

- **VOC Concentrations in the Worker Breathing Zone.** Due to the concentrations of VOCs present and the potential for release into the breathing zone as a result of the soil mixing activities, real-time air monitoring will be conducted during the course of all intrusive work associated with soil mixing consistent with the requirements of the project-specific Health and Safety Plan for the remedial action.

- **Shroud Extraction Vacuum, Temperature, and Flow Rate.** Continuous monitoring and recording of shroud vacuum at each boring location to document vacuum requirements achieved. Continuous monitoring of shroud temperature and air flow rate and documentation at each boring location that temperatures meet criteria and that flow rate from shroud exceeds air injection rate, as required.

- **Compressed Heated Air/Steam Delivery Pressure, Temperature and Flow Rate.** Continuous monitoring at each auger location to document heated air/steam delivery pressure, temperature and flow rate. Documentation at each boring location to include information on quantities delivered, confirmation of compressed heated air/steam and documentation at each boring location to document vacuum requirements achieved. Continuous monitoring of shroud temperature and air flow rate and documentation at each boring location that temperatures meet criteria and that flow rate from shroud exceeds air injection rate, as required.

- **ZVI Injection Quantity, Temperature, Pressure, and Flow Rate.** Continuous monitoring at each auger location to document ZVI mass applied, temperature, pressure, and flow rate. Documentation at each boring location to include information on quantities delivered, temperature, pressure, and flow rate during delivery.

- **Vapor-Phase Effluent Discharge Flow Rate and VOC Concentration.** Monitoring of vapor phase flowrate and VOC concentration and monitoring of vapor-phase carbon for efficiency and loading.

- **VOC Concentration in Condensed Liquids from the Vapor Stream.** Fluid sampling of condensed liquids.

- **PCB, PAH, Radionuclide, and Heavy Metals.** Concentration in a subset of condensed liquids from the vapor stream and vapor-phase effluent for each frac tank prior to release.

- **Heat Exchanger Air Temperatures and Relative Humidity.** Recorded and documented for each auger boring location.

## 6.2 SAMPLING AND MONITORING POSTREMEDIAL ACTION

Following the cessation of active remedial operations with *in situ* soil mixing with hot air/steam and ZVI injection, postremedial performance monitoring and sampling will be conducted to assess the performance of the remedial action and to support the five-year assessment period to evaluate remedial performance against the established objectives. Given the potential that residual TCE contamination may remain following soil mixing with steam injection, the addition of ZVI is used as polishing measure. The residual contaminant concentrations are expected to persist until such time that movement (based upon flow and/or diffusion) facilitates contact between the contaminant and the ZVI, thereby allowing the contamination to undergo chemical reduction. Field conditions also will have changed as a result of the soil mixing and injections. The field conditions following the treatment are expected to be as follows:

- Soil will be unstable due to mixing operations and destruction of soil structure,

- Increased water content resulting from hot air/steam injection may result in decreased density and soil strength, and

- Soil temperatures will be elevated due to injection of steam/hot air which will increase worker health and safety concerns.

Because of these field conditions and subsurface conditions, the implementation of postremedial sampling and monitoring will be delayed by six months following the completion of soil mixing. The requirements for the post-remedial work will be documented in a Postremedial Sampling and Analysis section of the Remedial Action Work Plan (RAWP) with specifics on boring approach, locations, sampling, contaminant analysis, and the collection of information necessary to complete the required five-year assessments. The areas to be evaluated generally will include the following:

- Postremedial soil sampling for VOCs and levels and distribution profiles in mixed and unmixed areas;

- Installation of postremedial monitoring wells to monitor the progress of contaminant reduction in the RGA groundwater following the mixing process and placement of the ZVI;

- Postremedial soil temperature evaluation; and

- Postremedial evaluation of soil homogeneity and ZVI distribution.

Following completion of the soil mixing process, the previously excavated surface soils will be respread to bring the ground surface back to grade with the surrounding unmixed area. The soils contained in the mixing area will require recharacterization due to being disturbed by the mixing process. DOE intends to recharacterize those soils as part of the Soils OU at the appropriate time in the future.

# 7. DATA MANAGEMENT

A project-specific data management and implementation plan will be included in the RAWP.

# 8. HEALTH AND SAFETY

A general health and safety plan overview will be included in the RAWP and a project-specific health and safety plan will be developed for field implementation.

# 9. WASTE MANAGEMENT

The sitewide Waste Management Plan (PAD-PLA-ENV-001) will be the basis for all waste management activities. Any deviations from this sitewide plan will be documented in the project-specific RAWP.

# 10. REFERENCES

DOE (U.S. Department of Energy) 1999. *Remedial Investigation Report for Waste Area Grouping 27 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-1777&D2, U.S. Department of Energy, Paducah, KY, June.

DOE 2000a. *Remedial Investigation Report for Waste Area Grouping 3 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* DOE/OR/07-1895&D1, U.S. Department of Energy, Paducah, KY, September.

DOE 2000b. *Data Report for the Sitewide Remedial Evaluation for Source Areas Contributing to Off-Site Groundwater Contamination at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-1845/D1 (also known as Data Gaps document), U.S. Department of Energy, January.

DOE 2007. *Site Investigation Report for the Southwest Groundwater Plume at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-2180&D2/R1, U.S. Department of Energy, Paducah, KY, June.

DOE 2010a. *Focused Feasibility Study for the Southwest Groundwater Plume Volatile Organic Compound Sources (C-747-C Oil Landfarm and C-720 Northeast and Southeast Sites) at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* DOE/LX/07/0186&D2/R1, U.S. Department of Energy, Paducah, KY, June.

DOE 2010b. *Remedial Design Support Investigation Characterization Plan for the C-747-C Oil Landfarm and C-720 Northeast and Southeast Sites at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (Draft in Progress), U.S. Department of Energy, Paducah, KY, July.

DOE 2010c. *Memorandum of Agreement for Resolution of Information dispute for the Focused Feasibility Study for the Southwest Plume Volatile Organic Compound Sources Oil Landfarm and C-720 Northeast and Southeast Site at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-0186&D2, signed May 20, 2010, by the Federal Facility Agreement parties.

DOE 2012a. *Record of Decision for Solid Waste Management Units 1, 211-A, 211-B, and Part of 102 Volatile Organic Compound Sources for the Southwest Groundwater Plume at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* DOE/LX/07-0365&D2/R1, U.S. Department of Energy, Paducah, KY, March.

DOE 2012b. *Remedial Design Work Plan for Solid Waste Management Units 1, 211-A, and 211-B Volatile Organic Compound Sources for the Southwest Groundwater Plume at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-1268&D2/R1, U.S. Department of Energy, Paducah, KY, April.

DOE 2012c. *Soils Operable Unit Remedial Investigation Report at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-0258&D2, U.S. Department of Energy, Paducah, KY, September.

USAF 2007. Corrective Measures Implementation Report Security Police Confidence Course (Facility 18003) Solid Waste Management Unit C091, Cape Canaveral Air Force Station, Florida, U.S. Air Force Space Command, Volume 1, May.

USAF 2008. Corrective Measures Implementation Report Ordnance Support Facility (Facility 1381) Solid Waste Management Unit C021, Cape Canaveral Air Force Station, Florida, U.S. Air Force Space Command, Volume 1, May.

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# APPENDIX A

# SWMU 1 SOURCE AREA EXISTING ANALYTICAL DATA

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**Appendix A information included on CD (see back cover).**

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# APPENDIX B

# ENVIRONMENTAL VISUALIZATION SOFTWARE EVALUATION AND VOC MASS ESTIMATE

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| Written by: | Raphael Siebenmann | Date: | 2/18/2013 | Reviewed by: | Jim Langenbach | Date: | 2/18/2013 |
|---|---|---|---|---|---|---|---|
| Client: | Paducah | Project: | SWMU 1 TCE Log-Normal Test | Project/ Proposal No.: | FR5082 | Phase No.: | 01 |

# SWMU 1 TCE Test for Lognormality of Depth-Averaged Remedial Design Support Investigation (RDSI) Dataset

## PURPOSE

Utilizing the results of LATA Kentucky-provided soil sampling data, Geosyntec has developed isoconcentration contours of trichloroethene (TCE) in soils above the Regional Gravel Aquifer (RGA) at Solid Waste Management Unit 1 (SWMU 1), using Golden Software's Surfer (Version 7.04) kriging algorithm. Provided soil sampling data was collected during Remedial Design Support Investigation (RDSI) (2012) sampling of SWMU 1 soils completed within and immediately surrounding the defined SWMU 1 source area to a maximum depth of 64.1 ft below land surface (ft bls). The purpose of this effort is to evaluate the appropriateness of using log-normally transformed data for kriging.

## INPUT DATA

Table 1 in the Draft 90% Remedial Design Report (RDR) provides the raw data and calculated depth-averaged concentrations used in this analysis. The input data used is presented below.

| Location | Draft Final Average concentration TCE (µg/kg) |
|---|---|
| 001-301 | 22 |
| 001-302 | 77 |
| 001-303 | 105 |
| 001-304 | 446 |
| 001-305 | 314 |
| 001-306 | 39 |
| 001-307 | 3 |
| 001-308 | 128 |
| 001-309 | 1,948 |
| 001-310 | 133,034 |
| 001-311 | 2,471 |

| Location | Draft Final Average concentration TCE (µg/kg) |
|---|---|
| 001-312 | 31 |
| 001-313 | 3,731 |
| 001-314 | 291 |
| 001-315 | 2,490 |
| 001-316 | 600 |
| 001-317 | 64 |
| 001-318 | 47 |
| 001-319 | 22 |
| 001-320 | 456 |
| 001-321 | 9 |
| 001-322 | 25 |

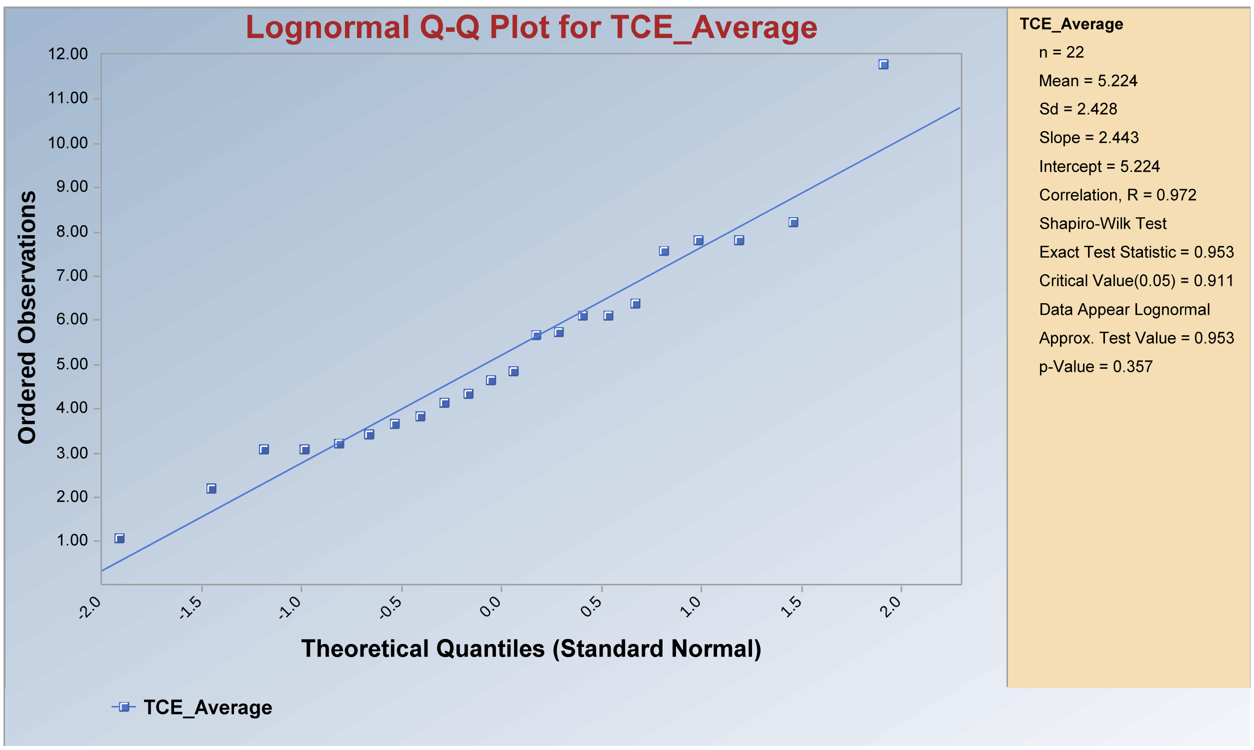
| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Written by: | **Raphael Siebenmann** | Date: | **2/18/2013** | Reviewed by: | **Jim Langenbach** | Date: | **2/18/2013** |
| Client: | **Paducah** | Project: | **SWMU 1 TCE Log-Normal Test** | Project/ Proposal No.: | **FR5082** | Phase No.: | **01** |

## METHODS

The data was evaluated for log-normality by graphing the data using a quantile-quantile (Q-Q) plot and using the Shapiro Wilk Test in the U.S. Environmental Protection Agency's ProUCL statistical software package (Version 4.1.01).

## RESULTS

The Q-Q plot along with the Shapiro Wilk Statistic are presented below.




## CONCLUSIONS

The depth-averaged dataset appears to be lognormally distributed because the test statistic of 0.953 exceeds the Critical value of 0.911 at a confidence level of 95% (i.e. an alpha level of 0.05 or 5%); therefore the use of a log-transformation prior to kriging is a valid technique.

| Written by: | Raphael Siebenmann | Date: | 2/4/2013 | Reviewed by: | Jim Langenbach | Date: | 2/4/2013 |
|---|---|---|---|---|---|---|---|

| Client: | Paducah | Project: | SWMU 1 TCE Mass Estimate | Project/ Proposal No.: | FR5082 | Phase No.: | 01 |
|---|---|---|---|---|---|---|---|

# SWMU 1 TCE Mass Estimate

## PURPOSE

Utilizing the sampling results from the 2012 Remedial Design Support Investigation (RDSI) sampling of Solid Waste Management Unit (SWMU) 1 soils completed within and immediately surrounding the defined SWMU 1 source area to a maximum depth of 64.1 ft below land surface (ft bls), Geosyntec has developed an estimate of the mass of trichloroethene (TCE) in soils above the Regional Gravel Aquifer (RGA) using C Tech's Environmental Visualization Software (EVS).

## METHODS

Sampling results from the 2012 RDSI were interpolated using kriging. Kriging is a stochastic technique similar to inverse distance weighted averaging in that it uses a linear combination of weights at known points to estimate the value at the grid nodes. Kriging is named after D.L. Krige, who used kriging's underlying theory to estimate ore content. Kriging uses a variogram (i.e., semivariogram), which is a representation of the spatial and data differences between some or all possible "pairs" of points in the measured data set. The variogram then describes the weighting factors that will be applied for the interpolation.

## ABOUT EVS

EVS is a software suite for the earth sciences that provides analysis and visualization tools for a wide range of applications. One of the main functions of the software is to interpolate data in both three and four dimensions.

C Tech's software is used by government agencies, universities and companies around the world. Customers include the United Nations, U.S. Environmental Protection Agency (USEPA), Environment Canada, U.S. Geological Survey, British Geological Survey, U.S. Army Corps of Engineers, U.S. Department of Energy (DOE) Laboratories, U.S. Nuclear Regulatory Commission, U.S. Department of Transportation, and the majority of the world's largest engineering and environmental consulting firms (C Tech 2013).

EVS employs an expert system variogram analysis procedure that examines the spatial distribution and number of points in the input data set, and calculates a variogram that is a best fit to the data under the constraints imposed upon it by the user. In all of EVS's variogram algorithms, if a parameter has a default value of 0 and the user does not change it, then no constraints are being placed on the procedure and the algorithm will calculate, use, and return those parameters that provide the best fit of the variogram to the data (C Tech 2013).

EVS is similar to other Environmental Decision Support Software (DSS), such as SitePro and Spatial Analysis and Decision Assistance (SADA), and was evaluated by USEPA and DOE in 1998 alongside five other DSS packages. EVS underwent an environmental technology verification report in March 2000 (USEPA 2000) that concluded that "the main strengths of EVS-PRO are its outstanding 3-D visualization capabilities and its capability to rapidly process, analyze and visualize data" and "the demonstration showed the EVS-PRO software can be used to generate reliable and useful analyses for evaluating environmental contamination problems."

| | | | | | |
|---|---|---|---|---|---|
| Written by: | **Raphael Siebenmann** | Date: **2/4/2013** | Reviewed by: | **Jim Langenbach** | Date: **2/4/2013** |

Client: **Paducah** Project: **SWMU 1 TCE Mass Estimate** Project/ Proposal No.: **FR5082** Phase No.: **01**

## MODEL INPUT PARAMETERS

| Parameter[1] | Default (Yes/No)[2] | Value/Setting | Description/Explanation[3] |
|---|---|---|---|
| **Geology Setup** | | | |
| Search Distance | Yes | 0 | The search distance (reach) field defines the radial distance (in user units-ft in this case) from any given model node that the kriging module will look for data points to be included in the estimation of the model parameter at that node. The default value of reach is 0, which results in the module calculating a reach value that is approximately two-thirds of the longest distance between any two data points in the data set. |
| Points | Yes | 20 | The Points parameter defines the maximum number of data points (within the specified reach) that will be considered for the parameter estimation at a model node. The default value for points is 20, which generally provides reasonably smooth modeled parameter distributions. |
| Quadrant Search | Yes | Disabled | The Quadrant Search toggle changes the method by which data sample points are selected for inclusion in the kriging matrix. If this is on, the "Points" parameter switches to "Max Points in Quadrant." The geology was modeled as one unit, therefore, quadrant search was disabled. |
| X Res/ Y Res | Yes | 81 / 81 (results in approx. 4.2 $ft^2$ grid) | The X Res and Y Res parameters specify the number of grid nodes that will be included within the model domain. |
| Convex Hull Offset | Yes | 10% | The Boundary Offset parameter sets the distance that the convex hull for the kriging domain will be set outside of the actual convex hull of the data. This parameter allows the user to specify the distance outside of the actual data in which the parameter values will be extrapolated. The distance is a percentage of the diagonal extent in the X-Y plane. |
| **Geology Model Semivariogram Output Parameters** | | | |
| Range | Yes | 65 ft | Range—the approximate distance at which spatial autocorrelation between data point pairs ceases or the distance at which the difference between the semivariogram and the sill is negligible. |
| Sill | Yes | 0.05 $ft^2$ | Sill—the semivariance value at which the variogram model levels out (plateau). |

Written by: **Raphael Siebenmann** Date: **2/4/2013** Reviewed by: **Jim Langenbach** Date: **2/4/2013**

Client: **Paducah** Project: **SWMU 1 TCE Mass Estimate** Project/ Proposal No.: **FR5082** Phase No.: **01**

| | | | |
|---|---|---|---|
| Nugget | Yes | 0 ft | Nugget—the intercept of the semivariance model. EVS uses a nugget of zero, which forces the estimated value to be equal to the known value of data points that fall exactly on a grid point in the modeled domain, thus honoring actual data points. |
| **Chemistry Setup** | | | |
| X / Y / Z Resolution | Yes | 70 | The X/Y/Z resolution parameters specify the number of grid nodes that will be included within the model domain. |
| Adaptive Gridding | Yes | Active | Adaptive Gridding refines the grid automatically to place grid nodes at all of the measured data points. The adaptive grid will result in a kriged parameter distribution that honors all of the measured data points exactly. |
| Proportional Gridding | Yes | Active | Proportional gridding results in the number of nodes specified for the Z Resolution will be distributed (proportionately) over the geologic layers in a manner that is approximately proportional to the fractional thickness of each layer relative to the total thickness of the geologic domain. |
| Min Cells Per Layer / Units | Yes | 2 | Min Cells per layer—establishes a minimum number of cells (in the Z direction) per layer. |
| Min Layer Thickness | Yes | 0.00001 | Minimum layer thickness forces layers thinner than the specified value to have a minimum thickness and therefore not pinch out completely. |
| Krig 3D Chemistry Input | | TCE | TCE concentrations in soil were kriged in the model domain. 1/2 the detection limit was used for non-detect results. |
| Statistical Method | Yes | Ordinary Kriging | |
| Octant Search | No | Enable | An Octant is any of the eight parts into which three mutually perpendicular planes divide space. Octant search—a maximum of N points (defined by user) in each of the eight octants surrounding the interpolation point are used in the calculations. This method results in better performance with clustered data. The Octant Search toggle changes the method by which data sample points are selected for inclusion in the kriging matrix. If this is on, the "Points" parameter switches to "Max Points in Octant." Searching is performed for each of the eight Octants surrounding the point to be kriged. Within each octant, a maximum number of points (up to one-fourth of the total points) are selected. Then, points are taken sequentially from each octant up to the maximum number of total points or until all octant's points have been used. |

Written by: **Raphael Siebenmann** Date: **2/4/2013** Reviewed by: **Jim Langenbach** Date: **2/4/2013**

Client: **Paducah** Project: **SWMU 1 TCE Mass Estimate** Project/ Proposal No.: **FR5082** Phase No.: **01**

| | | | |
|---|---|---|---|
| Anisotropy | No[4] | 1 | The Horiz./Vert. Anisotropy Ratio parameter allows the model to consider the effects of anisotropy in the conductivity of soil matrices to fluid flow. In most cases, geologic materials are deposited with platy clay minerals oriented horizontally, and thus flow of water in both the saturated and unsaturated zone can be slower in the vertical direction than in the horizontal direction. Also, ore deposition can occur along horizontal or vertical fault or fracture systems. Chemical constituents being transported with flowing fluids may therefore show a larger degree of spreading in one or the other direction. The Horiz./Vert. Anisotropy Ratio allows the kriging algorithm to specify a multiplication factor to be used to apply biased weighting on data points in horizontal and vertical directions away from a given model node. The default value for fluid flow is 10, which allows data points in a horizontal direction away from a model node to influence the kriged value at that node 10 times more than data points an equal distance away in a vertical direction. When the property being modeled is not related to fluid flow or other processes that might be affected by matrix anisotropy, then the recommended value is 1, (i.e., isotropic). |
| **Chemistry Model Semivariogram Output Parameters** | | | |
| Range | Yes | 106 ft | Range—the approximate distance at which spatial autocorrelation between data point pairs ceases or the distance at which the difference between the semivariogram and the sill is negligible. |
| Sill | Yes | 3 ft2 | Sill—the semivariance value at which the variogram model levels out (plateau). |
| Nugget | Yes | 0 ft | Nugget — the intercept of the semivariance model. EVS uses a nugget of zero, which forces the estimated value to be equal to the known value of data points that fall exactly on a grid point in the modeled domain, thus honoring actual data points. |
| **Volumetric Parameters** | | | |
| Soil Density | Yes | 1.85 g/cc | Soil density of the soil matrix in which the chemicals resides. |

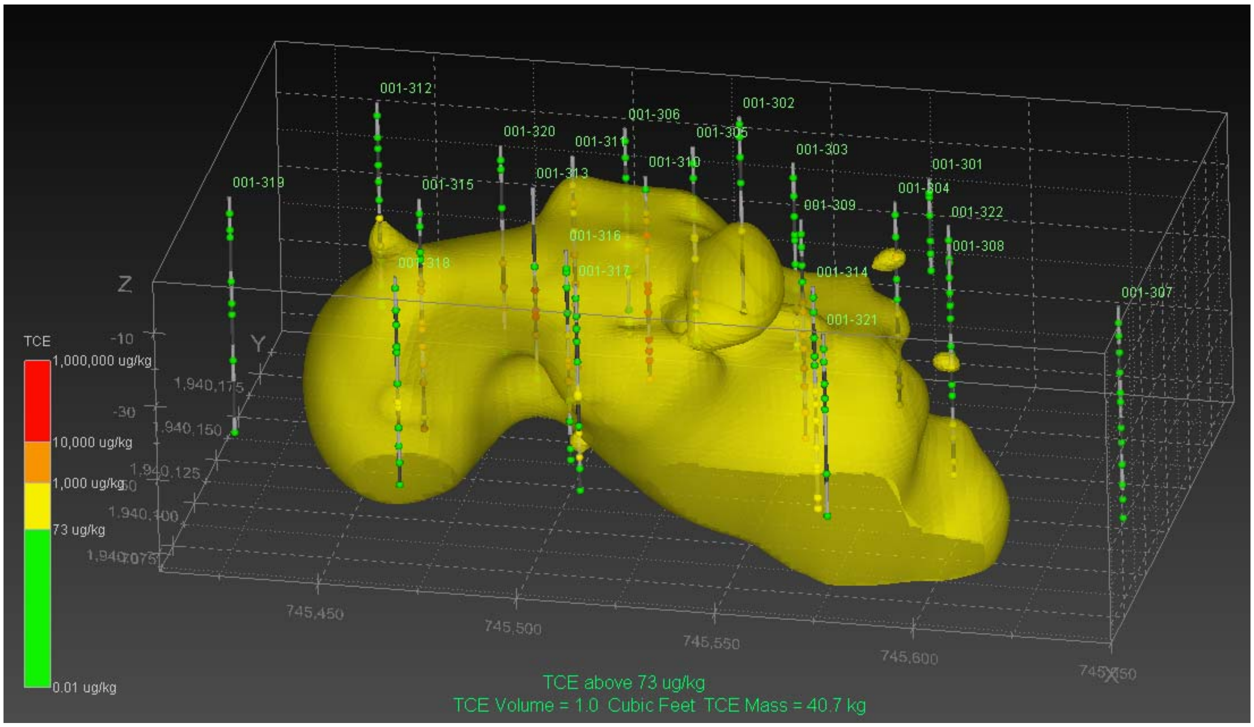
**Notes:**

1. Input parameters for kriging software (Environmental Visualization System - Premier 9.82, C-Tech Corporation).
2. Indicates whether value used is the software default.
3. Parameter descriptions adapted from "C Tech Help System for EVS & MVS 9.8," by C Tech Development Corp.
4. Software default assumes fluid flow. 1 is the software's suggested value for vadose zone modeling.

| Written by: | Raphael Siebenmann | Date: | 2/4/2013 | Reviewed by: | Jim Langenbach | Date: | 2/4/2013 |
|---|---|---|---|---|---|---|---|
| Client: | Paducah | Project: | SWMU 1 TCE Mass Estimate | Project/ Proposal No.: | FR5082 | Phase No.: | 01 |

## RESULTS

As shown below, the interpolation of the 2012 RDSI investigation estimates that 40.7 kg of TCE is present is SWMU 1 soils.




## REFERENCES

C Tech Development Corporation. Web. February 4 ,2013. http://www.ctech.com

USEPA 2000. "Environmental Technology Verification Report." Environmental Decision Support Software. C Tech Development Corporation, Environmental Visualization System Pro (EVS-PRO), EPA/600/R-00/047, March.

**Appendix B information included on CD (see back cover).**

# APPENDIX C

# STANDARD PENETRATION TEST RESULTS SUMMARY AND GEOTECHNICAL DATA

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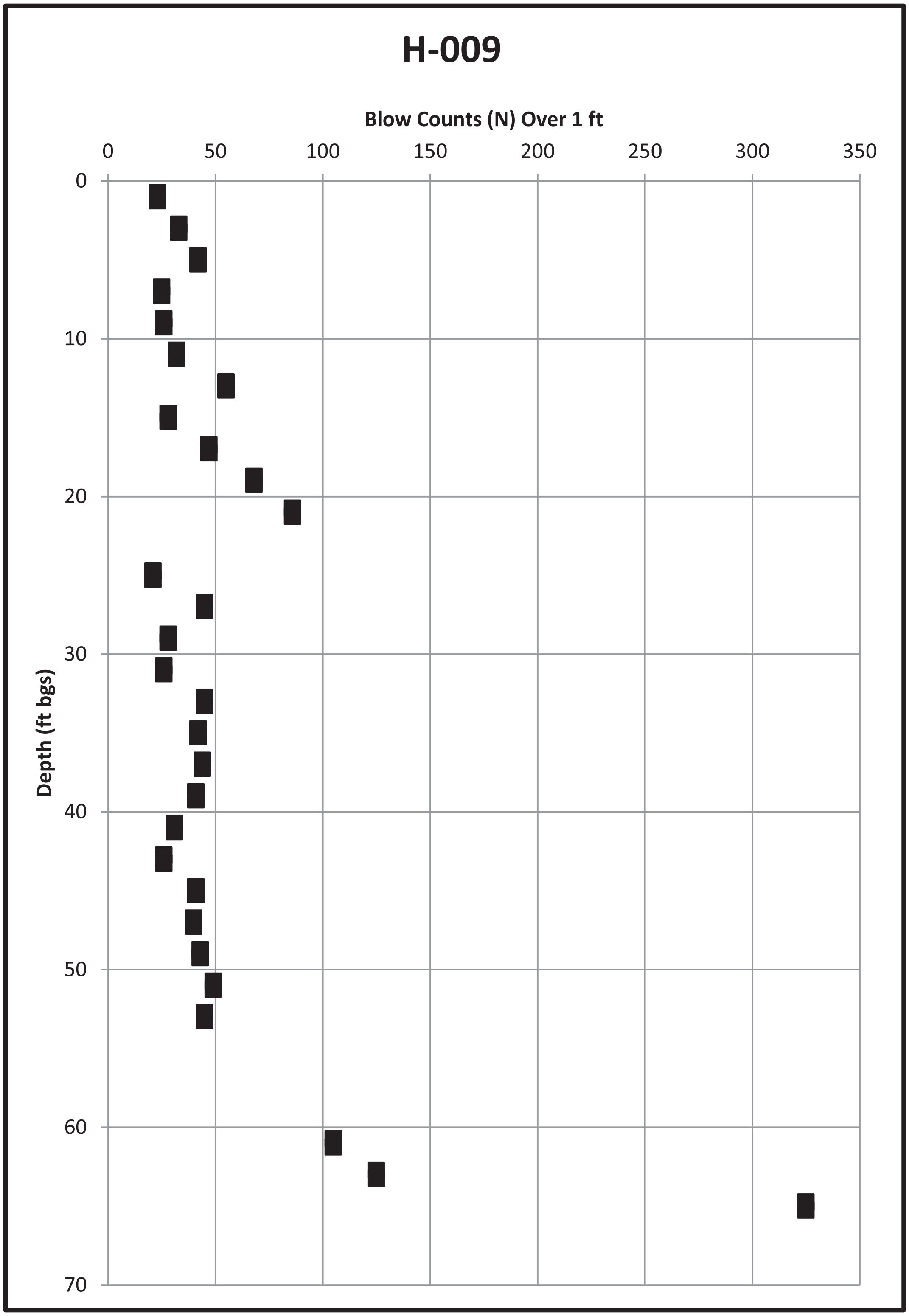
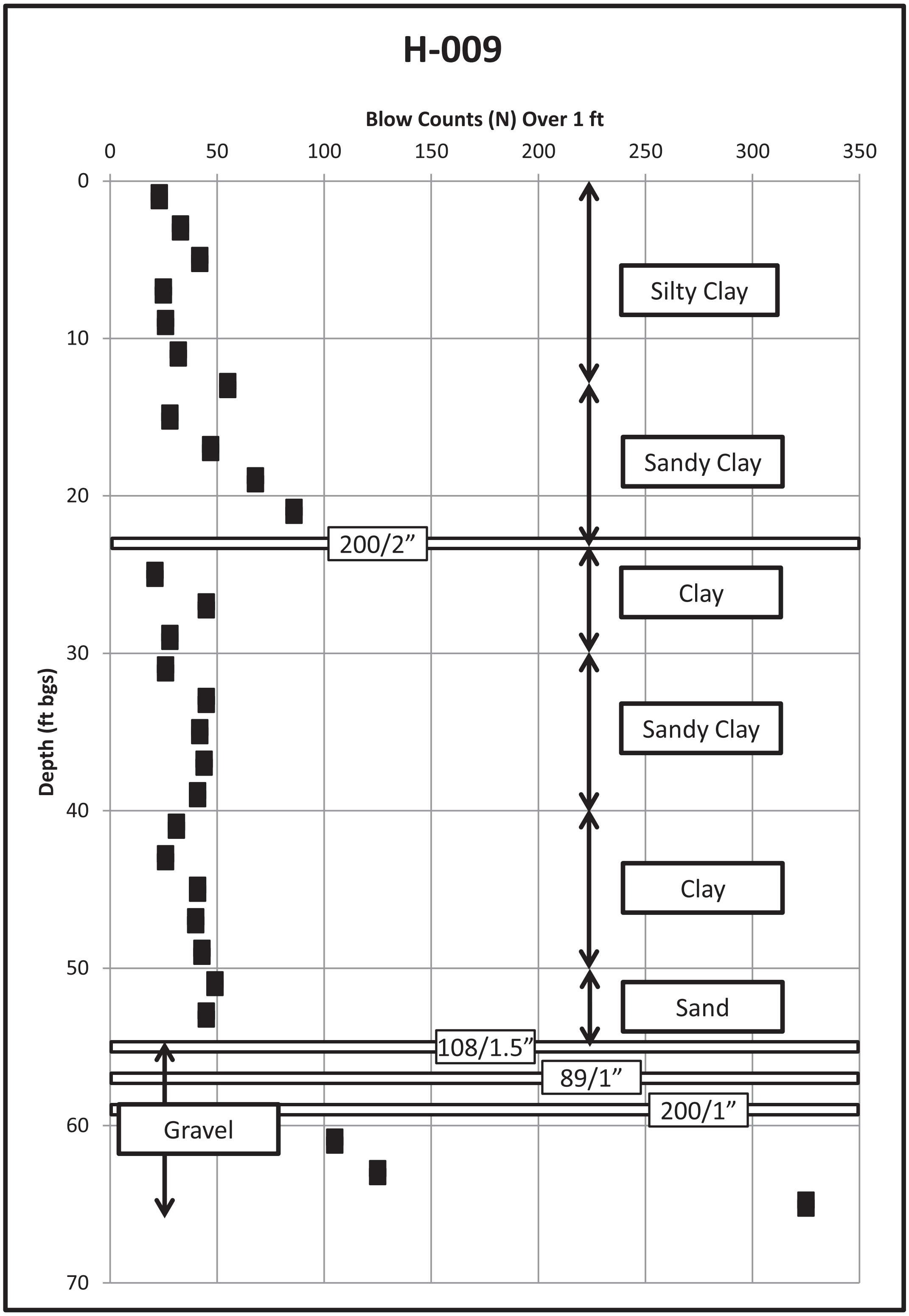

H-009
Blow Counts (N) Over 1 ft
0
50
100
150
200
250
300
350
Depth (ft bgs)
0
10
20
30
40
50
60
70


H-009
Blow Counts (N) Over 1 ft
0
50
100
150
200
250
300
350
0
10
20
30
40
50
60
70
Depth (ft bgs)
Silty Clay
Sandy Clay
200/2”
Clay
Sandy Clay
Clay
Sand
108/1.5”
89/1”
200/1”
Gravel

Location Inside PGDP, (W6875 - S1766)

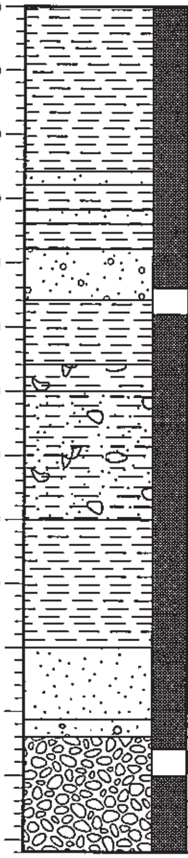
# H-009

TD 66'

GL 372.5'

| ELEV (FT) | DEPTH (FT) |
|---|---|
| | 0.0 |
| 370.0 | |
| | -5.0 |
| 365.0 | |
| | -10.0 |
| 360.0 | |
| | -15.0 |
| 355.0 | |
| | -20.0 |
| 350.0 | |
| | -25.0 |
| 345.0 | |
| | -30.0 |
| 340.0 | |
| | -35.0 |
| 335.0 | |
| | -40.0 |
| 330.0 | |
| | -45.0 |
| 325.0 | |
| | -50.0 |
| 320.0 | |
| | -55.0 |
| 315.0 | |
| | -60.0 |
| 310.0 | |
| | -65.0 |

LITHOLOGY / Sample REC.



LITHOLOGIC DESCRIPTION / COMMENTS

**Silty Clay** stiff, with some sand and organic matter, lt. gray and red-brown with black staining

**Silty Clay** as above, moderate yellow-brown

**Silty Clay** stiff, lt. gray

**Clay** stiff, lt. gray

**Sand** dense, f-m, with some silt and clay, yellow-brown, dry

**Sandy Clay** stiff, lt. gray, moist

**Sand** dense, f-m, with clay, yellow-brown, dry

**Sandy Clay** hard, lt. gray and yellow-brown, damp

**Gravelly Sand** dense with some clay, clay decreases downward, lt. brown-gray, moist

**Clay** plastic, dk. yellow-orange to red-brown, some quartz grains, moist to wet

**Clay** stiff, with some gravel, lt. gray and red-brown, moist

**Sandy Clay** stiff, with gravel and sand, lt. gray and red-brown, moist

**Sandy Clay** stiff, with gravel and interbeds of sand, m, dk. yellow-orange and red-brown, moist

**Clay** lean, hard, with 10% sand, pale yellow-brown, dk. yellow-brown with orange mottling, damp

**Clay** as above with tr. gravel

**Clay** as above with no gravel and lt. red streaks, damp to moist

**Sand** well sorted, m-c, pale yellow-brown, orange-pink, and dk. yellow-orange, moist

**Gravelly Sand** c, with 45% gravel, gray-orange and pale yellow-brown, moist

**Gravel** dense, 80% chert gravel, 1/4 to 11/4 in, with 20% sand, pale yellow-brown, wet

**Gravel** dense, as above, grades to dk. yellow-orange, wet

**Gravel** dense, with 15% sand, c, pale yellow-brown, wet

# H-009

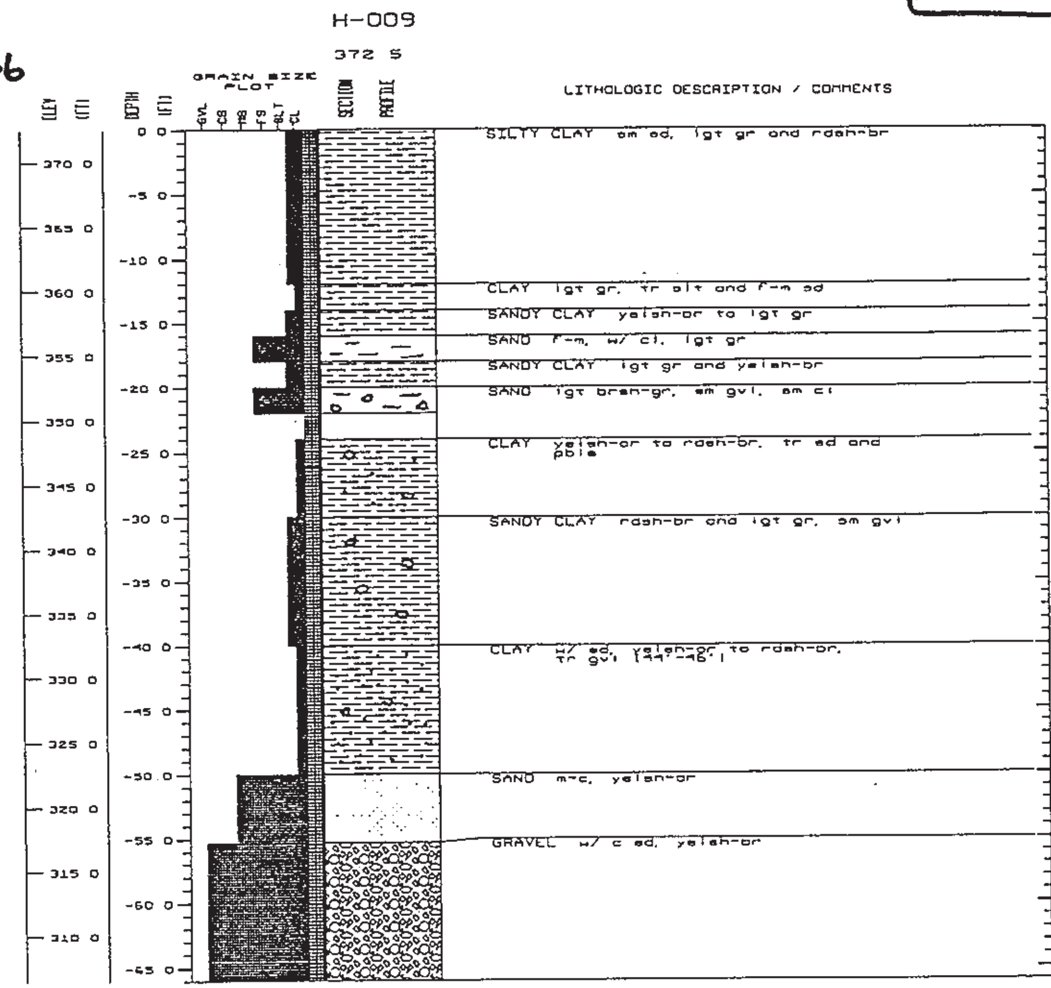
W 6875 - S1766

See location Map H-050

loc. Inside P6DP, SW1/4, C-745 cluster

near MW 161 ( H-208

TD 66




# MAP D

Detailed Loc. Map CH2M Hill Phase II, Vol. 2, Fig 4-2

| PROJECT NUMBER | BORING NUMBER |
|---|---|
| SED28178.FS | H-009 SHEET 1 OF 3 |

# SOIL BORING LOG

PROJECT PGDP Phase I Site Investigation LOCATION WMU 1, Oil Landfarm
ELEVATION ___ DRILLING CONTRACTOR Geotek Engineering
DRILLING METHOD AND EQUIPMENT Mobile B-53, Hollow Stem Auger
WATER LEVEL AND DATE ___ START 1/6/90 FINISH 1/10/90 LOGGER Bill Cocke

| DEPTH BELOW SURFACE (FT) | SAMPLE INTERVAL | SAMPLE TYPE AND NUMBER | SAMPLE RECOVERY (FT) | STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N) | SOIL DESCRIPTION (SOIL NAME, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL) | COMMENTS (DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION) |
|---|---|---|---|---|---|---|
| 0 | 0-2 | | 0.75' | 9-11-12-12 (23) | SILTY CLAY WITH SAND, VERY LIGHT GRAY (N8) WITH IRON STAINING, MODERATE REDDISH BROWN (10 YR 4/6) AND BLACK ORGANIC STAINING, DAMP, LOW PLASTICITY, VERY STIFF, SOME VEGETABLE MATTER, (CL) | BACKGROUND RAD-40-45 CPM<br>HNU-0 PPM<br>SAMPLE<br>HNU-0 PPM<br>RAD-160 CPM |
| 2 | 2-4 | 4213 | | 14-14-19-30 (33) | SAME AS ABOVE, BUT WITHOUT VEGETABLE MATTER, HARD, (CL) | HNU-0.8 PPM<br>RAD-40-45 CPM |
| 4 | 4-6 | | 1.0' | 30-24-18-30 (42) | SAME AS ABOVE, COLOR CHANGING TO MODERATE YELLOWISH BROWN (10 YR 5/4), HARD, (CL) | HNU-20 PPM (IN SPOON)<br>RAD-40 CPM<br>COMPOSITED SAMPLE 4213 AT 1500 |
| 6 | 6-8 | | 1.25' | 13-12-13-14 (25) | SAME AS ABOVE, COLOR CHANGING BACK TO GRAY (N8), VERY STIFF, (CL) | HNU-18 PPM (IN SPOON)<br>RAD-40 CPM |
| 8 | 8-10 | 4214 | 1.5' | 11-12-14-18 (26) | SAME AS ABOVE, COLOR GRAY (N8) AND YELLOWISH BROWN (10 YR 5/4), VERY STIFF, (CL) | HNU-30 PPM (IN SPOON)<br>RAD-40 CPM |
| 10 | 10-12 | | 2.0' | 13-13-19-19 (32) | SAME AS ABOVE, VERY LIGHT GRAY (N8), HARD, (CL) | HNU-30 PPM (IN SPOON)<br>RAD-45 CPM<br>COMPOSITED SAMPLE 4214 AT 1520 |
| 12 | 12-14 | | 2.0' | 13-19-36-48 (55) | CLAY (CH), VERY LIGHT GRAY (N8), MOIST, HARD, PLASTIC, CHANGING TO WELL-GRADED SAND, WITH SOME SILT AND CLAY, MODERATE YELLOWISH BROWN (10 YR 5/4), DRY, VERY DENSE, FINE-MEDIUM, (SW-SC) | HNU-31 PPM<br>RAD-45 CPM |
| 14 | 14-16 | 4215 | 2.0' | 6-14-14-15 (28) | SANDY CLAY, VERY LIGHT GRAY AND MODERATE YELLOWISH BROWN (N8 AND 10 YR 5/4), MOIST, VERY STIFF, (CL) | HNU-0.2 PPM<br>RAD-45 CPM |
| 16 | 16-18 | | 1.5' | 19-20-27-30 (47) | WELL GRADED SAND, WITH CLAY, LIGHT GRAY (N7), MOIST, DENSE, FINE-MEDIUM, (SW), CHANGING TO SANDY CLAY, LIGHT GRAY (N7), AND YELLOWISH BROWN (10 YR 5/4), DAMP, HARD, (CL) | HNU-85 PPM<br>RAD-40 CPM<br>COMPOSITED 4215 AT 1600 |
| 18 | 18-20 | | | 26-32-36-48 (68) | SANDY CLAY SAME AS ABOVE, (CL), CHANGING TO WELL-GRADED SAND, LIGHT BROWNISH GRAY (5 YR 6/1), VERY DENSE, DAMP-MOIST, COARSE PEBBLES AND SOME CLAY, (SW) | HNU-16 PPM<br>RAD-0 CPM |
| 20 | 20-22 | | | 26-40-46-50 (86) | WELL GRADED SAND AS ABOVE, MOIST, VERY DENSE, VERY LITTLE CLAY WITH LENSES OF GRAVEL (SW) | HNU- 14.5 PPM<br>RAD- |
| 22 | 22-24 | 4216 | | 200/2" | NO SAMPLE | |
| 24 | 24-26 | | 2.0' | 7-7-14-19 (21) | CLAY, DARK YELLOWISH ORANGE (10 YR 6/6), MOIST, VERY STIFF, PLASTIC, (CH) | HNU-20 PPM<br>RAD-35-40 CPM<br>COMPOSITED SAMPLE 4216 AT 0825 |
| 26 | 26-28 | | 1.8' | 14-18-27-30 (45) | CLAY SAME AS ABOVE, COLOR CHANGING TO MODERATE REDDISH BROWN (10 R 4/6), MOIST-WET, HARD, SOME COARSE SAND GRAINS, (CH) | HNU-31 PPM<br>RAD-40 CPM |
| 28 | 28-30 | 4218 | 2.0' | 15-15-13-14 (28) | CLAY SAME AS ABOVE, MODERATE REDDISH BROWN AND LIGHT GRAY (10 R 4/6 AND N7), MOIST, VERY STIFF, LOW PLASTICITY, SOME LARGE PEBBLES, (CL) | HNU-25 PPM<br>RAD-40-45 CPM<br>AUGER TO 30', STOP TO SET CASING |
| 30 | | | | | | |

| PROJECT NUMBER | BORING NUMBER |
|---|---|
| SED28178.FS | H-009 SHEET 2 OF 3 |

# SOIL BORING LOG

PROJECT PGDP Phase I Site Investigation LOCATION WMU 1, Oil Landfarm
ELEVATION ______ DRILLING CONTRACTOR Geotek Engineering
DRILLING METHOD AND EQUIPMENT Mobile B-53, Hollow Stem Auger
WATER LEVEL AND DATE ______ START 1/6/90 FINISH 1/10/90 LOGGER Bill Cocke

| DEPTH BELOW SURFACE (FT) | SAMPLE | | | STANDARD PENETRATION TEST RESULTS | SOIL DESCRIPTION | COMMENTS |
|---|---|---|---|---|---|---|
| | INTERVAL | TYPE AND NUMBER | RECOVERY (FT) | 6"-6"-6" (N) | SOIL NAME, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL | DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION |
| 30 | 30-32 | 4218 | 2.0' | 6-9-17-29 (26) | SANDY CLAY, MODERATE REDDISH BROWN AND LIGHT GRAY (10 R 4/6 AND N7), MOIST, VERY STIFF, LOW PLASTICITY, WITH GRAVEL SOME LARGE PEBBLES, (CL) | HNU=0.2 PPM RAD=40-45 CPM RESUMED SAMPLING 1/9/90, COMPOSITED SAMPLE 4218 AT 1345 |
| 32 | 32-34 | | 2.0' | 17-19-26-21 (45) | SANDY CLAY, SAME AS ABOVE , MODERATE REDDISH BROWN AND DARK YELLOWISH ORANGE (10 YR 6/6), HARD, WITH GRAVEL, (CL) | HNU=0 PPM RAD=40-45 CPM |
| 34 | 34-36 | 4219 | 2.0' | 17-17-25-29 (42) | SANDY CLAY, SAME AS ABOVE, MODERATE REDDISH BROWN, HARD, WITH GRAVEL AND LAYERS OF MEDIUM SAND, (CL) | HNU=0.2 PPM RAD=40 CPM |
| 36 | 36-38 | | 2.0' | 18-18-26-27 (44) | SANDY CLAY SAME AS ABOVE | HNU=3.0 PPM RAD=40 CPM COMPOSITED SAMPLE 4219 AT 1420 |
| 38 | 38-40 | | 2.0' | 16-17-24-26 (41) | CLAY SAME AS ABOVE | HNU=0 PPM RAD=40 CPM |
| 40 | 40-42 | 4220 | 2.0' | 13-13-18-21 (31) | LEAN CLAY WITH SAND, PALE YELLOWISH BROWN (10 YR 6/2) WITH DARK YELLOWISH ORANGE (10 YR 6/6) STREAKING, SOME MOTTLING WITH ORANGE, DARK DISCOLORATION, DAMP, HARD, <10% FINE SAND, (CL) | RESUMED SAMPLING 1/10/90 AT 1000 HNU=0 PPM RAD=40 CPM |
| 42 | 42-44 | | 2.0' | 13-13-13-14 (26) | LEAN CLAY WITH SAND SAME AS ABOVE, VERY STIFF, =15% SAND IN LOWER =0.3' OF SPOON, (CL) | HNU=0 PPM RAD=45 CPM |
| 44 | 44-46 | | 2.0' | 18-17-24-26 (41) | LEAN CLAY WITH SAND SAME AS ABOVE, HARD, MODERATE RED STREAKS (5 R 5/4), 2 SMALL (=<1" DIAMETER) PIECES OF GRAVEL, (CL) | HNU=0.2 PPM RAD=45 CPM |
| 46 | 46-48 | 4221 | 2.0' | 18-18-22-25 (40) | LEAN CLAY WITH SAND SAME AS ABOVE, HARD, NO GRAVEL, (CL) | HNU=0.2 PPM RAD=45 CPM |
| 48 | 48-50 | | 2.0' | 18-18-25-26 (43) | LEAN CLAY WITH SAND, PALE YELLOWISH BROWN (10 YR 6/2) WITH DARK YELLOWISH ORANGE (10 YR 6/6) AND LIGHT RED (5 R 6/6) STREAKS, DAMP-MOIST, HARD, 1 PEBBLE, COAL LENSES, (CL) | HNU=0.2 PPM RAD=45 CPM COMPOSITED SAMPLE 4221 AT 0900 |
| 50 | 50-52 | | 1.75' | 18-23-26-27 (49) | POORLY GRADED SAND, PALE YELLOWISH BROWN (10 YR 6/2), SLIGHT MODERATE ORANGE PINK (10 R 7/4) AND DARK YELLOWISH ORANGE (10 YR 6/6) STREAKS, MOIST, DENSE, MEDIUM GRAINED, NO GRAVEL, (SP) | HNU=0.2 PPM RAD=45CPM |
| 52 | 52-54 | 4223 | 2.0' | 25-18-27-28 (45) | SAND SAME AS ABOVE, (SP) | HNU=0.8 PPM RAD=52-54 CPM |
| 54 | 54-56 | | 1.7' | 108/1.5" | POORLY GRADED SAND, PALE YELLOWISH BROWN (10 YR 6/2), SOME MODERATE ORANGE PINK (10 R 7/4) AND DARK YELLOWISH ORANGE (10 YR 6/6) STREAKS, MOIST, VERY DENSE, MEDIUM-COARSE GRAINED, GRAVEL IN LOWER =0.4', (SP) | HNU=0.8 PPM RAD=45 CPM COMPOSITED SAMPLE 4223 AT 0930 |
| 56 | 56-57 | | 0.8' | 89/1" | WELL-GRADED SAND, COARSE SAND WITH '45% GRAVEL, QUARTZ CRYSTALS, PALE YELLOWISH BROWN (10 YR 6/2) WITH GRAYISH ORANGE (10 R 7/4) STREAKS, WET, VERY DENSE. | HNU=0 PPM RAD=40 CPM |
| | 57-58 | | 1.2' | 200/1" | GRAVEL, (GW) | |
| 58 | 58-60 | 4224 | NO SAMPLE TAKEN | | | |
| 60 | | | | | | |

| PROJECT NUMBER | BORING NUMBER |
|---|---|
| SED28178.FS | H-009 SHEET 3 OF 3 |

# SOIL BORING LOG

PROJECT PGDP Phase I Site Investigation LOCATION WMU 1, Oil Landfarm

ELEVATION ______ DRILLING CONTRACTOR Geotek Engineering

DRILLING METHOD AND EQUIPMENT Mobile B-53, Hollow Stem Auger

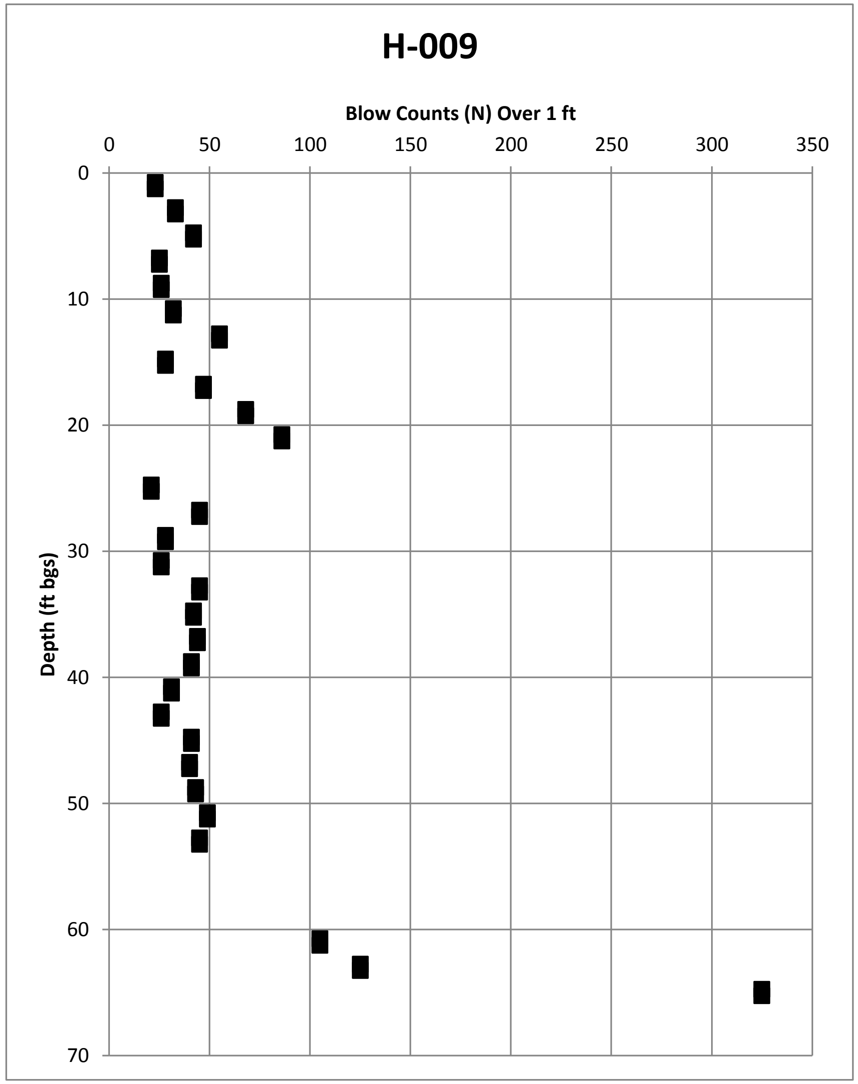
WATER LEVEL AND DATE ______ START 1/6/90 FINISH 1/10/90 LOGGER Bill Cocke

| DEPTH BELOW SURFACE (FT) | SAMPLE | | | STANDARD PENETRATION TEST RESULTS | SOIL DESCRIPTION | COMMENTS |
|---|---|---|---|---|---|---|
| | INTERVAL | TYPE AND NUMBER | RECOVERY (FT) | 6"-6"-6" (N) | SOIL NAME, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL | DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION |
| 60 | 60-62 | 4224 | 0.5' | 60-40-65-100 (105) | WELL GRADED GRAVEL WITH SAND, PALE YELLOWISH BROWN (10 YR 6/2), SAND ≈20%, WET, VERY DENSE, SAND ≈20%, GRAVELS ≈1/4" TO 1-1/4" DIAMETER, QUARTZ, CHERT, (GW) | HNU=0 PPM<br>RAD=40 CPM |
| 62 | 62-64 | | 1.5' | 60-65-60-74 (125) | WELL GRADED GRAVEL WITH SAND, PALE YELLOWISH BROWN (10 YR 6/2), GRADES INTO DARK YELLOWISH ORANGE (10 YR 6/6), WET, VERY DENSE, GRAVELS ≈1/4">1/2" DIAMETER, QUARTZ, CHERT, (GW) | HNU=0 PPM<br>RAD=40 CPM<br>COMPOSITED SAMPLE 4224 AT 1215, (56-58' AND 60-64' NO SAMPLE AT 58-60') |
| 64 | 64-66 | 4225 | 1.7' | 135-160-165-175 (325) | WELL GRADED GRAVEL, WET, VERY DENSE, GRAVEL ≈1/4-2" DIAMETER, MOSTLY CHERT, SOME SAND ≈15%, COARSE GRAINED, PALE YELLOWISH BROWN (10 YR 6/2), (GW) | HNU=0 PPM<br>RAD=30-40 CPM<br>COMPLETED SAMPLE 4225 AT 1606 (64-66')<br>TD OF BORING, 66.0' |
| 66 | | | | | | |
| 68 | | | | | | |
| 70 | | | | | | |
| 72 | | | | | | |
| 74 | | | | | | |
| 76 | | | | | | |

**H-009**

| SPT Results (N)* | | SPT Results Refusal | Depth |
|---|---|---|---|
| 23 | | | 0.75 |
| 23 | | | 1.25 |
| 33 | | | 2.75 |
| 33 | | | 3.25 |
| 42 | | | 4.75 |
| 42 | | | 5.25 |
| 25 | | | 6.75 |
| 25 | | | 7.25 |
| 26 | | | 8.75 |
| 26 | | | 9.25 |
| 32 | | | 10.75 |
| 32 | | | 11.25 |
| 55 | | | 12.75 |
| 55 | | | 13.25 |
| 28 | | | 14.75 |
| 28 | | | 15.25 |
| 47 | | | 16.75 |
| 47 | | | 17.25 |
| 68 | | | 18.75 |
| 68 | | | 19.25 |
| 86 | | | 20.75 |
| 86 | | | 21.25 |
| | 200 | 200/2" | 22.75 |
| | 200 | 200/2" | 23.25 |
| 21 | | | 24.75 |
| 21 | | | 25.25 |
| 45 | | | 26.75 |
| 45 | | | 27.25 |
| 28 | | | 28.75 |
| 28 | | | 29.25 |
| 26 | | | 30.75 |
| 26 | | | 31.25 |
| 45 | | | 32.75 |
| 45 | | | 33.25 |
| 42 | | | 34.75 |
| 42 | | | 35.25 |
| 44 | | | 36.75 |
| 44 | | | 37.25 |
| 41 | | | 38.75 |

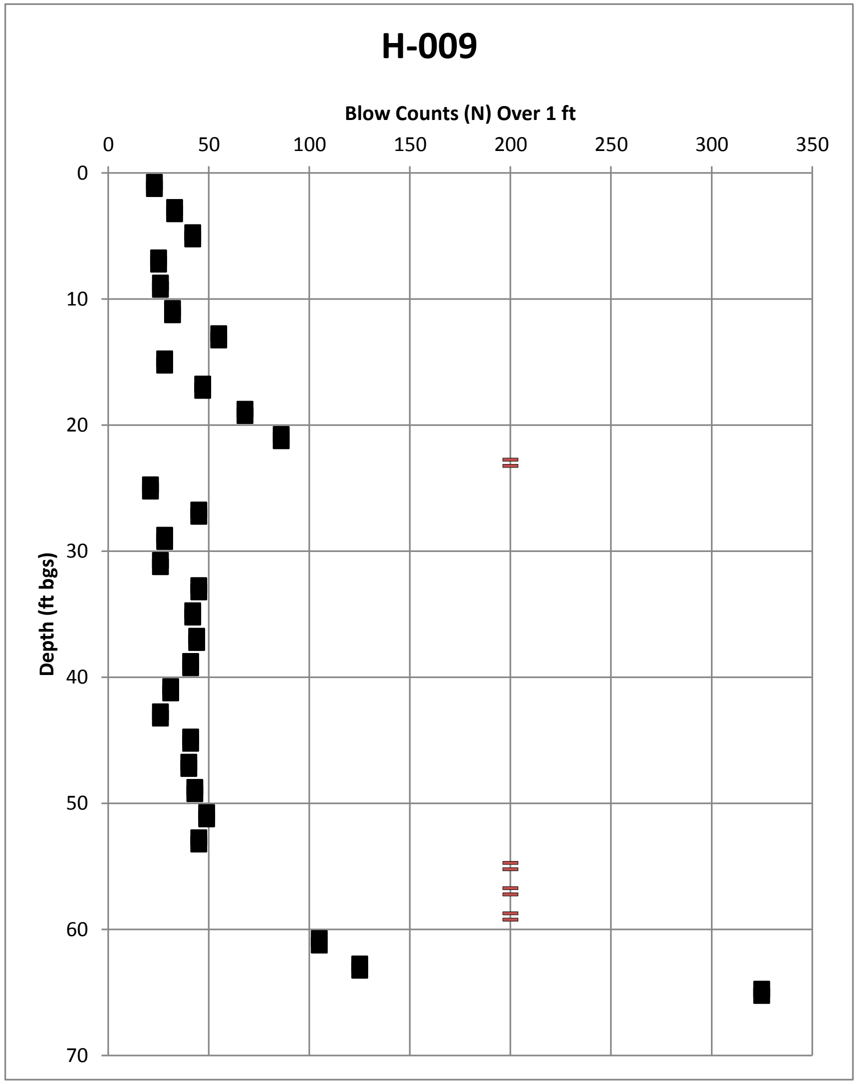
* sum of middle two 6-inch intervals



**H-009**

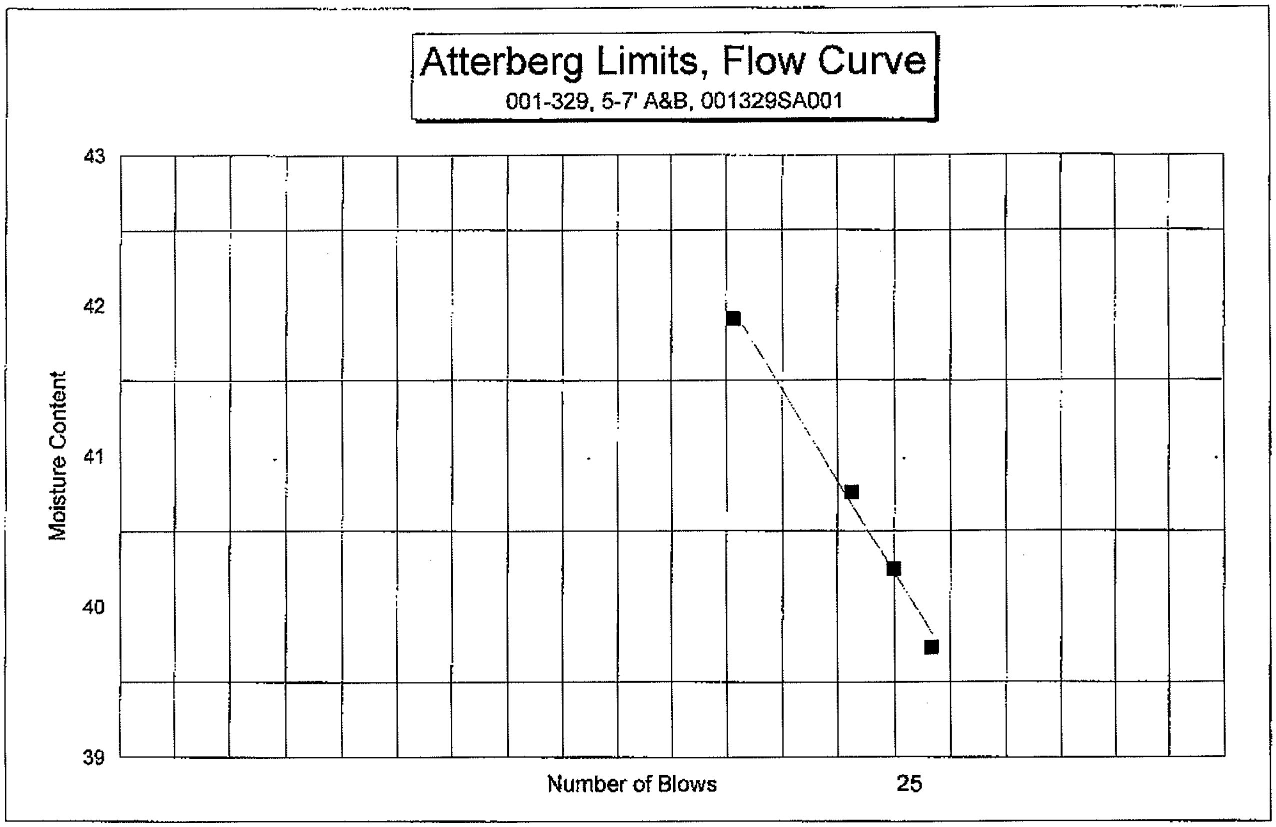
| SPT Results (N)* | | SPT Results Refusal | Depth |
|---|---|---|---|
| 41 | | | 39.25 |
| 31 | | | 40.75 |
| 31 | | | 41.25 |
| 26 | | | 42.75 |
| 26 | | | 43.25 |
| 41 | | | 44.75 |
| 41 | | | 45.25 |
| 40 | | | 46.75 |
| 40 | | | 47.25 |
| 43 | | | 48.75 |
| 43 | | | 49.25 |
| 49 | | | 50.75 |
| 49 | | | 51.25 |
| 45 | | | 52.75 |
| 45 | | | 53.25 |
| | 200 | 108/1.5" | 54.75 |
| | 200 | 108/1.5" | 55.25 |
| | 200 | 89/1" | 56.75 |
| | 200 | 89/1" | 57.25 |
| | 200 | 200/1" | 58.75 |
| | 200 | 200/1" | 59.25 |
| 105 | | | 60.75 |
| 105 | | | 61.25 |
| 125 | | | 62.75 |
| 125 | | | 63.25 |
| 325 | | | 64.75 |
| 325 | | | 65.25 |

* sum of middle two 6-inch intervals

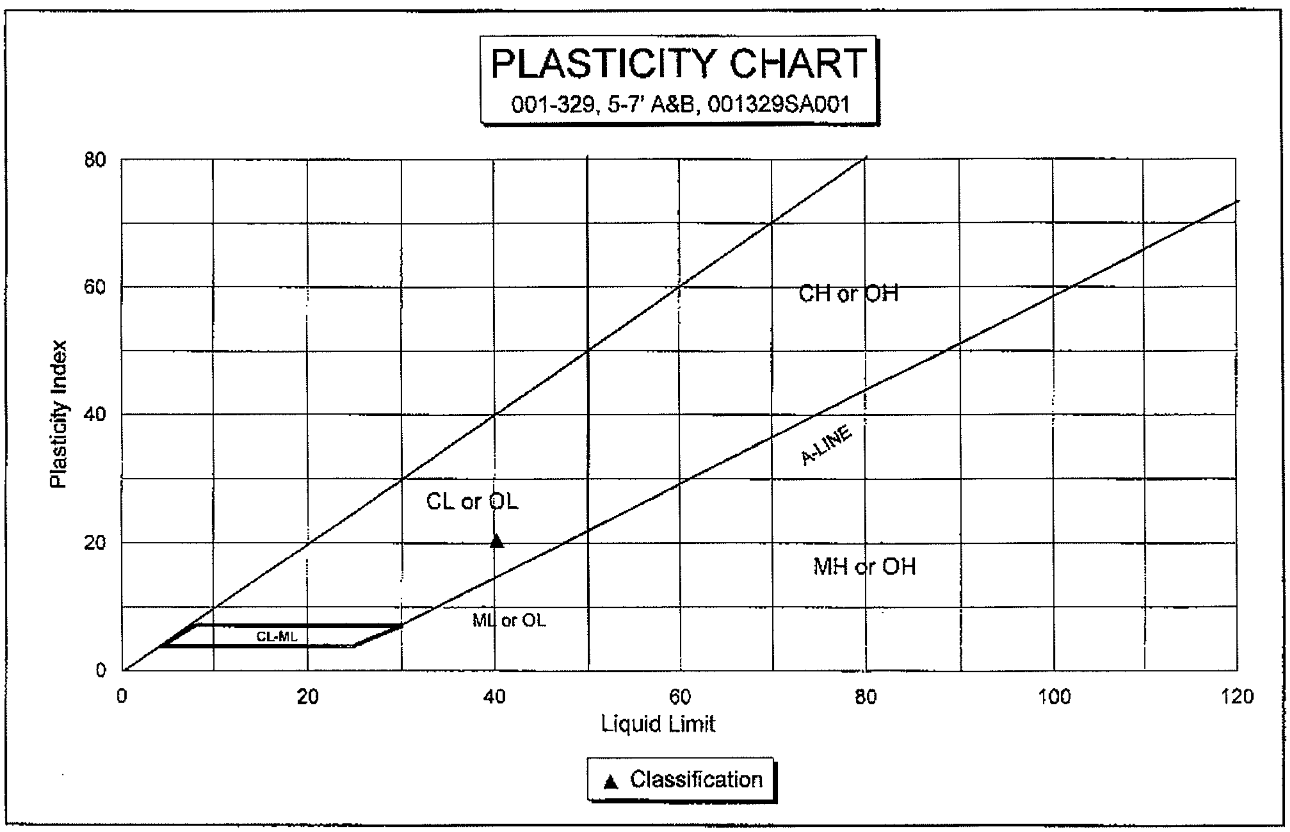


**Geotechnical Soil Data**
**Soil Boring: 001-239**
**SWMU 1: C-746-C Oil Landfarm**

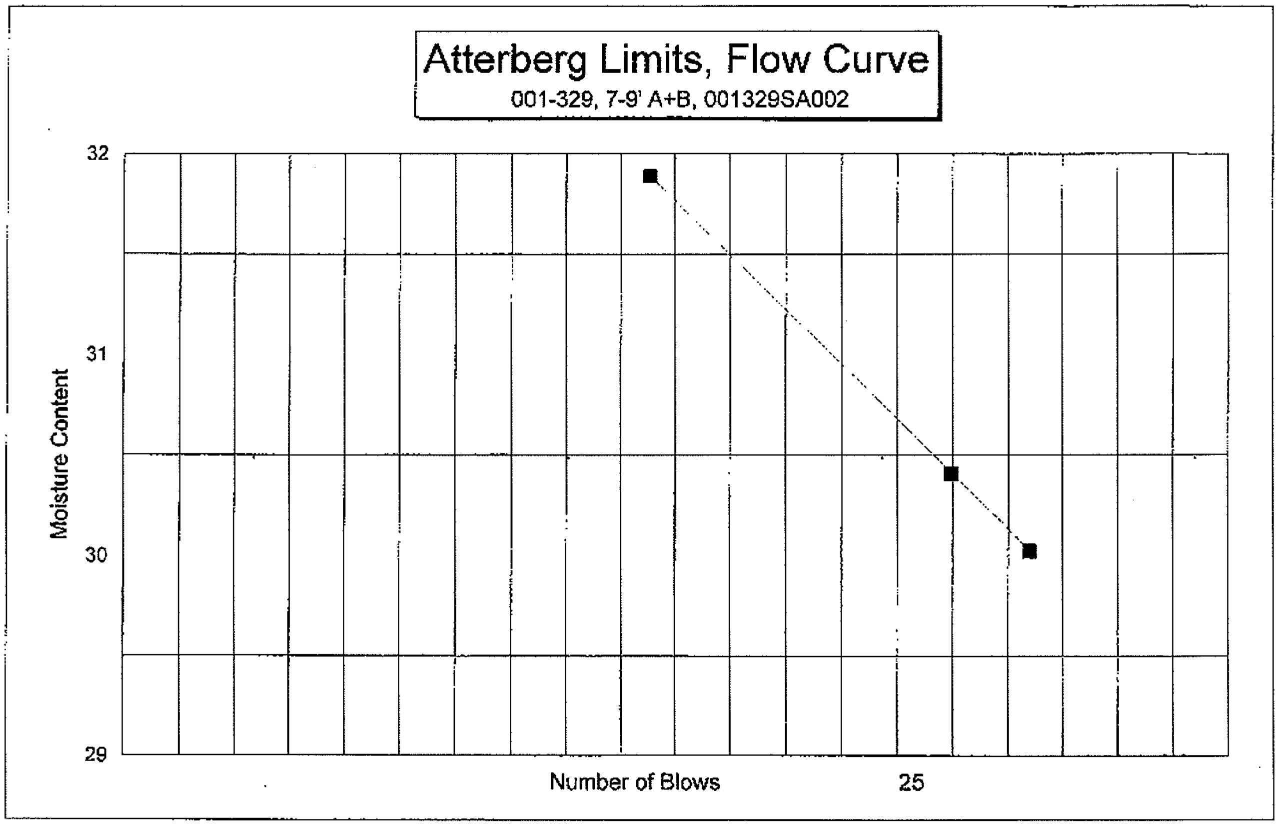
| Sample | Depth | Moisture Content | pH | Liquid Limit | Plastic Limit | Plasticity Index | Atterberg Classificatiion | Fraction of Organic Carbon |
|---|---|---|---|---|---|---|---|---|
| | (ft) | (%) | (Std Units) | | | | | (mg/Kg) |
| 001329SA001 | 5.0-7.0 | 22.8 | 5.54 | 40.2 | 19.9 | 20.4 | CL | |
| 001329SA002 | 7.0-9.0 | 23.3 | 7.15 | 30.7 | 18.6 | 12.1 | CL | |
| 001329SA003 | 10.0-12.0 | 21.4 | 6.63 | 30.1 | 15.2 | 15.0 | CL | |
| 001329SA004 | 16.5-17.5 | 15.8 | 6.97 | 24.3 | 14.2 | 10.1 | CL | |
| 001329SA005 | 18.5-19.5 | 8.2 | 7.49 | 30.1 | 12.4 | 17.7 | CL | |
| 001329SA006 | 20.5-21.5 | 12.2 | 7.42 | 36.6 | 11.1 | 25.6 | CL | |
| 001329SA007 | 30.0-32.0 | 19.6 | 7.51 | 25.3 | 10.5 | 14.8 | CL | |
| 001329SA008 | 40.0-42.0 | 14.2 | 7.08 | 18.7 | 13.6 | 5.1 | CL-ML | |
| 001329SA009 | 50.0-50.9 | 17.9 | 7.53 | 20.7 | 11.8 | 8.9 | CL | |
| 001304FOC1 | 14.9 | | | | | | | 5,900 |
| 001304FOC2 | 26.5 | | | | | | | 430 |
| 001304FOC3 | 42.5 | | | | | | | 230 |
| 001307FOC1 | 12.5 | | | | | | | 740 |
| 001307FOC2 | 23.5 | | | | | | | 680 |
| 001307FOC3 | 33 | | | | | | | 360 |
| 001318FOC1 | 13 | | | | | | | 290 |
| 001318FOC2 | 20.5 | | | | | | | 240 |
| 001318FOC3 | 41 | | | | | | | 920 |



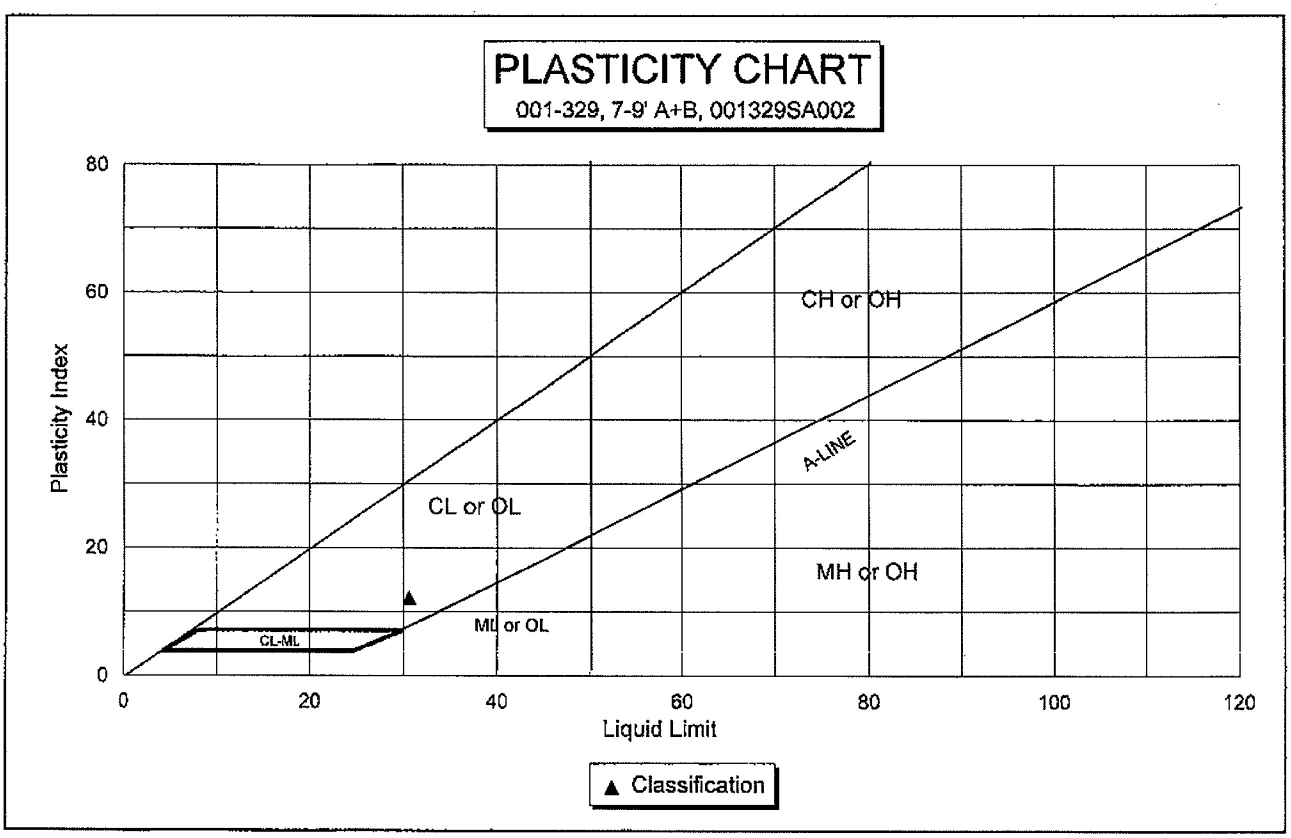
Atterberg Limits, Flow Curve
001-329, 5-7' A&B, 001329SA001
43
42
41
40
39
Moisture Content
Number of Blows
25

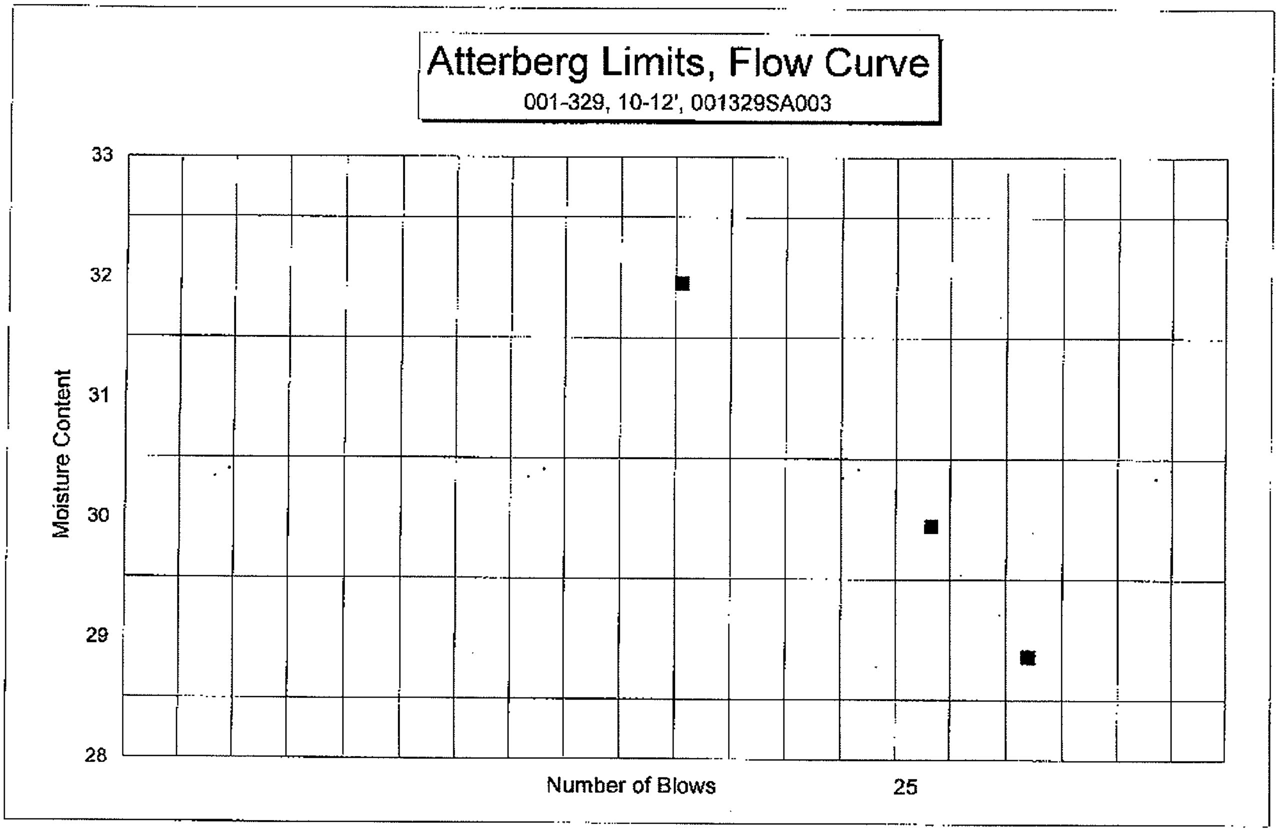
PLASTICITY CHART
001-329, 5-7' A&B, 001329SA001
80
60
40
20
0
Plasticity Index
CH or OH
A-LINE
CL or OL
MH or OH
ML or OL
CL-ML
0
20
40
60
80
100
120
Liquid Limit
▲ Classification

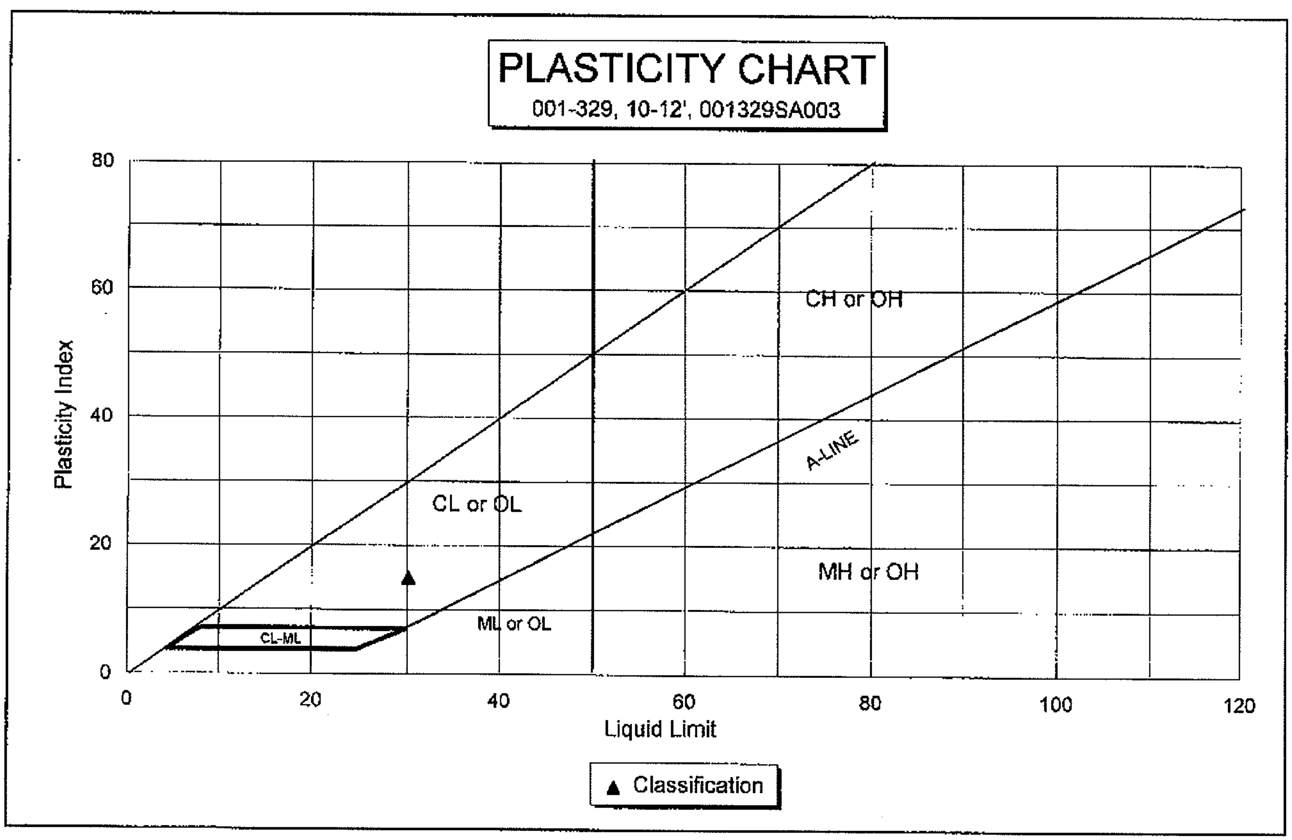


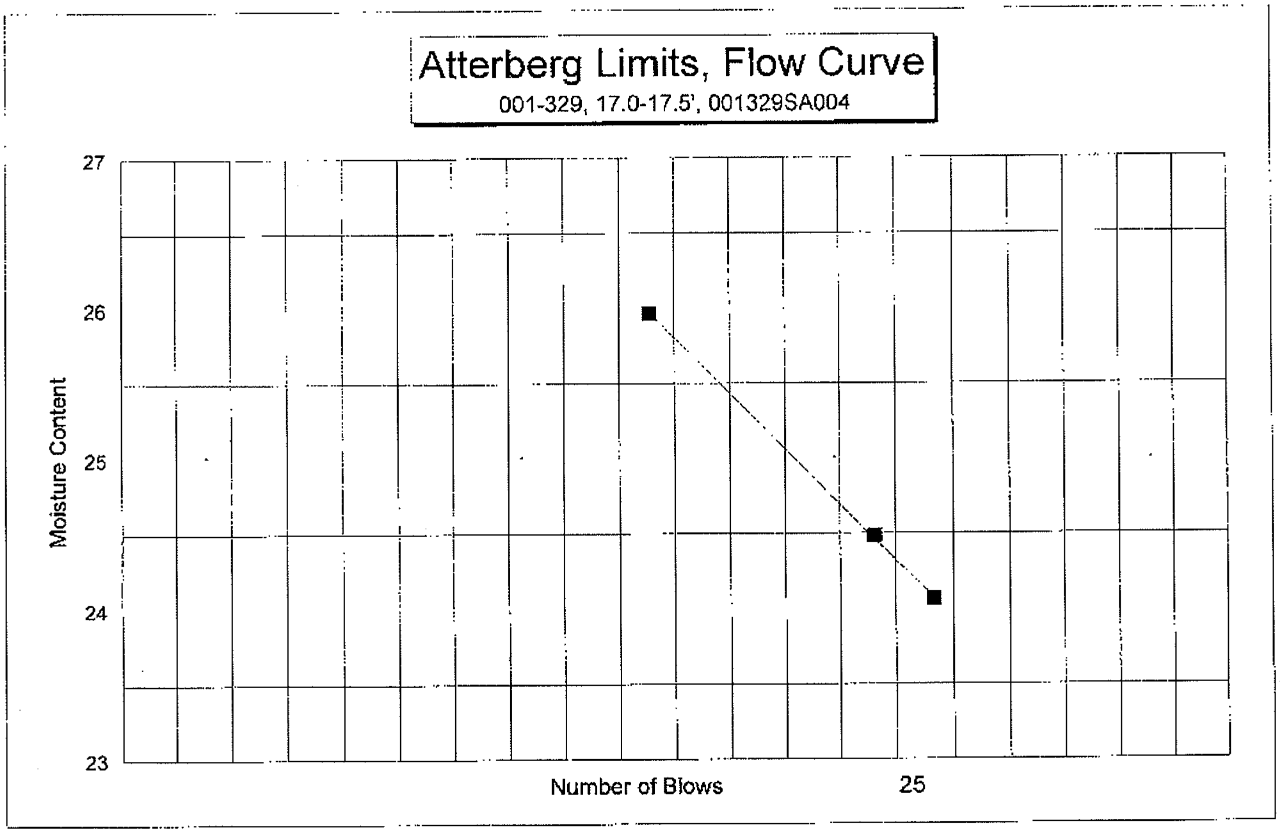
Atterberg Limits, Flow Curve
001-329, 7-9' A+B, 001329SA002
32
31
30
29
Moisture Content
Number of Blows
25

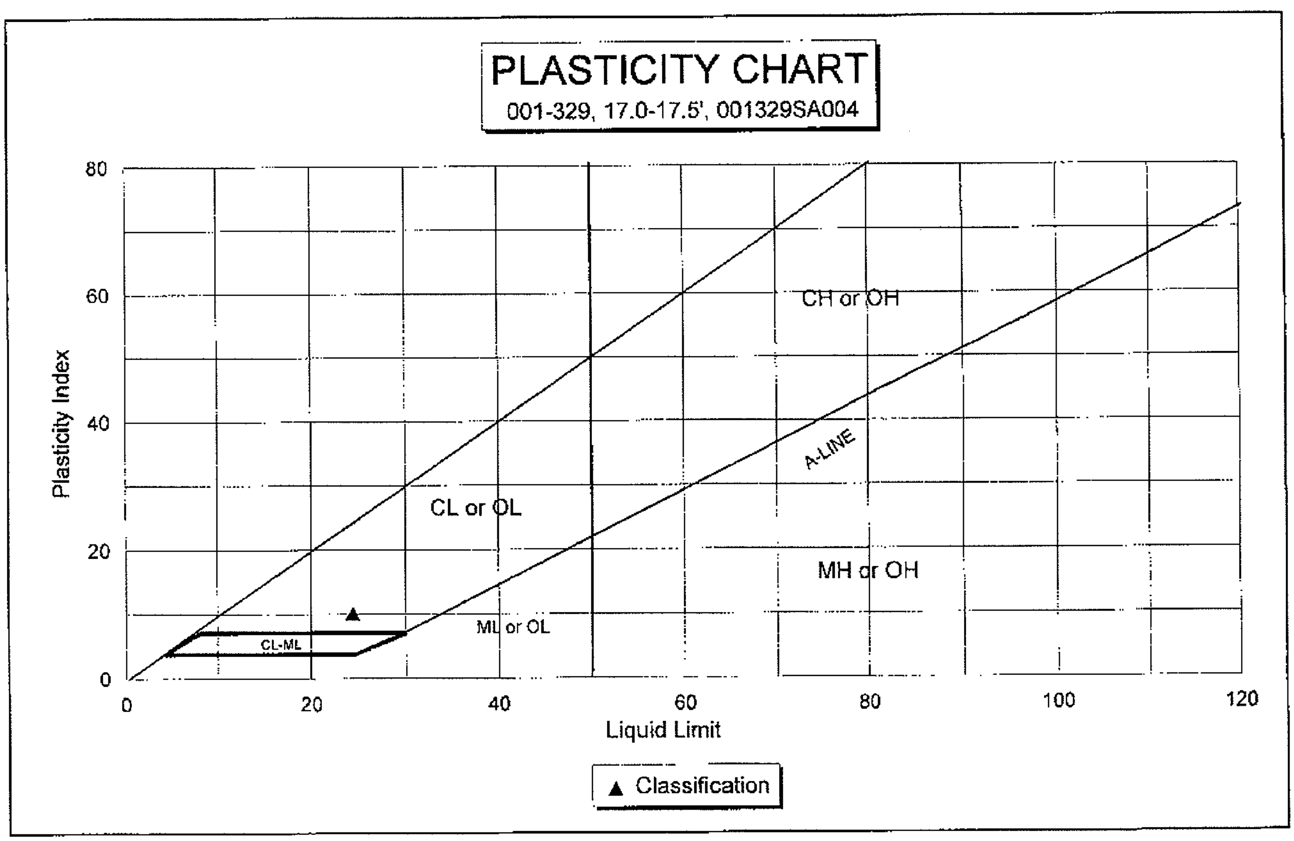



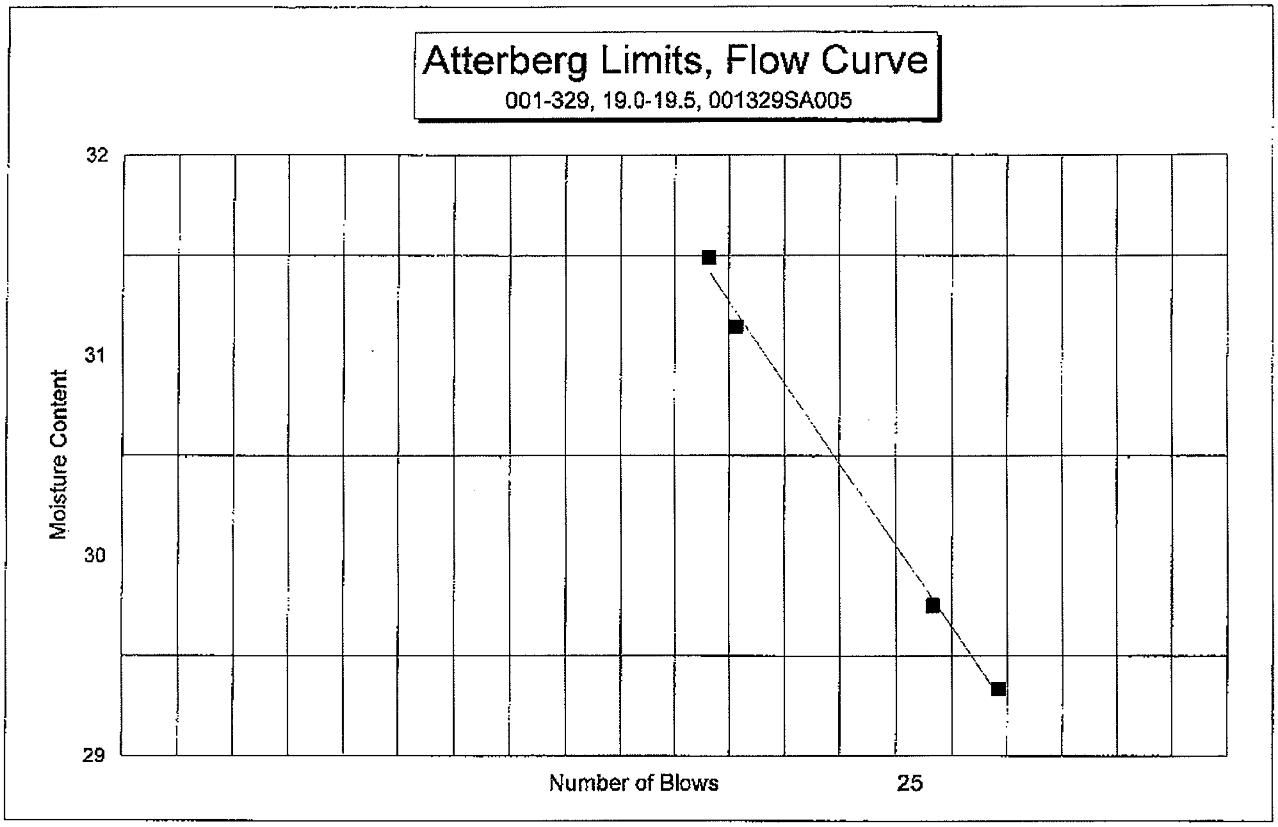
PLASTICITY CHART
001-329, 7-9' A+B, 001329SA002
80
60
40
20
0
Plasticity Index
CH or OH
A-LINE
CL or OL
MH or OH
ML or OL
CL-ML
0
20
40
60
80
100
120
Liquid Limit
▲ Classification

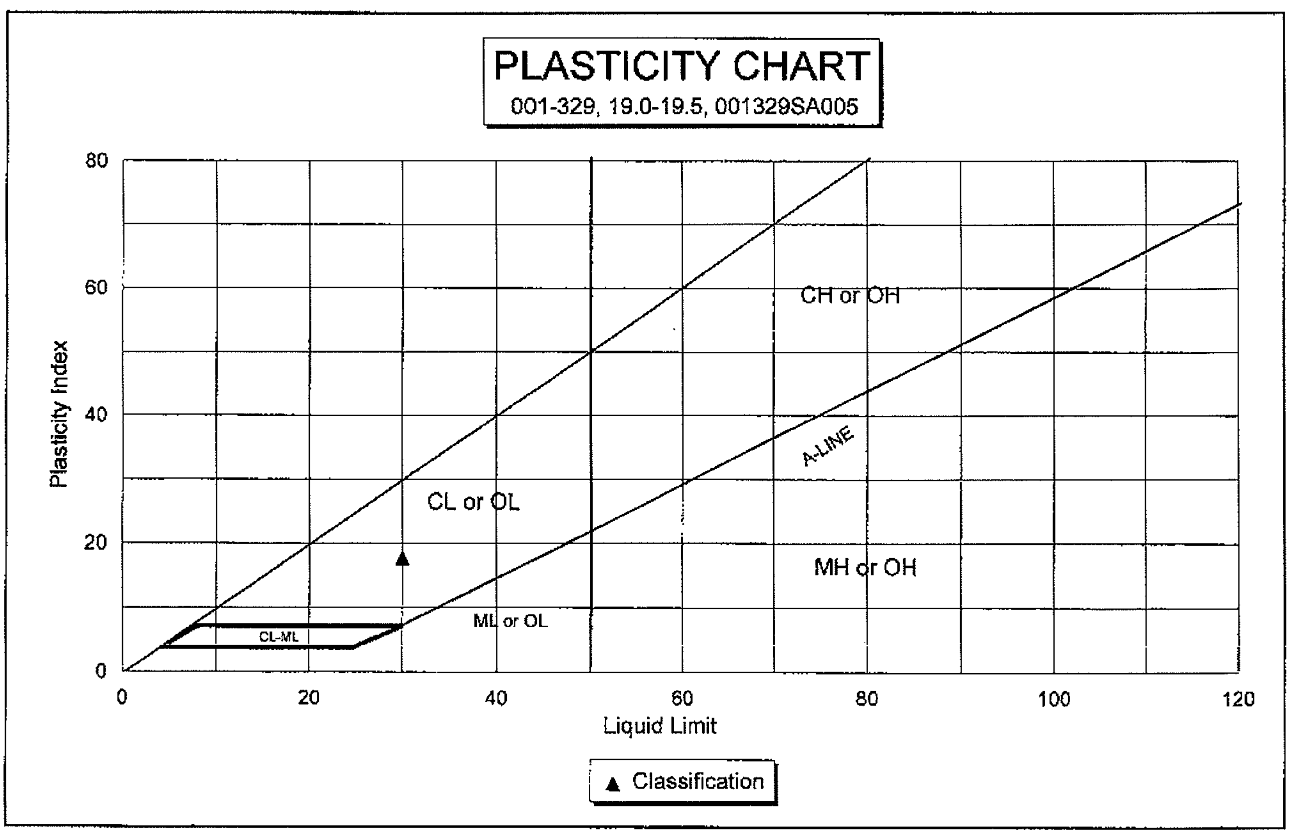

Atterberg Limits, Flow Curve
001-329, 10-12', 001329SA003
33
32
31
30
29
28
Moisture Content
Number of Blows
25

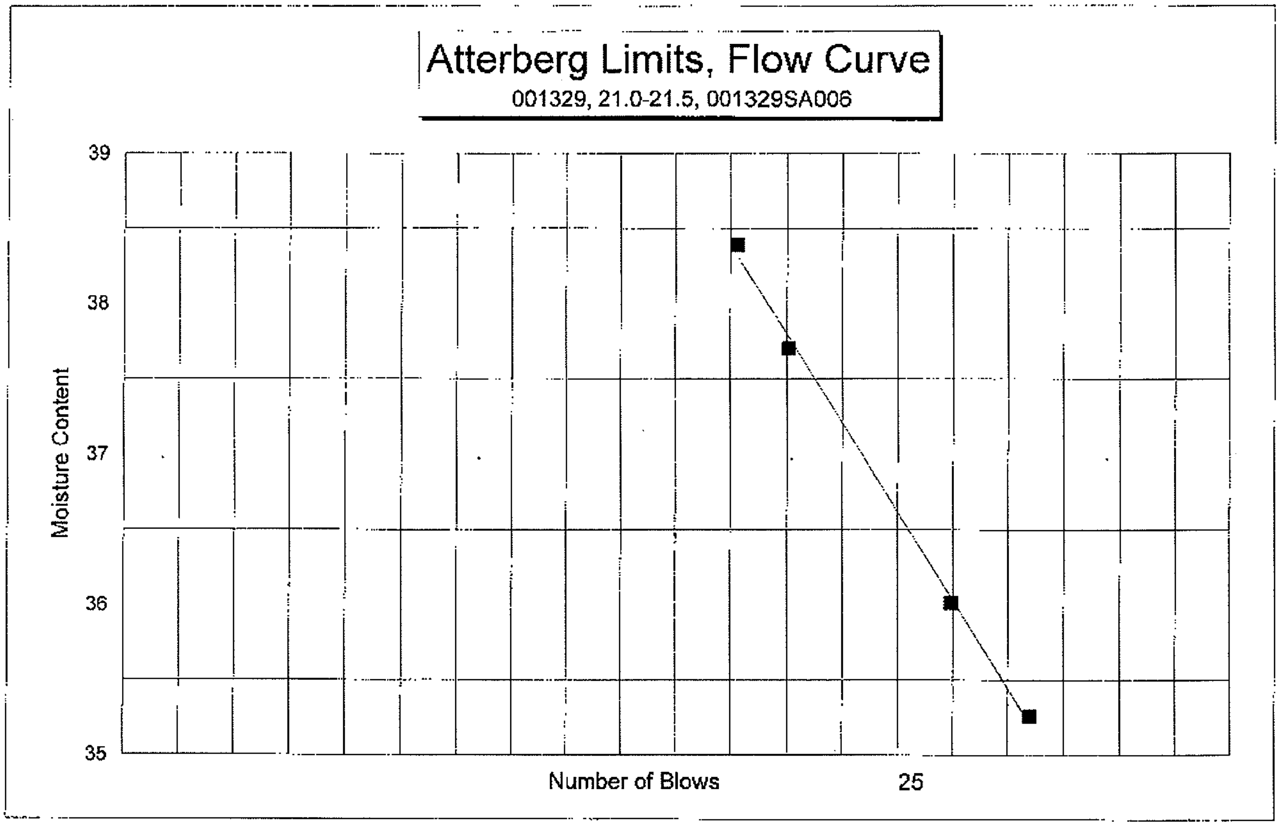

PLASTICITY CHART
001-329, 10-12', 001329SA003
80
60
40
20
0
Plasticity Index
CH or OH
A-LINE
CL or OL
MH or OH
ML or OL
CL-ML
0
20
40
60
80
100
120
Liquid Limit
▲ Classification

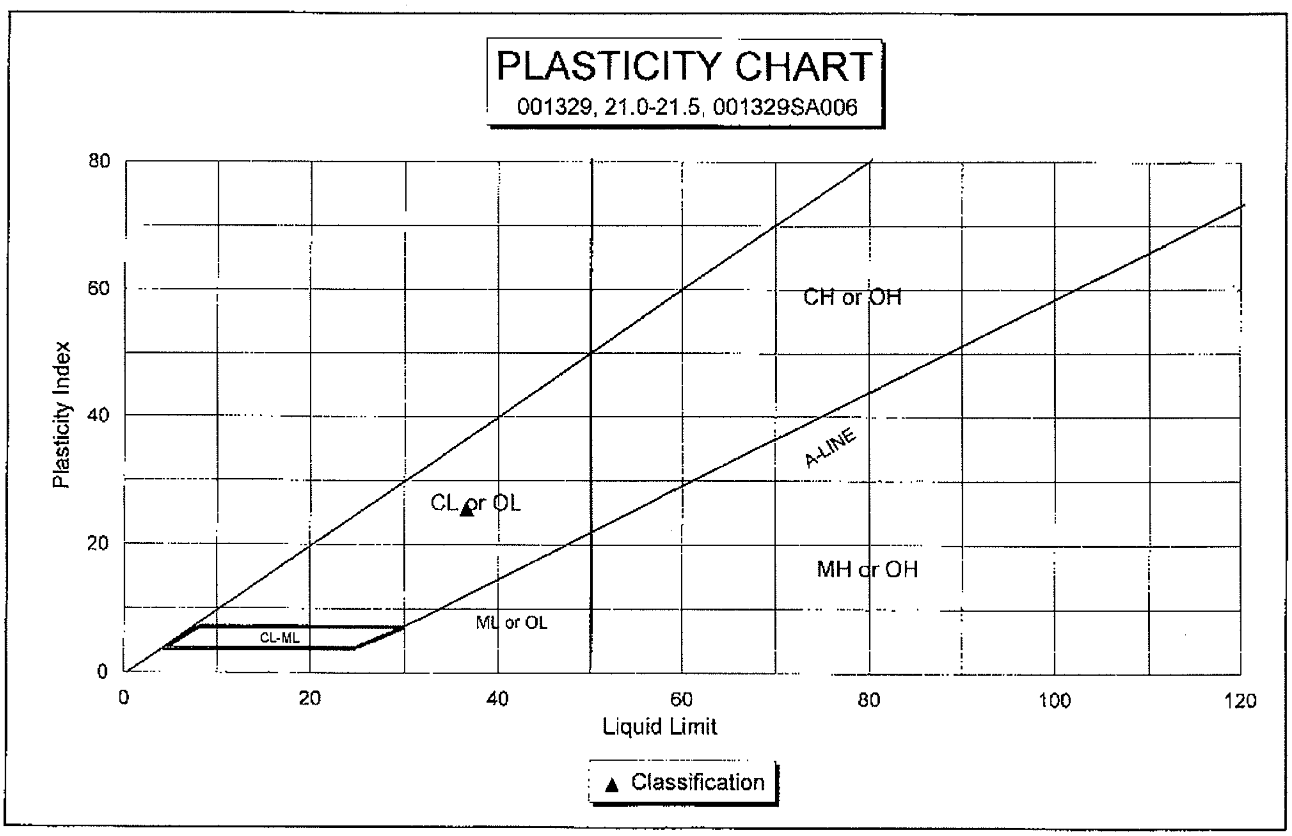

Atterberg Limits, Flow Curve
001-329, 17.0-17.5', 001329SA004
27
26
25
24
23
Moisture Content
Number of Blows
25

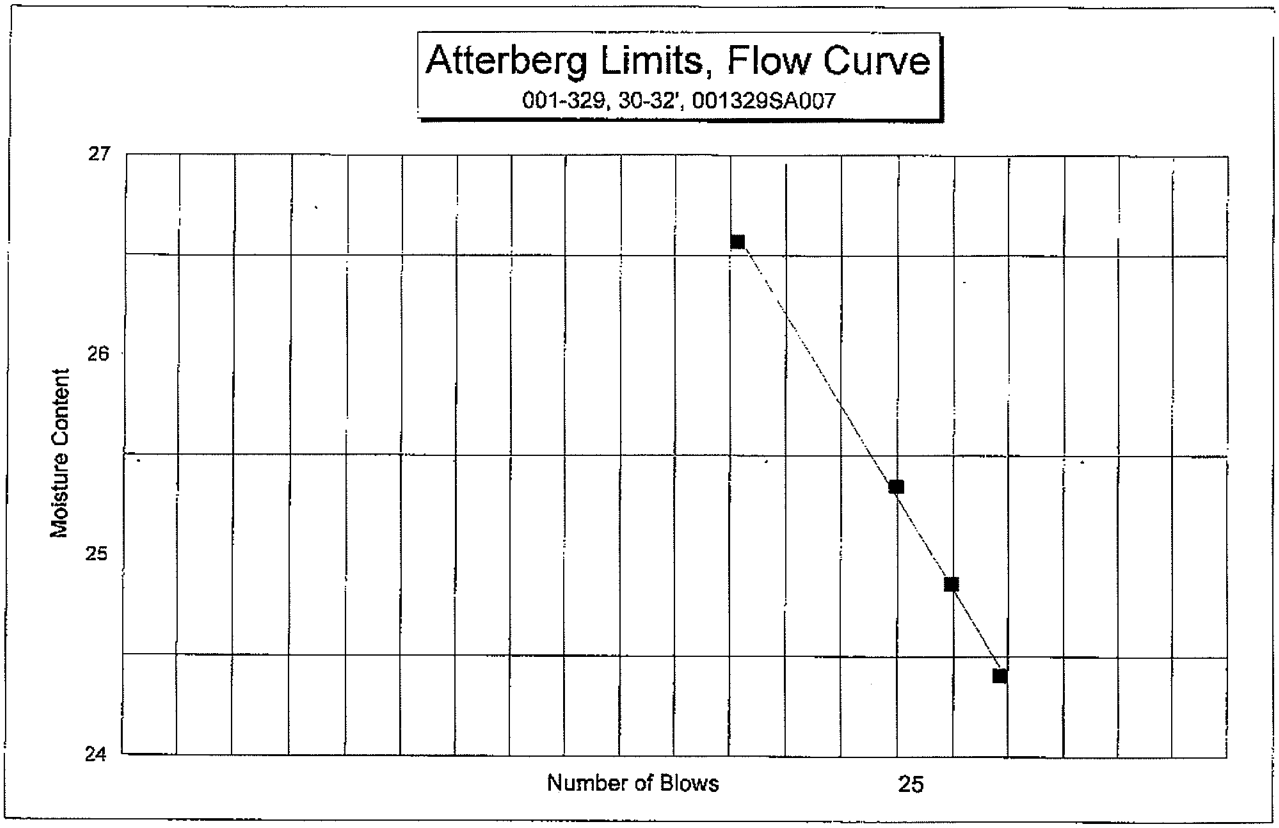

PLASTICITY CHART
001-329, 17.0-17.5', 001329SA004
80
60
40
20
0
Plasticity Index
0
20
40
60
80
100
120
Liquid Limit
CH or OH
A-LINE
CL or OL
MH or OH
ML or OL
CL-ML
▲ Classification

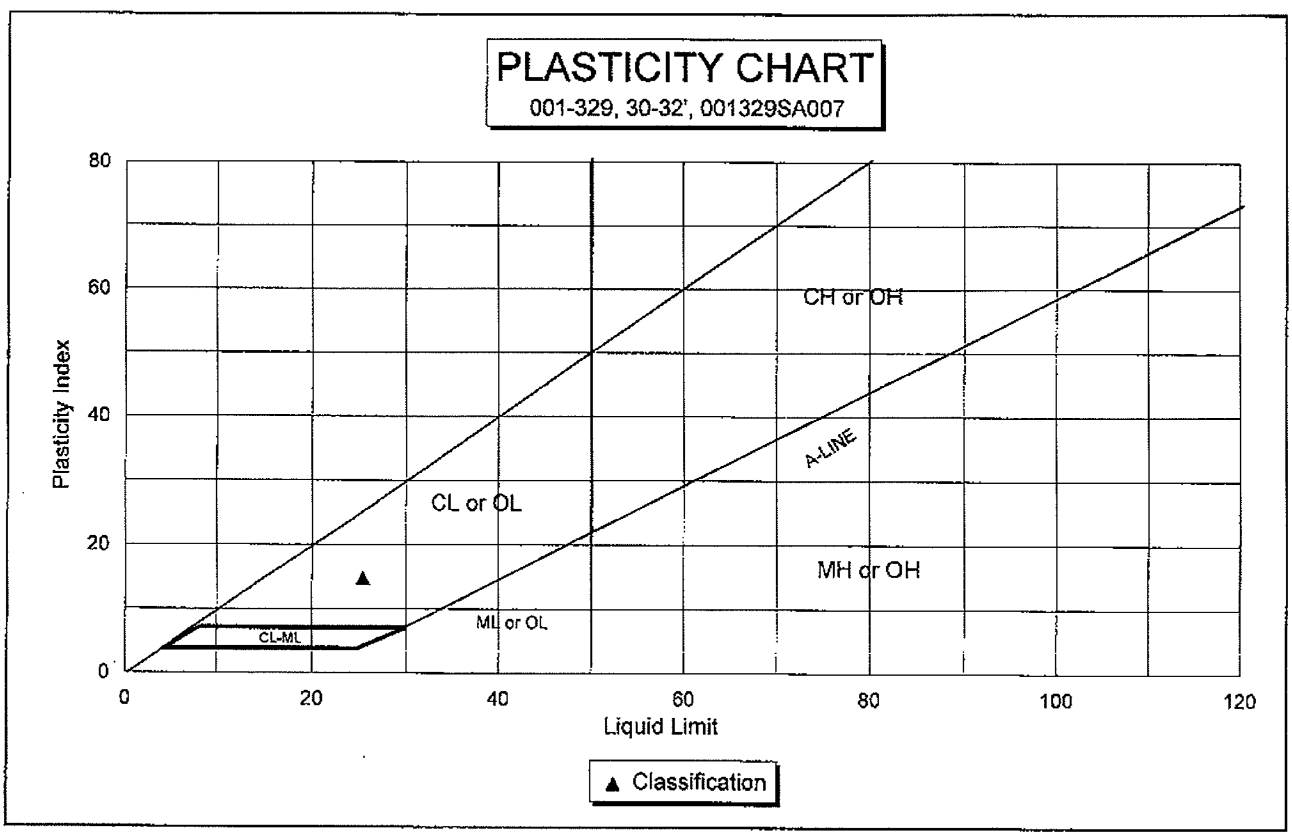

Atterberg Limits, Flow Curve
001-329, 19.0-19.5, 001329SA005
32
31
30
29
Moisture Content
Number of Blows
25

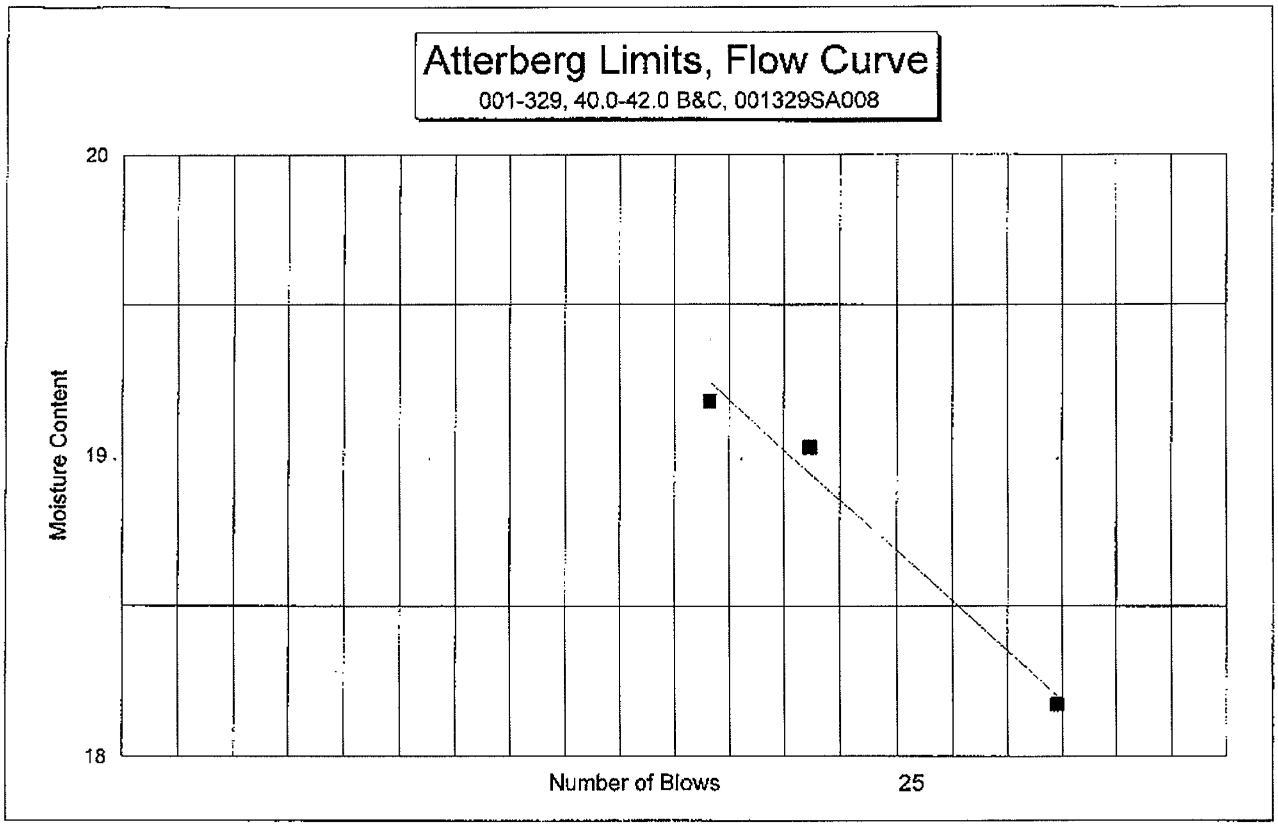

PLASTICITY CHART
001-329, 19.0-19.5, 001329SA005
80
60
40
20
0
Plasticity Index
0
20
40
60
80
100
120
Liquid Limit
CH or OH
A-LINE
CL or OL
MH or OH
ML or OL
CL-ML
▲ Classification

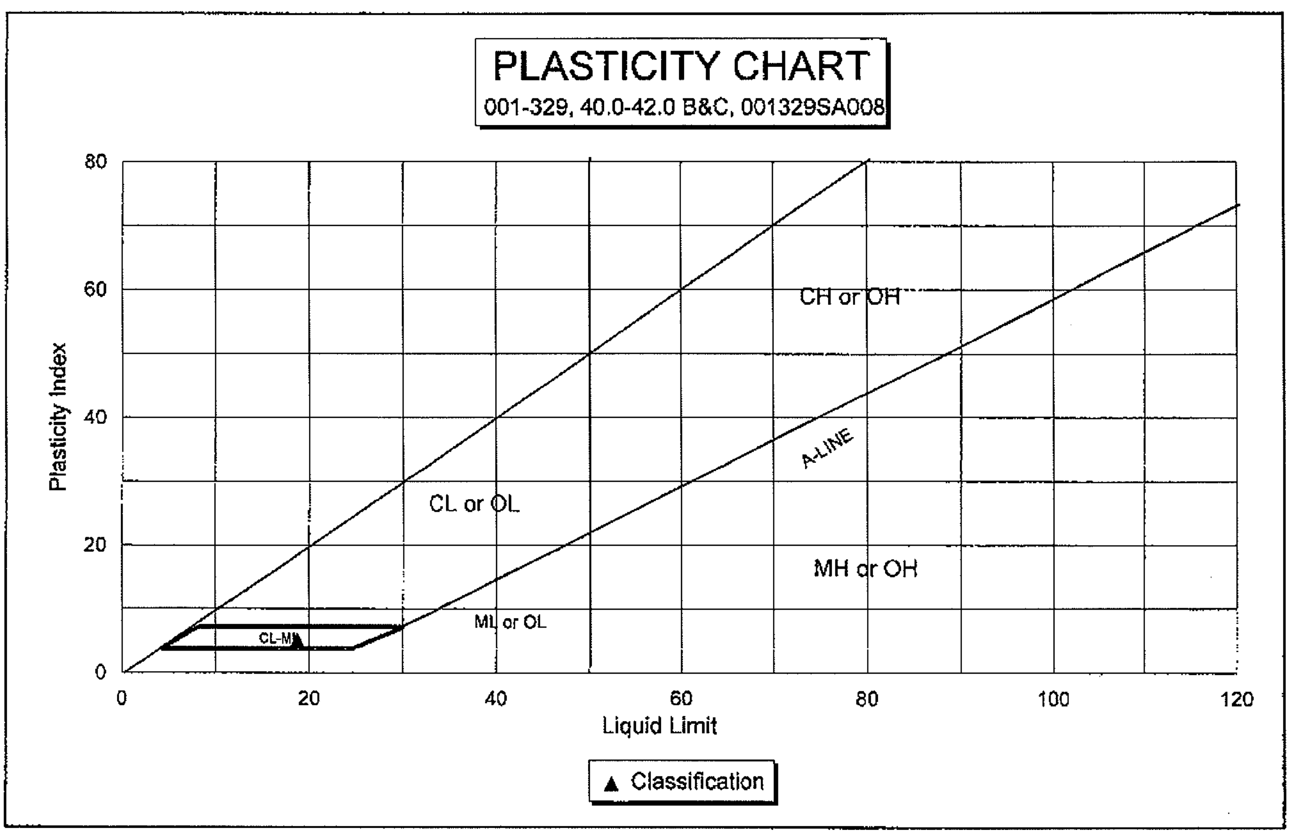

Atterberg Limits, Flow Curve
001329, 21.0-21.5, 001329SA006
39
38
37
36
35
Moisture Content
Number of Blows
25

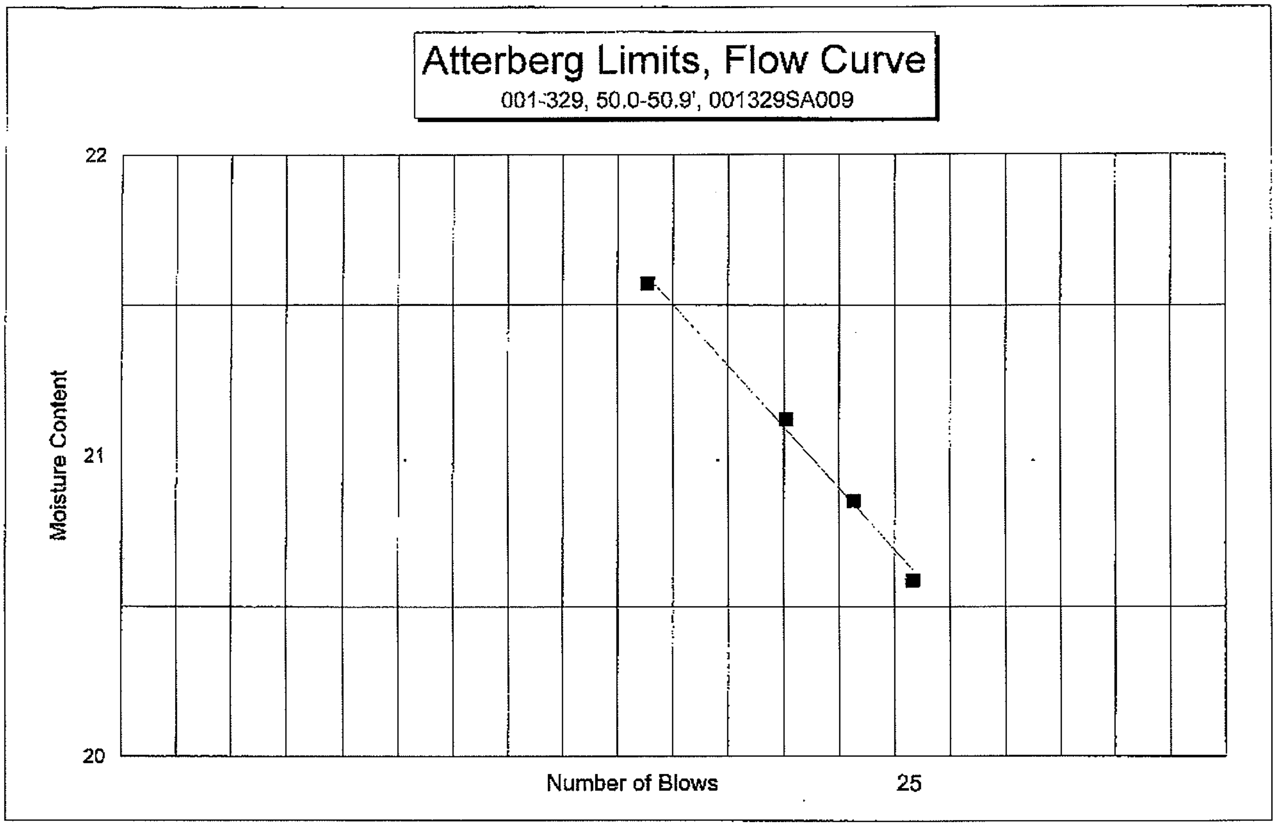

PLASTICITY CHART
001329, 21.0-21.5, 001329SA006
80
60
40
20
0
Plasticity Index
0
20
40
60
80
100
120
Liquid Limit
CH or OH
A-LINE
CL or OL
MH or OH
ML or OL
CL-ML
▲ Classification


Atterberg Limits, Flow Curve
001-329, 30-32', 001329SA007
27
26
25
24
Moisture Content
Number of Blows
25


PLASTICITY CHART
001-329, 30-32', 001329SA007
80
60
40
20
0
Plasticity Index
CH or OH
A-LINE
CL or OL
MH or OH
CL-ML
ML or OL
0
20
40
60
80
100
120
Liquid Limit
▲ Classification


Atterberg Limits, Flow Curve
001-329, 40.0-42.0 B&C, 001329SA008
20
19
18
Moisture Content
Number of Blows
25


PLASTICITY CHART
001-329, 40.0-42.0 B&C, 001329SA008
80
60
40
20
0
Plasticity Index
0
20
40
60
80
100
120
Liquid Limit
CH or OH
A-LINE
CL or OL
MH or OH
ML or OL
CL-ML
▲ Classification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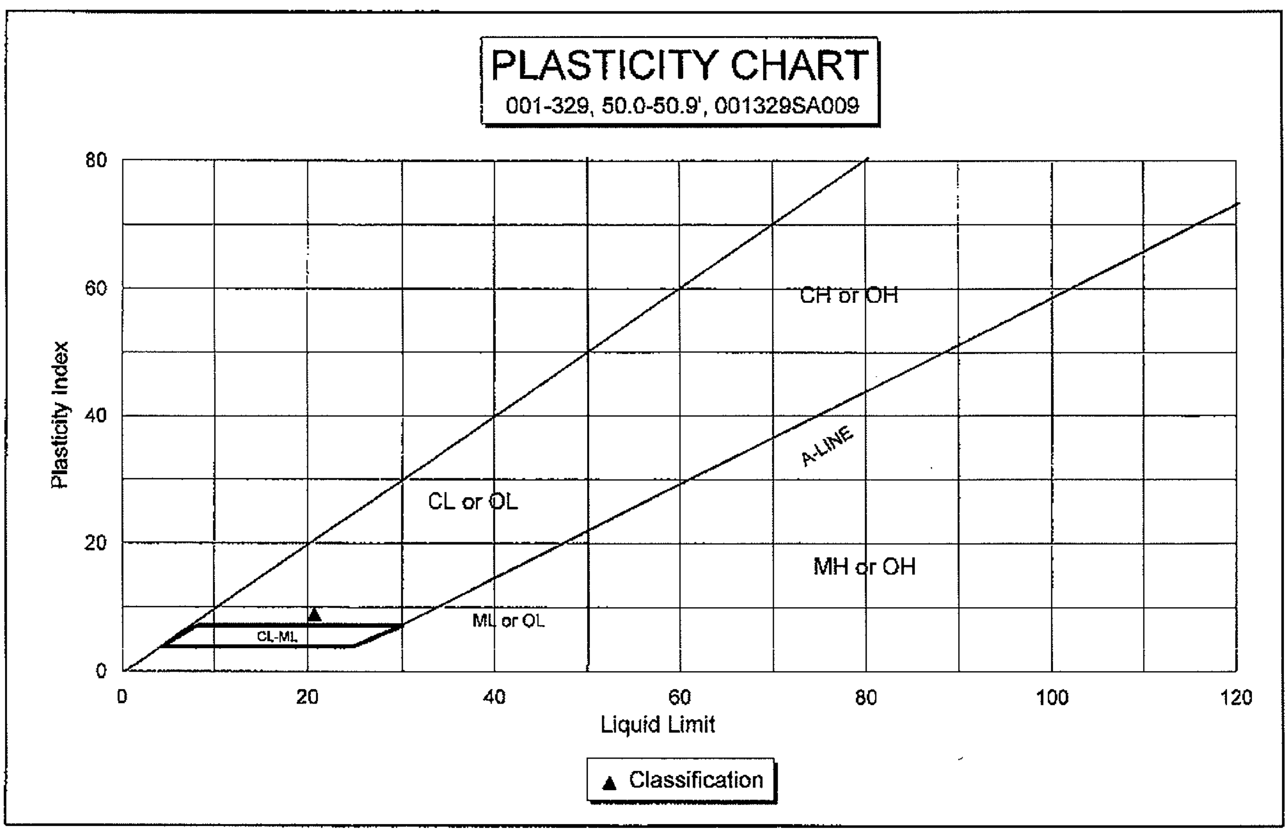
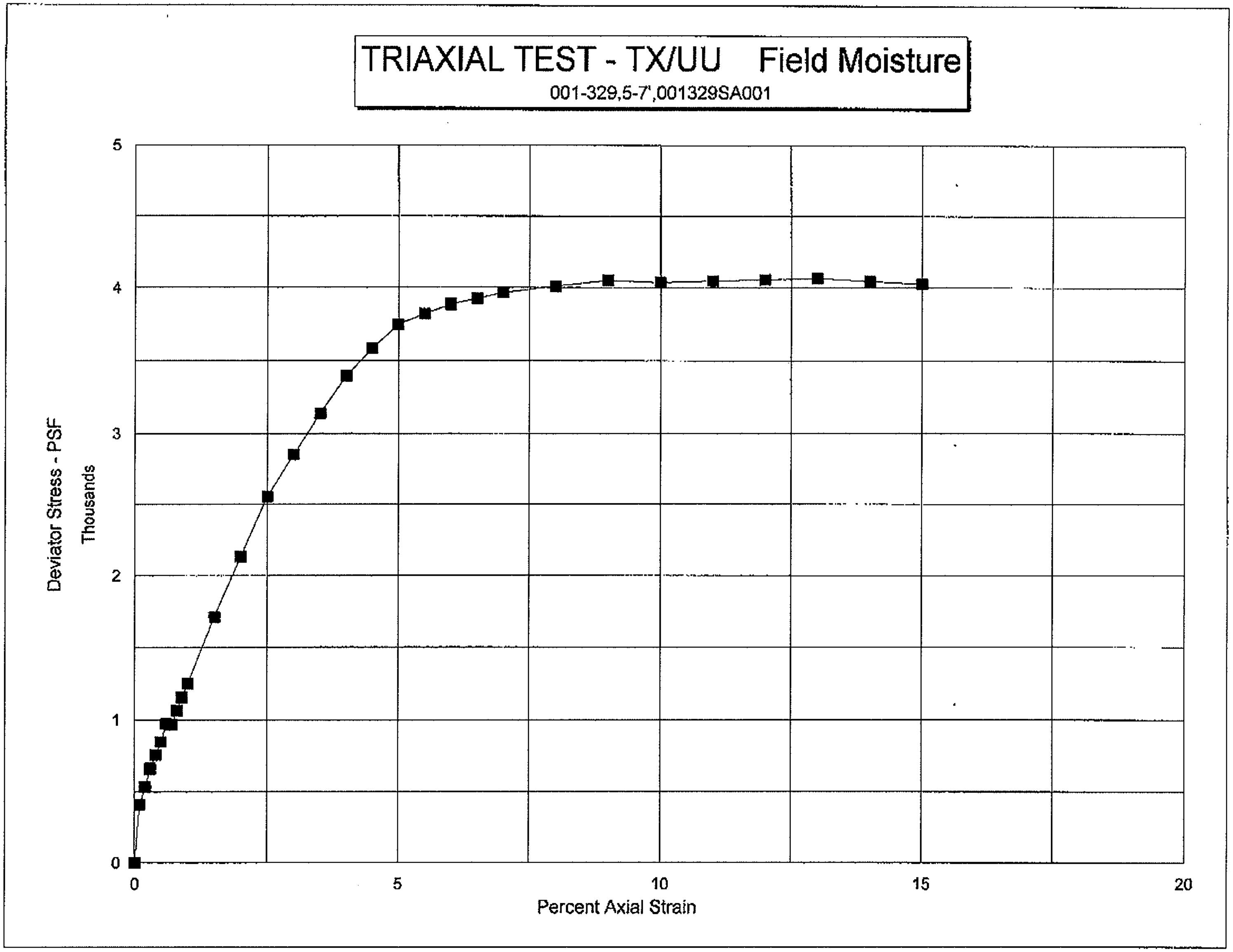
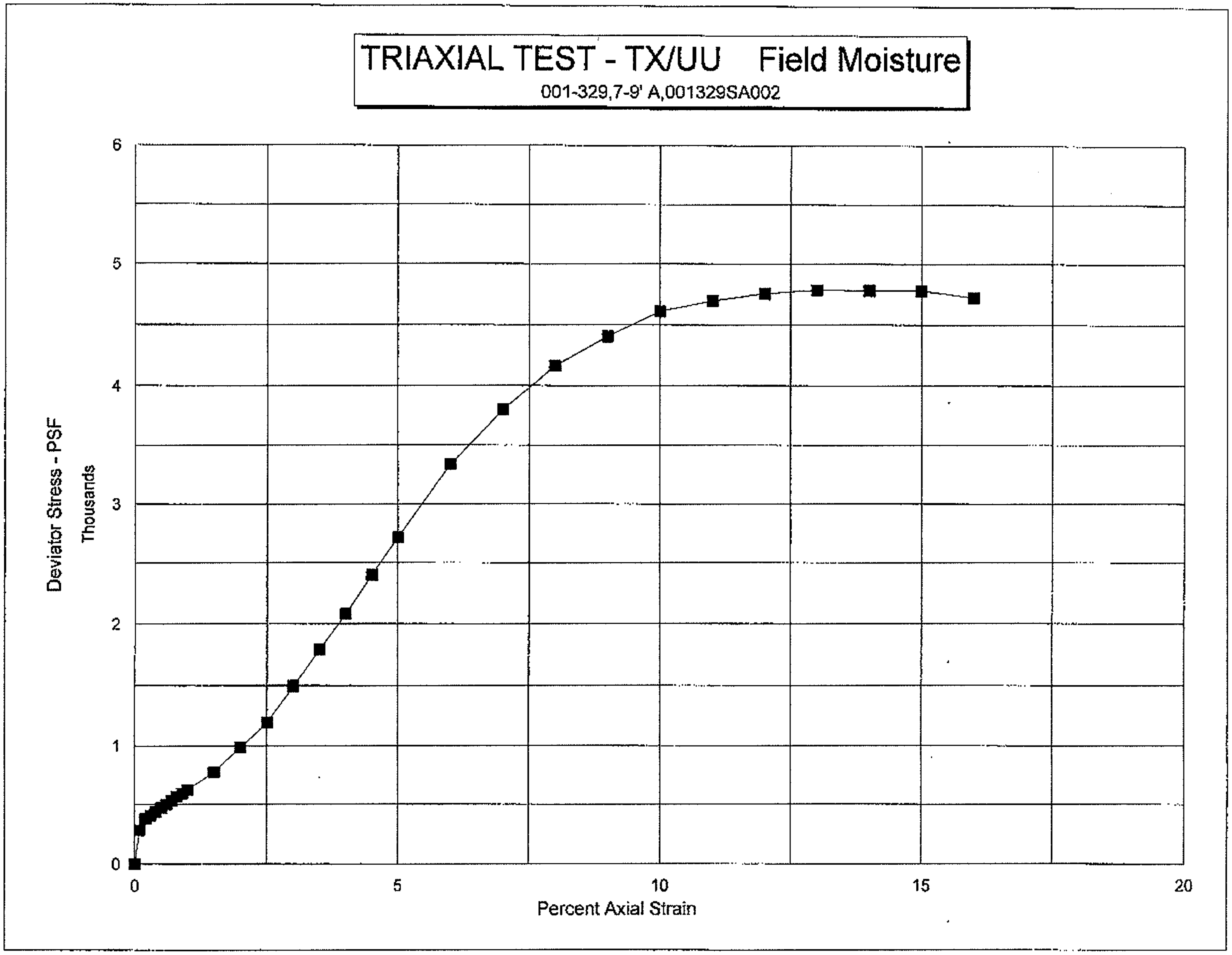
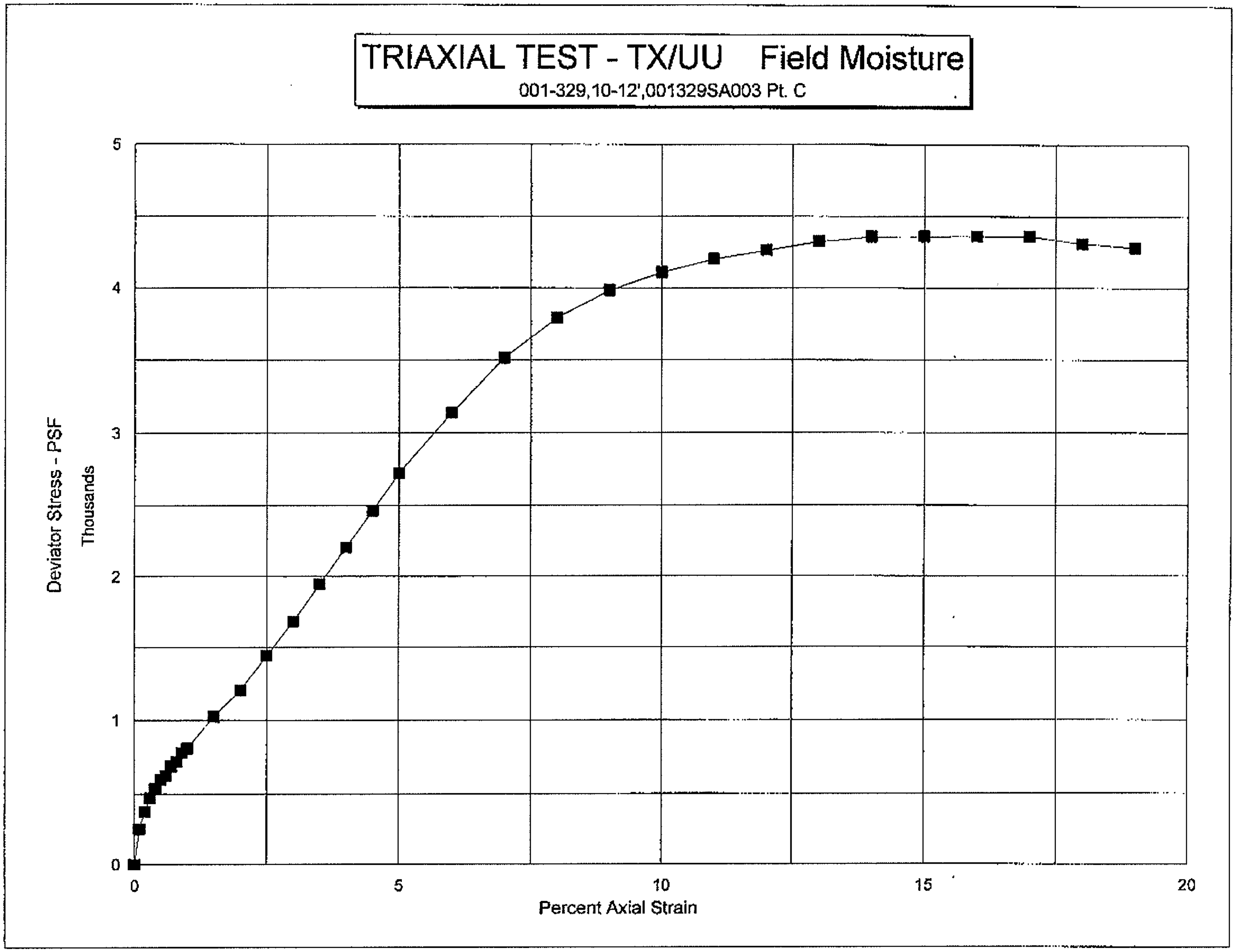
001-329, 50.0-50.9', 001329SA009
22
21
20
Moisture Content
Number of Blows
25

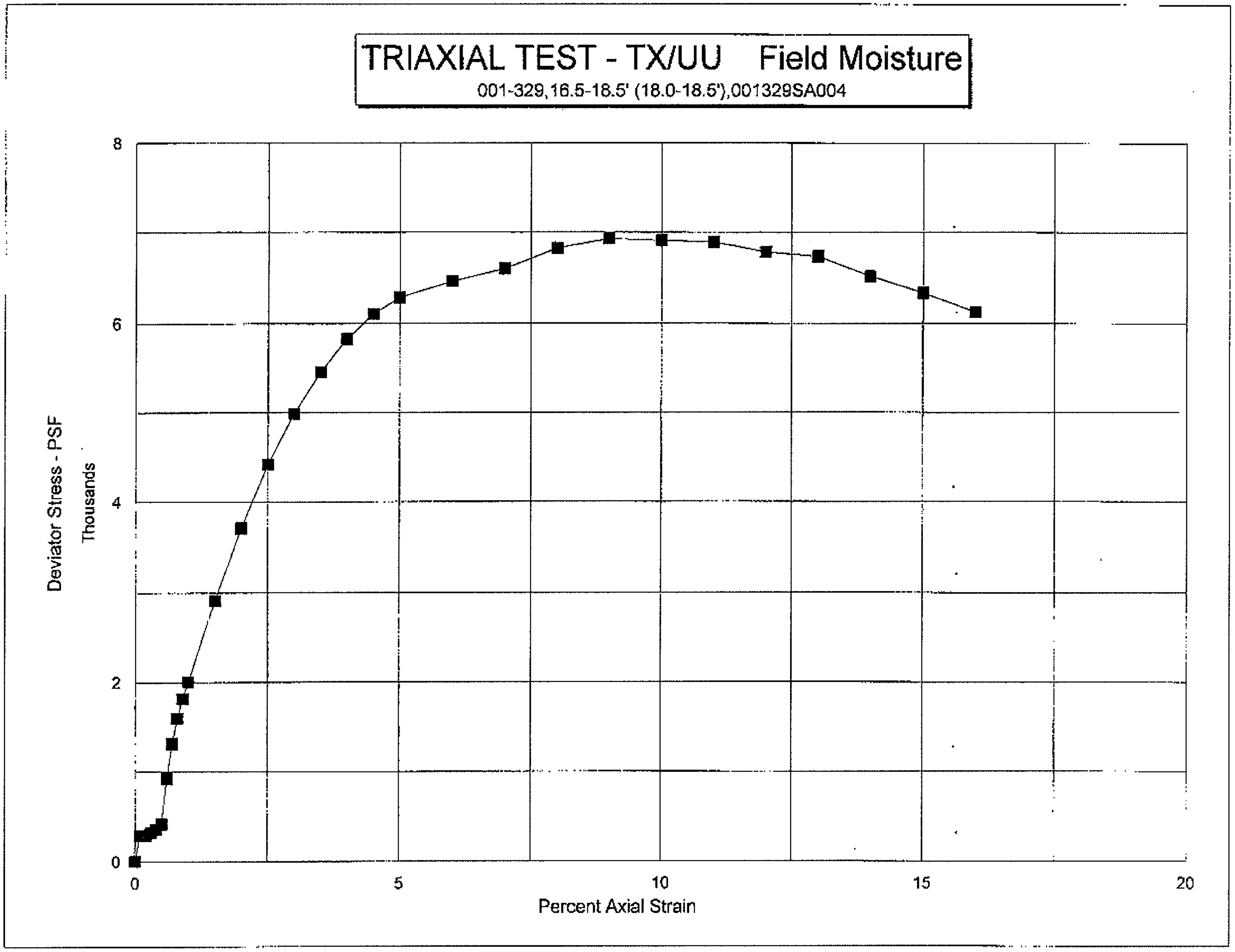

PLASTICITY CHART
001-329, 50.0-50.9', 001329SA009
80
60
40
20
0
Plasticity Index
CH or OH
A-LINE
CL or OL
MH or OH
CL-ML
ML or OL
0
20
40
60
80
100
120
Liquid Limit
Classification

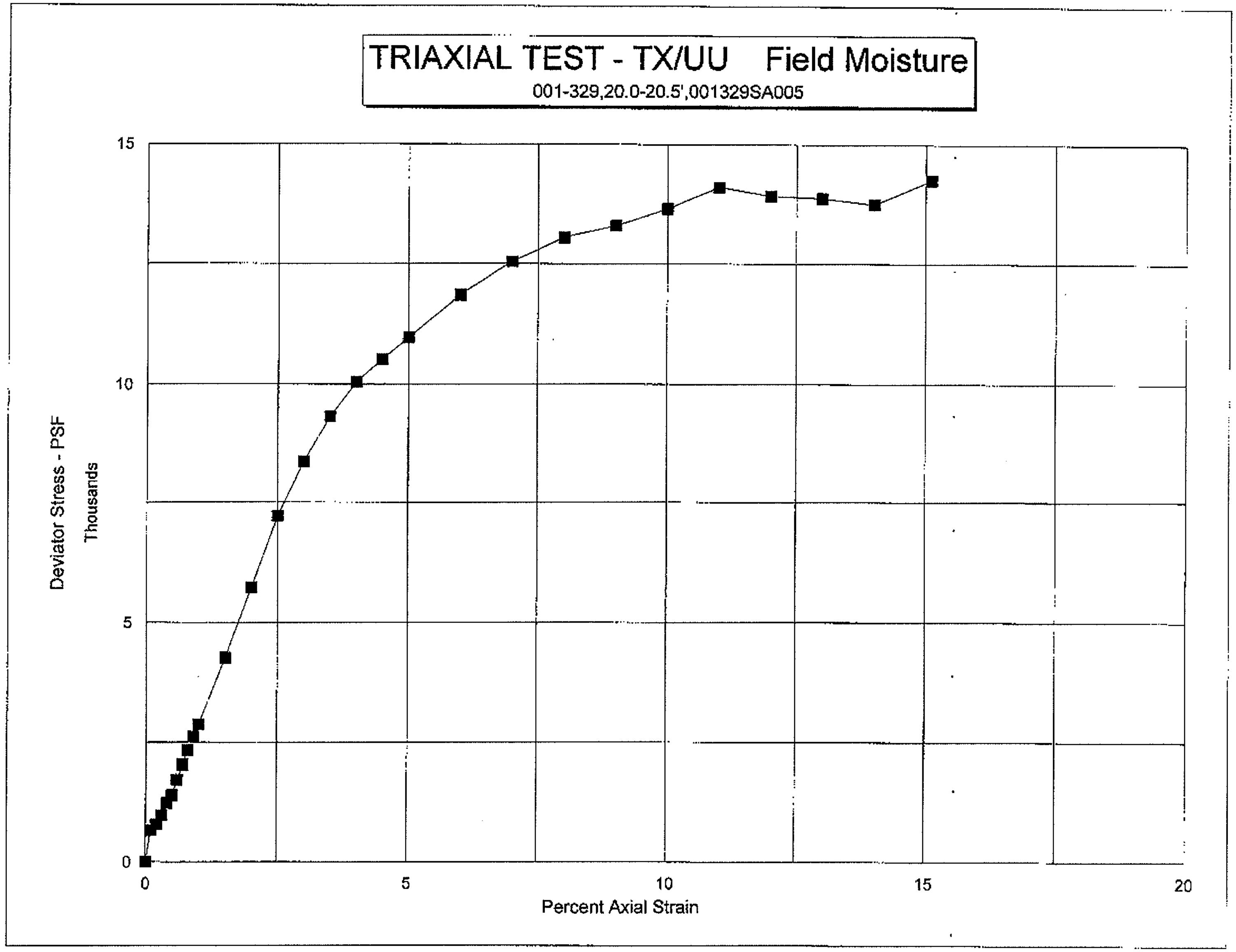

TRIAXIAL TEST - TX/UU Field Moisture
001-329,5-7',001329SA001
Deviator Stress - PSF
Thousands
0
1
2
3
4
5
0
5
10
15
20
Percent Axial Strain



TRIAXIAL TEST - TX/UU Field Moisture
001-329,7-9' A,001329SA002
Deviator Stress - PSF
Thousands
6
5
4
3
2
1
0
0
5
10
15
20
Percent Axial Strain


TRIAXIAL TEST - TX/UU Field Moisture
001-329,10-12',001329SA003 Pt. C
Deviator Stress - PSF
Thousands
Percent Axial Strain
0
1
2
3
4
5
0
5
10
15
20


TRIAXIAL TEST - TX/UU Field Moisture
001-329,16.5-18.5' (18.0-18.5'),001329SA004
Deviator Stress - PSF
Thousands
0
2
4
6
8
0
5
10
15
20
Percent Axial Strain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Deviator Stress - PSF
Thousands
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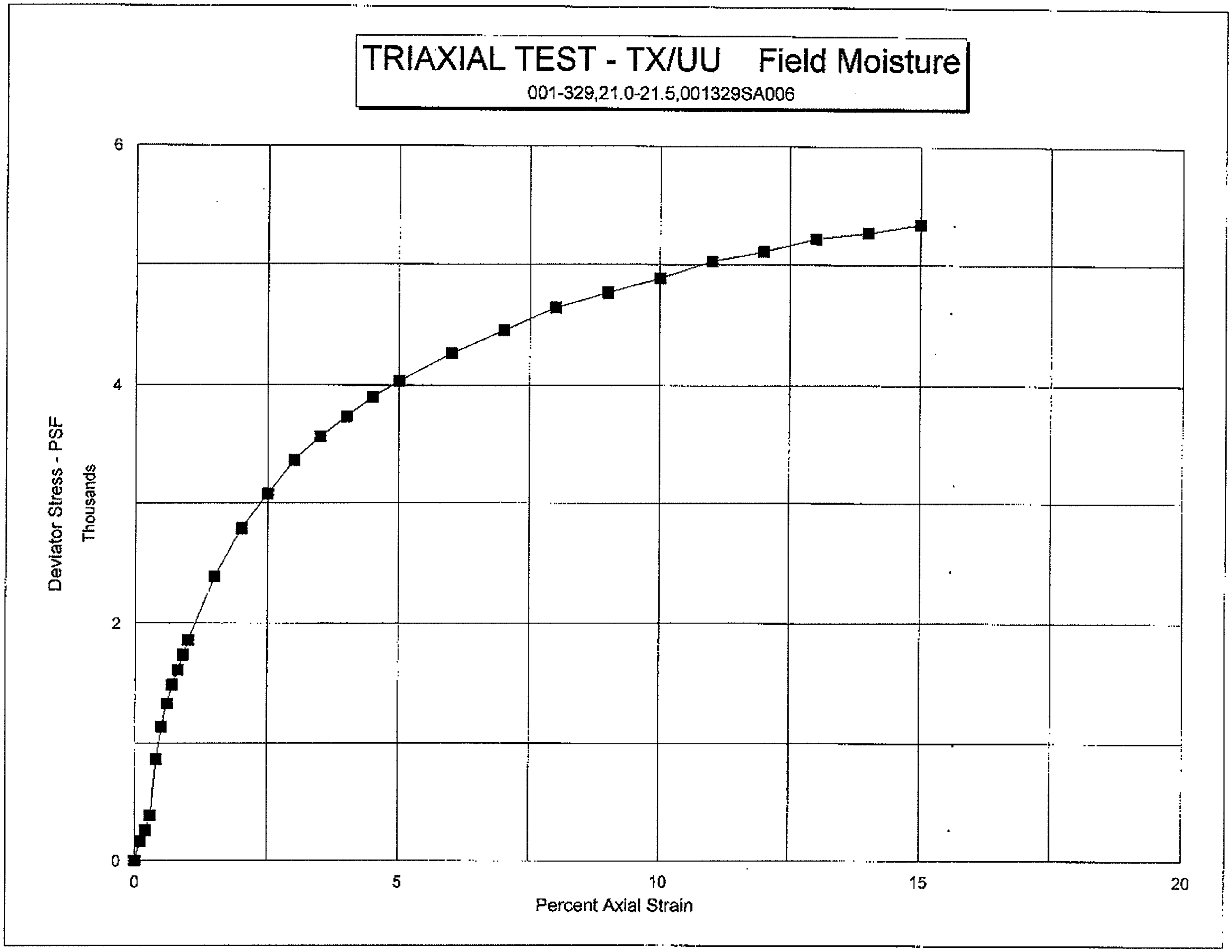
10
5
0
0
5
10
15
20
Percent Axial Strain

C-26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001-329,21.0-21.5,001329SA006
Deviator Stress - PSF
Thousands
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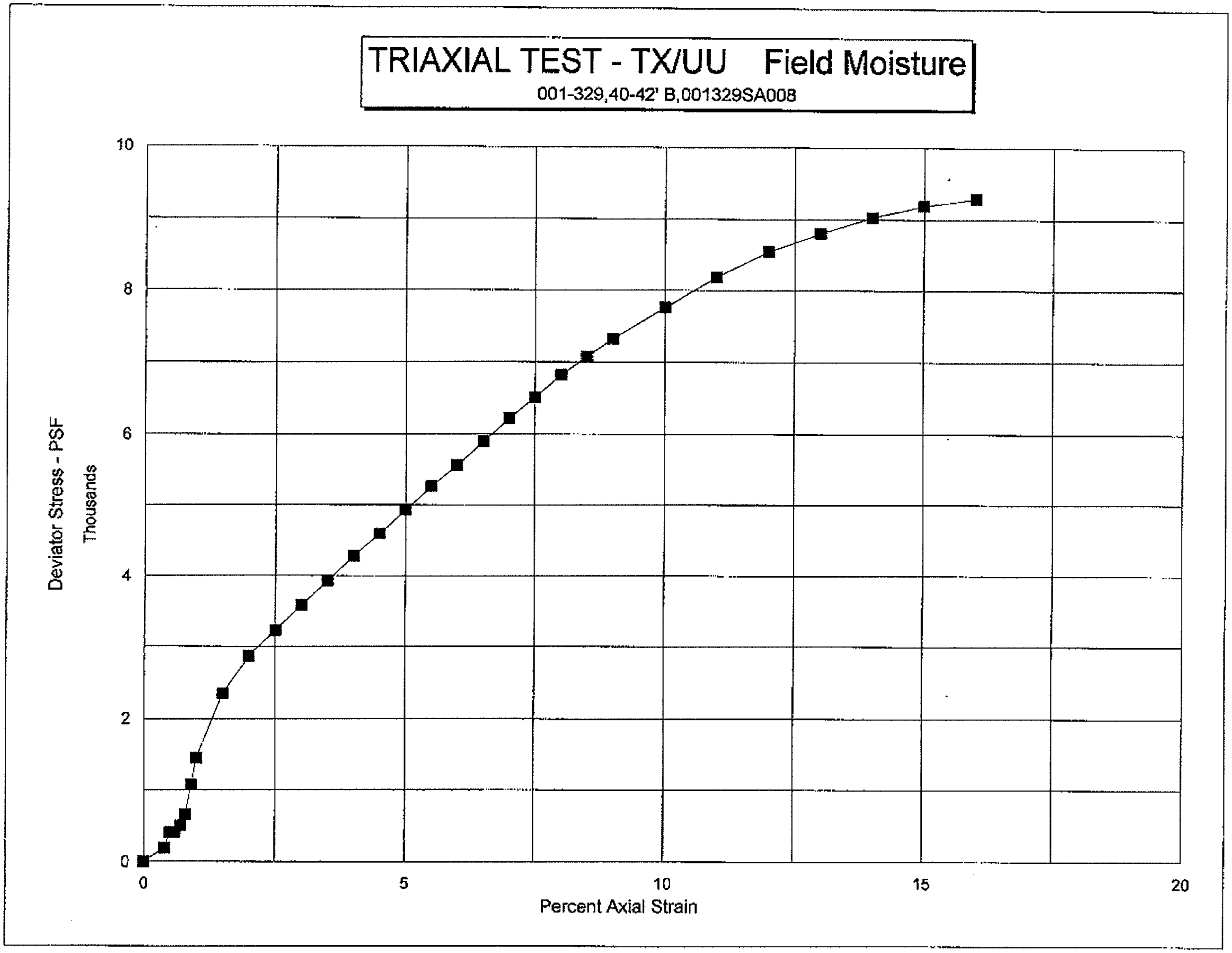
2
4
6
0
5
10
15
20
Percent Axial Strain



TRIAXIAL TEST - TX/UU Field Moisture
001-329,40-42' B,001329SA008
Deviator Stress - PSF
Thousands
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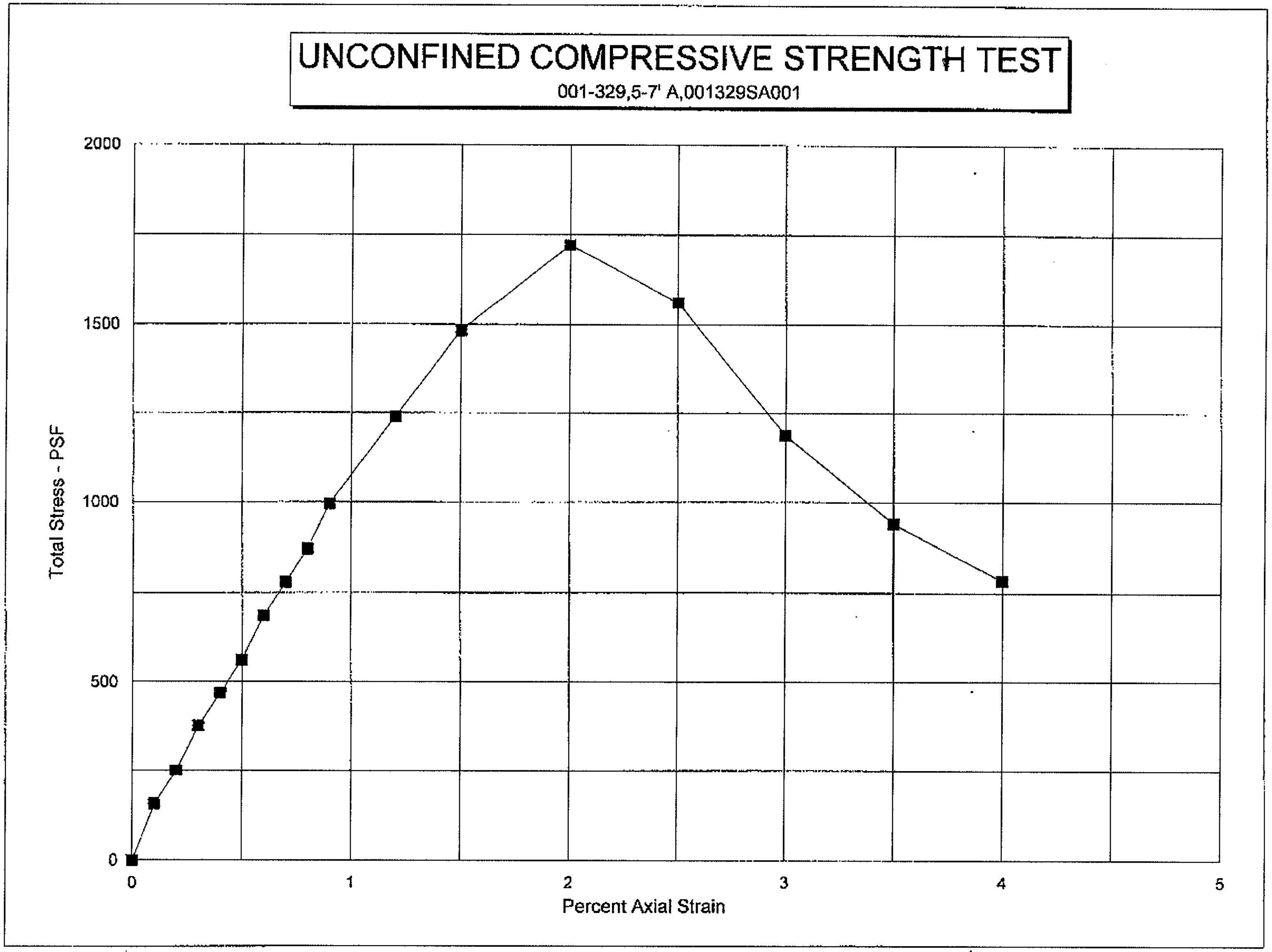
4
6
8
10
0
5
10
15
20
Percent Axial Strain



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500
0
Total Stress - PSF
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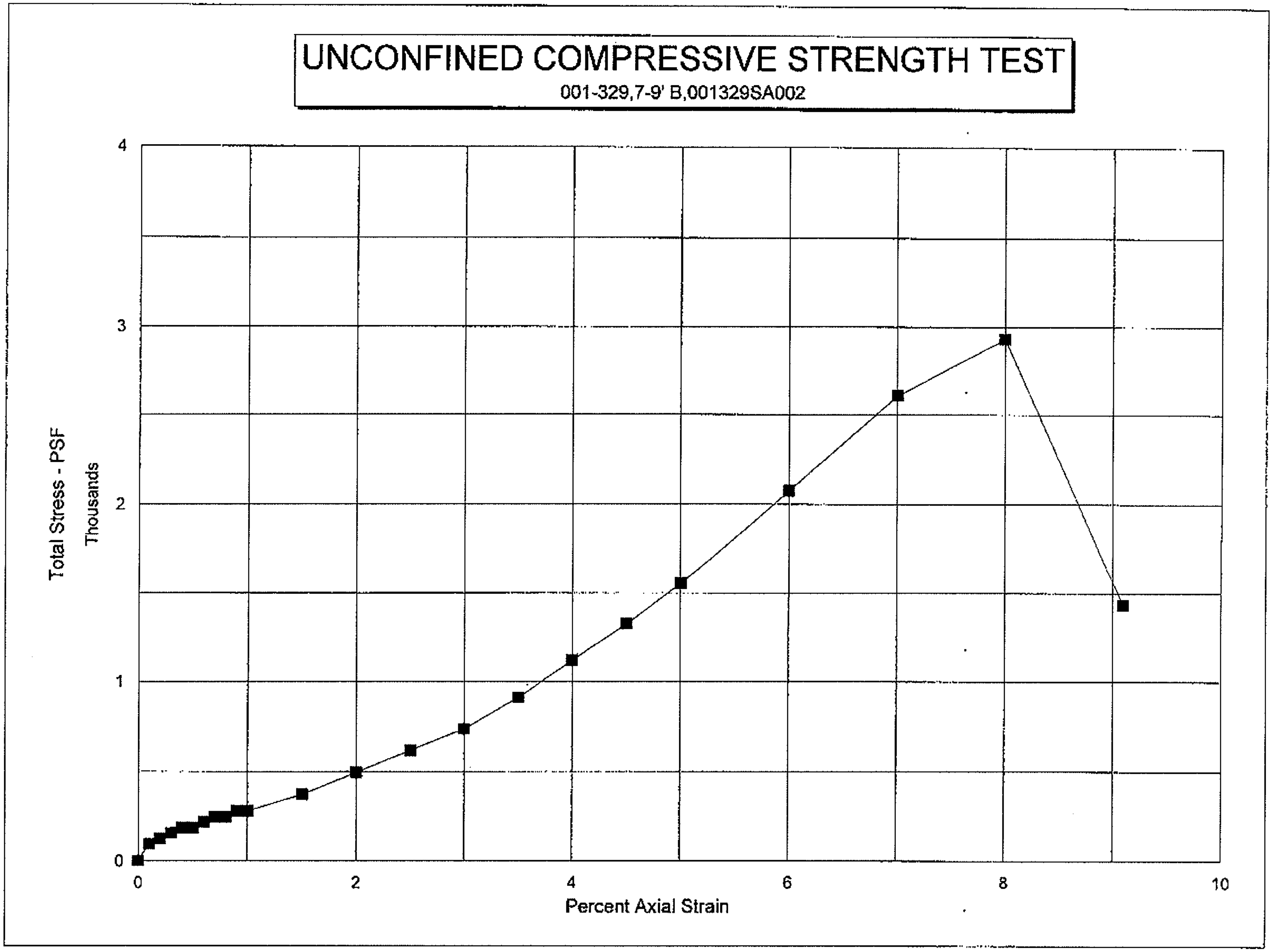
3
4
5
Percent Axial Strain



UNCONFINED COMPRESSIVE STRENGTH TEST
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Total Stress - PSF
Thousands
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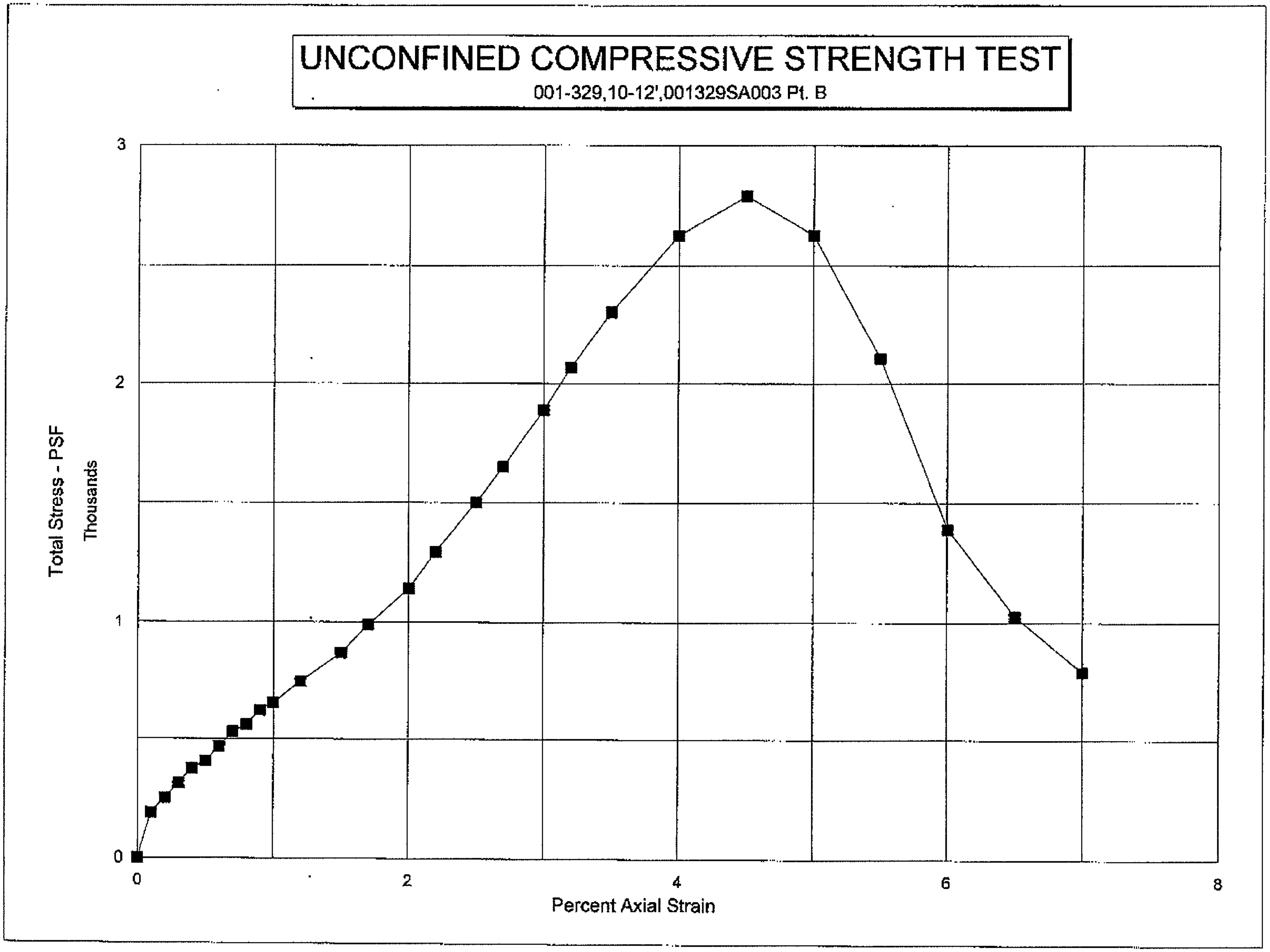
3
4
0
2
4
6
8
10
Percent Axial Strain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001-329,10-12',001329SA003 Pt. B
Total Stress - PSF
Thousands
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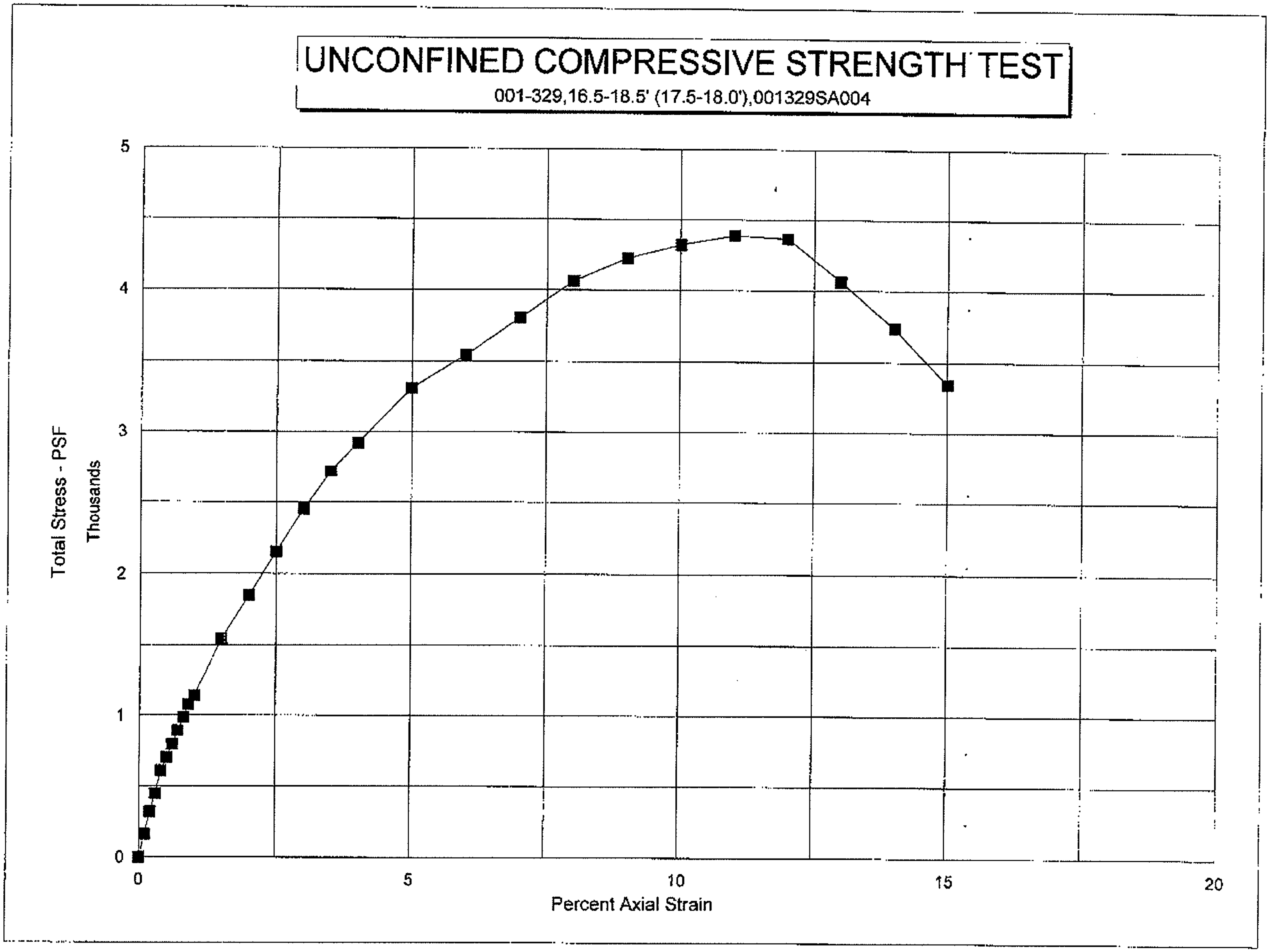
1
2
3
0
2
4
6
8
Percent Axial Strain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001-329,16.5-18.5' (17.5-18.0'),001329SA004
Total Stress - PSF
Thousands
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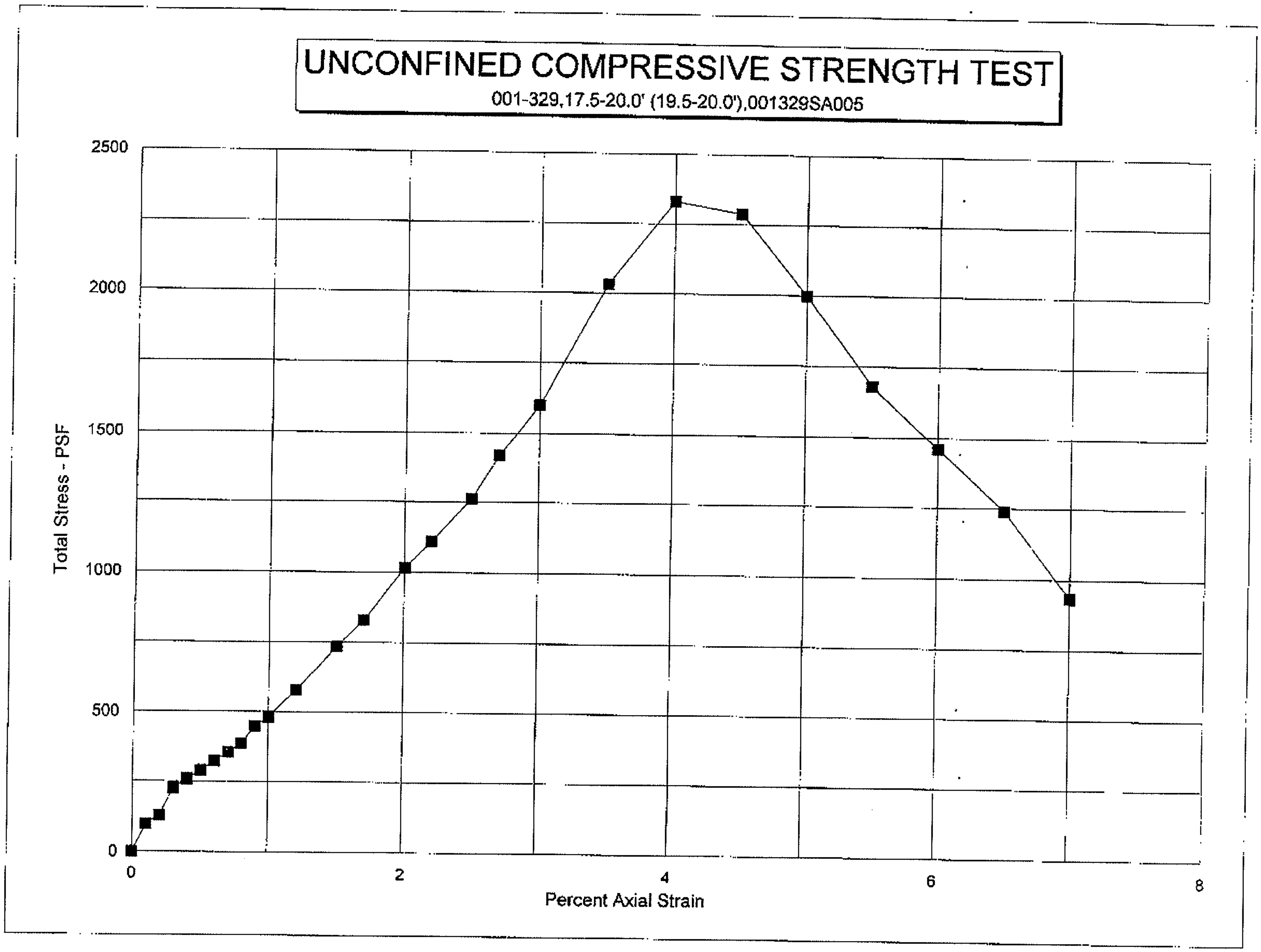
1
2
3
4
5
0
5
10
15
20
Percent Axial Strain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Total Stress - PSF
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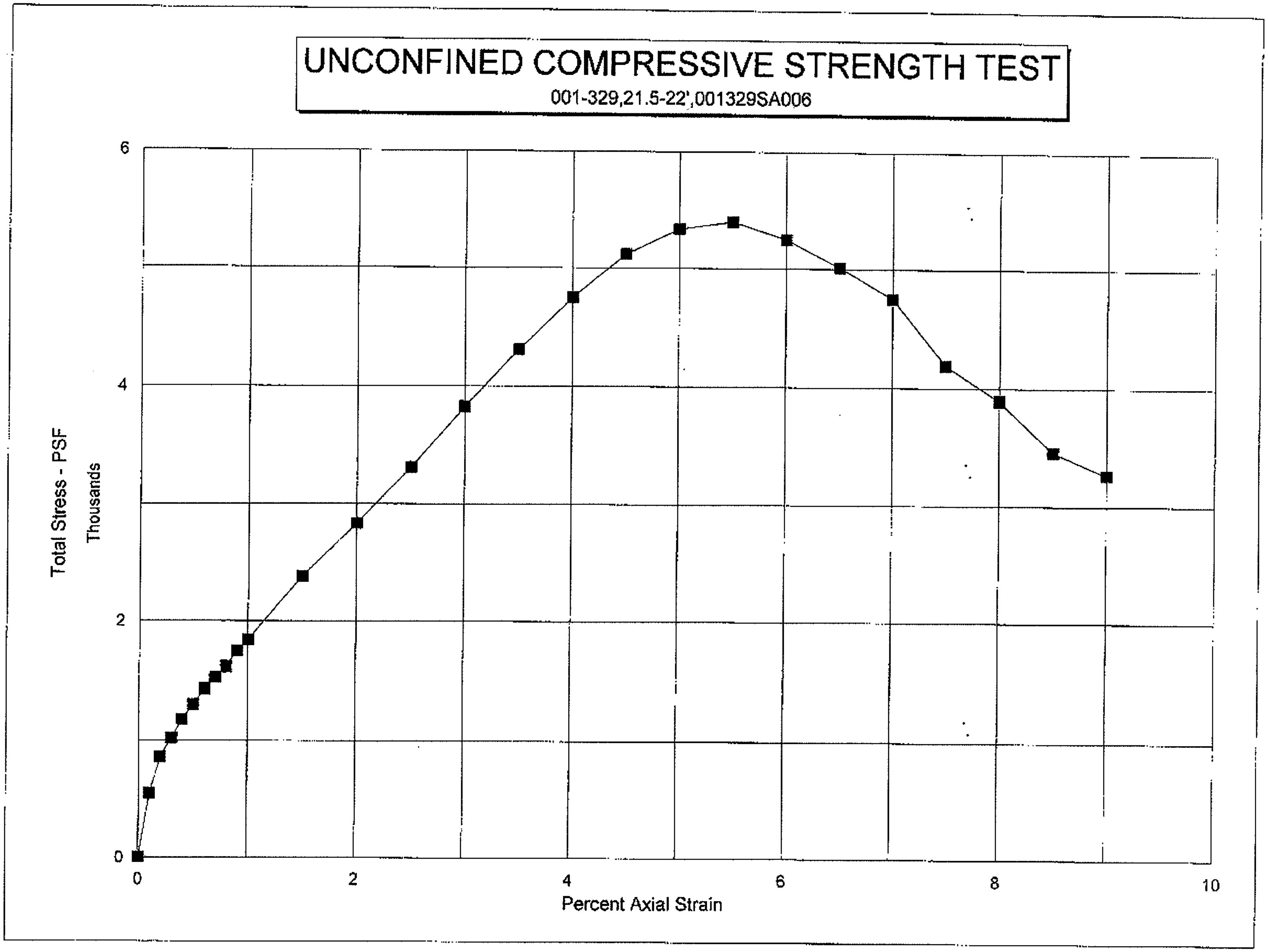
0
0
2
4
6
8
Percent Axial Strain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001-329,21.5-22',001329SA006
Total Stress - PSF
Thousands
Percent Axial Strain
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4
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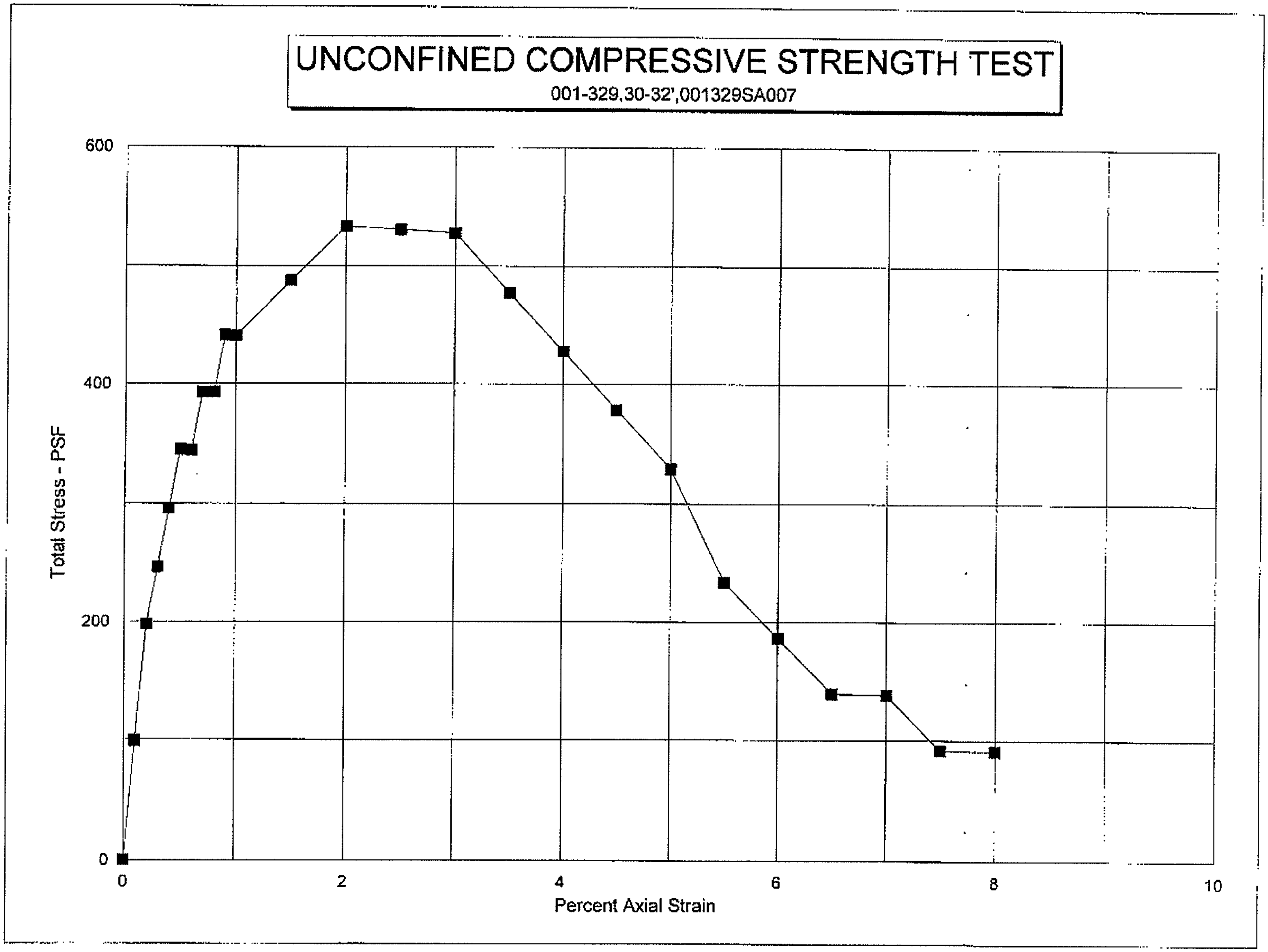
2
4
6
8
10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Total Stress - PSF
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200
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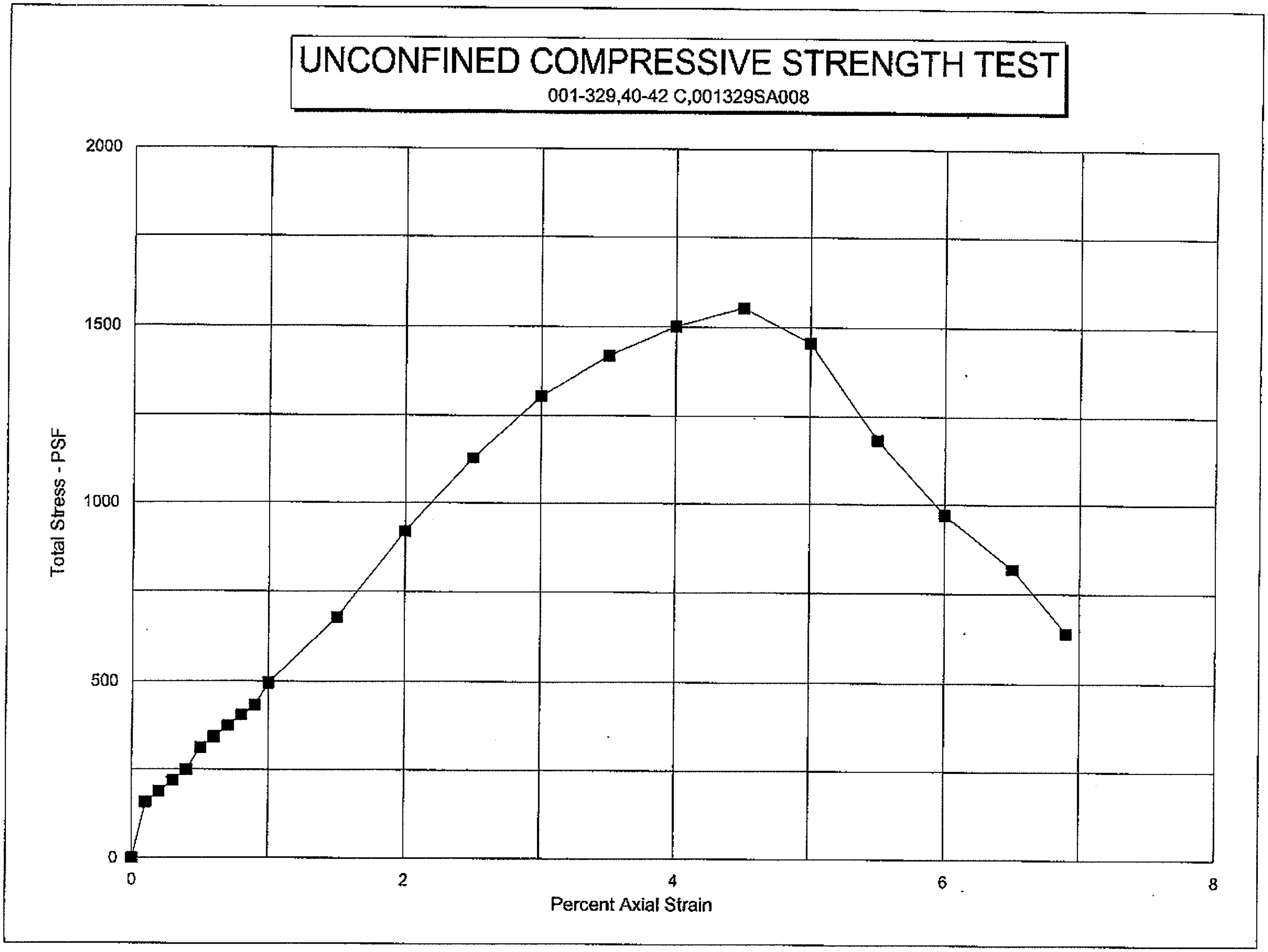
0
2
4
6
8
10
Percent Axial Strain


UNCONFINED COMPRESSIVE STRENGTH TEST
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Total Stress - PSF
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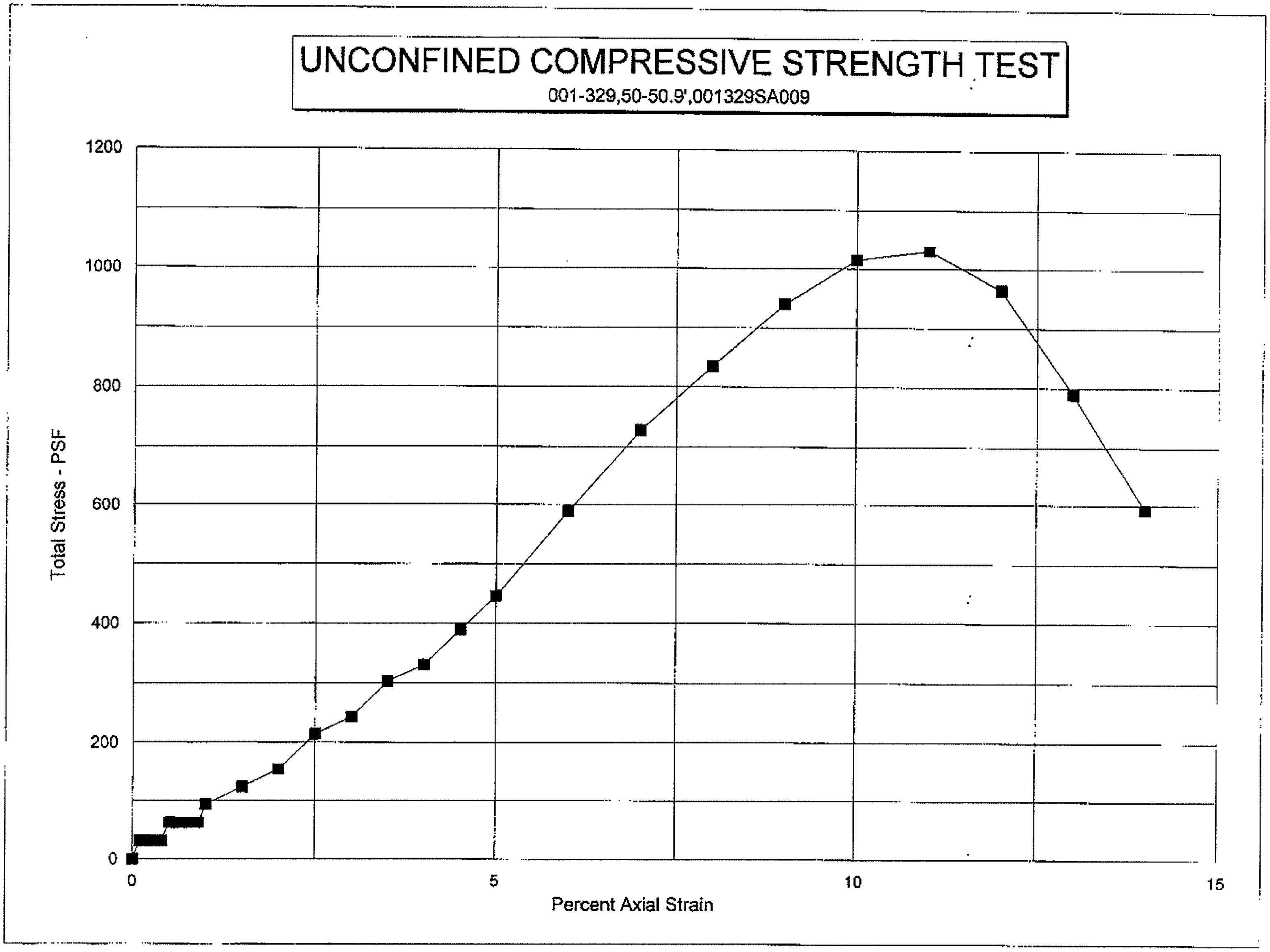
1500
1000
500
0
0
2
4
6
8
Percent Axial Strain


UNCONFINED COMPRESSIVE STRENGTH TEST
001-329,50-50.9',001329SA009
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1000
800
600
400
200
0
Total Stress - PSF
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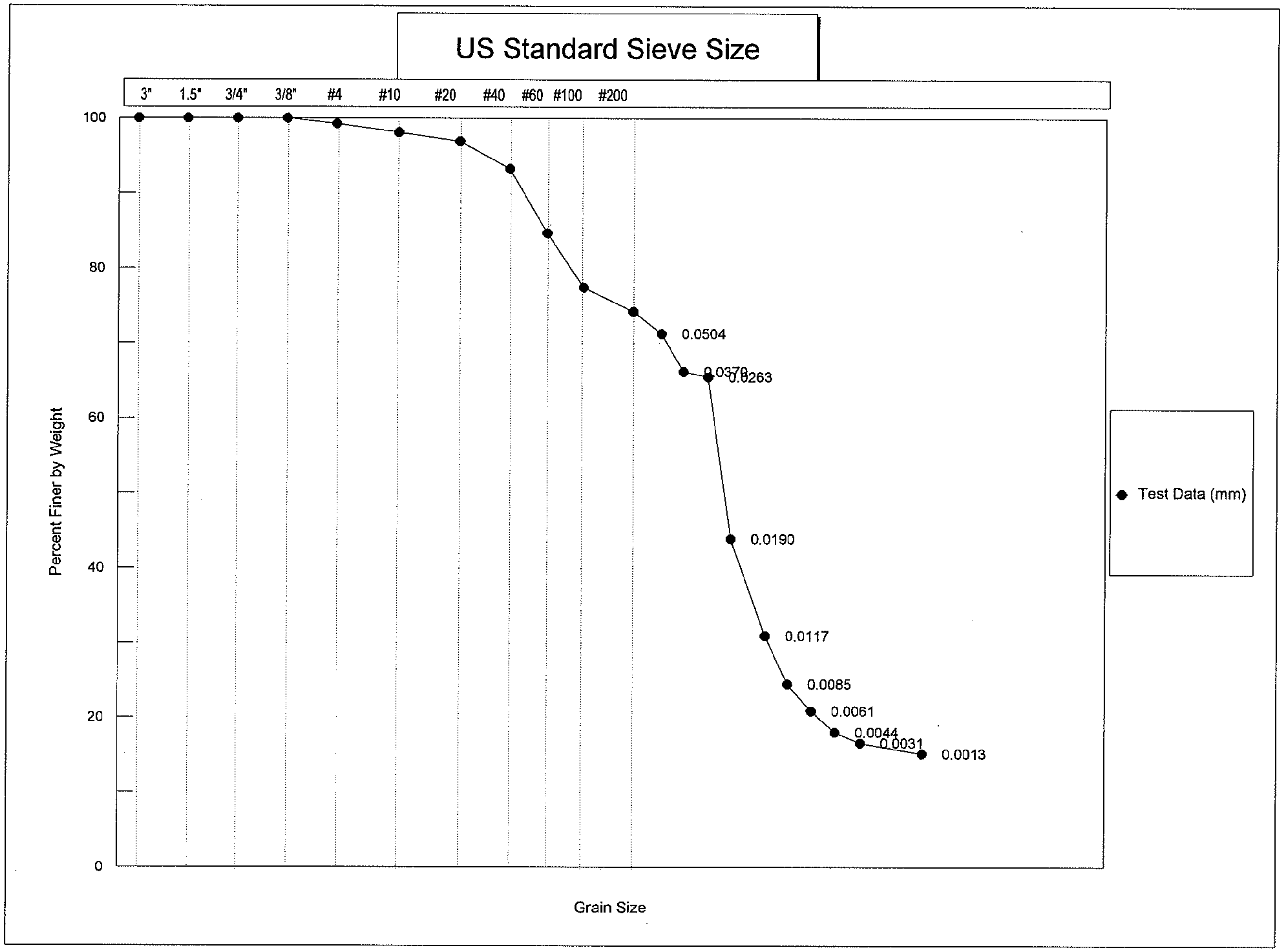
5
10
15
Percent Axial Strain



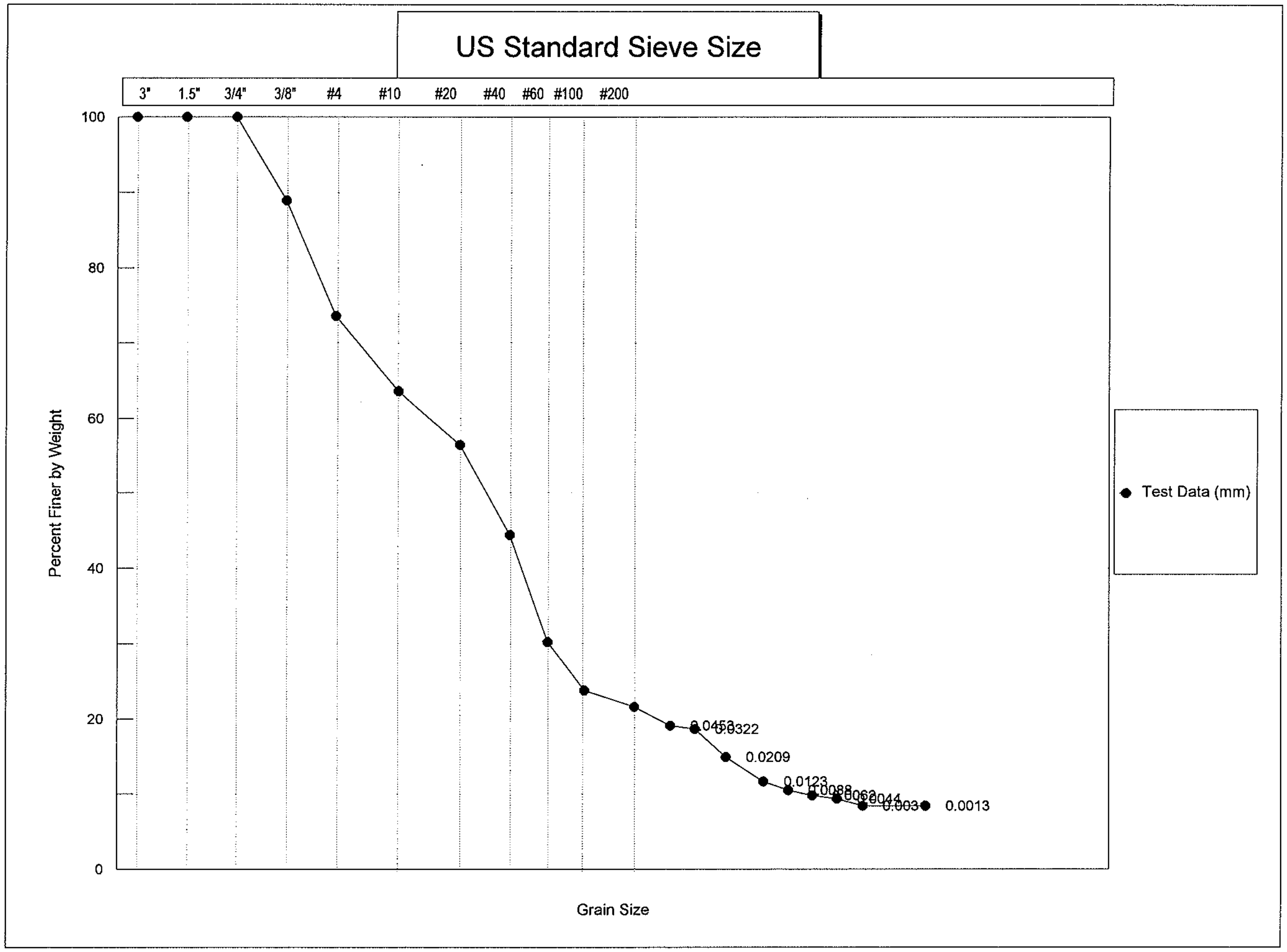

| COBBLES | GRAVEL | | SAND | | | SILT OR CLAY (mm) | USCS |
|---|---|---|---|---|---|---|---|
| | COARSE | FINE | CRS | MEDIUM | FINE | | |

| COBBLES TO BOULDERS | PEBBLE GRAVEL | | | | SAND | | | SILT | CLAY | WENTWORTH |
|---|---|---|---|---|---|---|---|---|---|---|
| | COARSE | MED | FINE | GRAN | COARSE | MED | FINE | | | |

Client: LATA Kentucky    Boring No.: 001-306    Sample No.: 001306GRNSZ1

Job Number: 2855-01    Depth: 10-13'

Classification: **Classification Not Performed**



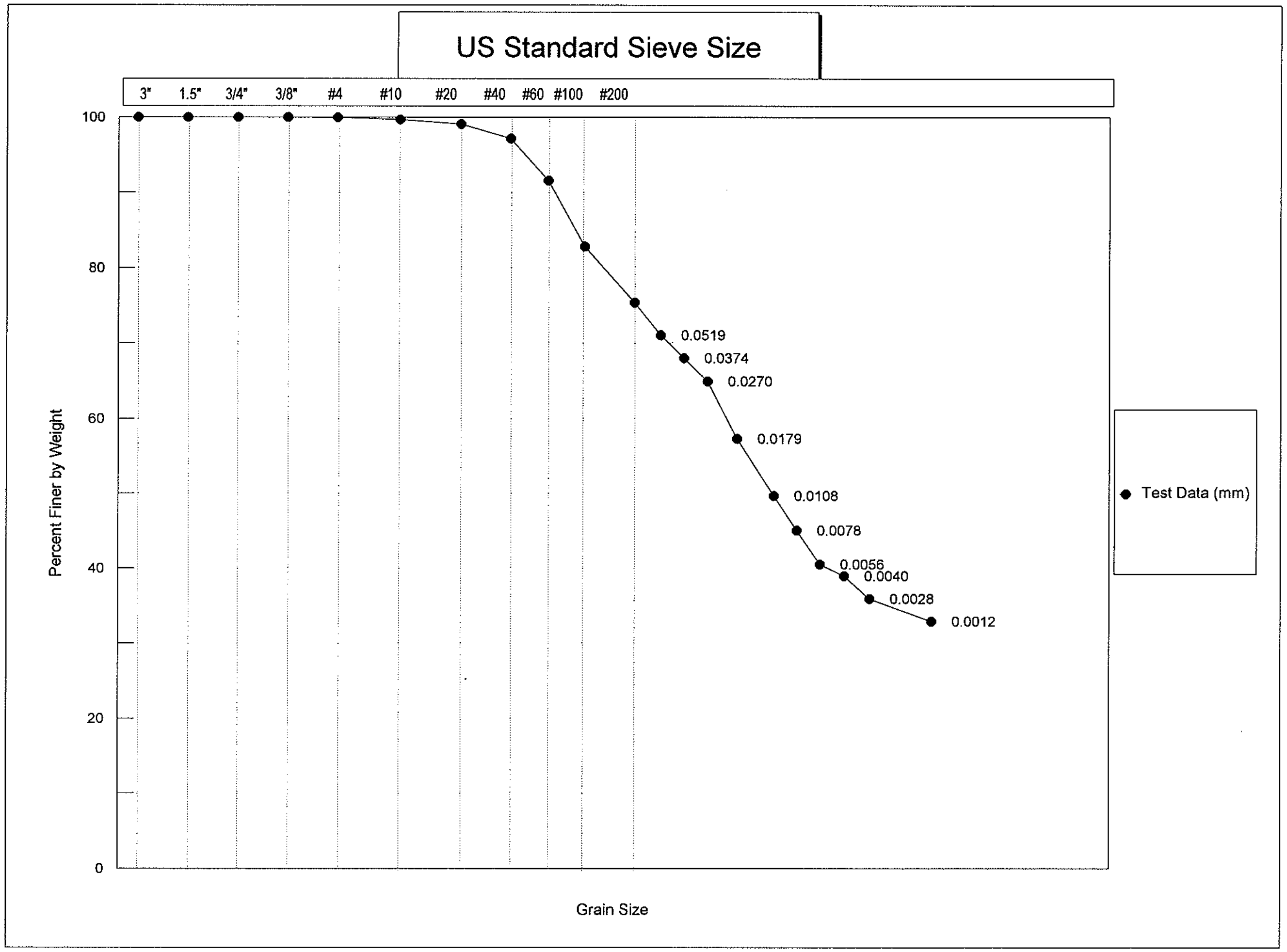

| COBBLES | GRAVEL | | SAND | | | SILT OR CLAY (mm) |
|---|---|---|---|---|---|---|
| | COARSE | FINE | CRS | MEDIUM | FINE | |

USCS

| COBBLES TO BOULDERS | PEBBLE GRAVEL | | | | SAND | | | SILT | CLAY |
|---|---|---|---|---|---|---|---|---|---|
| | COARSE | MED | FINE | GRAN | COARSE | MED | FINE | | |

WENTWORTH

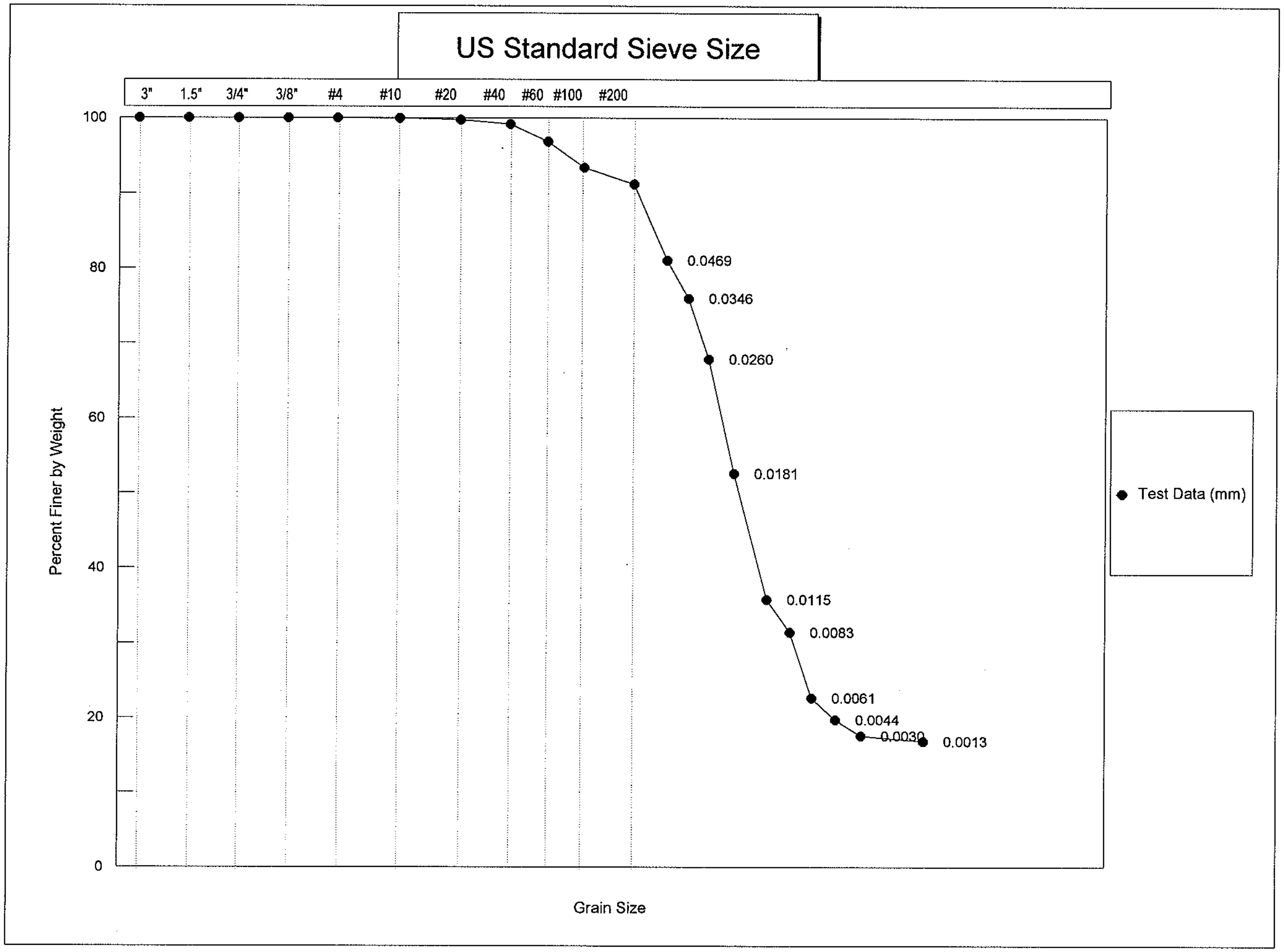
Client: LATA Kentucky
Boring No.: 001-306
Sample No.: 001306GRNSZ2
Job Number: 2855-01
Depth: 15-20'
Classification: **Classification Not Performed**




| COBBLES | GRAVEL | | SAND | | | SILT OR CLAY (mm) | |
|---|---|---|---|---|---|---|---|
| | COARSE | FINE | CRS | MEDIUM | FINE | | USCS |

| COBBLES TO BOULDERS | PEBBLE GRAVEL | | | | SAND | | | SILT | CLAY | |
|---|---|---|---|---|---|---|---|---|---|---|
| | COARSE | MED | FINE | GRAN | COARSE | MED | FINE | | | WENTWORTH |

Client: LATA Kentucky
Boring No.: 001-306
Sample No.: 001306GRNSZ3
Job Number: 2855-01
Depth: 32.7-34.0'
Classification: **Classification Not Performed**




| COBBLES | GRAVEL | | SAND | | | SILT OR CLAY (mm) |
|---|---|---|---|---|---|---|
| | COARSE | FINE | CRS | MEDIUM | FINE | |

USCS

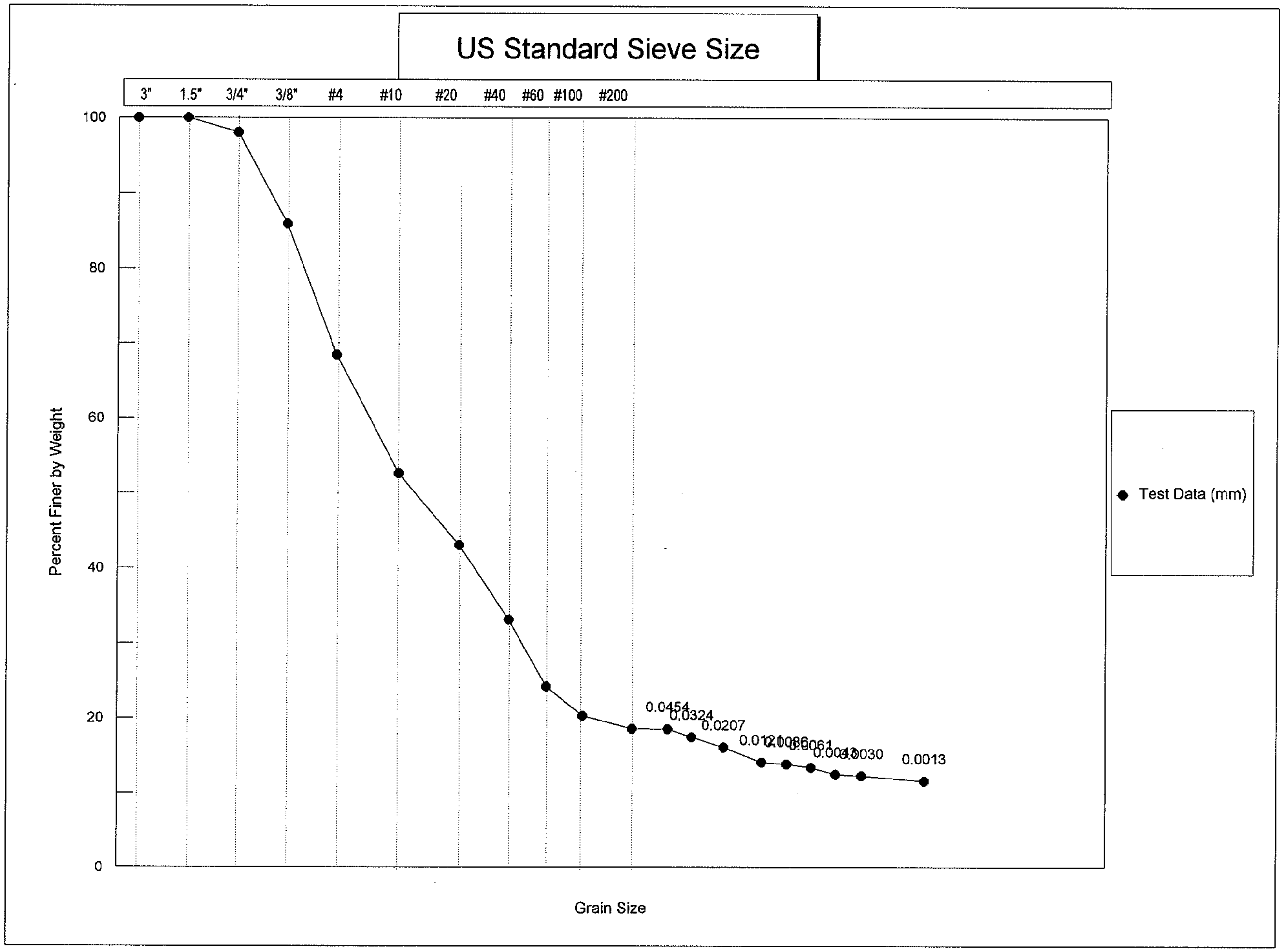
| COBBLES TO BOULDERS | PEBBLE GRAVEL | | | | SAND | | | SILT | CLAY |
|---|---|---|---|---|---|---|---|---|---|
| | COARSE | MED | FINE | GRAN | COARSE | MED | FINE | | |

WENTWORTH

Client: LATA Kentucky Boring No.: 001-307 Sample No.: 001307GRNSZ1

Job Number: 2855-01 Depth: 12.5-14.6'

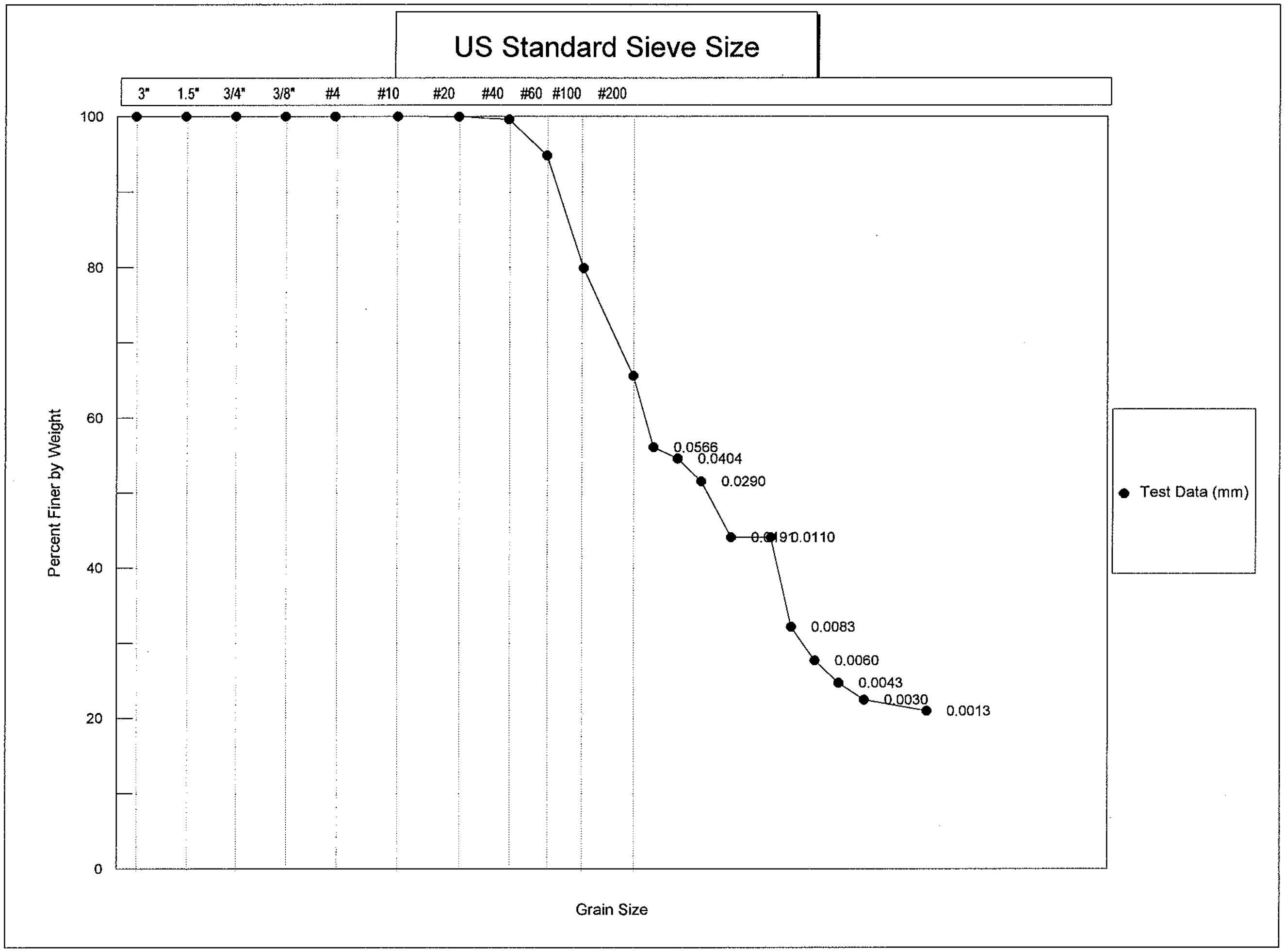
Classification: **Classification Not Performed**




| COBBLES | GRAVEL | | SAND | | | SILT OR CLAY (mm) | USCS |
|---|---|---|---|---|---|---|---|
| | COARSE | FINE | CRS | MEDIUM | FINE | | |

| COBBLES TO BOULDERS | PEBBLE GRAVEL | | | | SAND | | | SILT | CLAY | WENTWORTH |
|---|---|---|---|---|---|---|---|---|---|---|
| | COARSE | MED | FINE | GRAN | COARSE | MED | FINE | | | |

Client: LATA Kentucky
Job Number: 2855-01
Boring No.: 001-307
Depth: 19.4-21.9'
Sample No.: 001307GRNSZ2
Classification: <u>**Classification Not Performed**</u>



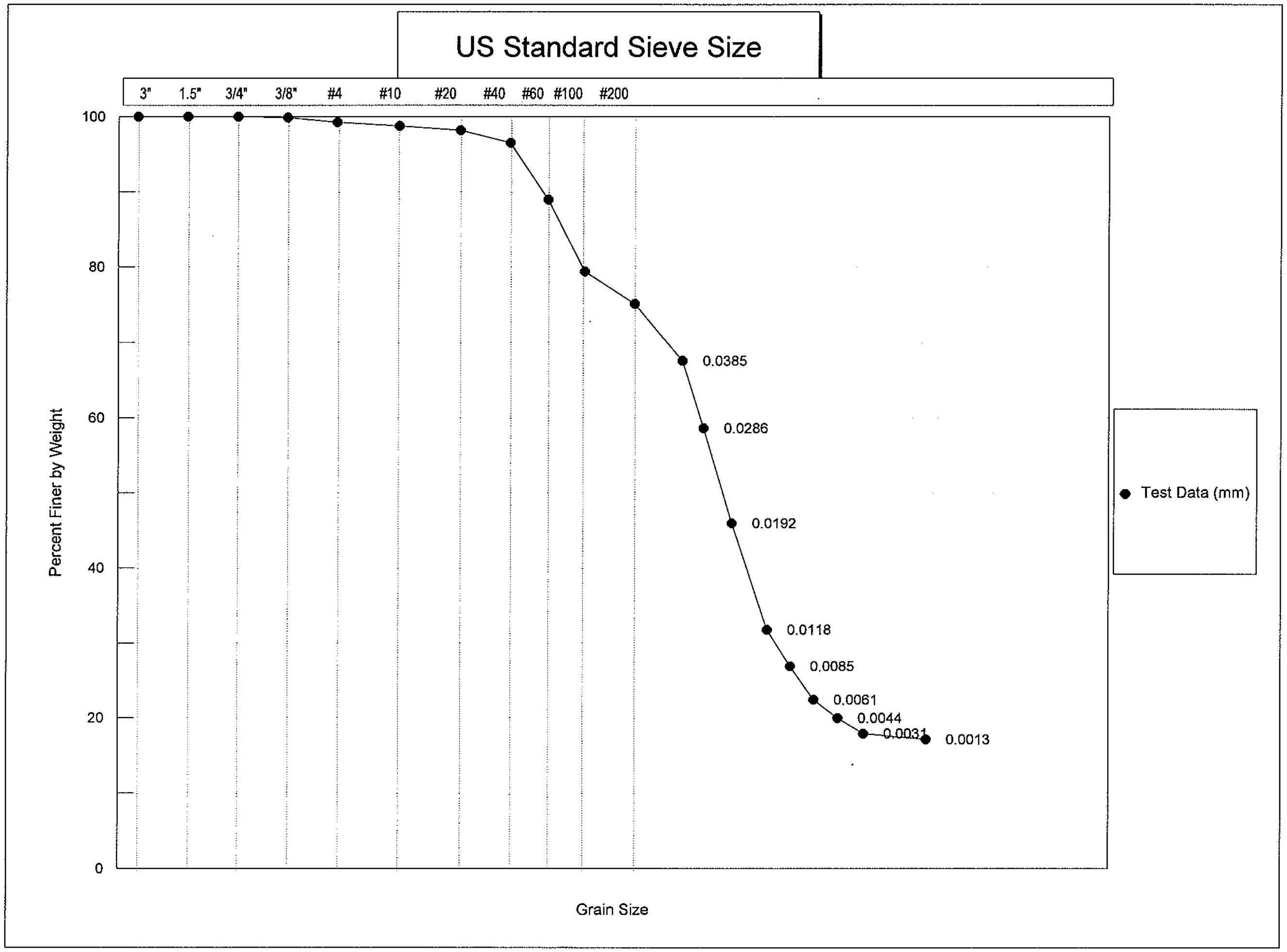

| COBBLES | GRAVEL | | SAND | | | SILT OR CLAY (mm) |
|---|---|---|---|---|---|---|
| | COARSE | FINE | CRS | MEDIUM | FINE | |

USCS

| COBBLES TO BOULDERS | PEBBLE GRAVEL | | | | SAND | | | SILT | CLAY |
|---|---|---|---|---|---|---|---|---|---|
| | COARSE | MED | FINE | GRAN | COARSE | MED | FINE | | |

WENTWORTH

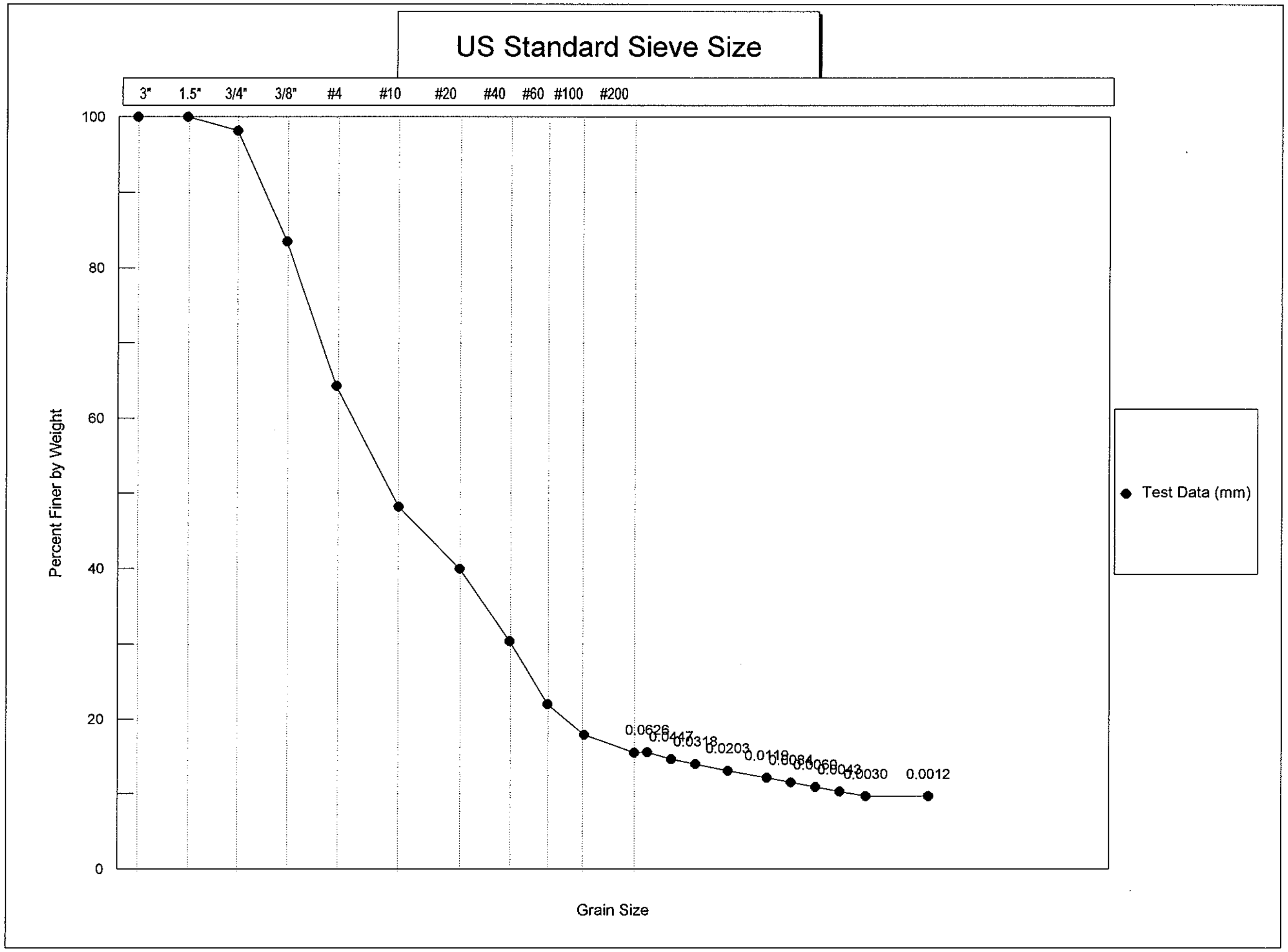
Client: LATA Kentucky
Boring No.: 001-307
Sample No.: 001307GRNSZ3
Job Number: 2855-01
Depth: 30.0-33.7'
Classification: **Classification Not Performed**




| COBBLES | GRAVEL | | SAND | | | SILT OR CLAY (mm) | USCS |
|---|---|---|---|---|---|---|---|
| | COARSE | FINE | CRS | MEDIUM | FINE | | |

| COBBLES TO BOULDERS | PEBBLE GRAVEL | | | | SAND | | | SILT | CLAY | WENTWORTH |
|---|---|---|---|---|---|---|---|---|---|---|
| | COARSE | MED | FINE | GRAN | COARSE | MED | FINE | | | |

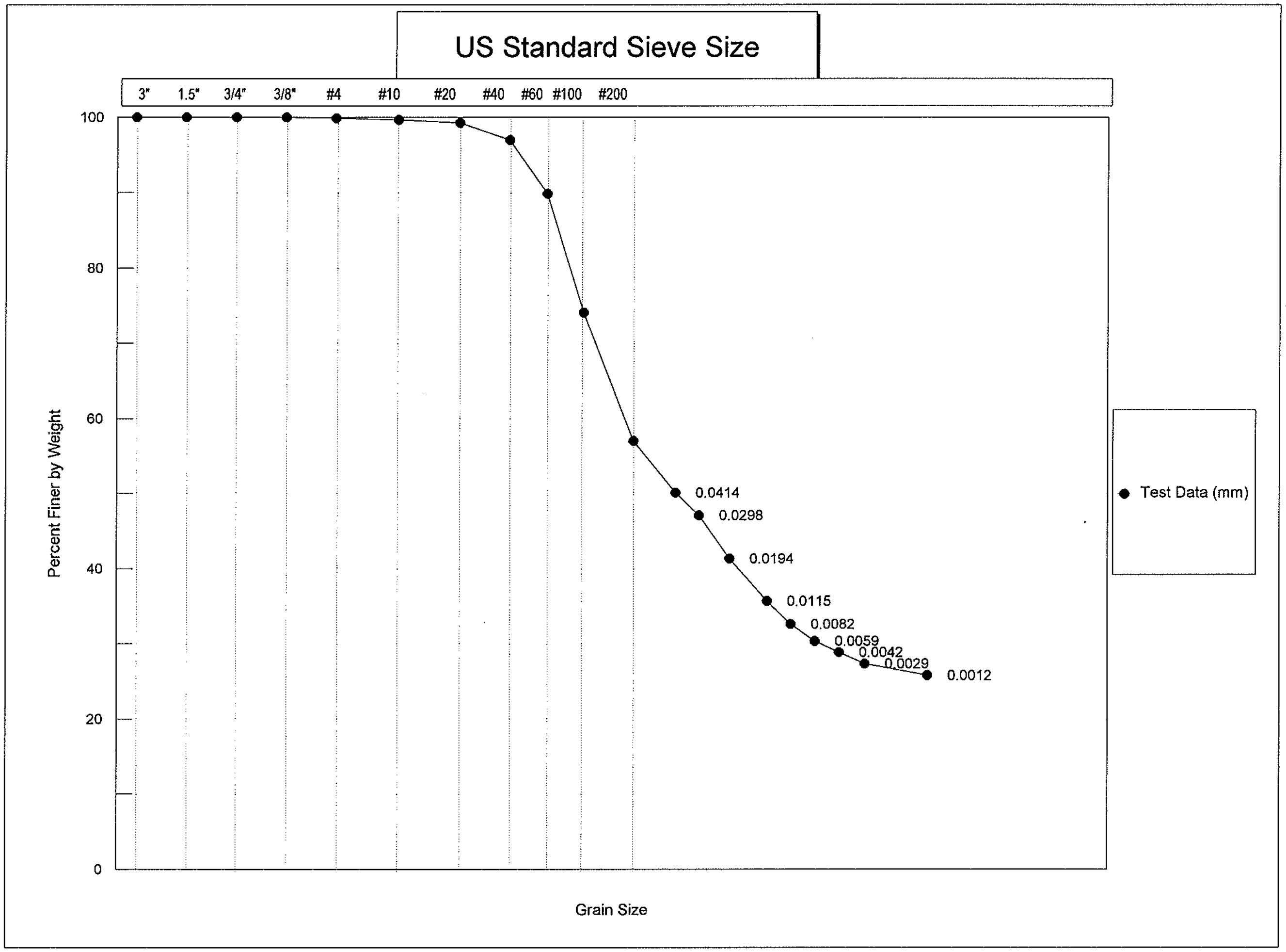
Client: LATA Kentucky  Boring No.: 001-316  Sample No.: 001316GRNSZ1
Job Number: 2855-01  Depth: 10-14'
Classification: **Classification Not Performed**




| COBBLES | GRAVEL | | SAND | | | SILT OR CLAY (mm) | USCS |
|---|---|---|---|---|---|---|---|
| | COARSE | FINE | CRS | MEDIUM | FINE | | |

| COBBLES TO BOULDERS | PEBBLE GRAVEL | | | | SAND | | | SILT | CLAY | WENTWORTH |
|---|---|---|---|---|---|---|---|---|---|---|
| | COARSE | MED | FINE | GRAN | COARSE | MED | FINE | | | |

Client: LATA Kentucky    Boring No.: 001-316    Sample No.: 001316GRNSZ2
Job Number: 2855-01    Depth: 20-23'
Classification: **Classification Not Performed**




| COBBLES | GRAVEL | | SAND | | | SILT OR CLAY (mm) | USCS |
|---|---|---|---|---|---|---|---|
| | COARSE | FINE | CRS | MEDIUM | FINE | | |

| COBBLES TO BOULDERS | PEBBLE GRAVEL | | | | SAND | | | SILT | CLAY | WENTWORTH |
|---|---|---|---|---|---|---|---|---|---|---|
| | COARSE | MED | FINE | GRAN | COARSE | MED | FINE | | | |

Client: LATA Kentucky Boring No.: 001-316 Sample No.: 001316GRNS~~23~~Z3 gkm 8/27/12

Job Number: 2855-01 Depth: 32-35'

Classification: **Classification Not Performed**

# APPENDIX D

# AIR DISPERSION ANALYSIS

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# D.1 AIR DISPERSION ANALYSIS

## D.1.1 INTRODUCTION

This appendix describes the air dispersion analysis of potential hazardous air pollutant emissions from the implementation of the remedial action (RA) to be implemented at the Southwest Groundwater Plume source area at Paducah Gaseous Diffusion Plant at Solid Waste Management Unit (SWMU) 1. The property boundary concentrations for potential hazardous air pollutant (HAP) and/or toxic air pollutant (TAP) emissions were estimated using BREEZE AERMOD version 7.6. Report printouts and electronic model-ready input files are included in the attachment to this appendix.

The BREEZE AERMOD version 7.6 program conducts air dispersion modeling using the latest version (12060) of the American Meteorological Society Environmental Protection Agency Regulatory Model (AERMOD) to estimate maximum ground-level concentrations. AERMOD is a steady-state plume model that incorporates air dispersion based on planetary boundary layer turbulence structure and scaling concepts, including treatment of both surface and elevated sources, and both simple and complex terrain.

Ground-level concentrations were calculated within one Cartesian receptor grid and at receptors placed along the property line. The property line grid receptors were spaced at a maximum of approximately 50 m apart and the Cartesian receptor grid extending out beyond the property line to 600 m were spaced 200 m apart in all directions. The Cartesian receptor grid was generated to ensure concentrations were decreasing away from the property line. All resultant maximum concentrations occur well within this distance.

AERMOD uses advanced terrain characterization to account for the effects of terrain features on plume dispersion and travel. AERMOD's terrain pre-processor, AERMAP (latest version 11103), imports digital terrain data and computes a height scale for each receptor from National Elevation Dataset (NED) data files. A height scale is assigned to each individual receptor and is used by AERMOD to determine whether the plume will go over or around a hill.

The receptor terrain elevations input into AERMAP are the highest elevations extracted from United States Geological Survey 1:24,000 scale (7.5-minute series) NED data for the area surrounding the site. For each receptor, the maximum possible elevation within a box centered on the receptor of concern and extending halfway to each adjacent receptor was chosen. This is a conservative technique for estimating terrain elevations in that it ensures that the highest terrain elevations are accounted for in the analysis.

The emission unit was evaluated in terms of its proximity to nearby structures. The purpose of this evaluation was to determine if stack discharge might become caught in the turbulent wakes of these structures leading to downwash of the plume. Wind blowing around a building creates zones of turbulence that are greater than if the building were absent. The current version of the AERMOD dispersion model treats building wake effects following the algorithms developed by Schulman and Scire. This approach requires the modeler to input wind direction specific building dimensions for structures located within 5L of a stack, where L is the lesser of the height or projected width of a nearby structure. Stacks taller than the structure height plus 1.5L are not subject to the effects of downwash in the AERMOD model. The emissions unit's stack height is greater than the good engineering practice stack height. Therefore, there are no buildings which are considered nearby for the purposes of modeling and no further evaluation of cavity or wake effects is required.

### D.1.2 IDENTIFICATION OF TOXIC POLLUTANTS

The potential HAPs/TAPs that could be emitted by the RA (large diameter auger soil mixing with steam and zero-valent iron injection) have been identified based on soil characterization. The soil treatment area characterization is documented in the 90% Remedial Design Report and previous investigation reports for SWMU 1. The potential HAPs/TAPs that could be emitted are trichloroethene (TCE), vinyl chloride, *trans*-1,2-dichloroethene (DCE), *cis*-1,2-DCE, and 1,1-DCE.

### D.1.3. ALLOWABLE OFF-SITE CONCENTRATIONS CALCULATIONS

The treated vapor/gases must comply with the contaminant concentration requirements of 401 *KAR* 63:020. This states that no owner or operator shall allow any affected facility to emit potentially hazardous matter or toxic substances in such quantities or duration as to be harmful to the health and welfare of humans, animals and plants.

#### D.1.3.1 TCE and Vinyl Chloride Allowable Off-Site Concentrations

The allowable off-site concentrations of TCE and vinyl chloride are based on the U.S. Environmental Protection Agency (EPA) Air Toxics Risk Assessment Reference Library, Volume 2, Facility Specific Assessment. These values were obtained from the EPA Web site, located at the following address: http://www.epa.gov/ttn/atw/toxsource/table1.pdf.

Both TCE and vinyl chloride are possible carcinogens. The cancer chronic inhalation value for each is used in calculating the maximum allowable concentration. The value for TCE is 4.1E-06 per µg/m$^3$ and the value for vinyl chloride is 0.0000088 per µg/m$^3$. The allowable risk is assumed to be 1 x 10$^{-6}$. The maximum allowable concentration is calculated by the following formula:

Allowable Risk = Estimate of continuous inhalation exposure × Inhalation Unit Risk Estimate

Or

Estimate of continuous inhalation exposure = Allowable Risk/Inhalation Unit Risk Estimate

For TCE the calculation would be as follows:

TCE Allowable concentration = 1 x 10$^{-6}$/4.1E-06 per µg/m$^3$

TCE Allowable concentration = 0.24 µg/m$^3$

Using the same approach for vinyl chloride, the allowable concentration would be 0.11 µg/m$^3$.

#### D.1.3.2 DCE Allowable Off-Site Concentrations

The maximum allowable air concentrations for dichloroethene were calculated using the EPA Region 9 regional screening levels (RSLs), formerly referred to as preliminary remediation goals, which are available from the EPA's Web site at http://www.epa.gov/region9/superfund//prg/index.html. These values are based on the noncancer risks posed by long-term exposure to DCE. The health effects of exposure to DCE are measured by a hazardous index, with a hazard index of 1 being an indication of the nearest off-site receptor having detrimental health effects from exposure to that chemical. Two distinct RSLs apply for each chemical form of DCE for residential and industrial. The residential RSLs were used to develop allowable off-site concentration limits since they are lower and more conservative than industrial.

DCE is present in three chemical forms, 1,1-DCE; *cis*-1,2-DCE, and *trans*-1.2-DCE. The ambient air allowable off-site concentration for each chemical form is 1,1-DCE—210 μg/m$^3$; *cis*-1,2-DCE—37 μg/m$^3$; and *trans*-1,2-DCE—63 μg/m$^3$. The allowable off-site concentrations for 1,1-DCE and *trans*-1,2-DCE were selected from the most recent EPA publication of RSLs, which occurred in April 2012. The allowable off-site concentration value for *cis*-1,2-DCE was selected from the list of PRGs since EPA has not published a revised value for that chemical form since October 2004.

All of the allowable off-site concentrations are shown in Table D.1.

**Table D.1. Allowable Off-site Concentration Limits**

| Pollutant | Allowable Off-site Concentration (μg/m$^3$ ) | Reference Source |
|---|---|---|
| TCE | 0.24 | EAP Air Toxics Risk Assessment Reference Library, Volume 2, Facility Specific Assessment |
| Vinyl chloride | 0.11 | EAP Air Toxics Risk Assessment Reference Library, Volume 2, Facility Specific Assessment |
| 1,1-DCE | 210 | Regional Screening Levels, last updated April 2012 |
| *cis*-1,2-DCE | 37 | Preliminary Remediation Goals, last updated October 2004 |
| *trans*-1,2-DCE | 63 | Regional Screening Levels, last updated April 2012 |

## D.1.4 ESTIMATED EMISSION RATES

### D.1.4.1 Emissions

During operation of the project, the hazardous constituents in the subsurface will be volatilized underground and recovered by an off-gas extraction and vapor conditioning system. The system will capture the soil vapors, which will be treated and released through a stack. The current design uses three vapor-phase granular activated carbon (VGAC) units to remove hazardous constituents from the off-gas prior to discharge to the atmosphere. The current design criteria for the treatment system are such that each VGAC will have a removal efficiency of a minimum of 90% for HAP/TAP.

In order to estimate the maximum off-site concentration the exhaust was assumed to contain the maximum concentration of each HAP. The following preliminary design parameters for the stack were used in the model to estimate the dispersion of the hazardous constituents:

- 6-inch diameter
- 15-ft high
- 600 to 1,500 scfm flow rate
- 90°F exhaust gas temperature
- Stack will be equipped with a raincap

The vertical component of the stack exit velocity is required to be used in the air dispersion modeling analysis. Because the proposed stack will be outfitted with a raincap, the modeled stack exit velocity was set to 0.001 m per second.

The maximum emission rate in kilograms per day was estimated based on the following:

- A boring installation rate of 4 borings per 10-hour workday;
- The average mass concentration for each individual HAP/TAP for each boring, based on recent sampling results; and
- The estimated daily emission rates were converted to a gram-per-second emission rate using 24-hour averaging period.

The maximum emission rates during operation are listed in Table D.2 in both kilograms per day and grams per second.

**Table D.2. Estimated Emission Rates**

| **Chemical** | **Stack Design Concentration** | | |
|---|---|---|---|
| | Uncontrolled | Uncontrolled | Controlled |
| | kg/day | g/s | g/s |
| TCE | 68 | 7.87E-1 | 7.87E-04 |
| Vinyl chloride | 0.00256 | 2.96E-5 | 2.96E-08 |
| 1,1-DCE | 0.00152 | 1.76E-5 | 1.76E-08 |
| *cis*-1,2-DCE | 0.6 | 6.94E-3 | 6.94E-06 |
| *trans*-1,2-DCE | 0.00052 | 6.02E-6 | 6.02E-09 |

### D.1.4.3 Maximum Off-Site Concentrations

The property boundary ambient concentration for each HAP/TAP was estimated using the air dispersion model BREEZE AERMOD version 7.6.

Surface meteorology data from station number 3816 (Paducah, KY) and the nearest available upper air meteorology data from station 00013897 (Nashville, TN) were used. Dispersion analysis was performed using meteorological data from these stations for calendar year 2011 (January 1, 2011, through December 31, 2011). The AERMOD-ready meteorological files were purchased from Trinity Consultants, Inc.

The air dispersion modeling analysis was performed assuming an emission rate of one gram per second. The resulting maximum modeled concentration, averaged over the entire year, was then multiplied by the aforementioned pollutant-specific controlled emission rate to estimate the off-site concentration for each pollutant. The results of the air dispersion modeling analysis suggest that the maximum annual average concentration occurs at a receptor (338083.60, 4109076.70) along the property boundary southeast of the proposed stack location, as illustrated in Figure D.1.


**Figure D.1. Maximum Annual Average Concentration Receptor Location**

The estimated maximum annual average concentration for each pollutant is shown in Table D.3.

**Table D.3. Estimated Off-Site Concentrations**

| Chemical | Off-Site Concentration Limit | Annual Average Maximum Off-Site Concentration |
|---|---|---|
| | μg/m$^3$ | μg/m$^3$ |
| TCE | 0.24 | 1.37E-02 |
| vinyl chloride | 0.11 | 5.14E-07 |
| 1,1-DCE | 210 | 3.05E-07 |
| *cis*-1,2-DCE | 37 | 1.2E-04 |
| *trans*-1,2-DCE | 63 | 1.04E-07 |

The results of this air dispersion modeling analysis show the estimated maximum annual average concentration for each pollutant will be below the corresponding maximum allowable off-site concentration. Therefore, emissions associated with this project are not expected to be harmful to the health and welfare of humans, animals, or plants.

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# ATTACHMENT

# AIR DISPERSION ANALYSIS REPORTS AND MODEL-READY INPUT FILES

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**Attachment to this appendix information included on CD (see back cover).**

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