# SAMPLING AND ANALYSIS PLAN

FORMER CE CAST FACILITY / MUSE PROJECT
CECIL TOWNSHIP
WASHINGTON COUNTY, PENNSYLVANIA

Prepared For:
ABB, Inc.

AUGUST 2009
REF. NO. 055986 (2)

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## 1.0 INTRODUCTION

Conestoga-Rovers & Associates (CRA) has prepared this Sampling and Analysis Plan (SAP) for the former CE Cast Facility located in Muse, Pennsylvania (Site). CRA has prepared this SAP on behalf of ABB, Inc. (ABB). The SAP provides the procedures and analytical methods that will be used to further characterize the southern berm of the former landfill located on Site.

ABB has voluntarily closed the landfill at the Site as described in the Final Closure Report – Solid Waste Landfill (Final Closure Report). The objectives of the closure were to remove the landfill (cap, contents, and liner) and dispose of impacted material off Site. A secondary objective was to maximize the potential opportunity to demonstrate attainment with the Pennsylvania Land Recycling and Environmental Remediation Standards Act (Act 2) attainment standards at some time in the future. The Final Closure Report was submitted to the Pennsylvania Department of Environmental Protection (PADEP) in August 2009. PADEP has advised ABB that its successful execution of the work and subsequent approval of the Final Closure Report will supersede the requirements of the 1980 Consent Order and Agreement (COA).

During the completion of the landfill closure, ABB discovered that coal and coal fines were present in the southern berm that formed the outside southern boundary of the landfill. Based on this discovery, ABB's contractor, MACTEC Engineering and Consulting, Inc. (MACTEC), excavated five test pits into the southern berm to investigate and visually classify the material. The results of MACTEC's investigation are summarized in Section 2.0, below. MACTEC concluded that a layer of coal material was present in this berm. This coal material was not similar to the landfill waste.

Based on this finding, the PADEP requested additional characterization of the southern berm. In addition, the PADEP requested that ABB submit a SAP for the characterization on, or prior to September 1, 2009.

### 1.1 SITE DESCRIPTION AND HISTORY

The former CE Cast facility is located on Muse Bishop Road in Cecil Township, Washington County, Pennsylvania (Figure 1). The property is approximately 87 acres in size and was utilized for coal mining and manufacturing from 1923 to 1987. The H.C. Frick Coal Company (Frick) and the United States Steel Co. (US Steel) operated the coal mine from 1923 until January 26, 1953, when US Steel closed the mine.

In 1953, US Steel reportedly sold the property, to Chemical and Solvents, Inc. (CSI), which managed a chemical recovery and recycling operation at the Site. CSI's recovery facilities included a railroad siding, aboveground storage tanks (ASTs), and a large distillation or cracking tower and other smaller stills. The primary products produced at the facility over its history included:

- Foundry binders from alcohols, urea formaldehyde, linseed oil, anhydride, and aromatic and aliphatic solvents
- Potting compounds from asphalt and natural resins
- Electrical jointing compounds from grease and powdered aluminum
- Recovered triethylene glycol
- Industrial adhesives
- Organic chemicals

In 1968, the property was sold to Combustion Engineering (CE). CE Cast, a subsidiary of CE, recovered chemicals and manufactured and sold chemical additives and equipment to the casting industry.

CE Cast discontinued chemical recovery operations after approximately 1970, but the manufacturing of additives and equipment continued until 1985. In 1985, Combustion Engineering sold the CE Cast business and leased the property to CastAmerica. Reportedly, CastAmerica ceased operations in May 1987. CE became a wholly-owned subsidiary of ABB in 1990.

During the 1970s, CE Cast began investigating soil at the Site and the surface water in the unnamed tributary in conjunction with Pennsylvania Department of Environmental Resources (PADER – currently known as the PADEP). Those activities culminated in a COA between the PADER and CE Cast, which was executed on May 8, 1980. The agreement required CE Cast to remove impacted soil and drums from an area along the unnamed tributary and to construct a landfill on Site to contain this material. The COA further required the black water lagoon, which had reportedly been used during the earlier mining operations, be drained, backfilled, and capped.

By the mid 1990, over 90 ASTs and at least three underground storage tanks (USTs), which were used to store raw product and fuel, had been removed from the Site as part of the facility closure.

## 1.2 LANDFILL CLOSURE

Upon approval from the PADEP, the landfill was closed in accordance with the revised Closure Plan and Erosion and Sediment Control Plan prepared by MACTEC. On behalf of ABB, MACTEC directed the landfill closure beginning in 2008. Between October 6, 2008 and May 30, 2009, MACTEC directed excavation and stockpiling of approximately 8,029 cubic yards ($yds^3$) of top soil and clean cap material for later use as backfill. A total of 24,493 $yds^3$ of waste material was excavated and properly disposed of off Site and a total of 160,518 gallons of leachate and storm water was collected and properly disposed of off Site. Final backfill, grading, and Site restoration were completed on June 10, 2009.

The landfill closure was completed in accordance with the approved Closure Plan with the following exceptions (which were communicated and approved by the PADEP and Washington County Conservation District):

- The cap stockpile area was moved from east of the landfill to southwest of the landfill to satisfy a request from Mr. Jack Rossman, who operates an oil well near the landfill
- The bedding sand beneath the liner was left in place
- The final grading plan was revised to show the landfill berm along the southern side would remain essentially intact since black coal and coal fines were observed outside of the landfill
- Less than 2 feet of clean soil was placed over the former bottom of the landfill since the confirmatory data met the non-residential surface soil Statewide Health Standards (SHS) Medium-Specific Concentrations (MSC)

The landfill closure is documented in the Final Closure Report (MACTEC, 2009A).

## 1.3 REPORT ORGANIZATION

This SAP provides a brief summary of the Site description, history, and the findings of the landfill's closure activities. The remainder of this report is organized as follows:

- Section 2.0 – Results and Findings of the Southern Berm Test Pits
- Section 3.0 – Site-Specific Health and Safety Plan
- Section 4.0 – Characterization Activities
- Section 5.0 – Quality Assurance/ Quality Control Plan
- Section 6.0 – Proposal Schedule and Reporting

- Section 7.0 – References

## 2.0 RESULTS AND FINDINGS OF THE SOUTHERN BERM TEST PITS

During the excavation of the southern most portions of the landfill cap and waste material in March 2009, it was observed that coal and coal fines were present in the berm that formed the outside southern boundary of the landfill (the southern landfill berm or SLFB). Based on this unanticipated finding, ABB directed its contractor, MACTEC, to further investigate the SLFB. In April 2009, MACTEC excavated five test pits to visually evaluate the nature and extent of the black coal like material discovered in the SLFB. The test pits ranged in depth from 6 to 11 feet (ft), but did not extend laterally to the toe of the slope, due to excavation activities established for the landfill closure project being confined to an area within the silt fence. The results of the test pits indicated that a layer of black coal like material (1 to 5 ft thick) existed at depths of approximately 0.5 to 3 ft below ground surface (bgs) throughout the entire SLFB, above geotextile filter fabric and plastic mesh.

The black coal like material was determined to be unrelated to the "black waste" removed from the landfill, based upon the findings that the black coal like material contained significantly more "red-dog", coal, and coal fines; it did not contain debris such as broken glass and metal. Furthermore, the SLFB material did not have an odor similar to the "black waste". Based on these characteristics and the placement of the material on top of the geotextile filter fabric, MACTEC determined that the black coal like material is not likely the same as the "black waste" material removed from the landfill. Further details of the MACTEC test pit results are presented in the Revised Final Grading Plan – Solid Waste Landfill Closure included in Appendix A.

## 3.0 SITE-SPECIFIC HEALTH AND SAFETY PLAN

CRA has developed a Site-Specific Health and Safety Plan (HASP) to address the characterization activities. The purpose of the HASP is to provide specific guidelines and establish procedures for the protection of personnel performing the field activities and minimize adverse impacts to the environment. The information in the HASP has been developed in accordance with state and federal applicable standards and industry standards, and has, to the extent possible, been developed based on information available to date. The HASP is also a living document in that it will continually evolve as new Site conditions and knowledge of the Site work activities develop. The HASP is available for the PADEP's review upon request.

## 4.0 CHARACTERIZATION ACTIVITIES

### 4.1 BOREHOLE ADVANCEMENT

Prior to mobilizing to the Site, CRA will contact the Pennsylvania One Call System to locate utilities that may be present, prior to commencing intrusive subsurface work.

CRA will advance a total of six borings (SLFB-B-1 through SLFB-B-6) to further characterize the SLFB. The soil borings will be advanced on the crest of the berm, to depths that correspond with the elevation of the toe of the berm slope and until indigenous soil or bedrock is encountered (estimated depth from 12 ft-bgs to 24 ft-bgs). The approximate boring locations are depicted on Figure 2.

The boreholes will be advanced from existing ground surface on the crest of the berm using direct-push technology via a track-mounted Geoprobe® (GP6600DT), which also has the ability to use hollow stem augers if necessary to advance the borehole based on subsurface conditions.

### 4.2 SAMPLING AND ANALYSIS

CRA will sample and classify the material in the SLFB in accordance with CRA's Standard Operating Procedure (SOP) for soil sampling, which is included in Appendix B. Continuous soil samples will be collected from each boring in dedicated-acetate liners at 2-foot intervals. CRA will visually examine and describe the SLFB material and collect a sample for field screening for the presence of volatile organic compounds (VOCs) with a photoionization detector (PID) via the headspace test.

The headspace test is a field test utilized to measure total VOC concentrations. Upon collection, the sample is removed from the liner and placed directly into a ziplock container or a container covered with aluminum foil and secured with the container lid. The container is sealed and placed in a warm area for approximately fifteen minutes. The probe of the PID is then inserted into the container. VOCs (if present) will volatilize inside the container and the concentration of organic vapors will be measured with the PID. The total VOC concentration is measured in parts per million and recorded for each sample.

The proposed analytical program is summarized in Table 1. Based on the results of the headspace screening, visual inspection, and olfactory observation, a maximum of two samples from each boring will be collected for the following laboratory analyses:

- Target Compound List (TCL) VOCs – U.S. Environmental Protection Agency (USEPA) Method SW-846 8260B
- TCL Semi-volatile organic compounds (SVOCs)– USEPA Method SW-846 8270C
- Target Analyte List (TAL) Metals – USEPA Method SW-6010B (plus mercury using SW-846 7471A)
- Polychlorinated Biphenyls (PCBs) – USEPA Method SW-846 8082

In addition, CRA will collect a sample from the deepest interval (i.e., indigenous soil) from borings SLFB-B-1, SLFB-B-3, and SLFB-B-6. This sample will be analyzed for the following parameters: VOCs, SVOCs, and metals using the Synthetic Precipitation Leaching Procedure (SPLP). The results of the SPLP analyses will be used to determine whether or not the berm material is contributing to the Site groundwater impacts.

After collection, the samples will be contained in coolers with wet ice to ensure that they are properly preserved. The samples shall be packed with proper packaging material (i.e., bubble wrap) to avoid breakage, and the coolers will be taped shut with packaging tape and custody seals. CRA will hand deliver the samples to Test America in Pittsburgh, Pennsylvania (Pennsylvania NELAC No. 02-00416) within the allowable holding time requirements for each parameter.

A chain-of-custody record shall be maintained for each sample in order to document sample possession form the time of collection to the time of final laboratory analysis. At a minimum, the chain-of-custody record will contain the following information:

- CRA project number
- Site name and location
- Date and time of collection
- Matrix type (e.g., soil, water)
- Sample type (composite or grab)
- Sample identification
- Total number of containers
- Parameter for analysis
- Analysis methods

- Signature of collectors and all recipients in the chain of possession
- Inclusive dates for time of possession

The procedures that will be used for soil sampling and handling are further described in CRA's SOP. A copy of the SOP is included in Appendix B.

## 4.3 DECONTAMINATION PROCEDURES

For all non-dedicated sampling equipment, decontamination will be conducted in accordance with the procedures listed in CRA's SOP Section 5.6 (Appendix B).

All drilling equipment (i.e., drill rods, augers, bits) used for borehole advancement will be decontaminated between boring locations and upon completion of the drilling program using a hot high-pressure potable water wash. In addition, drilling equipment will be decontaminated upon arrival to the Site prior to commencing drilling, if deemed appropriate by CRA. Additional decontamination procedures may be used based on the project requirements and material encountered in the SLFB.

## 4.4 WASTE MANAGEMENT AND DISPOSITION

Investigative-Derived Waste (IDW) (i.e., drill cuttings and excess sample) will be contained in Department of Transportation- (DOT-) approved 55-gallon steel drums, properly labeled, and staged on Site. A composite sample will be collected from the drums for Resource Conservation and Recovery Act (RCRA) hazardous characteristics analyses. After characterization is complete, ABB will contract with an approved waste facility to transport and dispose of the IDW from the Site. Any liquids generated during equipment decontamination will be spread in a vegetated area on Site.

## 4.5 SITE SURVEYING

CRA will locate the boring locations horizontally using Site-specific references (i.e., monitoring wells or a Site benchmark). The ground surface elevations will be inferred from the elevations surveyed during the landfill closure activities.

## 5.0 QUALITY ASSURANCE/QUALITY CONTROL PLAN

To evaluate field quality control, Quality Assurance/Quality Control (QA/QC) samples will be collected at a general rate of one per 20 investigative samples. Therefore, assuming a total of 12 samples from the SLFB will be submitted to the laboratory for analyses, 1 duplicate sample, and 1 matrix spike/1 matrix spike duplicate (MS/MSD) sample will also be collected, for a total of 15 berm samples submitted for laboratory analyses. CRA will also collect one aqueous equipment blank sample and one aqueous trip blank sample will accompany the samples for VOC analysis.

The following is a brief discussion defining each type of field derived quality control samples collected during a sampling program.

- **Equipment Blanks** - Equipment field blanks are defined as QA/QC samples used to determine if cleaning procedures are effective and adequate. Equipment field blanks are prepared by collecting laboratory distilled deionized water which has been "run through" or "poured over" the cleaned sample collection equipment. If dedicated, new sampling devices are used, the equipment blank may be collected to ensure that the devices material is inert and does not compromise the sample's integrity.
- **Trip Blanks** - Trip blanks are prepared before the sampling event and sent to the Site in the shipping container(s) designated for the project. These samples are intended to be kept with investigative samples, and then submitted for analysis with the project samples. The samples should not be opened, and are intended to determine if the sample shipping or storage procedures influence the analytical results. Trip blanks are usually submitted for VOC analyses only, and only one set per cooler containing VOC samples.
- **Field Duplicates** - Field duplicates are collected and submitted to assess the potential for laboratory data inconsistency and the adequacy of the sampling and handling procedures. A duplicate sample is collected from the same source utilizing identical collection procedures and typically submitted "blind" to the laboratory by providing a false identification number. The sampling key to ensure proper sample identification must be submitted to the appropriate personnel to enable completion of the QA/QC review process.
- **Laboratory QA/QC Sample Volumes** – MS/MSD sample volumes are additional sample aliquots provided to the laboratory to evaluate the accuracy and precision of the sample preparation and analysis technique. Typically, three times the normal sample aliquot is required to conduct MS/MSD procedures. Sample collection is identical to the technique described for collection of field duplicates. Sample labeling identifies the respective sample location and each additional container that is labeled as the "MS/MSD" volume.

## 6.0 PROPOSED SCHEDULE AND REPORTING

Upon PADEP's approval of this SAP, CRA will adhere to the following schedule:

- Subcontractor procurement, project planning and coordination – 4 weeks
- Berm sampling – 2 days
- Laboratory analyses – 3 weeks
- IDW characterization and disposal - within 90 days of generation
- Preparation and submittal of a letter report – within 4 weeks after receipt of final analytical data

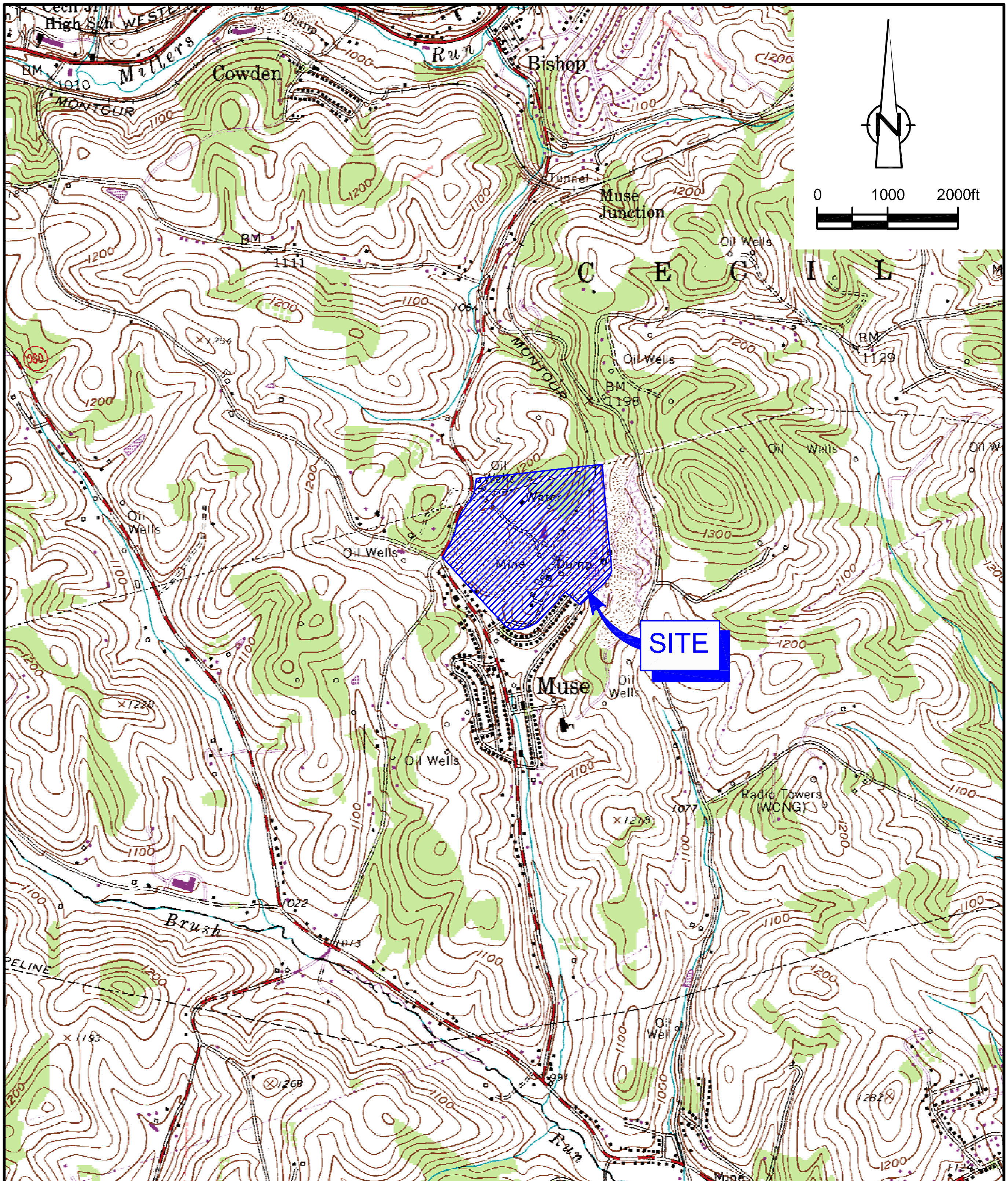
CRA will provide the PADEP with one week notice prior to completing the SLFB sampling.

## 7.0 REFERENCES


Conestoga-Rovers & Associates, Inc., 2008. *Standard Operating Procedures,* June.

MACTEC Engineering and Consulting, Inc., 2009A. *Final Grading Plan Solid Waste Landfill*, Former CE Cast Facility, Muse, Pennsylvania. May.

MACTEC Engineering and Consulting, Inc., 2009B. *Final Closure Report Solid Waste Landfill*, Former CE Cast Facility, Muse, Pennsylvania. July.




SOURCE: USGS QUADRANGLE MAP: CANONSBURG, PA.

figure 1

SITE LOCATION MAP
FORMER CE CAST FACILITY
*Muse, Pennsylvania*

CRA

55986-00(002)GN-WA002 AUG 24/2009

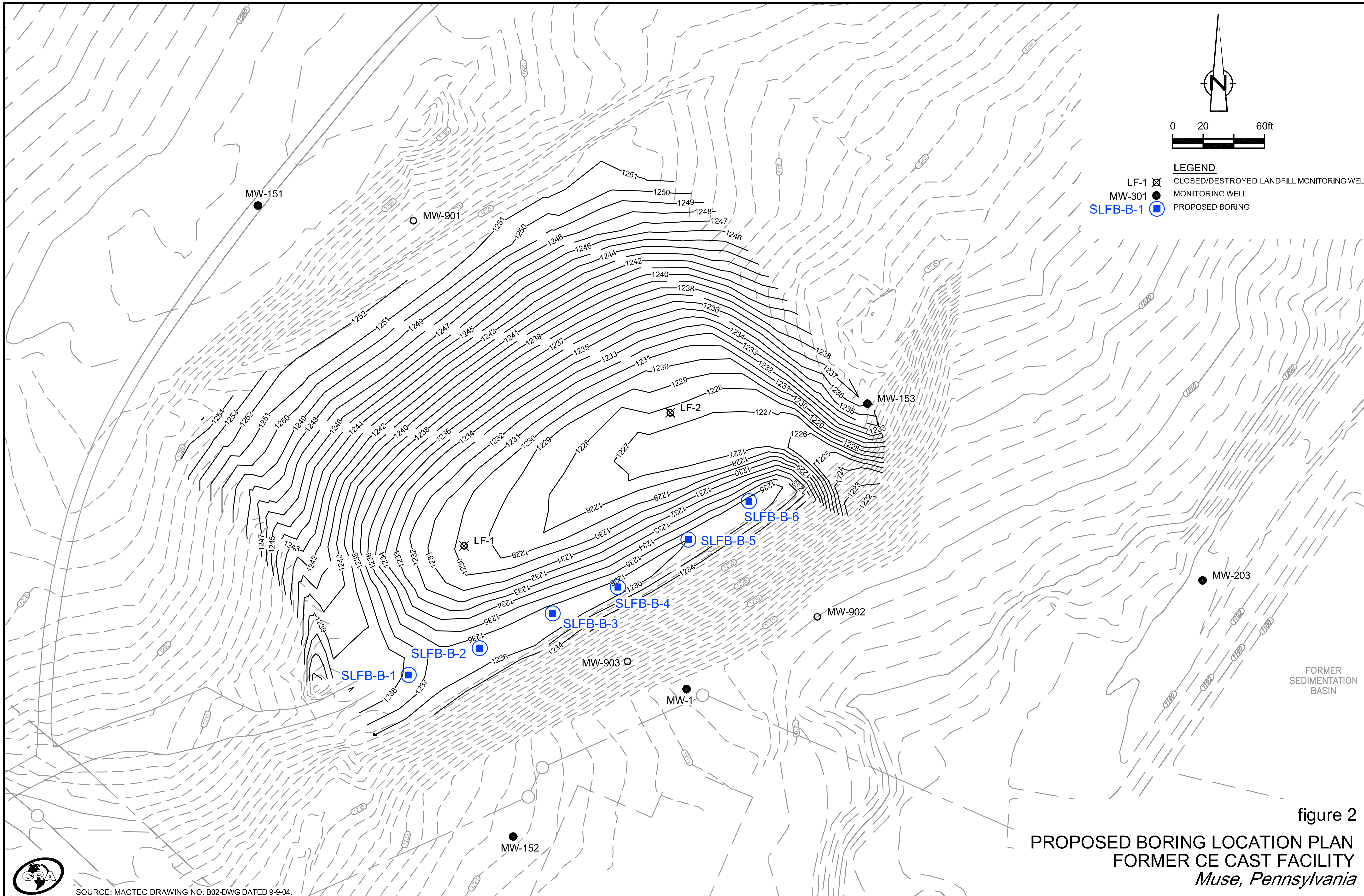



figure 2

PROPOSED BORING LOCATION PLAN
FORMER CE CAST FACILITY
*Muse, Pennsylvania*

55986-00(002)GN-WA003 AUG 25/2009

TABLE 1

ANALYTICAL PARAMETERS
FORMER CE CAST FACILITY
MUSE, PENNSYLVANIA

| Boring ID | Parameters and Analytical Methods | | | | | | |
|---|---|---|---|---|---|---|---|
| | TCL VOCs SW-846 8260B | TCL SVOCs SW-846 8270C | TAL METALS PLUS MERCURY SW-6010B/7471A | PCBs SW-846 8082 | SPLP VOCs SW-846 1311/8260 | SPLP SVOCs SW-846 1311/8270 | SPLP METALS SW-846 1311/6010/7470 |
| SLFB-B-1 | X | X | X | X | X(7) | X(7) | X(7) |
| SLFB-B-2 | X | X | X | X | | | |
| SLFB-B-3 | X | X | X | X | X(7) | X(7) | X(7) |
| SLFB-B-4 | X | X | X | X | | | |
| SLFB-B-5 | X | X | X | X | | | |
| SLFB-B-6 | X | X | X | X | X(7) | X(7) | X(7) |

Notes:
1) TCL - Target Compound List.
2) TAL - Target Analyte List.
3) VOCs - Volatile Organic Compounds.
4) SVOCs - Semi-Volatile Organic Compounds.
5) PCBs - Polychlorinated biphenyls.
6) SPLP - Synthetic Precipitation Leaching Procedure.
7) Only one sample from the identified borings for SPLP analysis will be submitted.

APPENDIX A

REVISED FINAL GRADING PLAN –
SOLID WASTE LANDFILL CLOSURE

MACTEC

engineering and constructing a better tomorrow

May 19, 2009

3410080603

Mr. Robert Popichak
Pennsylvania Department of Environmental Protection
400 Waterfront Drive
Pittsburgh, Pennsylvania152224745

Subject: **Revised Final Grading Plan – Solid Waste Landfill Closure**
**Former CE-Cast Facility**
**Muse, Pennsylvania**

Dear Mr. Popichak:

On April 22, 2009 I met at the above referenced site with you, Mr. Carl Spadaro, Mr. Dale Burns of the Pennsylvania Department of Environmental Protection (PADEP) along with Mr. Matt Golden of the Washington County Conservation District (WCCD). During that meeting we:

1) Discussed the general status of the landfill closure activities which ABB, Inc. is completing.

2) Discussed the occurrence and extent of black coal, coal fines and red-dog observed in the berm which forms the southern boundary of the former landfill. That material is referred to here as the "black coal like material". We also discussed how the characteristics of the observed black coal like material are different than those of the "black waste" which has been removed from the landfill and appropriately disposed of off-site in accordance with the approved landfill closure plan.

3) Reviewed the conceptual final grading plan figures that would allow the landfill closure activities to be completed in the immediate future with further characterization of the black coal like material in the berm to be evaluated later.

As discussed during our meeting, MACTEC completed 5 test pits into the berm during April 2009 to visually assess the nature and extent of the black coal like material in the berm. Generalized cross sections depicting each test pit are attached. In general, a layer of black coal like material (between approximately 1 to 5 ft thick) occurs at depths of approximately 6 inches to 3 feet below ground surface throughout the entire length of the berm. The layer of black coal like material rests on top of a geotextile filter fabric and plastic mesh. Note that the test pits did not extend laterally to the toe of the berm since excavation activities were confined to the area within the silt fence established for the landfill closure project.

The key differences observed between the "black waste" which has been removed from the landfill and the black coal like material observed in the berm are that the material in the berm:

1) Contains significantly more red-dog, coal, and coal fines
2) Does not contain debris such as broken glass, metal, etc.
3) Does not exhibit any odor.

Given that description and its apparent placement on-top of filter fabric geotextile used during the berm repair activities in the late 1980's, we agreed that it is likely that the material observed in the berm is not the same as the waste that was removed from the landfill. However, PADEP has indicated that additional characterization is warranted. The original approved final grading plan indicated that the crest of the berm along its entire length would be lowered during establishment of the final grade.

Due to the presence of the black coal like material outside of the landfill, MACTEC revised the final grading plan to essentially leave the berm intact except at the southeast end. A "cut" will be made to allow runoff to escape as depicted on the attached final grading plan. The attached plan is the same as that reviewed during our meeting except that the existing contours reflect the final surveyed elevations of the bottom of the former landfill.

During our meeting we agreed to the following with respect to finishing the landfill removal work and addressing the coal and coal fines outside the landfill:

1) The remediation contractor, EAP, would place a layer of "clean" soil over the top of the berm to cover any "coal and coal fines outside the landfill" that was exposed during removal of the landfill. (Clean soil is the top soil and clay cap material that was removed during landfill closure and stockpiled on-site.) That work was completed by April 24, 2009.

2) EAP would remove the last of the landfill liner and waste from the landfill and place in the waste stockpile area for sampling and subsequent off-site disposal according to the approved closure plan. As of May 1, 2009 all of the waste and liner was removed from the landfill and placed in the stock pile area awaiting off-site disposal

3) During removal of the liner, EAP would begin excavation of the berm "cut". Any black coal like material encountered outside of the landfill during excavation of the berm "cut" would be stored in the waste stockpile area and handled as waste. Soil (i.e., non-coal coal like material) encountered during the excavation outside of the landfill would be used to establish the final grade. By May 1, 2009 approximately 50 cubic yards of black coal and coal fines were excavated from the berm cut and placed with the waste and is currently awaiting off-site disposal.

4) The final grade would be established according to the revised final grading plan, compacted and, reseeded in accordance with the approved closure plan. The attached revised final grading plan is the same as that presented, with some slight modification to

the existing ground contours which reflect the actual surveyed elevations from the bottom of the former landfill. Final grading to this plan has begun and is expected to be completed by June 1, 2009 (weather permitting).

PADEP has requested that ABB provide a schedule for completing additional berm characterization activities. ABB proposes to provide PADEP with a scope of work for completing the additional characterization by September 1, 2009. As with other aspects of this project, ABB will collaborate closely with PADEP.

Thank you for your continued cooperation on this project and please contact me at (412) 279-6661 or Elaine Hammick at ABB (860) 285-5734.

Sincerely,

**MACTEC ENGINEERING & CONSULTING, INC.**

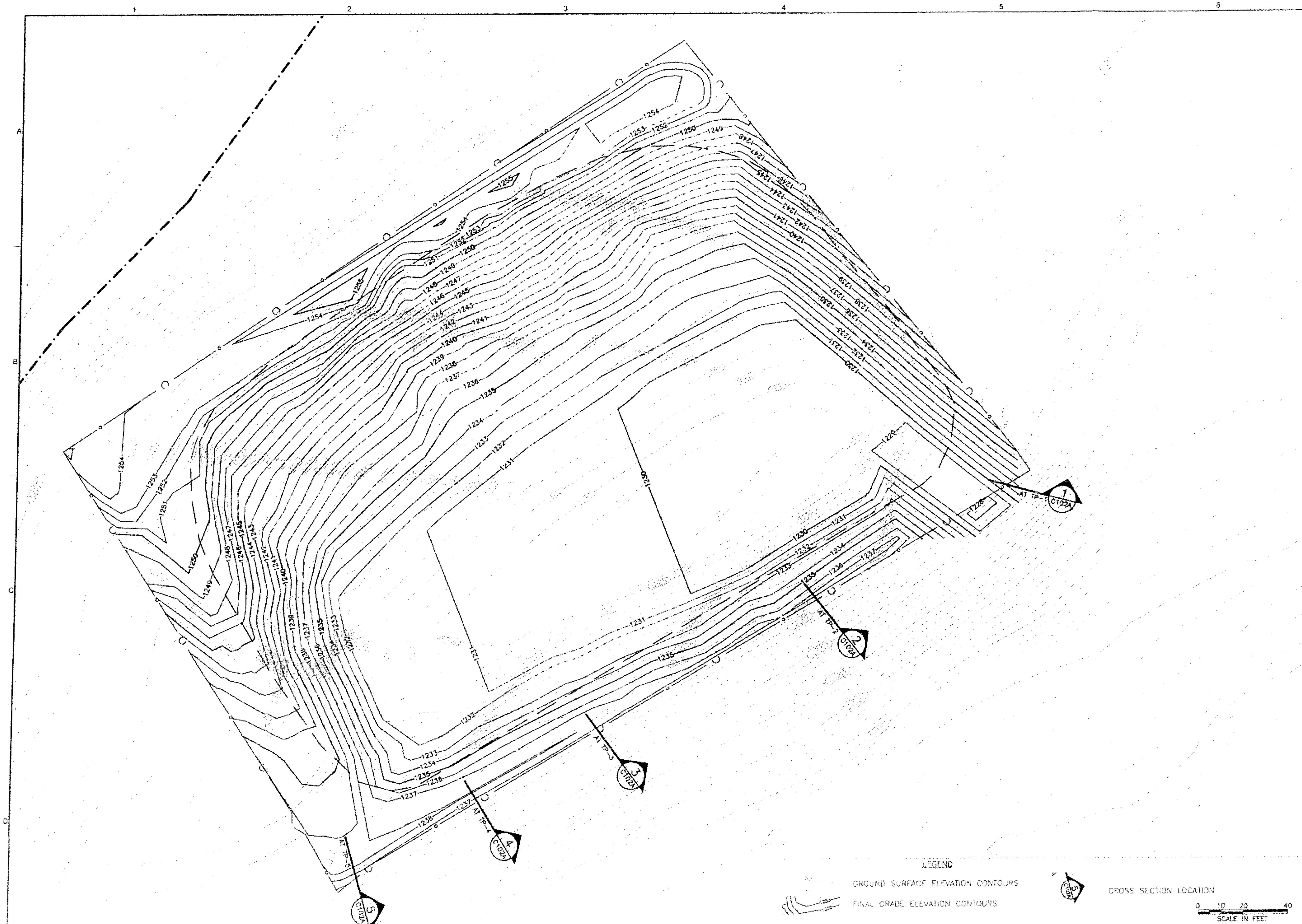
Joseph A. Senita
Principal Hydrogeologist

Dayne M. Crowley, P.G. FOR
Senior Principal

JAS: ESW/llg

Attachments

cc Elaine Hammick, ABB, Inc.
Dale Burns, PADEP
Matt Golden, WCCD




MACTEC

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P.O. Box 7050, 511 Congress Street
Portland, Maine 04112-7050
(207) 775-5401

CIVIL

REVISED FINAL SITE GRADING
5/11/2009

LANDFILL CLEANUP PLAN
FORMER CE-CAST FACILITY
MUSE, PENNSYLVANIA

| NO. | DATE | REVISION | BY | APVD |
|---|---|---|---|---|
| B | 05/11/09 | ADD SURVEYED EXCAVATION CONTOURS BY SURVEYOR | | |

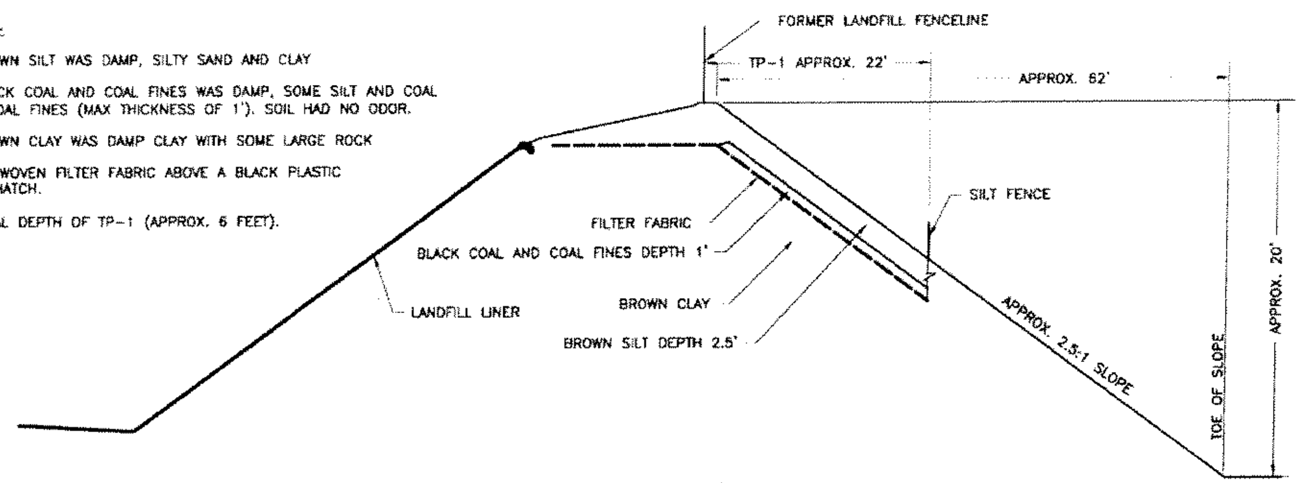
| DSGN | DR | CHK | APVD |
|---|---|---|---|
| | MAP | RHH | |

VERIFY SCALE
BAR IS ONE INCH ON ORIGINAL DRAWING
0 1"

| | |
|---|---|
| DATE | |
| PROJ | 3410070554 |
| DWG | C-101B |
| SHEET | 1 OF 2 |

NOTES–

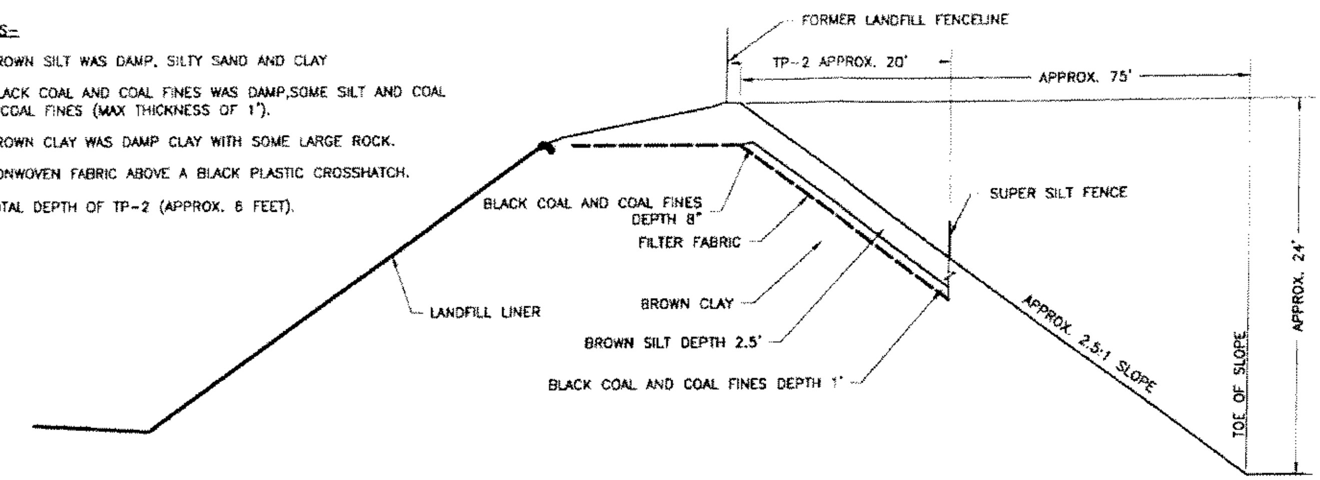
1. BROWN SILT WAS DAMP, SILTY SAND AND CLAY
2. BLACK COAL AND COAL FINES WAS DAMP, SOME SILT AND COAL AND COAL FINES (MAX THICKNESS OF 1'). SOIL HAD NO ODOR.
3. BROWN CLAY WAS DAMP CLAY WITH SOME LARGE ROCK
4. NONWOVEN FILTER FABRIC ABOVE A BLACK PLASTIC CROSSHATCH.
5. TOTAL DEPTH OF TP-1 (APPROX. 6 FEET).




TYPICAL SECTION 1 AT TEST PIT 1
NOT TO SCALE

NOTES–

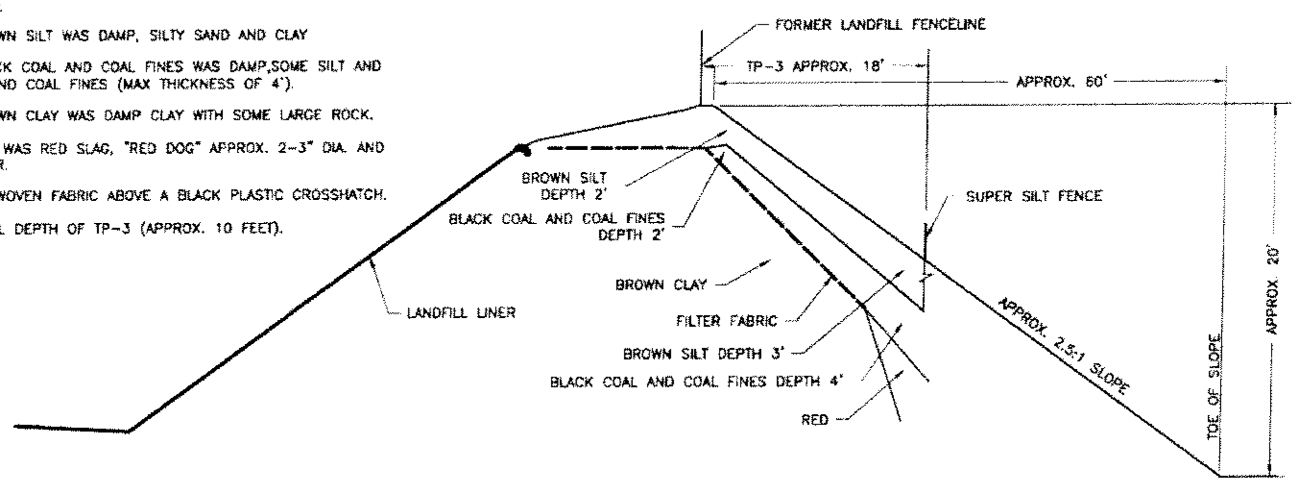
1. BROWN SILT WAS DAMP, SILTY SAND AND CLAY
2. BLACK COAL AND COAL FINES WAS DAMP,SOME SILT AND COAL AND COAL FINES (MAX THICKNESS OF 1').
3. BROWN CLAY WAS DAMP CLAY WITH SOME LARGE ROCK.
4. NONWOVEN FABRIC ABOVE A BLACK PLASTIC CROSSHATCH.
5. TOTAL DEPTH OF TP-2 (APPROX. 6 FEET).




TYPICAL SECTION 2 AT TEST PIT 2
NOT TO SCALE

NOTES–

1. BROWN SILT WAS DAMP, SILTY SAND AND CLAY
2. BLACK COAL AND COAL FINES WAS DAMP,SOME SILT AND COAL AND COAL FINES (MAX THICKNESS OF 4').
3. BROWN CLAY WAS DAMP CLAY WITH SOME LARGE ROCK.
4. RED WAS RED SLAG, "RED DOG" APPROX. 2-3" DIA. AND SMALLER.
5. NONWOVEN FABRIC ABOVE A BLACK PLASTIC CROSSHATCH.
5. TOTAL DEPTH OF TP-3 (APPROX. 10 FEET).

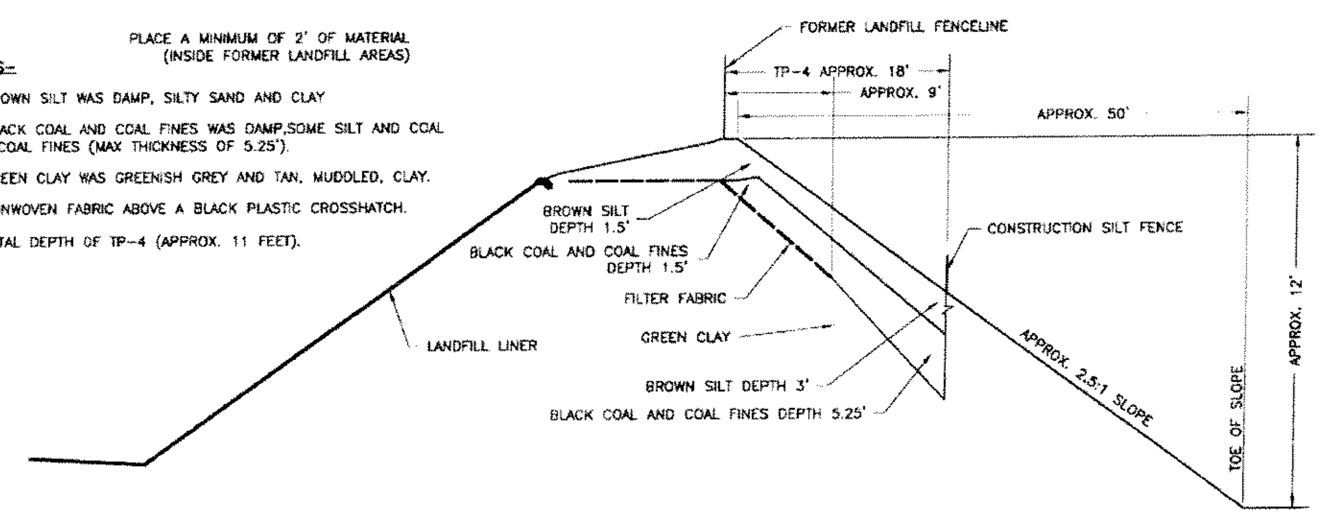



TYPICAL SECTION 3 AT TEST PIT 3
NOT TO SCALE

PLACE A MINIMUM OF 2' OF MATERIAL (INSIDE FORMER LANDFILL AREAS)

NOTES–

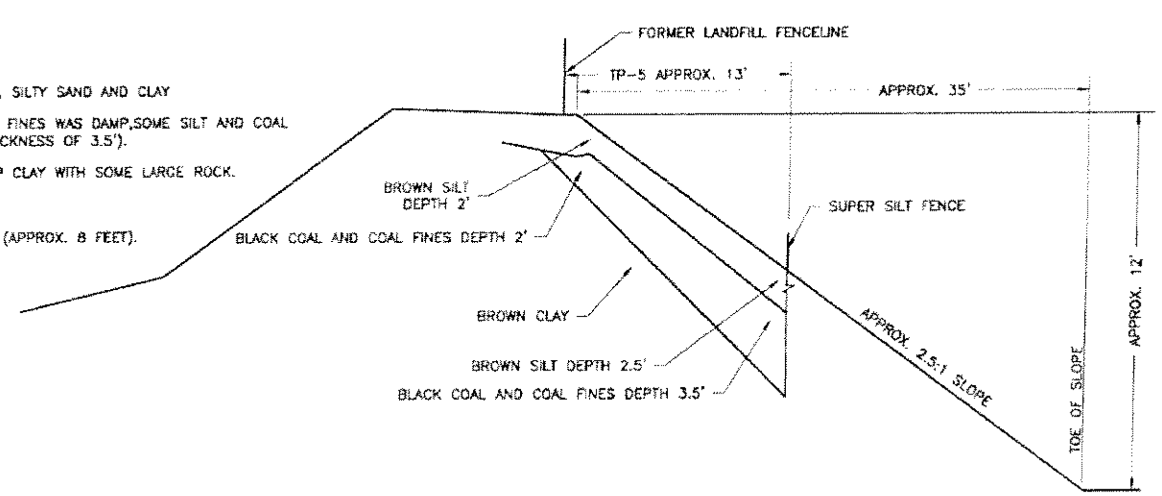
1. BROWN SILT WAS DAMP, SILTY SAND AND CLAY
2. BLACK COAL AND COAL FINES WAS DAMP,SOME SILT AND COAL AND COAL FINES (MAX THICKNESS OF 5.25').
3. GREEN CLAY WAS GREENISH GREY AND TAN, MUDDLED, CLAY.
4. NONWOVEN FABRIC ABOVE A BLACK PLASTIC CROSSHATCH.
5. TOTAL DEPTH OF TP-4 (APPROX. 11 FEET).



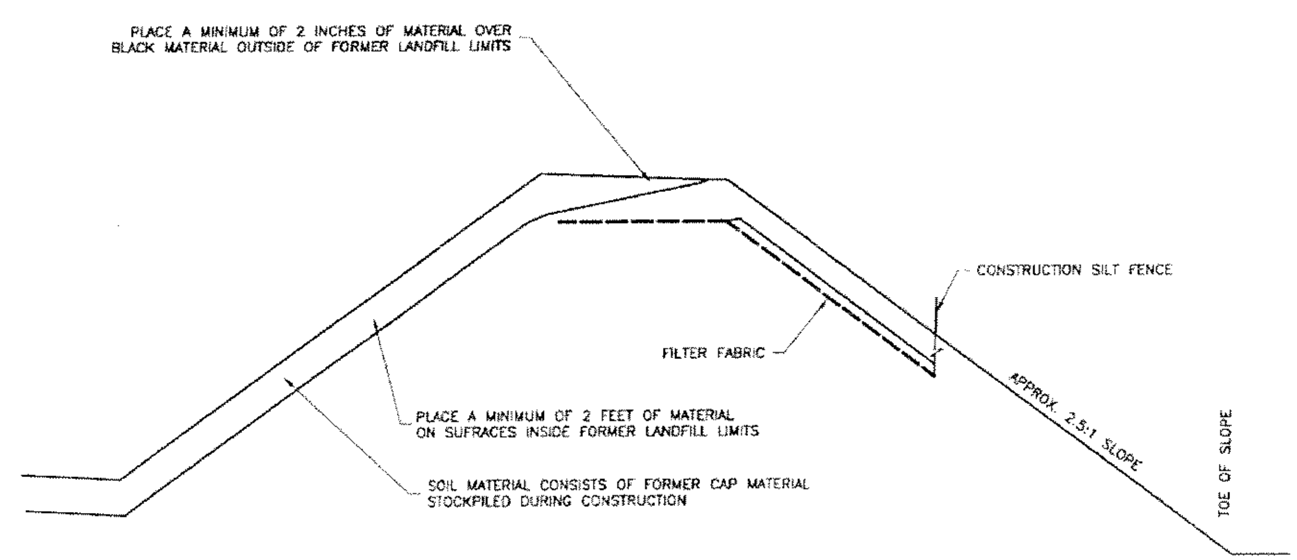

TYPICAL SECTION 4 AT TEST PIT 4
NOT TO SCALE

NOTES–

1. BROWN SILT WAS DAMP, SILTY SAND AND CLAY
2. BLACK COAL AND COAL FINES WAS DAMP,SOME SILT AND COAL AND COAL FINES (MAX THICKNESS OF 3.5').
3. BROWN CLAY WAS DAMP CLAY WITH SOME LARGE ROCK.
4. NO LINER PRESENT
5. TOTAL DEPTH OF TP-5 (APPROX. 8 FEET).




TYPICAL SECTION 5 AT TEST PIT 5
NOT TO SCALE




TYPICAL SECTION FOR FINAL SOIL PLACEMENT
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# APPENDIX B

# STANDARD OPERATING PROCEDURES

# CRA FIELD TRAINING MANUAL

## SECTION 5.0:

## SOIL SAMPLING STANDARD OPERATING PROCEDURES

PART 1: SURFICIAL SOIL SAMPLING, BOREHOLE INSTALLATION AND SAMPLE COLLECTION, AND TEST PIT EXCAVATION AND SAMPLING

(FLD-0102A)

PART 2: CRA APPROACH FOR SOIL MATERIALS DESCRIPTION AND CLASSIFICATION

(FLD-0102B)

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## 5.0 SOIL SAMPLING STANDARD OPERATING PROCEDURES

## 5.1 INTRODUCTION

Soil sampling is conducted to characterize the physical and/or chemical conditions at a site. Standard Operating Procedures (SOPs) are presented herein for obtaining a variety of soil samples for physical and chemical analyses, including:

- surficial soil samples (soil between ground surface and 6 to 12 inches (15 to 30 cm) below ground surface);
- subsurface samples that require borehole installation; and
- test pit excavations.

This guideline is not intended to provide the basis for designing a soil sampling program, but instead assumes that a soil sampling program has been designed, a Work Plan has been established, and the sampling team is preparing to mobilize to the field.

Soil sampling procedures vary from project to project due to different parameters of concern, different guidance provided by the state/province where the site is located, or the specific objectives for the project. Therefore, it is essential that the sampling team members carefully review the Work Plan. The primary goal of surface soil sampling is to collect representative samples for examination and chemical analysis (if required).

The remainder of this section is organized as follows:

- Section 5.2 Sampling Methods
- Section 5.3 Planning and Preparation
- Section 5.4 Safety and Health
- Section 5.5 Quality Assurance/Quality Control
- Section 5.6 Equipment Decontamination
- Section 5.7 Procedures for Soil Classification
- Section 5.8 Procedures for Surficial Soil Sampling
- Section 5.9 Procedures for Borehole Installation and Sampling
- Section 5.10 Procedures for Test Pit Excavation and Sampling
- Section 5.11 Follow-up Activities
- Section 5.12 References

## 5.2 SAMPLING METHODS

### 5.2.1 SURFICIAL SOIL SAMPLING

Surficial soil sampling is less frequently used than subsurface soil sampling (which involves borehole installation). Typically, surficial soil sampling is used when a large site is being assessed and the extent of contamination is unknown. In this case, surficial sampling is helpful in identifying the location of surface releases (e.g., historical spills of hydrocarbons) that may have contributed to subsurface contamination. A surficial soil sampling program is also recommended for sites with suspected atmospheric deposition of contaminants (e.g., stacks), areas of surface spills, or recent spills.

Surficial soil sampling is used when contamination is known to be restricted to the surficial region of the soil stratum. Thus, surficial sampling can be useful at brownfield sites, where it is necessary to determine if soils are contaminated with specific contaminants of concern (e.g., metals) as part of a purchaser's due diligence. Surficial soil sampling can also be required when obtaining data in order to perform a site-specific risk assessment.

For the purposes of this section, the surficial soil is considered to be the 0- to 6-inch (0 to 15 cm) soil horizon.

Samples are collected from areas where surficial soil contamination is known or suspected. Samples from a particular depth increment must not be mixed with soil from other depths. Soil horizons displaying different properties should be sampled separately, since they may behave very differently with respect to contaminant accumulation and movement.

### 5.2.2 BOREHOLE INSTALLATION AND SAMPLING

A significant portion of CRA's field activities involve borehole installation.

Several manual methods are available for the collection of shallow subsurface soil samples (e.g., hand augers, post-hole augers). However, the most common methods used by CRA to advance boreholes are a drill rig equipped with continuous flight hollow-stem augers (HSAs) and split-spoon samplers, or a direct-push drilling unit equipped with solid tube soil samplers.

### 5.2.3 TEST PIT EXCAVATION AND SAMPLING

Test pits are typically excavated to explore and define geologic conditions (or buried waste/debris) and to allow the collection of subsurface soil samples for geotechnical or chemical analysis. Test pits give a more complete view of the subsurface soil conditions than soil borings. Test pits are excavated using either a rubber-tired backhoe or track-mounted excavator, and can extend 10 to 15 feet (3.0 to 4.6 m) below ground surface.

The use of test pits for investigation is determined on a site-specific basis. Experience from past projects has identified the following issues:

1. The nature and extent of contamination which may be encountered may be unknown. The Site-Specific Health and Safety Plan (HASP) and Job Safety Analysis (JSA) must be specific to the level of Personal Protective Equipment (PPE); this may be Level A or B.
2. Waste materials, including drums, may be encountered. A plan must be in place specifying how this material will be handled.
3. Air emissions of some compounds may occur. A plan must be in place to ensure that employees and the public are adequately protected.
4. Community relations concerns may exist (e.g., workers in chemically protective "moon suits"). A notification plan may be required.
5. All underground utilities must be located utilizing documentation using the CRA Subsurface Clearance Protocol.

### 5.2.4 GRAB VERSUS COMPOSITE SAMPLES

A grab sample is collected to identify and quantify compounds at a specific location or interval. The sample is comprised of no more than the minimum amount of soil necessary to make up the volume of sample dictated by the required sample analyses. Composite samples are a mixture of a given number of sub-samples and are collected to characterize the average composition in a given surface area.

Samples to be analyzed for volatile organic compounds (VOCs) are always collected as grab samples. Mixing of soil samples to create a composite is not performed. Mixing of soil samples results in partial volatilization of VOCs from the soil, and thus compromises the integrity of the composite soil sample.

## 5.3 PLANNING AND PREPARATION

The following activities are required prior to undertaking a soil sampling program:

1. Review the Work Plan, project documents, and health and safety requirements with the Project Coordinator.
2. Complete an Field Equipment Requisition Form (QSF-014) and assemble all equipment, materials, log books, and forms. Form SP-02 (Project Planning, Completion, and Follow-Up Checklist) should be used for guidance throughout the project. Borehole Installation/Soil Sampling Equipment and Supply Checklist (Form SP-12) provides a summary of the typical equipment/materials required for soil sampling. Drilling/Well Construction Checklist (Form SP-13) provides a listing of pre-planning and site activities that is designed as an aid to preparing and completing the project.

3. Obtain a site plan and any previous stratigraphic logs. Determine the exact number, location, and depths of samples to be collected.

4. Complete a Vendor Evaluation Form (QSF-012) and file in the Project file for any Vendors that do not have full approval status or are not listed on the Approved Vendor List (QSL-004). Completion of a Safety and Health Schedule (QSF-030 for Canadian work; QSF-031 for U.S. work) is necessary for all Vendors who complete field services. Prior to mobilization on site, the Vendor must submit the form to the Regional Safety and Health Manager for review and approval (if not already posted on QSL-004).

5. Contact CRA's Chemistry group to arrange/determine:
   - SSOW (simplified Scope of Work)
   - glassware/sample jars;
   - cooler;
   - shipping details;
   - start date;
   - laboratory; and
   - expected sampling duration.

6. Initiate a Property Access/Utility Clearance Data Sheet (QSF-019), if necessary. In most instances, surface sampling activities do not require utility clearances.

7. Determine notification needs with the Project Coordinator. Have the regulatory groups, client, landowner, CRA personnel, and laboratory been informed of the sampling event?

8. Determine the methods for handling and disposal of wash waters and spent decontamination fluids.

In addition to the above, the following may be required when conducting a borehole or test pit program:

1. Establish a water source for drilling and decontamination activities. Pre-plan the methods for handling and disposal of drill cuttings, wash waters, and spent decontamination fluids.

2. Arrange with driller to provide paraffin wax, melting pot, and heat source (if required).

## 5.4 SAFETY AND HEALTH

CRA is committed to conducting field activities in accordance with sound safety and health practices. CRA adheres to high safety standards to protect the safety and health of all employees, subcontractors, customers, and communities in which they work. The safety and health of our employees takes precedence over cost and schedule implications.

Field personnel are required to implement the Safety Means Awareness Responsibility Teamwork (SMART) program as follows:

- Assure the HASP is specific to the job and approved by a Regional Safety & Health Manager.
- Confirm that all HASP elements have been implemented for the job.
- A JSA for each task has been reviewed, modified for the specific site conditions and communicated to all appropriate site personnel. The JSAs are a component of the HASP.
- Incorporate Stop Work Authority; Stop, Think, Act, Review (STAR) process; Safe Task Evaluation Process (STEP); Observations process; Near Loss and Incident Management process in the day-to-day operations of the job.
- Review and implement applicable sections of the CRA Safety & Health Policy Manual.
- Confirm that all site personnel have the required training and medical surveillance , as defined in the HASP.
- Be prepared for emergency situations, locating safety showers, fire protection equipment, evacuation route, rally point, and first aid equipment before you begin working, and make sure that the equipment is in good working order.
- Maintain all required PPE, safety equipment, and instrumentation necessary to perform the work effectively, efficiently, and safely.
- Be prepared to call the CRA Incident Hotline at 1-866-529-4886 for all incidents involving injury/illness, property damage, and vehicle incident and/or significant Near Loss.

It is the responsibility of the Project Manager to:

- Ensure that all CRA field personnel have received the appropriate health and safety and field training and are qualified to complete the work.
- Provide subcontractors with a Job Hazard Analysis to enable them to develop their own HASP.
- Ensure that all subcontractors meet CRA's (and the Client's) safety requirements.

## 5.5 QUALITY ASSURANCE/QUALITY CONTROL

A well-designed Quality Assurance/Quality Control (QA/QC) program will:

- ensure that data of sufficient quality are obtained in order to facilitate good site management;
- allow for monitoring of staff and contractor performance; and
- verify the quality of the data for the regulatory agency.

The QA/QC program is developed on a site-specific basis. QA/QC requirements are discussed in detail in Section 3.9.

## 5.6 EQUIPMENT DECONTAMINATION

Borehole Installation and Sampling

Prior to use and between each borehole location at an environmental site, the drilling and sampling equipment must be decontaminated in accordance with the Work Plan or the methods presented in this section.

The minimum wash procedures for decontamination of drilling or excavating equipment are:

1. High pressure hot water detergent wash (brushing as necessary to remove particulate matter).
2. Potable, hot water, high pressure rinse.

Cover the clean augers with clean plastic sheeting to prevent contact with foreign materials. For geotechnical, geologic, or hydrogeologic studies where contaminants are not present, it is sufficient to clean the drilling or excavating equipment simply by removing the excess soils.

On environmental sites, the soil sampler equipment (split spoons, trowel, spoons, shovels, bowls) are typically cleaned as follows:

1. Wash with clean potable water and laboratory detergent, using a brush as necessary to remove particulates.
2. Rinse with tap water.
3. Rinse with deionized water.
4. Air dry for as long as possible.

In addition, the following steps may be added when sampling for VOCs and metals:

1. Rinse with 10 percent nitric acid (only if samples are to be analyzed for metals).
2. Rinse with deionized water.
3. Rinse with appropriate solvent (pesticide grade isopropanol, methanol, acetone, hexane, if required).
4. Rinse again with deionized water.
5. Air dry for as long as possible.
6. Wrap split-spoon samplers in aluminum foil to prevent contamination.

> **Caution:** *Check the Quality Assurance Project Plan (QAPP) to confirm the cleaning protocol. Use of incorrect cleaning protocol could invalidate chemical data.*

## 5.7 PROCEDURES FOR SOIL CLASSIFICATION

This SOP for Soil Classification is not intended to provide complete training in soil classification. Soil Classification will require additional training and experience.

Criteria and procedures for soil classification and description include:

1. A standard method of describing the soil by name and group symbol.
2. Standard field identification methods based on visual examination and manual tests on representative soil samples by a qualified CRA representative for interpretation of subsurface conditions at the site.
3. Verifying field description descriptions through the inspection.
4. Confirming descriptive information by laboratory determination of selected soil characteristics if required in the Work Plan.
5. Factual overburden stratigraphic logs completed by CRA personnel responsible for interpreting the subsurface conditions at the site and review/confirmation of soil descriptions by the Project Coordinator.

The overburden stratigraphic log is the factual description of the soil at each borehole location and will be relied on to interpret soil characteristics at the site. The overburden stratigraphic log will also be used to interpret the soil characteristics' influence and significance on the subsurface environment. CRA personnel responsible for interpreting the subsurface conditions at the site will also verify overburden stratigraphic log accuracy. If practical, the Project Coordinator, Geologist, or Geotechnical Engineer should confirm the soil descriptions and examine representative soil samples.

Describing and classifying soils is a skill that is learned through experience and by systematic training using laboratory results of soil composition in comparison to field descriptions.

| *Note:* *Attendance at a soil identification course provided by CRA is mandatory.* |
|---|

Descriptions for natural undisturbed soils are recorded on a Stratigraphy Log (Overburden) (Form SP-14). An example of a completed Stratigraphy Log (Overburden) is presented on Figure 5.1.

Soil descriptions are completed in the following order:

1. Modified Unified Soil Classification System (modified USCS) group symbol(s) (e.g., SM) of primary soil components or dual or borderline symbols.
2. Name and adjective description of primary, secondary, and minor grain size components.
3. Relative density for non-cohesive soils or consistency for cohesive soils.
4. Gradation and soil structure for non-cohesive soils or structure and plasticity for cohesive soils.
5. Color.

6. Moisture content.

7. Other physical observations including presence of staining and or odors.

| | |
|---|---|
| *Note:* | *When describing observed odors, be as specific as possible to classify general odor category and strength of odor. Odors are generally chemical, petroleum, or septic related, varying from slight, to moderate, to strong. Identification of specific chemical compounds (i.e., benzene, gasoline) is not necessary and is often inaccurate as detailed chemistry commonly shows a array of chemicals present.* |

When describing vegetative matter presence in soils, do not use the term organic. The use of the term organic often leads to confusion regarding the presence of organic chemicals [i.e., VOCs, semi-volatile organic compounds (SVOCs)].

The description of fill soils is similar to those used to describe native undisturbed soils. Fill soils will be identified as fill [i.e., SP/GP-Sand and Gravel (Fill)]. To determine if soils are fill, look for evidence that the soil has been artificially placed (e.g., brick fragments, slag, glass, wood fragments). Relative or inconsistent soil density can also assist in determining if soils are fill.

Soils are identified and grouped consistently to determine subsurface pattern or changes and non-conformities in the soil stratigraphy. The stratigraphy of each soil boring or test pit is compared to ensure that patterns or changes in soil stratigraphy are noted and that consistent terminology is used.

Visual examination, physical observation, and manual tests (adapted from ASTM D2488, visual-manual procedures) are used to aid in classifying and grouping soil samples in the field. These procedures are described in the following subsection. ASTM D2488 should be reviewed for detailed explanations of the procedures. Visual-manual procedures used to aid in soil identification and classification include:

1. Visual determination of grain size, soil gradation, and percentage of fine grained soils (i.e., silts and clays).
2. Dry strength, dilatancy, toughness, and plasticity tests (i.e., thread or ribbon test) for identification of inorganic fine grained soils [e.g., CL or CH (clays), and ML or MH (silts)].
3. Soil compressive strength and consistency estimates based on thumb indent and or pocket penetrometer (preferred) methods.

The three main soil divisions are:

1. Coarse-grained soils (e.g., sand and gravel).
2. Fine-grained soils (e.g., silts and clays).
3. Soils with high natural organic and vegetative matter content (e.g., peat, marl).

### 5.7.1 COARSE GRAINED SOILS

The USCS symbols for coarse-grained soil are primarily based on grain size, grain size distribution (gradation), and percent of fines (silt and clay content).

Grain size classification used for describing soils is in terms of particle size and sieve size (e.g., gravelly sand, trace silt). Coarse-grained soil is composed of more than 50 percent by weight, sand size, or larger (75 μm diameter, No. 200 sieve size). Note that there are other definitions for coarse-grained or coarse textured soil and for sand and for sand size as soil having greater than 70 percent particles equal to or greater than 50 μm diameter (after "Guidelines for Contaminated Sites in Ontario") or 60 μm diameter ("Canadian Foundation Manual").

Grain size distribution of coarse-grained soils includes:

- poorly graded (i.e., soil having a uniform or predominantly one grain size, SP and GP); and
- well graded (i.e., poorly sorted, soils with a wide range of particle sizes with substantial percentage of intermediate sizes, SW and GW).

Coarse-grained soils are further classified based on the percentage of fine-grained soils (e.g., silts and clays) they contain. Coarse-grained soils containing greater than 12 percent fine-grained soils are commonly described as dirty. This description is attributed to soil particles that adhere when the soil sample is rubbed between the hands or adhere to the sides of sample jars after shaking, or rolling in the jar. The jar shake test will also result in the segregation of sand and gravel particles and can be used as a visual aid in determining sand and gravel content percentages.

Examples of the group symbol, name, and adjectives used to describe the primary, secondary, and minor components of soil are:

- GW-Sandy Gravel (e.g., 70 percent gravel and 30 percent sand, well graded);
- GW-Sandy Gravel-trace silt (less than 10 percent silt, well graded); and
- SP-Sand (a uniform sand, predominantly one sand grain size).

Relative density is important in establishing the engineering properties and behavior of coarse-grained soils. Relative density of non-cohesive (coarse-grained) soils is determined using the standard penetration test (SPT) blow counts (N-values) in accordance with ASTM D1586. A detailed discussion of the SPT and N values can be found in Section 5.9.2.1.

The SPT provides reliable indications of the relative density of sand and fine gravel. N-values in coarse-grained soil are influenced by a number of factors that result in overestimated relative densities. For example, in coarse-grained gravel, dilatent silty fine sands, sand below the water table and uniform coarse sand, N-values tend to be conservative and under estimate the relative density. The Project Geotechnical Engineer will assess these effects, if required.

Other methods, such as modified SPT and cone penetration tests, are used on occasion to supplement or replace the SPT method for certain site-specific conditions. All modifications to the SPT or substitute methods must be recorded as required to interpret test results and correlate relative density.

### 5.7.2 FINE-GRAINED SOIL

A fine-grained soil is made up of more than 50 percent silt and clay (i.e., fines greater than 50 percent by weight passing the 75 µm (No. 200) sieve size). Description of visual-manual field methods and criteria to further characterize and group fine-grained soil (e.g., CL, CH, ML, and MH) are discussed in ASTM D2488.

Further soil characterization tests include dry strength, dilatency, toughness, and plasticity (thread or ribbon test).

Criteria for Describing Dry Strength

| *Description* | *Criteria* |
|---|---|
| None | The dry specimen crumbles into powder with mere pressure of handling. |
| Low | The dry specimen crumbles into powder with some finger pressure. |
| Medium | The dry specimen breaks into pieces or crumbles with considerable finger pressure. |
| High | The dry specimen crumbles into powder with finger pressure. Specimen will break into pieces between thumb and a hard surface. |
| Very High | The dry specimen cannot be broken between the thumb and a hard surface. |

Criteria for Describing Dilatancy

| *Description* | *Criteria* |
|---|---|
| None | No visible change in small wetted specimen when rapidly shaken in palm of hand. |
| Slow | Water appears slowly on the surface of the specimen during shaking and does not disappear or disappears slowly upon squeezing. |
| Rapid | Water appears quickly on the surface of the specimen during shaking and disappears quickly upon squeezing or stretching. |

Criteria for Describing Toughness

| *Description* | *Criteria* |
|---|---|
| Low | Only slight pressure is required to roll the thread near the plastic limit. The thread and the lump are weak and soft. |

| | |
|---|---|
| Medium | Medium pressure is required to roll the thread to near the plastic limit. The thread and the lump have medium stiffness. |
| High | Considerable pressure is required to roll the thread to near the plastic limit. The thread and the lump have very high stiffness. |

Criteria for Describing Plasticity

| *Description* | *Criteria* |
|---|---|
| Nonplastic | 1/8-inch (3 mm) thread cannot be rolled at any water content. |
| Low | The thread can barely be rolled and the lump cannot be formed when drier than the plastic limit. |
| Medium | The thread is easy to roll and not much time is required to reach the plastic limit. The thread cannot be re-rolled after reaching the plastic limit. The lump crumbles when drier than the plastic limit. |
| High | It takes considerable time rolling and kneading to reach the plastic limit. The thread can be re-rolled several times after reaching the plastic limit. The lump can be formed without crumbling when drier than the plastic limit. |

Examples of group symbol identification based on visual-manual procedures and criteria for describing fine grained soil are:

| *Group Symbol* | *Dry Strength* | *Dilatancy* | *Toughness* | *Plasticity* |
|---|---|---|---|---|
| ML | None to low | Slow to rapid | Low or thread cannot be formed | Slight |
| CL | Medium to high | None to slow | Medium | Low |
| MH | Low to medium | None to slow | Low to medium | Low |
| CH | High to very high | None | High | High |

Positive classification by USCS group symbols as described in ASTM D2487, is laboratory determination of particle size characteristics, liquid limit, and plasticity index. The need for laboratory testing will be determined by the Project Hydrogeologist, Geologist, or Geotechnical Engineer and will be detailed in the Work Plan. If no laboratory testing is performed to confirm soil classification, a statement of qualification (method used) is required for group symbols.

Examples of terminology that accompany the group symbols are:

- ML-Sandy Silt (e.g., 30 percent sand); and
- CL- Clay (lean) with sand (e.g., 15 to 29 percent sand).

The USCS group symbols require the use of lean clay (CL) and fat clay (CH). The use of these symbols is dependent on the plasticity of the soil. Classification such as silty clay can only be used for a very narrow set of conditions, and will only be used if Atterberg Limit results are available. The lean and fat clay designations are not universally used, but adherence to the USCS requires that these symbols be used.

Correlation of N-values and consistency for clays is unreliable. Consistency determinations will be performed using more appropriate static test methods, especially for very soft to stiff clays. N-values are more reliable in hard clays.

Estimates of unconfined compressive strength (Su) can be obtained by a pocket penetrometer test. To estimate consistency and compressive strength with a pocket penetrometer, cut a minimum 4-inch (10 cm) soil core perpendicular to the soil core length. Hold the core with moderate confining pressure so as not to deform the soil core. Slowly insert the pocket penetrometer tip into the perpendicular face of the soil core until the pocket penetrometer indents the soil core to the mark indicated on the piston of the penetrometer. The pocket penetrometer estimate of the soil compressive strength (Su) is the direct reading of the value mark on the graduated shaft indicated by the shaft ring marker, or by the graduated piston reading at the shaft body. For average estimates, complete this procedure several times on the ends and middle of the soil core. For Shelby tube samples (or thin wall samplers), perform the pocket penetrometer test at several locations on the exposed ends of the sample.

In situ shear vane tests or other test methods provide better compressive strength estimates for very soft to stiff consistency clay soil.

Describing soil consistency is an important component in evaluating the engineering properties and strength characteristics of fine-grained cohesive soil. Consistency terms like soft and hard are based on the unconfined compressive strength (Su) and shear strength or cohesion (cu) of the soil.

Patterns of soil gas and groundwater movement in fine-grained soil are influenced by natural soil structure. Soil structure is dependent on the depositional method and to a lesser extent climate. The identification of fill soil is equally important in determining soil characteristics in fine-grained soils.

## 5.8 PROCEDURES FOR SURFICIAL SOIL SAMPLING

This section provides a limited discussion on considerations for the design of a soil sampling program in order to provide the sampling team members with a basic understanding of those considerations.

### 5.8.1 BACKGROUND

Soil sampling locations are selected in order to obtain representative soils with the minimum number of samples. Prior to conducting an investigation, a site inspection may eliminate many uncertainties with respect to site characteristics and result in a more complete soil sampling study. The site inspection should identify pertinent features (e.g., rock outcrops, drainage patterns, surface runoff, surface cover characteristics (e.g., grass, gravel, concrete), wet areas, and fill areas) and evaluate the relationship between those features and potential sources of contaminants. An understanding of these relationships and conditions is important in developing a sampling plan.

### 5.8.2 RANDOM, BIASED, AND GRID-BASED SAMPLING

Unless there is a strong indication of contaminant presence, such as staining, soil sample locations may be randomly selected from several areas within the site, such as near obvious potential sources of current or historic contamination. Potential sources include large transformers, aboveground storage tanks (ASTs), mandoors, outdoor storage racks, and drainage swales.

If an area shows evidence of contamination, such as staining or vegetative stress, biased samples are collected from the area to characterize the contamination. Background and control samples are also biased, since they are collected in locations typical of non-site-impacted conditions.

When a soil sampling investigation involves a large area, grid-based soil sampling is performed. There is no single grid size that is appropriate for all sites. Common grid sizes are developed on 50-foot and 100-foot (15 to 30 m) centers. It is acceptable to integrate several different grid sizes in a single investigation.

For a surficial soil sampling program, it is also important to consider the presence of structures and drainage pathways that might affect contaminant migration. It is sometimes desirable to select sampling locations in low-lying areas which are capable of retaining some surface water flow since these areas could provide samples which are representative of historic site conditions (worst-case scenario if surface water flow is a concern).

### 5.8.3 SAMPLE INTERVAL

Surficial soil is generally considered to be soil between ground surface and 6 to 12 inches (15 to 30 cm) below ground surface. However, for risk assessment purposes, regulatory authorities often consider soil from ground surface to 2 feet (0.6 m) below ground surface to be surficial soil.

*Note: Ontario regulations state that surficial soils are 0 to 6 inches (0 to 15 cm) below ground surface.*

The exact interval to be considered as surficial soil is often a matter of discussion with the regulatory authorities that review the Work Plan. The sample interval is important to the sample collection method and to the manner in which the data are ultimately interpreted. Another important factor is the type of soil. If there are different types of soil present at the site, this may have a bearing on the sample interval. For example, it may be important to separately sample a layer of material with high organic carbon content which overlies a layer of fine-grained soil.

### 5.8.4 PROCEDURES FOR SURFICIAL SAMPLING

Soil sampling methods are dependent upon the sample interval of interest, the type of soil material to be sampled, and the requirements for handling the sample after retrieval. The most common method for collection of surficial soil samples is the use of a stainless steel trowel. Soil samples may also be collected with spoons and push tubes. Often a shovel is required to open a trench such that sampling can be conducted. Soil that has come in contact with the shovel cannot be used as sample material.

In all cases, the sampling device must be constructed of an inert material with smooth surfaces which can be easily decontaminated. The decontamination protocol employs a sequence of cleaning agents and water designed to remove surface contaminants (refer to Section 5.6). All sampling equipment is cleaned between sample locations. A typical surficial soil sampling protocol is outlined below:

1. Collect surficial soil samples using a precleaned stainless steel trowel or other appropriate tool. Each sample consists of soil from the surface (or other starting depth) to the depth specified in the Work Plan. Sample in ditches only when there is no water present.
2. Use a new pair of disposable gloves at each sample location.
3. Prior to use, at each sample location, decontaminate all sampling tools as specified in the Work Plan or as described in Section 5.5.
4. Use a precleaned sampling tool to remove the sample from the layer of exposed soil. Place the collected soil directly into a clean, prelabeled sample jar and seal with a Teflon-lined cap. If a sample is to be split for duplicate analyses, first homogenize the soil in a precleaned stainless steel bowl.
5. After collection, place the samples on ice or cooler packs in a laboratory-supplied cooler.

Surficial debris (e.g., grass cover) should be removed from the area where the sample is to be collected using a separate precleaned device.

In the event that soil conditions are not as described in the Work Plan, or if there are unexpected distinct layers of soil present (e.g., a layer of high organic carbon content overlying a layer of fine-grained soil), sampling personnel should immediately report the conditions to the Project Coordinator for direction. Similarly, if a sampling location is in a gravel or paved area, sampling personnel should confirm with the Project Coordinator whether the surface samples are to be collected from the gravel/pavement subbase material or from the first layer of soil beneath these layers.

Also, sampling team members should immediately report any conditions to the Project Coordinator that they believe may have a negative effect on the quality of the results.

It is generally inadvisable to collect samples containing excessive amounts of large particles such as gravel. Gravel presents difficulties for the laboratory in terms of sample preparation and the results may not be truly representative of contaminant concentrations in nearby soil.

All conditions at the time of sample collection are properly documented in a field log book. This includes a thorough description of the sample characteristics including grain size, color, and general appearance; date/time of sampling; and labeling information. The location of the sampling point is described in words, and three measurements are taken from adjacent permanent structures so that, if necessary, the sample location can be readily identified in the field at a future date. It is often advisable to have a licensed land surveyor accurately survey the locations.

Soil samples are homogenized in a stainless steel bowl prior to filling sample containers. This step can be bypassed if only one sample container is required to be filled, as long as the laboratory will homogenize the sample upon receipt. It is important that soil samples be mixed thoroughly to ensure that the sample is as representative as possible of the sample interval. When using a round bowl, mixing is achieved by stirring the material in a circular motion and occasionally turning the material over. Fill the sample container completely, leaving no headspace.

Do not mix soil for samples for VOC analyses as this promotes the partial volatilization of compounds from the soil.

In 1997, EPA adopted new methods for sampling soils for VOC analysis. Method 5035 calls for collecting soil using a coring device (EnCore). For analysis of low level VOCs (typically 1 to 200 μg/kg), soil is sealed in a specially prepared vial with a solution of sodium bisulfate. For higher levels of VOCs, the soil is placed in a vial with a volume of methanol. This method increases the complexity of collecting soils and makes it imperative that the sampler and laboratory work closely together. For some soil sampling programs, multiple EnCores are required for each sample interval. The number of EnCores required per sample interval should be ascertained during the prior planning and preparation stage.

<u>Discrete Grab Sampling Methodology for Surficial Soils</u>

Discrete grab sampling is employed when the sampling location is considered to be a small area [approximately 1 square foot (0.1 square meter)] that has both a consistent soil type and a consistent level of contaminant impact.

When collecting a discrete grab surficial soil sample, use the following procedure:

1. Using the sampling device (e.g., trowel, spoon, Oakfield sampler) scoop soil from the top 2 inches (5 cm) into the sample container. If the sample is being collected for VOC analyses, perform this step as quickly as possible in order to minimize the loss of volatile compounds from the soil.
2. Collect a field screening sample from the same sampling location as the discrete grab sample and at the same time. Scoop soil into a zip-loc bag until it is no more than one quarter full.
3. Do not mix the soil for samples collected for VOC analyses (for sample homogenization purposes) as this will promote the loss of volatile compounds from the soil. The laboratory will obtain a representative sample from the container by using coring techniques before the laboratory analysis is performed.

Composite Sampling Methodology for Surficial Soils

A composite sample can be obtained directly from the soil surface by combining a number of discrete grab samples from a number of sampling locations on the soil surface. For preparation of a meaningful composite sample, the soils from the sub-samples taken from the different sampling locations should have (by visual observation) similar contaminant concentrations.

When collecting a composite surface soil sample, use the following procedure:

1. Choose a number of discrete sampling locations that will give a representative sample of the defined composite area at each sampling location.
2. Using the sampling device (e.g., trowel, spoon), scoop the soil from the top 2 inches (5 cm) into the sample container. As much as practical, try to put approximately the same volume of soil from each sampling location into the container.
3. Move to the next sampling location and repeat steps 1 and 2.
4. Collect a maximum of five surface samples (to avoid the complete dilution of any hot spots).
5. When the last location has been sampled, ensure the sample container is filled with soil, leaving no headspace.
6. Since composite samples are used for semi-volatile organic compounds (SVOCs) and inorganic parameters, minimizing the sample collection time is not as important as when discrete samples for VOC analyses are being collected. However, the preferred practice is that the sampler take no longer than necessary to obtain the sample.
7. Collect a field screening sample from the same sampling location as the composite sample and at the same time. As much as practical, try to put approximately the same volume of soil from each discrete grab sampling location into a zip-loc bag. The zip-loc bag should be no more than one quarter full after all the sub-samples have been added.

Since composite samples are not analyzed for VOCs, there is no reason to avoid mixing the sub-samples from the various sampling locations in the sample container (homogenization). However, since the laboratory will use coring techniques to ensure that a sample is representative of the entire container, there is no need to perform field homogenization of the soil within the sample container.

During the sampling program, the sampling team leader will stay in contact with the CRA chemist assigned to the project such that the CRA chemist can properly inform the contract laboratory of the progress of the work. This includes submitting sample summaries and/or copies of completed chain-of-custody forms to the CRA chemist.

Finally, some CRA QAPPs require a designation of a QA/QC officer for field activities. The sampling team leader may be required to conduct certain field audit activities and, at minimum, should be familiar with and responsible for completion of all QA/QC sample activities.

## 5.9 PROCEDURES FOR BOREHOLE INSTALLATION AND SAMPLING

Once the prior planning and preparation activities are completed, the drilling program can proceed. The typical series of events that takes place is:

1. Locating and marking boring locations.
2. Initiation of a Property Access/Utility Clearance Data Sheet (QSF-019), including obtaining appropriate signoffs by the client representative and drilling subcontractor representative.
3. Contractor mobilization; equipment and material check.
4. Site selection of decontamination pad and drum staging area (if applicable); final visual examination of proposed drilling area for utility conflicts.
5. Decontamination of sampling and drilling equipment prior to use in accordance with the Work Plan or as described in Section 5.6.
6. Borehole advancement utilizing the approved method as outlined in the Work Plan.
7. Soil sample collection; descriptions of the soil samples in accordance with CRA protocol.
8. Monitoring well installation (if applicable).
9. Sample preparation and packaging.
10. Abandonment of boreholes or installation of monitoring wells.
11. Collection of groundwater samples (if monitoring wells are installed).
12. Surveying of borehole location and elevations.
13. Field note completion and review.

### 5.9.1 LOCATION AND MARKING OF DRILL SITES/FINAL VISUAL CHECK

The proposed borehole locations marked on the site plan are located in the field and staked. On most sites, this will likely be done several days in advance of the drill rig arriving on site. Unless boreholes are to be installed on a fixed grid, the proposed locations are usually strategically placed to assess site conditions.

| | |
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| Note: | *Any borehole (and all the records thereof) which is completed with casing as a temporary or permanent monitoring well, will be designated by the monitoring well number only (i.e., MW1-yy). Boreholes drilled strictly as soil test borings in which no casing is set (even if an open-hole groundwater sample is collected) will be designated by the boring number only (i.e., BH1-yy).* |

Once the final location for the proposed boring has been selected and utility clearances are complete, one last visual check of the immediate area should be performed before drilling proceeds. This should confirm the locations of any adjacent utilities (subsurface or overhead) and verification of adequate clearance. If gravity sewers or conduits exist in the area, any access manholes or chambers should be opened and the conduit/sewer alignments confirmed. Do not enter manholes unless confined space procedures are followed.

If possible, it is prudent to use a hand auger or post-hole digging equipment to a sufficient depth to confirm that there are no buried utilities or pipelines. Alternatively, a Hydrovac truck can vacuum a large diameter hole to check for utilities, although soils collected this way may require containment on site. This procedure generally clears the area to the full diameter of the drilling equipment which will follow.

| | |
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| ***Caution:*** | *Do not assume site plan details regarding pipe alignments/position are correct. Visually check pipe position when drilling near sewers. Personnel should also be alert to additional piping presence if the plans are outdated.* |

If it is necessary to relocate a proposed borehole due to terrain, utilities, access, etc., the Project Coordinator must be notified and an alternate location will be selected.

### 5.9.2 SAMPLE COLLECTION

A boring is advanced incrementally to permit intermittent or continuous sampling. Test intervals and locations are normally stipulated by the Project Coordinator or Work Plan. Typically, the depth intervals for sampling is 2.5 to 5 feet (0.75 to 1.5 m), or less in homogeneous strata, with at least one test and sampling location at every change of stratum. In some cases samples are taken continuously (i.e., 2-foot (0.6 m) long samples at 2-foot (0.6 m) intervals).

Collected soil samples are described in the field using the modified USCS. The soil description is recorded on a Stratigraphic Log (Overburden) (Form SP-14) or field book in the following order:

1. USCS Soil Symbol of major component.
2. Native or fill.
3. Secondary and minor soil components.
4. Relative densities/consistency.
5. Grain-size/plasticity.
6. Gradation/structure.
7. Color.
8. Moisture content.
9. Observations of odor or visual chemical presence [i.e., non-aqueous phase liquid (NAPL)].
10. Additional descriptions.

For environmental sampling, always change gloves between collecting subsequent soil samples to prevent cross-contamination. Decontaminate all tools (e.g., samplers, spatulas) prior to use on each sample to prevent cross-contamination in accordance with the Work Plan or as described in Section 5.6.

Any drilling procedure that provides a suitably clean and stable hole before insertion of the sampler, and assures that the standard penetration test (SPT) or other sampling technique is performed on essentially undisturbed soil, is acceptable. The drilling method is selected based on the subsurface conditions. Each of the following methods has proven to be acceptable for specific subsurface conditions:

- HSA with inside diameter between 2.5 and 6.25 inches (5.7 to 15.9 cm);
- solid stem auger (SSA) with auger diameter between 2.5 and 6.25 inches (5.7 to 15.9 cm);
- direct-push (dual tube systems, discrete soil sample systems);
- open-hole rotary drilling; and
- wash boring.

Several drilling methods are not acceptable. These include:

- jetting through an open tube sampler and then sampling when the desired depth is reached;
- SSA use below the groundwater table in non-cohesive soils;
- casing driven below the sampling depth prior to sampling;
- advancing a borehole with bottom discharge bits; and
- advancing a boring for subsequent insertion of the sampler solely by means of previous sampling when performing SPT (the open hole must be larger in diameter than the split-spoon sampler).

Discrete Grab Sampling Methodology for Boreholes

When borehole drilling, the split-spoon sample retrieved from the borehole is considered a discrete grab sample that has been taken from one sampling location, as long as both the stratigraphy of the entire sample and the level of contamination are consistent over the length of the split-spoon sample. If a single split-spoon sample contains soils from two different stratigraphic units, the soils from each of these stratigraphic units are considered separate discrete grab samples.

If a single split-spoon sample contains soils from a single stratigraphic unit, but visual observation indicated that some of the soil was heavily impacted with contaminants, while the rest of the soil was only lightly impacted, then the soils representing each of the two levels of contamination are considered two separate discrete grab samples.

Composite Sampling Methodology for Boreholes

A composite sample is obtained by combining a number of discrete grab samples from the same borehole. For preparation of a meaningful composite sample, the soils from the sub-samples taken from the different split-spoon samples should be from a single stratigraphic unit and have (by visual observation) similar contaminant concentrations (or be physically similar for geotechnical testing purposes).

Use the following methodology for preparing a composite sample from these discrete grab split-spoon samples:

1. Prior to collecting a sample of the soil for field vapor screening or chemical analysis, if smearing of soil is apparent on the outside of the soil core, scrape away the outer layer of the soil using a decontaminated putty knife, stainless steel spoon, or similar implement. This should only be performed if the soil core sample is consolidated. Do not use this procedure for unconsolidated soil samples.
2. Split the sample longitudinally along the length of the split-spoon sampler. Use one half of the core sample to prepare a composite sample to be used in soil headspace vapor screening measurements, and the other half to prepare a composite sample to be submitted to the laboratory for chemical analysis or geotechnical testing.
3. Place sub-samples from various sampling locations (i.e., split-spoon samples) into a zip-loc bag for field screening. As much as practical, attempt to place approximately the same volume of soil from each sampling location into the zip-loc bag.
4. For samples where laboratory analysis is also desired, place sub-samples from various sampling locations into the appropriate soil sample containers. As much as practical, attempt to place approximately the same volume of soil from each sampling location into the sample container.

The following subsections describe specific protocols for split-spoon sampling, Shelby tube sampling, and methods for collecting soil samples using a direct-push rig.

#### 5.9.2.1 SPLIT-SPOON SAMPLERS

This method is used to obtain representative samples of subsurface soil materials and to determine a measure of the in situ relative density of the subsurface soils. The test methods described below must be followed to obtain representative samples.

SPT involves the use of split-barrel samplers (also known as split spoons). Split-spoon sampling is performed in accordance with ASTM D1586. The split-spoon sampler consists of an 18- or 24-inch (45 or 60 cm) long, 2-inch (5 cm) outside diameter tube, which comes apart lengthwise into two halves. An example of a split-spoon sampler is presented on Figure 5.2.

*Note: A typical 2-inch (5 cm) outside diameter split-spoon is 1 3/8-inch (3.5 cm) diameter at the drive shoe and 1 1/2-inch (3.8 cm)diameter within the barrel of the split spoon. The volume of the soil in a completely filled 24-inch (61 cm) long split-spoon is approximately 19.8 oz (586 mL), thus the sample volume requirements are important if multiple types of parameters requiring differing analytical techniques are required [i.e., VOCs, SVOCs, metals, petroleum hydrocarbon compounds (PHC)]. Soil recovery in a split spoon is often less than 24 inches (61 cm), resulting in less available volume.*

Once the borehole is advanced to the target depth and cleared of cuttings, representative soil samples are collected in the following manner:

1. The split-spoon sampler is inspected to ensure it is properly cleaned and decontaminated. The driving shoe (tip) should be relatively sharp and free of severe dents and distortions.
2. The cleaned split-spoon sampler is attached to the drill rods and lowered into the borehole. Do not allow the sampler to drop onto the soil in the bottom of the borehole.
3. After the sampler has been lowered to the bottom of the hole, it is given a single blow to seat it and make sure that it is in undisturbed soil. If there still appears to be excessive cuttings in the bottom of the borehole, remove the sampler from the borehole and remove the cuttings.
4. Mark the drill rods in three or four successive 6-inch (15 cm) increments, depending on sampler length, so that the advance of the sampler under the impact of the hammer can be easily observed for each 6-inch (15 cm) increment.

The sampler is then driven continuously for either 18 or 24 inches (45 or 60 cm) by use of a 140-pound (63.5 kg) hammer. The hammer may be lifted and dropped by either the cathead and rope method, or by using a trip, automatic, or semi-automatic drop system. The hammer should free-fall a distance of 30 inches (±1 inch) (75 cm, ±25 mm) per blow. Measure the drop at least daily to ensure that the drop is correct. To ensure a free-falling hammer, no more than 2 1/4 turns of the rope may be wound around the cathead (see ASTM D1586). The number of blows applied in each 6-inch (15 cm) increment is counted until one of the following occurs:

1. A total of 50 blows have been applied during any one of the 6-inch (15 cm) increments described above.
2. A total of 100 blows have been applied.
3. There is no advancement of the sampler during the application of ten successive blows of the hammer (i.e., the spoon is 'bouncing' on a stone or bedrock).
4. The sampler has advanced the complete 18 or 24 inches (45 or 60 cm) without the limiting blow counts occurring as described above.

In some cases where the limiting number of blow counts has been exceeded, CRA may direct the driller to attempt to drive the sampler more if collection of a greater sample length is essential, as long as the sampler is still being advanced.

On the field form, record the number of blows required to drive each 6-inch (15 cm) increment of penetration. The first 6 inches (15 cm) is considered to be a seating drive. The sum of the number of blows required for the second and third 6 inches (15 cm) of penetration is termed the 'standard penetration resistance' or the "N-value".

> Note: *If the borehole has sloughed and there is caved material in the bottom, the split spoon may push through this under its own weight, but now the spoon is partially 'pre-filled'. When the spoon is driven the 18 or 24 inches (45 or 60 cm) representing its supposedly empty length, the spoon fills completely before the end of the drive interval. Three problems arise:*
>
> 1. *The top part of the sample is not representative of the in-place soil at that depth.*
> 2. *The SPT value will be artificially higher toward the bottom of the drive interval since the spoon was packed full. These conditions should be noted on the field log.*
> 3. *The available sample volume is significantly reduced.*

The sampler is then removed from the borehole and unthreaded from the drill rods. The open shoe (cutting end) and head of the sampler are partially unthreaded by the drill crew and the sampler is transferred to the geologist/engineer work surface.

> Note: *A table made out of two sawhorses and a piece of plywood is appropriate, or a drum, both covered with plastic sheeting.*

The open shoe and head are removed by hand by the drill crew or CRA representative, and the sampler is tapped so that the tube separates.

> Note: *Handle each split spoon with clean disposable gloves if environmental samples are being collected from that split-spoon sample.*

Measure and record the length of sample recovered making sure to discount any sloughed material that is present on top of the sample core.

Caution must be used when conducting split-spoon sampling below the groundwater table, particularly in sand or silt. These soils tend to heave or "blow back" into the HSA due to the difference in hydraulic pressures between the inside of the HSA and the undisturbed soil. To equalize the hydraulic pressure, it may be necessary to fill the inside of the HSA with potable water from a reliable and pre-tested source. Drilling mud is uncommonly used and presents problems for sample collection and well development. The water level within the boring or HSA needs to be maintained at or above the in situ groundwater level at all times during drilling, removal of drill rods, and sampling. Since heave or blow back is not always obvious to the driller, it is essential that the water level in the borehole always be maintained at or above the groundwater level. Split-spoon sampling below the water table in sands and silt occasionally results in non-representative samples being collected due to the heaving effect disturbing the soil. This is particularly important if the water level in the hole has not been maintained at the in situ water level.

Heaving conditions and the volume of potable water used should be noted on a Stratigraphic Log (Overburden) (Form SP-14). The volume of water added must be removed during well development prior to groundwater sampling. This practice may not be acceptable if environmental samples are to be collected.

Suspected low N-values should be noted on the field logs. If it is critical to have accurate N-values below the water table, other methods can be employed, such as conducting a dynamic cone penetration test. This quick and easy test involves attaching a cone shaped tip to the end of the drill rods, and driving the tip into the ground similar to the split-spoon method, except that the borehole is not pre-augered. Cones may be driven 20 to 40 feet (6.1 to 12.2 m) through a formation without augering. Blow counts are recorded for each 1 foot (0.3 m) of advancement. Consult the Project Manager if such conditions are unexpectedly encountered.

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| *Note:* | *A 3-inch (7.5 cm) outside diameter split spoon is available in order to obtain larger sample volumes. However, the SPT values from driving this sampler are typically much higher than those for the 2-inch (5 cm) split spoon.* |

Larger-Diameter Barrels

A variation of split-barrel sampling involves the use of a longer, larger diameter barrel in conjunction with a HSA. The sampling barrel is installed inside the auger with a swivel attachment to limit rotation of the barrel. After completion of a 5-foot (1.5 m) auger penetration, the auger is left in place and the barrel retrieved from the borehole. This method provides a larger diameter core, which may be desirable for bench-scale testing or where a large volume of soil is required for sample analyses. The sampler should be handled and the sample retrieved in the same way as described above for split-spoon sampling.

### 5.9.2.2 SHELBY TUBE SAMPLERS

Thin-walled samplers such as Shelby tubes are used to collect relatively undisturbed samples (as compared to split-spoon samples) of soft to stiff clayey soils. The Shelby tube has an outside diameter of 2 or 3 inches (5 to 7.5 cm) and is 3 feet (0.9 m) long. These undisturbed samples are used for certain laboratory tests of structural properties (consolidation, hydraulic conductivity, shear strength) or other tests that might be influenced by sample disturbance. Procedures for conducting thin-walled tube sampling are provided in ASTM D1587, and are briefly described below:

1. The soil deposit being sampled must be cohesive in nature, and relatively free of gravel and cobble materials, as contact with these materials will damage or collapse the sampler.
2. Clean out the borehole to the sampling elevation using whatever method that will ensure the material to be sampled is not disturbed. If groundwater is encountered, maintain the liquid level in the borehole at or above groundwater level during the sampling operation.

3. Bottom discharge bits are not permitted. Side discharge bits may be used, with caution. Jetting through an open-tube sampler to clean out the borehole to sampling elevation is not permitted.

4. Remove loose material from the center of the casing or HSA as carefully as possible to avoid disturbance of the material to be sampled.

5. Place the sample tube so that its bottom rests on the bottom of the hole. Advance the sampler into the formation without rotation by a continuous and relatively rapid motion. Usually hydraulic pressure is applied to the top of the drill rods.

6. Determine the length of advance by the resistance and condition of the formation, but the length shall never exceed 5 to 10 diameters of the tube in sands and 10 to 15 diameters of the tube in clays.

7. In no case should the length of advance be greater than the sample-tube length minus an allowance for the sampler head and a minimum of 3 inches (7.5 cm) for cuttings.

8. The tube may be rotated to shear the bottom of the sample 2 to 3 minutes after pressing in, and prior to retrieval to ensure the sample does not slide out of the tube. Lift the weight of the rods off of the tube prior to rotating.

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

10. Package and transport the sample in accordance with project-specific requirements.

Occasionally, the Project Manager/Coordinator may require extraction of the sample from the tube in the field. Use the following procedure:

1. A sample extruder, which consists of a clamp arrangement to hold the tube and a hydraulic ram to push the sample through the tube, is usually provided by the driller. To prevent cross-contamination, ensure the extruder is field cleaned between each sample.

2. The sample is then extruded into a carrying tray; these are often made from a piece of 4-inch (10 cm) or 6-inch (12.5 cm) diameter polyvinyl chloride (PVC) pipe cut lengthwise. Ensure the carrying tray is field cleaned between each sample. The sample is carried to the work station for geologic description. Trim the potentially cross-contaminated exterior and place it in the appropriate container.

3. The Shelby tube sampler is then thoroughly field cleaned and decontaminated for reuse. Since they are thin-walled, the tubes are easily damaged, crimped, or otherwise distorted during handling or pushing. The Shelby tube should be inspected before use and, if significantly damaged, rejected.

### 5.9.2.3 DIRECT-PUSH SAMPLING SYSTEMS

Direct-push refers to the sampler being 'pushed' into the soil material without the use of rotation to remove the soil. This method relies on the drill unit static weight combined with rapid hammer percussion for advancement of the tool string. Soil samples are continuously obtained. Groundwater and vapor samples can also be collected utilizing this method and appropriate tooling. Subsurface investigations typically sample to depths of 30 feet (9.1 m) or more; however, depth will vary based on the site-specific geology.

Direct-push methods are widely used for underground storage tank (UST) investigations and property investigations. This method is used extensively for initial site screening activities to establish site geology and to delineate vertical and horizontal plume presence. Small diameter wells [3/4 or 1 inch (2 or 2.5 cm)] diameter can be installed using direct-push methods, often using a pre-packed screen. SPT values cannot be obtained when sampling with a direct–push discrete soil sampler.

This method is also popular due to the limited cuttings produced during the drilling and sampling process and the increased sampling process speed, which can be much quicker than the sample description and sample preparation process. (It is often helpful to have two people, depending on the nature of the work program.)

Continuous soil samples are collected in tube samplers (various lengths), affixed with a cutting shoe and internal liner (PVC, Teflon, or acetate are available). The soil sampler may be operated in open-mode (when borehole collapse is not a concern), or closed-mode (when minimization of sample slough is desired). Closed-mode operation involves the placement of a temporary drill-point in the cutting shoe and driving the assembled sampler to depth. Once at the required depth, the temporary drill–point is released (via internal threading) and the sampler is driven to the desired soil interval. The drill-point slides inside the sample liner, riding above the collected soil column. Once driven to depth, the sampler is retrieved to the ground surface and the sample liner with soil, is removed for examination.

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| ***Caution:*** *Be careful when opening interval liners with knives, as severe cuts may result from the knife slipping. A special two-blade hooked knife is available for opening the liners. Generally the driller/helper will open the liner for you.* |

### 5.9.3 FIELD SAMPLE SCREENING

When soil sampling at sites with known or suspected VOC impact, it is often required to measure the soil for the presence of undifferentiated organic vapors. This field screening can be performed using a photoionization detector (PID). Immediately upon the opening of the split-spoon or discrete soil sampler, the soil is screened with a PID (HNu, Microtip, or equivalent) for the presence of undifferentiated organic vapors. This is accomplished by running the PID along the length of the soil sample. Record the highest reading.

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| *Note: The PID measurement must be taken upwind of the drill rig or any running motors so that exhaust fumes will not affect the measurements.* |

Another method of field screening is head space measurement. This consists of placing a portion of the soil sample in a sealable glass jar, placing aluminum foil over the jar top, and tightening the lid. The jar is only partially filled. The jar is shaken and set aside for at least 30 minutes. After the sample has equilibrated, the lid of the jar is opened, the foil is punctured with the PID probe, and the air (headspace) above the soil sample is monitored. Record this headspace reading on the field form or in the field book. As an alternative, the soil can be placed in a sealable zip-loc bag.

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| Note: | *Perform headspace readings in an area that is not subject to wind. Also, in the winter, it is necessary to allow the samples to equilibrate in a warm area to ±70°F (20°C (e.g., site trailer or van, but not direct heat or sunshine). The portion of the sample used for headspace analysis cannot be used for VOCs analysis.* |

Representative portions of the soil sample must be retained for geologic record following description. Place the soil portions into labeled, sealable sample containers (usually mason jars or zip-loc bags) without destroying any apparent stratification. If a stratigraphic change is observed within the split-spoon sampler, a separate geologic record sample is kept.

All geologic record samples are to be retained by the client. Geologic record samples must not return to or be placed in storage at a CRA office. An example of a properly completed Stratigraphy Log (Overburden) is presented on Figure 5.2.

### 5.9.4 CHEMICAL DESCRIPTION

During soil examination and logging, carefully check for the presence of light or dense NAPL. NAPL may be present in gross amounts or present in small/minute quantities. The adjectives and corresponding quantities used when describing NAPL within a soil matrix are as follows:

| *Visual Description* | *Fraction of Soil Pore Volume Containing NAPL* |
|---|---|
| Saturated | >0.5 |
| Some | 0.5 - 0.25 |
| Trace | <0.25 |

A complete description of NAPL must describe the following:

- color;
- quantity;
- density (compared to water) (i.e., light/floats or heavy/sinks);
- odor (if observed); and
- viscosity (i.e., mobile/flowable, non-mobile/highly viscous-tar like).

The presence of an "iridescent sheen" by itself does not constitute "NAPL presence", but may be an indicator that NAPL is close to the area.

NAPL presence within a soil matrix may be confirmed by placing a small soil sample within water, shaking, and observing for NAPL separation (i.e., light or dense) from the soil matrix.

Trace amounts of NAPL are identified/confirmed by a close visual examination of the soil matrix, (i.e., separate soil by hand, wearing disposable gloves) and performing a careful inspection of the soil separation planes/soil grains for NAPL presence.

Often during sample examination with a knife, an iridescent sheen will be noted on the soil surface (i.e., clay/silts) if the knife has passed through an area of NAPL.

There are a number of more complicated tests available to confirm/identify NAPL presence, these are:

- ultra violet (UV) fluorescent analysis;
- hydrophobic dyes (use with care, consult the health and safety SOPs as some hydrophobic dyes are potential human carcinogens);
- centrifugation; and
- chemical analysis.

CRA typically utilizes organic vapor detection results, visual examination, soil/water shake testing, and chemical analysis, to confirm NAPL presence. The more complex techniques described may be incorporated on sites where clear colorless NAPL is present and its field identification is critical to the program.

### 5.9.5 CHEMICAL SAMPLE PREPARATION AND PACKAGING

Subsurface soil samples are usually grab samples, used to characterize the soil at a specific depth or depth interval [e.g., 2 to 4 feet (0.6 to 1.2 m)]. On occasion, composite samples are collected from a borehole over a greater depth interval (e.g., 5 to 15 feet (1.5 to 4.1 m)].

The following describes the collection of grab samples for chemical analysis (all soil from one split spoon). Figure 5.2 shows the split-spoon sample selection details.

Clayey Soils

1. Discard upper and lower ends of sample core [3 inches (7.5 cm)].
2. Use a precleaned stainless steel knife.
3. Cut the remaining core longitudinally.
4. With a sample spoon, remove soil from the center portion of the core and place in a precleaned stainless steel bowl.
5. Remove large stones and natural vegetative debris.

6. Homogenize the soil and place directly into sample jars.

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| *Note:* | *Samples for VOC analysis* ***must not be homogenized****. Collect soil from the length of the center portion of the core and place in the sample container. Completely fill the container. No air space (headspace) should remain in the sample container.* |

Sandy Soils

As sandy soils have less cohesion than clayey soils, it is not easy to cut the core longitudinally to remove the center of the sample. Therefore, with a stainless steel spoon, scrape away surface soils which have likely contacted the sampler and then sample the center portion of the soil core.

| | |
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| *Note:* | *Place all soil samples collected for chemical analysis immediately into a cooler with ice.* |

Record all soil samples in the sample log book. Label samples as specified in Section 3.9.1.2.

In 1997, EPA adopted new methods for sampling soils for VOC analysis. Method 5035 calls for collecting soil using a coring device (EnCore). For analysis of low-level VOCs (typically 1 to 200 µg/kg) soil is commonly sealed in a specially prepared vial with a solution of sodium bisulfate. For higher levels of VOCs, the soil is placed in a vial with a volume of methanol. This method increases the complexity of collecting soils and makes it imperative that the sampler and laboratory work closely together. For some soil sampling programs, multiple EnCores are required for each sample interval. Holding times for samples in EnCores may be 24 to 48 hours if not field preserved; therefore, the CRA sampler, laboratory, and CRA chemist should discuss sampling and shipping procedures prior to beginning the work program.

### 5.9.6 PHYSICAL SAMPLE PREPARATION AND PACKAGING

When a sample is collected for geotechnical or hydrogeologic properties, the sample needs to be prepared and packaged in a manner to maintain its physical properties. Soil samples are usually grab samples, collected from a specific depth or depth interval [e.g., 2 to 4 feet (0.6 to 1.2 m)]. On occasion, composite samples are collected from the borehole over a greater depth interval [e.g., 5 to 15 feet (1.5 to 4.6 m)].

The following describes the collection of grab samples for geotechnical or hydrogeologic purposes for common samplers, the split-spoon, thin-wall, and direct-push discrete soil sampler. For soil samples collected for geotechnical purposes, the samples must not be allowed to freeze.

#### 5.9.6.1 SPLIT-SPOON SAMPLES

1. Following completion of PID screening of the split spoon, remove and dispose of soil at the top of the sample that is obviously sloughed material not representative of the soil at the sampled depth.

2. Measure the length of the sample and record as the recovered length.

3. If cohesive, perform a pocket penetrometer reading and describe the soil.

4. Carefully transfer the sample onto a sheet of aluminum or tin foil, taking care to maintain structure and bedding of the soil sample as much as possible. This may not be possible with non-cohesive soils with low silt or clay contents. The sample may need to be packaged in three 6- to 8-inch (15 to 20 cm) segments.

5. Roll the sample in the tin foil and fold over the ends to seal. Wrap in a second layer of tin foil.

6. Identify the top, middle, and bottom segments with a T, M, and B using an indelible marker.

7. For each segment record the "up" direction with an arrow.

8. Place the foil wrapped sample in a plastic bag and write the sample identification on the bag using an indelible marker. Storing the sample in foil, as opposed to a jar, has the advantage of retaining the soil's in-place structure and preventing loss of moisture.

9. If the soils are sandy and it is not possible to retain the soils structure by rolling it in tin foil, packaging the sample in a jar or zip-loc bag is also acceptable, provided the jar or zip-loc bag is filled to eliminate air space which could result in the soil sample drying out.

A split-barrel sample is approximately 4 inches (10 cm) in diameter and requires different handling than a split-spoon or Shelby tube sample. For a cohesive core sample, the section of drill core is wrapped in several layers of cheesecloth, coated with paraffin wax, and the process repeated until the entire sample is sealed adequately. These samples are usually utilized for specific bench-scale tests.

#### 5.9.6.2 SHELBY TUBE SAMPLES

1. Remove any sloughed material from the top of the sample using a knife or similar long bladed instrument. If it is not possible to distinguish sloughed soil from intact soil, do not remove.

2. Following removal of sloughed material, measure the tube length and the air space in the tube above the sample and record the difference as the sample recovery. In the unusual circumstance that there is also air space at the bottom of the sample, subtract this as well and record this latter measurement as a separate entry.

3. Seal the top and bottom of the sample with wax (wax is normally provided and prepared by the driller) and first pour the liquefied wax into the top of the sample to a thickness of about 1 inch (2.5 cm). Once this is cooled, remove approximately 1/2 inch (1.3 cm) of soil from bottom of sample (unless there is already a cavity at bottom of sample) and seal similarly.

4. Fill the remaining air space above the sample with loose soil to prevent the sample from shifting in the tube, and then cap both ends of the sample with plastic caps. Tape the caps on using duct tape.

5. Write the sample identification number on the cap using an indelible marker.

Shelby tubes containing soft clays and wet silts need to be handled with care to avoid damage to the sample. Keep samples in an upright position at all times and transport either in a specifically designed cushioned box or position in your vehicle with cushioning under and around the individual tubes. Do not allow geotechnical soil samples to freeze.

### 5.9.6.3 DIRECT-PUSH SOIL SAMPLES

1. Once removed to the ground surface, open the discrete soil sampler by removing the cutting shoe, and extract the soil liner (with recovered soil) from the sampler body.
2. Place the soil liner into a holder and cut lengthwise (using a liner knife) to expose the collected soil core.
3. Perform PID screening for organic vapors and record readings.
4. Measure length of sample and record as the recovered length.
5. If cohesive, perform pocket penetrometer reading and describe soil.
6. Carefully transfer the sample onto a sheet of aluminum or tin foil taking care to maintain structure and bedding of the soil sample as much as possible. This may not be possible with non-cohesive soils with low silt or clay contents. The sample may need to be packaged in multiple 6- to 8-inch (15 to 20 cm) segments.
7. Roll the sample in the tin foil and fold over the ends to seal. Wrap in a second layer of tin foil.
8. Identify the depth interval of each segment using an indelible marker.
9. For each segment record the "up" direction with an arrow.
10. Place the foil-wrapped sample in a plastic bag and write the sample identification on the bag using an indelible marker. Storing the sample in foil, as opposed to a jar, has the advantage of retaining the soil's in-place structure and preventing loss of moisture. If the soils are sandy and it is not possible to retain the soils structure by rolling it in tin foil, packaging the sample in one or more jars or zip-loc bags is also acceptable, provided each jar or bag is filled to eliminate air space which could result in the soil sample drying out.

The soil core is split lengthwise to allow inspection. Chemical samples can be removed from the soil core (if required), or soil record samples can be retained (if a component of the project scope). Soil record samples are often retained to allow sample collection for analysis later (depending upon analyte sensitivity/holding times), or for later inspection/geotechnical testing if required.

### 5.9.7 COMMUNICATION OF FIELD FINDINGS

Field findings should be communicated frequently with the office technical staff responsible for the program. This communication allows the office staff to: confirm that the investigation meets the intent of the Work Plan; alter procedures and sampling protocol if soil conditions are markedly different from those assumed; and assist in determining screening intervals for piezometers or monitoring wells.

Call office staff no later than the completion of the first borehole, and sooner if possible. Be prepared to discuss the results by faxing the field logs beforehand (wherever possible) and by having a copy of the field log in hand when on the telephone. Call after each borehole and call before leaving the site.

### 5.9.8 BOREHOLE ABANDONMENT

Following completion of the borehole it must be properly abandoned in accordance with the project documents. Some jurisdictions have requirements or standards of practice that require filling the borehole with bentonite or cement grout.

| | |
|---|---|
| *Note:* | *The integrity of any underlying confining layer must be restored to prevent chemical cross-contamination or hydraulic cross-connection. This is true for all sites, regardless of the known presence or absence of contaminants. This normally requires grouting of the borehole within the zone of the confining layer.* |

Whenever possible, the cuttings are returned to the borehole to within 1 foot (0.3 m) of the ground surface. The remainder of the borehole is topped off with material consistent with the surrounding ground surface. Excess cuttings are usually collected in drums or a lugger box or spread on the surrounding ground surface consistent with the protocols specified in the Work Plan and as required by federal, state, provincial, and local regulations.

Check with the Project Coordinator to determine the method for handling drill cuttings.

| | |
|---|---|
| *Note:* | *Always include the method of abandonment in the field log book or on a Stratigraphic Log (Overburden) (Form SP-14)* |

### 5.9.9 BOREHOLE TIE-IN/SURVEYING

Recording the locations of boreholes on the site plan is extremely important, and may be accomplished by manual measurement (i.e., swing ties) and surveying. Manual measurements for each borehole must be tied into three permanent features (e.g., buildings, utility poles, hydrants). Include diagrams with measurements in the field book.

In addition to manual measurements, surveying with respect to a geodetic benchmark and a site coordinate system is often completed at larger sites for horizontal and vertical control.

| | |
|---|---|
| *Note:* | *Manual field measurements are always necessary regardless of whether a survey is completed.*<br>*Manual measurements in field notes allow future identification of the sample/drill site without the need for a survey crew to locate positions using a grid system. This becomes important when trying to locate flushmount wells buried by snow or soils.* |

### 5.9.10 FIELD NOTES

Field notes must document all the events, equipment used, calibration activities, and measurements collected during the sampling activities. The field notes must be legible and concise such that the entire borehole installation and soil sampling event can be reconstructed for future reference.

Field notes documenting events, equipment used, and related items are typically recorded in a standard CRA field book, while soil descriptions and PID readings are recorded on a Stratigraphic Log (Overburden) (Form SP-14). Standard CRA field books are available from all CRA equipment administrators. Form SP-14 is available as a printable linked document in this file or as a bound pad from each office.

> Note: *Use a Stratigraphic Log (Overburden) for recording all soil descriptions and related notes unless otherwise approved by the Project Coordinator/Manager.*

Field book/form entries are made in black ink and any changes/corrections are stroked out with a single line, initialed, and dated to indicate when and by whom the correction was made.

The field notes should document the following for each borehole completed:

1. Identification of borehole.
2. Depth.
3. Static water level depth and measurement technique.
4. Time started and completed.
5. Measured field parameters.
6. Sample appearance.
7. Sample odors (if respiratory protection is not required).
8. Types of sample containers and sample identification numbers.
9. Parameters requested for analysis.
10. Field analysis data and method(s).
11. Sample distribution and transporter.
12. Laboratory shipped to.
13. Chain-of-custody number for shipment to laboratory.
14. Field observations on sampling event.
15. Name of collector(s).
16. Climatic conditions including air temperature.
17. Problems encountered and any deviations made from the established sampling protocol.

## 5.10 PROCEDURES FOR TEST PIT EXCAVATION AND SAMPLING

Once the prior planning and preparation activities are completed, the test pit excavation and subsurface soil sampling program can proceed. The typical series of events which takes place is:

1. Location and marking of test pit locations.
2. Final visual examination of proposed excavation area for utility conflicts.
3. Excavation of test pits and collection of the soil samples.
4. Field screening of soil sample with specific air monitoring equipment (e.g., PID, LEL meter).
5. Description of soil sample and test pit.
6. Completion of Test Pit Stratigraphy Log (Form SP-03).
7. Documentation, including photographs and/or videotape, as required.
8. Chemical sample preparation and packaging.
9. Backfilling of test pit excavation.
10. Surveying of test pit locations.
11. Field note completion and review.

### 5.10.1 LOCATION AND MARKING OF TEST PITS/FINAL VISUAL CHECK

Proposed test pit locations marked on the site plan are located in the field and staked. The proposed test pit locations are usually strategically placed to assess site conditions, former facilities, waste areas, etc.

Once the final location for the proposed test pit has been selected and utility clearances are complete, one last check of the immediate area is performed before excavation proceeds to confirm the locations of any adjacent utilities (subsurface or overhead) and verify adequate clearance. If gravity sewers or conduits exist in the area, any access manholes or chambers are opened and the conduit/sewer alignments confirmed.

> ***Caution:*** *Do not assume site plan details regarding pipe alignments/position are correct. Visually check pipe position when excavating near sewers. Personnel should also be alert to the presence of additional piping, especially if the plans are outdated.*

If it is necessary to relocate a proposed test pit due to terrain, utilities, access etc., the Project Coordinator must be notified and an alternate location will be selected.

### 5.10.2 TEST PIT LOCATION SETUP

The test pit location is set up as follows:

1. The excavator is positioned such that the excavation spoils are deposited by the excavator downwind of all staff.
2. A sheet of polyethylene is placed downwind of the test pit location to accept spoils, if required by the Work Plan.
3. To the extent practicable, the investigation area is set up such that water or liquids that may be excavated, freely drain back into the excavation.
4. The excavation begins at one location with the excavator backing up (as required) to extend the pit.

### 5.10.3 SAMPLE COLLECTION

Soil samples can be collected from the backhoe/excavator bucket or from the test pit excavation face. Samples which require a discrete depth interval are collected from the excavator bucket following excavation of all or a portion of the test pit. Samples are collected using a cleaned steel trowel, shovel, or stainless steel spoon. Samples are placed in a stainless steel bowl and mixed (except VOCs). **Do not enter the test pit**. (Confined Space Entry requirements apply and proper shoring of the excavation walls may be necessary.)

> ***Caution:*** *Personnel observing or sampling test pit operations must never stand within the "turning radius" or "reach-zone" of the excavation equipment. Operator error or equipment failure could result in severe injury or death if struck by the backhoe bucket or the backhoe itself. Stand opposite the backhoe well beyond the far end of the trench for communication.*
>
> *Personnel should also be alert to test pit side wall conditions which typically undermine the ground surface and create unstable soils surrounding the test pit area.*

Discrete Grab Sampling From Test Pits

When taking discrete grab samples from a test pit using an excavator bucket, the sampling location is considered a volume of soil in the bucket that has both a consistent soil type and a consistent level of contaminant impact. When sampling using an excavator bucket, the operator will dig to the desired depth and then provide a small volume of soil from a discrete position and depth in the test pit.

When collecting a discrete grab sample from the excavator bucket, use the following procedure:

1. Scrape off the top 2 inches (5 cm) of soil at the sampling location in the excavator bucket.

2. Using the sampling device (e.g., trowel, spoon) scoop the freshly exposed soil into the sample container. Ensure that the samples taken were not in contact with the excavator bucket to avoid the potential for cross-contamination.

3. Pushing the sample container into the soil in order to fill the container is not recommended. This could result in breaking the sample container and potential injury to field personnel (e.g., cutting hands on broken glass).

4. If the sample is being collected for VOC analyses, perform this step as quickly as possible in order to minimize the loss of volatile compounds from the soil.

5. Collect a field screening sample from the same sampling location as the discrete grab sample and at the same time. Scoop soil into a zip-loc bag until it is no more than one quarter full.

6. Do not mix the soil for samples collected for VOC analyses (for sample homogenization purposes) as this will promote the loss of volatile compounds from the soil. The laboratory will obtain a representative sample from the container by using coring techniques before the laboratory analysis is performed.

Composite Sampling

A composite sample can be obtained by combining a number of discrete grab samples from a test pit sampling location (i.e., excavator bucket). For preparation of a meaningful composite sample, the soils from the sub-samples taken from the different sampling locations should be from a single stratigraphic unit and have (by visual observation) similar contaminant concentrations.

When taking composite samples from multiple excavator buckets, consider each excavator bucket of soil to be a sampling location. When taking a composite sample using the excavator, use the following procedure:

1. Pick a number of discrete sampling locations that will give a representative sample of the horizon of interest in the test pit.

2. From each of these sampling locations, obtain a soil sample from the excavator bucket using the same methodology described in the previous subsection for a discrete grab sample.

3. The sample container should be partially filled with soil from each discrete grab sampling location. As much as practical, try to put approximately the same volume of soil from each sampling location into the container.

4. Move to the next sampling location and obtain another discrete grab soil sample.

5. Collect a maximum of five surface samples (to avoid the complete dilution of any hot spots).

6. When the last location has been sampled, ensure the sample container is filled with soil, leaving no headspace.

7. Since composite samples are used for SVOCs and inorganic parameters, minimizing the sample collection time is not as important as when discrete samples for VOC analyses are being collected. However, the preferred practice is that the sampler take no longer than necessary to obtain the sample.

8. Collect a field screening sample from the same sampling location as the composite sample and at the same time. As much as practical, try to put approximately the same volume of soil from each discrete grab sampling location into a zip-loc bag. The zip-loc bag should be no more than one quarter full after all the sub-samples have been added.

### 5.10.4 FIELD SAMPLE SCREENING

Upon collection of a soil sample, the soil is screened with a PID (HNu, Microtip, or equivalent) for the presence of undifferentiated organic vapors. This is accomplished by running the PID across the soil sample. Record the highest reading and sustained readings.

| | |
|---|---|
| *Note:* | *The PID measurement must be taken upwind of the excavating equipment or running motors so that exhaust fumes will not affect the measurements.* |

Another method of field screening is head space measurement. This consists of placing a portion of the soil sample in a sealable glass jar, placing aluminum foil over the jar top, and tightening the lid. The jar should only be partially filled. Shake the jar and set aside for at least 30 minutes. After the sample has equilibrated, open the lid of the jar, puncture the foil with the PID probe, and monitor the air (headspace) above the soil sample. Record this headspace reading on a Test Pit Stratigraphy Log (Form SP-03) or in the field book.

| | |
|---|---|
| *Note:* | *Perform all headspace readings in an area that is not subject to wind.*<br>*Also, in winter it is necessary to allow the samples to equilibrate in a warm area (e.g., site trailer or van). This requirement is usually dictated by the Work Plan.* |

### 5.10.5 SAMPLE DESCRIPTION AND LOGGING OF TEST PITS

During the excavation of a test pit, samples may be collected to provide a geologic record, to assist the geologist/engineer in completing or characterizing the stratigraphic units, and to allow for physical or chemical testing.

Soil samples collected are described in the field using the modified USCS. The soil descriptions are recorded on the field form or field book in the following order:

1. USCS Soil Symbol of major component.
2. Native or fill.
3. Secondary and minor soil components.
4. Relative densities/consistency.
5. Grain size/plasticity.
6. Gradation/structure.

7. Color.
8. Moisture content.
9. Observations of odor or visual chemical presence (i.e., NAPL).

In addition to describing the soil properties, enter the following information into a Test Pit Stratigraphy Log (Form SP-03):

1. Presence of groundwater and the rate of seepage (if groundwater is encountered).
2. Thickness of each stratigraphic unit.
3. Description of bedding plane features (e.g., continuous, discontinuous, graded, wavy bedding).
4. Description of joints, fractures and faults, if bedrock is encountered (number and orientation).
5. Any appearance of weathering.
6. Description of fill and waste materials.

*Note:* *When describing observed odors, be specific in terms of general odor category and strength of odor noted. Odors may typically be chemical, petroleum, or septic related, varying from slight, to moderate, to strong. Identification of specific chemical compounds (i.e., TCE or C-56 odor) is usually unnecessary and often inaccurate as a detailed analysis commonly shows an array of chemistry present.*

*When describing the presence of vegetative matter in the soil sample, do not use the term "organic" as this often leads to confusion with regards to the presence of organic chemicals (i.e., NAPL).*

When describing the soil samples and the stratigraphy observed in the test pit, it is imperative that the sampler use consistent terms from one test pit to the next. As test pits are installed, compare the stratigraphy of completed test pits to the stratigraphy of the test pit you are currently excavating. Be aware of patterns and confirm all inconsistencies at the time the test pit is being excavated. Since soil stratigraphy is so important to understanding site conditions, soil samples are collected from each stratigraphic unit, and described in full.

### 5.10.6 CHEMICAL DESCRIPTION

Representative portions of the soil sample should be retained as a geologic record along with a description. Place the soil portions into labeled, sealable, sample containers (usually mason jars) without destroying any apparent stratification.

All geologic record samples are to be retained by the client. Geologic record samples must not return to or be placed in storage at a CRA office.

An example of a properly completed Test Pit Stratigraphy Log is presented on Figure 3.12 and described in Section 3.4.1.5.

During soil examination and logging, carefully check for the presence of light or dense NAPL. NAPL may be present in gross amounts or present in small/minute quantities. The adjectives and corresponding quantities used when describing NAPL within a soil matrix are as follows:

| *Visual Description* | *Fraction of Soil Pore Volume Containing NAPL* |
|---|---|
| Saturated | >0.5 |
| Some | 0.5 - 0.25 |
| Trace | <0.25 |

A complete description of NAPL includes the following:

- color;
- quantity;
- density (compared to water) (i.e., light/floats or heavy/sinks);
- odor (if observed); and
- viscosity (i.e., mobile/flowable, non-mobile/highly viscous-tar like).

The presence of an iridescent sheen by itself does not constitute NAPL presence, but may be an indicator that NAPL is close to the area.

NAPL presence within a soil matrix may be confirmed by placing a small soil sample within water, shaking, and observing for NAPL separation (i.e., light or dense) from the soil matrix.

Trace amounts of NAPL are identified/confirmed by a close visual examination of the soil matrix, [i.e., separate soil by hand (wearing disposable gloves)] and perform a careful inspection of the soil separation planes/soil grains for NAPL presence.

Often during the sample examination with a knife, an iridescent sheen will be noted on the soil surface (i.e., clay/silts) if the knife has passed through an area of NAPL.

There are a number of more complicated tests available to confirm/identify NAPL presence, these are:

- UV fluorescent analysis;
- hydrophobic dyes;
- centrifugation; and
- chemical analysis.

CRA typically utilizes organic vapor detection results, visual examination, soil/water shake testing, and chemical analysis, to confirm NAPL presence. The more complex techniques described may be incorporated on sites where clear colorless NAPL is present and its field identification is critical to the program.

### 5.10.7 CHEMICAL SAMPLE PREPARATION AND PACKAGING

Subsurface soil samples are usually grab samples, used to characterize the soil at a specific depth or depth interval [e.g., 2 to 4 feet (0.6 to 1.2 m)]. On occasion, composite samples are collected from a test pit over a greater depth interval [e.g., 5 to 15 feet (1.5 to 4.6 m)].

The following describes the collection of grab samples for chemical analysis:

Clayey Soils

Scrape away the surface soils and collect the sample. Remove large stones and natural vegetative debris and homogenize the soil and place it directly into the sample jars.

> *Note: Samples for VOC analysis must not be homogenized. Remove the outer layer of soil from the excavation face then collect the sample and place it in the sample container. Completely fill the container. No air space (headspace) should remain.*

Sandy Soils

As sandy soils have less cohesion than clayey soils, with a stainless steel spoon or other device scrape away surface soils which have likely contacted the backhoe/excavator bucket, then collect the sample.

> *Note: All soil samples collected for chemical analysis must be placed immediately into a cooler with ice.*

Record all soil samples recorded in the sample log book as described in Section 3.4.1. Labeling of samples shall be consistent with Section 3.9.1.2.

### 5.10.8 DOCUMENTATION

In addition to completing all field logs and books, it will generally be necessary for test pits to be documented with photographs and/or video tape. This requirement should be fully ascertained and coordinated in advance of field activities.

### 5.10.9 TEST PIT ABANDONMENT

Following completion of the test pit, backfill the excavation using the soil excavated from the pit. To the extent practicable, replace materials in the test pit in the same intervals from which they were extracted.

It should be noted that the material will tend to "bulk" after excavation. As a result, the excavator operator must be informed to compact the materials as they are replaced within the excavation.

### 5.10.10 RESTORATION

The test pit location must be fully restored. Ensure that restoration activities are properly designed and incorporated within the scope of services for the test pit contractor.

Restoration could include:

- landscaping;
- paving; and
- concrete.

## 5.11 FOLLOW-UP ACTIVITIES

Complete the following activities at the conclusion of the field work:

1. Double check the Work Plan to ensure all samples have been collected and confirm this with the Project Coordinator.
2. Ensure that all sample locations are surveyed such that the sample location could be readily re-established.
3. Clean equipment and return to the equipment administrator with the appropriate form dated and signed. Complete water disposal (if required), and cleaning fluid disposal requirements as specified in the Work Plan.
4. Notify the contract laboratory as to when to expect the samples. Enclose the chain-of-custody and covering letter, indicating the parameters and number of samples, in the sample cooler. Ensure that the CRA chemist has all relevant information required to track the progress of the sample analysis.
5. Submit a memo to the Project Coordinator indicating sampling procedures and observations (such as surface staining), grid layout, and all QA/QC documentation.
6. Prepare and distribute a Project Planning, Completion, and Follow-Up Checklist (Form SP-02).

## 5.12 REFERENCES

For additional information pertaining to this topic, the user of this manual may reference the following:


Surficial Soil Sampling

| | |
|---|---|
| ASTM D4547 | Practice for Sampling Waste and Soils for Volatile Organics |
| ASTM D6044 | Guide for Representative Sampling for Management of Waste and Contaminated Media |
| ASTM D6051 | Guide for Composite Sampling and Field Subsampling for Environmental Waste Management Activities |

Subsurface Soil Sampling

| | |
|---|---|
| ASTM D420 | Guide for Site Characterization for Engineering, Design, and Construction Purposes |
| ASTM PS 89 | Guide for Expedited Site Characterization of Hazardous Waste Contaminated Sites |
| ASTM D5434 | Guide for Field Logging of Subsurface Explorations of Soil and Rock |
| ASTM D2487 | Classification of Soils for Engineering Purposes (Unified Soil Classification System) |
| ASTM D2488 | Practice for Description and Identification of Soils (Visual-Manual Procedure) |
| ASTM D5781 | Guide for Use of Dual-Wall Reverse-Circulation Drilling for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices |
| ASTM D5782 | Guide for Use of Direct Air-Rotary Drilling for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices |
| ASTM D5783 | Guide for Use of Direct Rotary Drilling with Water-Based Drilling Fluid for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices |
| ASTM D5784 | Guide for Use of Hollow-Stem Augers for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices |
| ASTM D5872 | Guide for Use of Casing Advancement Drilling Methods for Geoenvironmental Exploration and Installation of Subsurface Water-Quality Monitoring Devices |
| ASTM D5875 | Guide for Use of Cable-Tool Drilling and Sampling Methods for Geoenvironmental Exploration and Installation of Subsurface Water-Quality Monitoring Devices |
| ASTM D5876 | Guide for Use of Direct Rotary Wireline Casing Advancement Drilling Methods for Geoenvironmental Exploration and Installation of Subsurface Water-Quality Monitoring Devices |
| ASTM D4700 | Guide for Soil Sampling from the Vadose Zone |
| ASTM D1586 | Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils |
| ASTM D1587 | Practice for Thin-Walled Tube Geotechnical Sampling of Soils |
| ASTM D4220 | Practices for Preserving and Transporting Soil Samples |
| ASTM D6001 | Guide for Direct-Push Water Sampling for Geoenvironmental Investigations |

FIGURES

## TEST PIT STRATIGRAPHY LOG

| | | | |
|---|---|---|---|
| PROJECT NAME: CRA FIELD MANUAL | CONTRACTOR: ACME | TEST PIT DESIGNATION: TP 13 | PAGE 1 of 1 |
| PROJECT NUMBER: 91001-00 | SURFACE ELEVATION: 586.5 ft AMSL | DATE STARTED: APR. 5 1998 | |
| CLIENT: CRA | TEST PIT METHOD: BACKHOE (F-150) | DATE COMPLETED: APR. 6 1998 | |
| LOCATION: ONTARIO LANDFILL | | CRA SUPERVISOR: D.H. | |

| DEPTH (ft) FROM | AT | TO | SAMPLE DESCRIPTION SOIL SYMBOL, PRIMARY COMPONENT, SECONDARY COMPONENTS, RELATIVE DENSITY/CONSISTENCY, GRAIN SIZE/PLASTICITY, GRADATION/STRUCTURE, COLOUR, MOISTURE CONTENT, SUPPLEMENTARY DESCRIPTORS | SAMPLE # | PID (ppm) |
|---|---|---|---|---|---|
| 0 | | 0.8 | TOPSOIL | | |
| | 3.5 | | DRUM FRAGMENT | | |
| 0.8 | | 5 | SM SAND/SILT LOOSE FINE TO MEDIUM GRAINED LIGHT BROWN, MOIST FILL | | |
| 5 | | 10 | OH CLAY/SILT MEDIUM TO HIGH PLASTICITY, SOME GRAVEL, DARK BROWN, MOIST, FILL | | |

LOCATION: TEST PIT 13

GEOLOGIC PROFILE

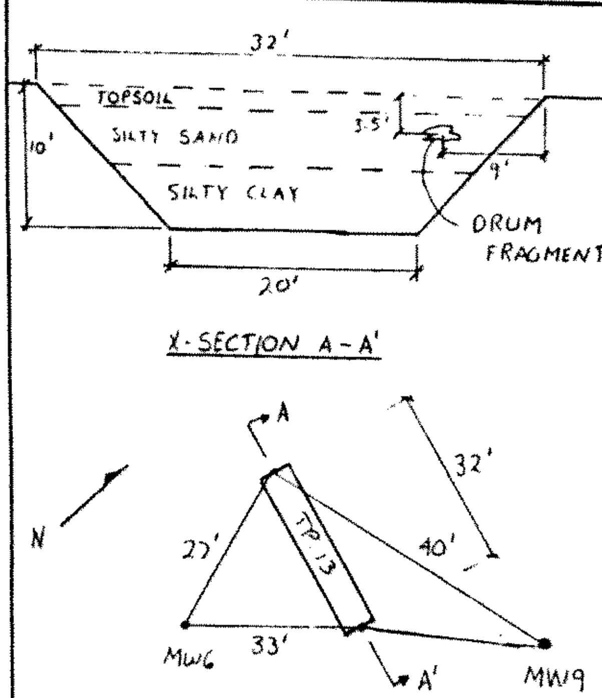



figure 3.12

TYPICAL TEST PIT LOG ENTRY

# STRATIGRAPHY LOG (OVERBURDEN)

PAGE 1 OF 1

PROJECT NAME Hydrogeologic Investigation
PROJECT NUMBER 200010-110
CLIENT CRA
LOCATION As Per Plan (100' N, 175' E of NE Building Corner)

DRILLING CONTRACTOR Deep Drilling
DRILLER Donny
SURFACE ELEVATION 1262.6 FT AMSL
WEATHER (A.M.)
(P.M.) Sunny @ 37°

HOLE DESIGNATION BH 1-08
DATE/TIME STARTED 4/30/08
DATE/TIME COMPLETED 4/30/08
DRILLING METHOD 4¼" ID HSA
CRA SUPERVISOR Sandy Brown

| STRATIGRAPHIC INTERVALS (DEPTHS IN (ft)/m BGS) FROM | AT | TO | SAMPLE DESCRIPTION: ORDER OF DESCRIPTORS: SOIL TYPE SYMBOL(S) – PRIMARY COMPONENT(S), (NATURE OF DEPOSIT), SECONDARY COMPONENTS, RELATIVE DENSITY/CONSISTENCY, GRAIN SIZE/PLASTICITY, GRADATION/STRUCTURE, COLOUR, MOISTURE CONTENT, SUPPLEMENTARY DESCRIPTORS. NOTE: PLASTICITY DETERMINATION REQUIRES THE ADDITION OF MOISTURE IF THE SAMPLE IS TOO DRY TO ROLL (INDICATE IF MOISTURE WAS ADDED OR NOT). | SAMPLE # | SAMPLING METHOD | 6" | 6" | 6" | 6" | N | R | SAMPLE INTERVAL | PID/FID (ppm) | CHEMICAL ANALYSIS | GRAIN SIZE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | ½ | ML-SILT (TOPSOIL) trace fine sand, trace clay, soft, low plasticity, brown, moist, rootlets | 1 | SS | 2 | 2 | 1 | 1 | 3 | 21" | 0/2 | 0 | | |
| ½ | | 2 | ML-SILT (FILL) with clay, trace sand, soft, low plasticity, brown, very moist, occasional bronze fragment @ 1½", dilatent | | | | | | | | | | | | |
| 2 | | 6 | CL-CLAY (TILL) with silt, trace fine sand, trace gravel, stiff, low plasticity, brown, moist, mottled, diagonal fissures (oxidized & calcite infilling), medium dry strength, medium toughness | 2 | SS | 3 | 5 | 5 | 6 | 10 | 19" | 2/4 | 0 | | |
| | 5 | 5½ | boulder - spoon refusal at 5' | | | | | | | | | | | | |
| 6 | | 8 | SP-SAND - trace silt, trace gravel, compact, fine to medium grained, poorly graded, brown, wet, slight chemical odour | 3 | SS | 10 | 60/6" | | | >50 | 8" | 4/5 | | | |
| | | | | 4 | SS | 8 | 9 | 10 | 7 | 19 | 22" | 6/8 | 50 | ✓ | ✓ SB-01 |
| 8 | | 10 | GW-Gravel - trace sand, compact, fine to coarse grained, well graded, grey, wet | 5 | SS | 10 | 10 | 10 | 10 | 20 | 10" | 8/10 | 10 | | |

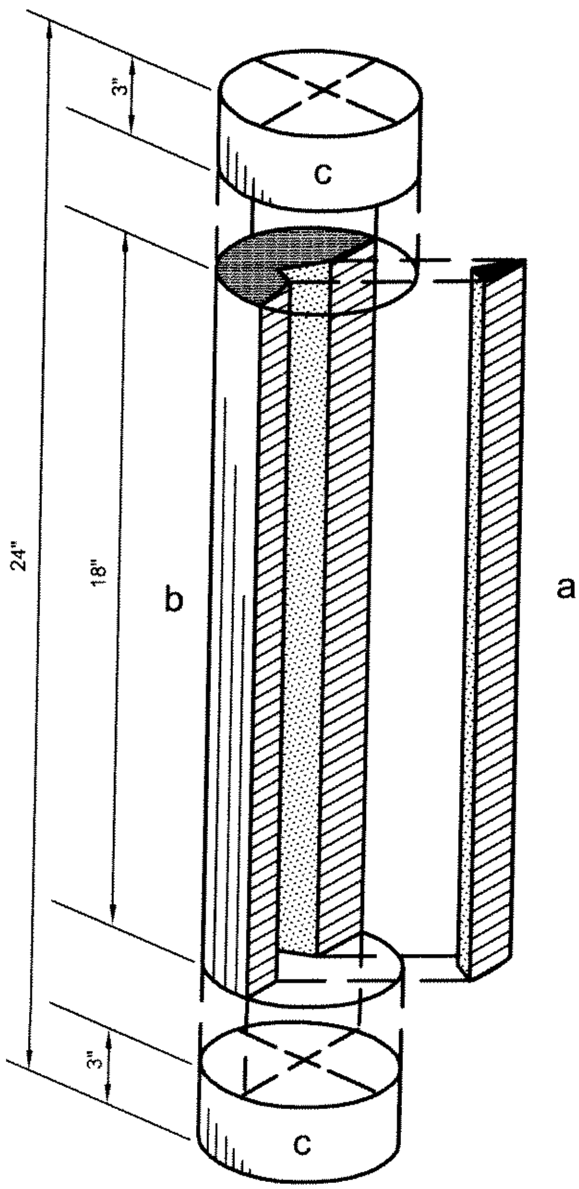
**NOTES AND COMMENTS**

DEPTH OF BOREHOLE CAVING 6'
DEPTH OF FIRST GROUNDWATER ENCOUNTER 6
TOPSOIL THICKNESS 6"
WATER LEVEL IN OPEN BOREHOLE ON COMPLETION 6' AFTER 1 HOURS 5.5 ft
COMPLETION DETAILS: Borehole sealed to surface (0-10) with Bentonite Gravel

NOTE: FOR EACH SPLIT-SPOON SAMPLE, RECORD BLOW COUNTS, N-VALUE, SAMPLE RECOVERY LENGTH, AND SAMPLE INTERVAL.
NOTES: S-200010-43008-SB-01 6'-8' VOCs, SVOCs, METALS, GRAIN SIZE

figure 5.1

TYPICAL OVERBURDEN LOG




TYPICAL SOIL CORE

## a

PORTION OF SAMPLE FOR CHEMICAL ANALYSIS

-CONTACT WITH UNSTERILIZED MATERIALS IS NOT ACCEPTABLE

-STORAGE - REFRIGERATED (4°C)

-SHIPPING - ON ICE BY COURIER TO DESIGNATED LAB

## b

PORTION OF SAMPLE TO BE RETAINED FOR GEOLOGIC RECORDS

-CONTACT WITH UNSTERILIZED MATERIALS IS NOT A PROBLEM

-CONTAINER: - CLEAN GLASS JAR
- CLEAR GLASS IS SUITABLE

-STORAGE - IN STANDARD SHIPPING CARTON
- NO REFRIGERATION REQUIRED

## c

PORTION OF SAMPLE TO BE DISCARDED

-DISCARDED WITHIN 55 GALLON DRUM MAINTAINED ON-SITE

figure 5.2

SPLIT SPOON SAMPLE SELECTION DETAILS

CRA

FORMS

Date: ______________________________ Reference No.: ____________

## PROJECT PLANNING COMPLETION AND FOLLOW-UP CHECKLIST

PRIOR PLANNING AND COORDINATION:

- ☐ Confirm well numbers, location and accessibility
- ☐ Review of project documents, Health and Safety Plan (HASP), sampling Quality Assurance/Quality Control (QA/QC) and site-specific sampling requirements
- ☐ Historical well data; depth, pH, performance and disposition of purge water
- ☐ Site access notification and coordination
- ☐ Coordination with laboratory through CRA Chemistry Group
- ☐ Procurement, inventory and inspection of all equipment and supplies
- ☐ Prior equipment preparation, calibration or maintenance
- ☐ All utilities located and approved

FIELD PROCEDURE:

- ☐ Instruments calibrated daily
- ☐ Sampling equipment decontaminated in accordance with the QAPP
- ☐ Field measurements and sampling details logged in appropriate field books or an appropriate field form
- ☐ Well volume calculated and specified volumes removed
- ☐ Specified samples, and QA/QC samples taken per Quality Assurance Project Plan (QAPP)
- ☐ Samples properly labeled, preserved and packed
- ☐ Sampling locations secured or completed according to Work Plan
- ☐ Sample date times, locations and sample numbers have all been recorded in applicable log(s)
- ☐ Samples have been properly stored if not shipped/delivered to lab same day
- ☐ Samples were shipped with complete and accurate Chain of Custody Record

FOLLOW-UP ACTIVITIES:

- ☐ Questionable measurements field verified
- ☐ Confirm all samples collected
- ☐ All equipment has been maintained and returned
- ☐ Sampling information reduced and required sample keys and field data distributed
- ☐ Chain of Custody Records filed
- ☐ Expendable stock supplies replaced
- ☐ CRA and client-controlled items returned (i.e., keys)
- ☐ Arrange disposal of investigation generated wastes with client
- ☐ Confirm all samples collected

Completed by: ______________________________ Date: ____________________

**CRA**

## TEST PIT STRATIGRAPHY LOG



| | | |
|---|---|---|
| Project Name: | Contractor: | Test Pit Designation: |
| Project Number: | | Date/Time Started: |
| Client: | Surface Elevation: | Date/Time Completed: |
| Location: | Test Pit Method: | CRA Supervisor: |

| *Depth (m/ft)* | | | *Soil Symbol, Primary Component, Secondary Components, Relative Density/Consistency, Grain Size/Plasticity, Gradation/Structure, Colour, Moisture Content, Supplementary Descriptors* | *Sample No.* | *Sample Interval* | *PID* | *Location:* |
|---|---|---|---|---|---|---|---|
| *From* | *At* | *To* | | | | | *Geologic Profile* |
| | | | | | | | |

Notes:

CRA

*Date:*______________________ *Reference No.* ______________________

# BOREHOLE INSTALLATION/SOIL SAMPLING EQUIPMENT AND SUPPLY CHECKLIST

*INSTRUMENTS*

- ☐ Steel Tape (50 foot)
- ☐ Air Monitoring Equipment
- ☐ Water Level Meter
- ☐ Pocket Penetrometer

*SUPPLIES*

- ☐ Foil
- ☐ Plastic Sample Bags
- ☐ Paper towels
- ☐ Decontamination Fluids (as required by QAPP)
- ☐ Deionized water
- ☐ Labels
- ☐ Sample knives
- ☐ Trash bags
- ☐ Plastic spray bottles
- ☐ Sampling Glassware
- ☐ Coolers

*PERSONAL PROTECTIVE EQUIPMENT*

- ☐ Tyveks (assorted sizes and types)
- ☐ Protective gloves
- ☐ Hard hats/liner(s)
- ☐ Field overboots
- ☐ Work gloves (cotton and chemical resistant)
- ☐ Safety glasses or OSHA-approved prescription lenses
- ☐ First Aid Kit
- ☐ Respirators and Cartridges
- ☐ Check Health and Safety Plan

*DOCUMENTATION*

- ☐ Notebook/Field book
- ☐ Photolog
- ☐ Site pass/badge
- ☐ Previous well logs/previous historical well data
- ☐ Site map
- ☐ Access Agreement Documentation
- ☐ Utility Clearance Documentation
- ☐ Stratigraphic Log (Overburden) - at least one for each 20 feet of drilling
- ☐ Chain-of-Custody Forms

*MISCELLANEOUS*

- ☐ Camera/film
- ☐ Spare batteries for instruments
- ☐ Carpenters Rule (6 foot)
- ☐ Clipboard
- ☐ Indelible Pen/pencil/indelible marking pen
- ☐ Tool box
- ☐ Spare locks/keys
- ☐ On Site Transportation (all Terrain Vehicle/Snowmobiles)

* Do not use pen with water soluble ink

*Completed by:*______________________ *Date:* ______________________

**CRA**

*Date:*______________________________ *Reference No.* __________________

# DRILLING/WELL CONSTRUCTION CHECKLIST

*PRE-DRILLING SITE REVIEW*

Private Property:

- ❑ Access permission
- ❑ Underground utilities located
- ❑ Boring locations clearly marked

Public Right-of-Way:

- ❑ Copies of permits
- ❑ Boring locations clearly marked
- ❑ Utility services notified
- ❑ Underground utilities marked/drilling locations cleared
- ❑ Documentation of utility clearance or clearance number
- ❑ Prepared for traffic control requirements

General:

- ❑ Well permits or construction permits required
- ❑ Site personnel notified

*DRILL CREW AND EQUIPMENT*

- ❑ Job requirements reviewed with the drill crew
- ❑ Job safety requirements reviewed with drill crew

*FIELD CLEANING*

- ❑ Cleaning station selected
- ❑ Onsite water and power
- ❑ Casing, well screen, etc. field cleaned

*DRILLING*

- ❑ Driller checked for utility clearance
- ❑ Borehole at the EXACT location cleared for utilities
- ❑ First four feet hand-augered
- ❑ Drilling procedure in accordance with work plan
- ❑ Measured first water level
- ❑ Drilling returns (cuttings or mud) properly contained
- ❑ Soil sampling tools field cleaned between samples
- ❑ Measured length of augers, rods, casing, etc.
- ❑ Sampled any added fluids

*WELL CONSTRUCTION*

- ❑ Recorded type of and quantity of materials used
- ❑ Measured the depths (top of filter pack, top of seal, etc.)
- ❑ Measured casing/screen lengths and diameters
- ❑ Surface completion neat and professional

*GENERAL*

- ❑ All boring log entries completed before moving to next hole
- ❑ Well completion detail completed
- ❑ Survey and plot borehole location
- ❑ Survey elevation of top-of-casing
- ❑ Site policed, trash removed, pavement swept, etc.
- ❑ Drums in inconspicuous area

*Completed by:*______________________________ *Date:* __________________

**CRA**

# STRATIGRAPHY LOG (OVERBURDEN)

PAGE ____ OF ____

PROJECT NAME ______________________
PROJECT NUMBER ______________________
CLIENT ______________________
LOCATION ______________________

DRILLING CONTRACTOR ______________________
DRILLER ______________________
SURFACE ELEVATION ______________________
WEATHER (A.M.) ______________________
(P.M.) ______________________

HOLE DESIGNATION ______________________
DATE/TIME STARTED ______________________
DATE/TIME COMPLETED ______________________
DRILLING METHOD ______________________
CRA SUPERVISOR ______________________

| STRATIGRAPHIC INTERVALS (DEPTHS IN ft/m BGS) | | | SAMPLE DESCRIPTION | SAMPLE DETAILS | | | | | | | | | | CHEMICAL ANALYSIS | GRAIN SIZE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | ORDER OF DESCRIPTORS: SOIL TYPE SYMBOL(S) – PRIMARY COMPONENT(S), (NATURE OF DEPOSIT), SECONDARY COMPONENTS, RELATIVE DENSITY/CONSISTENCY, GRAIN SIZE/PLASTICITY, GRADATION/STRUCTURE, COLOUR, MOISTURE CONTENT, SUPPLEMENTARY DESCRIPTORS<br>NOTE: PLASTICITY DETERMINATION REQUIRES THE ADDITION OF MOISTURE IF THE SAMPLE IS TOO DRY TO ROLL (INDICATE IF MOISTURE WAS ADDED OR NOT). | SAMPLE # | SAMPLING METHOD | PENETRATION RECORD SPLIT SPOON BLOWS (RECORD N-VALUES & RECOVERIES) | | | | | | SAMPLE INTERVAL | PID / FID (ppm) | | |
| FROM | AT | TO | | | | 6" | 6" | 6" | 6" | N | R | | | | |
| | | | | | | | | | | | | | | | |
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**NOTES AND COMMENTS**

DEPTH OF BOREHOLE CAVING ________ DEPTH OF FIRST GROUNDWATER ENCOUNTER ________ TOPSOIL THICKNESS ________

WATER LEVEL IN OPEN BOREHOLE ON COMPLETION ________, AFTER ____ HOURS ____

COMPLETION DETAILS: ______________________

NOTE: FOR EACH SPLIT–SPOON SAMPLE, RECORD BLOW COUNTS, N–VALUE, SAMPLE RECOVERY LENGTH, AND SAMPLE INTERVAL.

NOTES:

CRA

# SOIL CLASSIFICATION SYSTEM (MODIFIED U.S.C.S.)

| MAJOR DIVISIONS | | | GROUP SYMBOL | TYPICAL DESCRIPTION |
|---|---|---|---|---|
| HIGHLY ORGANIC SOILS | | | PT | PEAT AND OTHER HIGHLY ORGANIC SOILS |
| COARSE-GRAINED SOILS (MORE THAN HALF BY WEIGHT LARGER THAN NO. 200 SIEVE SIZE) | GRAVELS MORE THAN HALF OF COARSE FRACTION LARGER THAN NO.4 SIEVE SIZE | CLEAN GRAVELS | GW | WELL GRADED GRAVEL, GRAVEL-SAND MIXTURES, < 5 % FINES |
| | | | GP | POORLY GRADED GRAVELS AND GRAVEL-SAND MIXTURES, < 5 % FINES |
| | | DIRTY GRAVELS | GM | SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURES, > 12 % FINES |
| | | | GC | CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES, > 12 % FINES |
| | SANDS MORE THAN HALF OF COARSE FRACTION SMALLER THAN NO.4 SIEVE SIZE | CLEAN SANDS | SW | WELL GRADED SANDS, GRAVELLY SANDS, < 5 % FINES |
| | | | SP | POORLY GRADED SANDS, OR GRAVELLY SAND, < 5 % FINES |
| | | DIRTY SANDS | SM | SILTY SANDS, SAND-SILT MIXTURES > 12 % FINES |
| | | | SC | CLAYEY SANDS, SAND-CLAY MIXTURES > 12 % FINES |
| FINE-GRAINED SOILS (MORE THAN HALF BY WEIGHT PASSES NO. 200 SIEVE SIZE) | SILTS BELOW "A" LINE ON PLASTICITY CHART; NEGLIGIBLE ORGANIC CONTENT | | ML | INORGANIC SILTS AND VERY FINE SAND, ROCK FLOUR, SILTY SANDS OF SLIGHT PLASTICITY |
| | | | MH | INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS, FINE SANDY OR SILTY SOILS |
| | CLAYS ABOVE "A" LINE ON PLASTICITY CHART; NEGLIGIBLE ORGANIC CONTENT | | CL | INORGANIC CLAYS OF LOW PLASTICITY, GRAVELLY, SANDY, OR SILTY CLAYS, LEAN CLAYS |
| | | | CI | INORGANIC CLAYS OF MEDIUM PLASTICITY, SILTY CLAYS |
| | | | CH | INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS |
| | ORGANIC SILTS & ORGANIC CLAYS BELOW "A" LINE ON PLASTICITY CHART | | OL | ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY |
| | | | OH | ORGANIC CLAYS OF HIGH PLASTICITY |

# CONVENTIONAL SOIL DESCRIPTIONS

## NON-COHESIVE (GRANULAR) SOIL

| RELATIVE DENSITY | BLOWS PER FOOT (N-VALUE) |
|---|---|
| Very loose | less than 5 |
| Loose | 5 to 9 |
| Compact | 10 to 29 |
| Dense | 30 to 50 |
| Very Dense | greater than 50 |

## COHESIVE (CLAYEY) SOIL

| CONSISTENCY | BLOWS PER FOOT (N-VALUE) |
|---|---|
| Very Soft | 0 to 2 |
| Soft | 3 to 4 |
| Firm | 5 to 8 |
| Stiff | 9 to 15 |
| Very Stiff | 16 to 30 |
| Hard | greater than 30 |

## GRAIN SIZE CLASSIFICATION

| | |
|---|---|
| COBBLES | Greater than 3 inches (76 mm) |
| GRAVEL | 3 in. to No. 4 (4.76 mm) |
| Coarse Gravel | 3 in. to 3/4 in. |
| Fine Gravel | 3/4 in. to No. 4 (4.76 mm) |
| SAND | No. 4 (4.76 mm) to No. 200 (0.074 mm) |
| Coarse Sand | No. 4 (4.76 mm) to No. 10 (2.0 mm) |
| Medium Sand | No. 10 (2.0 mm) to No. 40 (0.42 mm) |
| Fine Sand | No. 40 (0.42 mm) to No. 200 (0.074 mm) |
| SILT | No. 200 (0.074 mm) to 0.002 mm |
| CLAY | Less than 0.002 mm |

NOTE: The "No. __ " refers to the standard sieve sizes.

## COMPONENT PERCENTAGE DESCRIPTORS

| | |
|---|---|
| Noun(s) (e.g. SAND and GRAVEL) | 35 to 50 % |
| Adjective (e.g. SANDY) | 20 to 35 % |
| With | 10 to 20 % |
| Trace | Less than 10 % |

## SOIL STRUCTURE TERMS

| | |
|---|---|
| Stratified | Blocky |
| Laminated | Lenses/Seams |
| Fissured | Homogeneous |