

VIA ELECTRONIC MAIL

26 March 2014

Mr. Bob Williams
Oregon Department of Environmental Quality
Northwest Region Portland Office
2010 SE 4th Avenue, Suite 400
Portland, OR 97201

Subject: CU1 Subsurface Investigation Work Plan
East Multnomah County Troutdale Sandstone Aquifer Remediation
Fairview, Oregon

Dear Bob:

Geosyntec Consultants (Geosyntec) has prepared this work plan to conduct a limited subsurface investigation as part of the East Multnomah County Troutdale Sandstone Aquifer (TSA) remedy being conducted jointly by the Cascade Corporation (Cascade) and The Boeing Company (Boeing). The area and depth targeted for the subsurface investigation are the northern edge (Troutdale Gravel Aquifer TGA) Off-Site remedy area (Site) and confining unit 1 (CU1), which is a siltstone/claystone that underlies the TGA. The purpose of this proposed sampling is to determine if there are significantly elevated concentrations of trichloroethene (TCE) in the CU1 that have a potential to migrate to the underlying TSA.

Both the CU1 and TGA are erosionally truncated and thin in the general area of the poplar tree field. Drilling locations have been placed within the poplar tree field at the location where the TGA and CU1 are thin and begin to pinch out. Drill cores will be used to 1) characterize the degree of fracturing in the CU1 near where it thins/pinches out on Site; and 2) to obtain samples for testing of volatile organic compounds (VOCs), specifically TCE.

The field data, observations, and sample results will be used to evaluate CU1 as a possible continuing source and migration route for persistent TCE mass in the upper TSA. This technical memorandum outlines the site geology/hydrogeology, and a description of the subsurface investigation (field procedures for drilling and sampling). This work plan follows the general procedures used for the high resolution core sampling conducted in 2012 by Prowell Environmental at three borings located south of the poplar tree field: VW-17d-42.5, VW-17d-75.5, and VW-17d-90.5.

GEOLOGY AND HYDROGEOLOGY

The TGA is a silty to sandy gravel and is underlain by a siltstone/claystone referred to as Confining Unit 1 (CU1) or Siltstone Unit 1 (Swanson, et al., 1993; Emcon and Landau, 1995; DEQ, 1996; Prowell Environmental, 2012) that typically is comprised of four subunits: 1) sandstone and siltstone (SU1A), 2) clayey siltstone (SU1B) (this unit alone is sometime referred to as CU1, 3) sandstone with siltstone (SU1C), and 4) siltstone with sandstone (SU1D). The upper sections of CU1 are clayey siltstone and claystone that grades into a weathered clayey siltstone and silty sandstone. CU1 is fine grained and dry to moist, and the lateral and vertical extent of fracturing in CU1 has not been well characterized in the vicinity of the proposed subsurface investigation. Detailed core and sampling descriptions are provided in Prowell Environmental (2012).

The TGA is erosionally truncated to the north of the poplar tree field as part of ancestral Columbia River migration. The TGA may be completely absent in the portion of the Site north of the poplar tree field. The thickness and continuity of CU1 present in the area proposed for sampling is unknown, as TGA borings/monitoring wells completed in this portion of the Site (CMW-45 and CMW-46) were completed only to the top of the CU1. CU1 is absent in borings located further north (CMW-14/CMW-14R), which were advanced into the TSA. Monitoring well EW-18 is located adjacent to the proposed boring locations described herein, and the TGA and CU1 were each logged as approximately 15 feet thick, with the TGA from 0-15 feet below ground surface (bgs) and CU1 from 15 to 30 feet bgs. Because the TGA and CU1 were not described in the boring/monitoring wells located further north (CMW-14/14R), the TGA and CU1 terminate laterally between these locations (Figure 1 and 2).

The depth to TGA groundwater encountered in this portion of the Site is approximately 15 feet bgs at CMW-45 and CMW-46. The water table in the TGA is perched above low permeability units within the CU1. The lower portion of the CU1 and the upper TSA are unconfined in this portion of the Site. Further north of the TGA and CU1 truncations, the first water table is in the TSA at approximately 100 feet bgs.

Higher total organic carbon (TOC) and VOC concentrations were reported in core/soil and calculated pore water samples from the upper portion of CU1 (approximately 10 feet) relative to deeper portions of CU1 (Prowell Environmental 2012; SSPA 2012). Groundwater samples were not obtained from CU1 during the 2012 field investigation; however, several TGA monitoring wells are screened all or partially within the CU1 (CMW-45, CMW-46, CMW-47c, CMW-48c, and B-6). TCE concentrations are higher in CU1 wells relative to TGA monitoring wells (Prowell Environmental, 2012; Geosyntec, 2013). Groundwater in CU1 monitoring wells recharges very slowly.

INVESTIGATION

Three boreholes are proposed near the northern edge of CU1 to gain a better understanding of both historic contaminant migration through the CU1 into the upper TSA, and the extent to which the CU1 represents a continuing source of VOCs to the TSA. The boreholes will be used to collect samples of TGA and cores of CU1 for lithologic description and processing for VOC analysis. Select core samples will also be submitted for TOC and grain size testing.

FIELD PROCEDURES

Subsurface Investigation

Three borings are proposed to characterize CU1 and obtain samples for VOC testing. The boring locations are located south of the CU1 truncation and south and west of monitoring well EW-18 and are approximately 60 feet apart. The borings will be placed along and inside the northern edge of the poplar tree field (Figure 1). Several (three to four) poplar trees may need to be removed to provide access for the drilling rig and support vehicle(s).

The three borings will be advanced using a track-mounted sonic drilling rig, and continuous soil/rock cores will be collected. Borings will be advanced to the base of the CU1 and terminated at the contact with the underlying TSA at approximately 30 feet bgs (based on contacts previously described at EW-18). Telescoping procedures (i.e. step-down) will be used at the TGA/CU1 and CU1/TSA contacts. Telescoping methods for borings involves setting a larger diameter casing into the base of the TGA (or CU1) above the underlying contact. A hydrated bentonite seal will be placed at the base of the casing and allowed to hydrate and expand, prior to advancing smaller-diameter drilling rods into the underlying formation. For example, borings will be advanced through the TGA using ten-inch diameter casing and eight-inch core barrel, stepped down to a 6-inch core barrel for drilling into CU1.

The CU1 will be cored using Lexan liners in the core barrel in two-foot runs to minimize the heat and volatilization of VOCs in the core. The Lexan core liners will be carefully cut open, the core photographed and logged, and sample locations selected. The total thickness of the CU1 will be cored (estimated to be approximately 15 feet thick based on EW-18) to characterize the lithology, fracturing, and to obtain samples for analytical and grain size testing. Soil/rock core sampling methods are described in Attachment A, and follow the procedures previously used at the Site (VW-17d; SSPA in Prowell Environmental, 2012), with the exception that core crushing and preservation will be conducted in the field by Stone Environmental personnel and VOC analytical testing will also be completed by Stone Environmental.

Once the contact with the underlying TSA (target depth of approximately 30 feet bgs) is achieved, the borings will be backfilled with bentonite grout to within 5 feet of the surface and

then bentonite chips to within 1 foot of the surface. Topsoil and/or gravel will be placed in the top 1-foot of the boring to match the surrounding surface materials.

Sample Processing and Analytical Testing

TGA samples will be collected for analytical testing based on field screening results (i.e. elevated PID readings). At a minimum, one soil sample from each boring will be selected for analytical testing at the contact between the TGA and CU1. If TGA samples are obtained, they will be collected using EPA Method 5035 and submitted to Stone Environmental Laboratory for testing of VOCs by EPA Method 8260. CU1 sampling is described below.

The two-foot core runs from CU1 will be processed in the field as described in Attachments 1 and 2. A Stone Environmental Laboratory field chemist will be on site to crush and field preserve the cores using their equipment. Preservation includes crushing the core and placing it in laboratory-supplied containers with methanol preservative. Preserved soil/rock core samples will be sent overnight to the Stone Environmental laboratory (New Hampshire) for analytical testing of VOCs by microwave assisted extraction (MAE). Additional information regarding MAE, field preservation, and core handling and sampling is provided in Attachment B.

At a minimum, nine samples (three samples from each of the three borings) are planned for analytical testing. Soil/core samples will be collected for analytical testing based on field screening results (e.g. PID measurements, visual staining, odors), degree of fracturing, and to provide adequately distributed samples. VOCs will be extracted from the crushed core samples using the MAE procedure and analyzed for VOCs by EPA Method 8260. Additional samples will be field preserved and held for potential analytical testing. If sufficient core remains from target sample intervals, samples will also be submitted for grain size testing and analysis of TOC. Otherwise, core samples from adjacent intervals will be sampled for grain size and TOC.

Investigative Derived Waste

Soil cuttings from the borings will be placed in drums, labeled, and staged in the on-Site, fenced compound pending analytical results and off-Site disposal. Decontamination water generated will be placed into the TSA central treatment system.

Preparation for Field Work

Prior to drilling, a public and private utility locate will be done to identify below ground utilities in the area. The borings will be placed to avoid hitting identified utilities running through the area. The site-specific health and safety plan will be updated prior to any field activities.

Data Evaluation and Reporting

Once field work is completed, field methods and results will be documented in a technical memorandum that will include boring logs, a site plan, analytical results, and an evaluation of the field observations and analytical results.

REFERENCES

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- DEQ, 1997. Order on Consent to The Boeing Company and Cascade Corporation. Troutdale Sandstone Aquifer. Oregon Department of Environmental Quality No. WMCSR-NWR-96-08, with amendments. 14 February 1997.
- Emcon and Landau Associates, Inc. 1995. Remedial Investigation and Feasibility Study, Troutdale Sandstone Aquifer, Part 1: Remedial Investigation. 6 October 1995.
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CLOSURE

Please do not hesitate to contact us at (503) 222-9518 if you have questions or require additional clarification on this work plan.

Sincerely,

Geosyntec Consultants, Inc.



Cindy Bartlett, R.G.
Geologist/Project Manager



Brent A. Miller, P.E.
Associate

Cc: John Cushing, Cascade Corporation
Charlie Andrews, SSPA
Ken Chaput, The Boeing Company
Eric Weber and Chris Kimmel, Landau Associates

Attachments:

Figure 1: Site Location and Proposed Boring Locations

Attachment A: Procedures for Rock Core Sampling (Attachment B from Work Plan for TSA Remedy Mount Area Well Installation, January 10, 2012).

Attachment B: Stone Environmental Inc., COREDFN Discrete Fracture Network Approach Summary

ATTACHMENT A

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Attachment B

Procedures for Rock Core Sampling

Introduction and Purpose

This memorandum describes the procedures for the sampling and analysis of core from the CU1 and TSA for volatile organic compounds (VOCs). The collection of core is described in the accompanying work plan. Rock core sampling will occur concurrently with drilling and field personnel will be in close communication with the drill rig operators.

Materials and Methods

The sampling method employed will be a simplified version of the CORE™ method developed by Dr. Beth Parker (Sterling 1999, Turner 2001, Hurley 2003, Meyer 2005, Kennel 2008) and implemented commercially by Stone Environmental (<http://www.stone-env.com/>). The major modifications are that the simplified method described here does not use a hydraulic crusher for crushing the samples and also requires fewer steps in the sample recording process due to fewer samples being taken in each core run. The basic method includes the following tasks:

1. Preparation of workspace and samples,
2. Geologic core logging,
3. Sub-sampling rock core,
4. Trimming and crushing rock samples,
5. Weighing and packaging bottled samples, and
6. Shipping/transport to laboratory

Bottle Preparation

Bottle preparation will be done just prior to sampling (same day or previous day). All labels will be placed on the bottles prior to weighing. The screw-top caps will be labeled using a fine tipped pen with a simplified sample ID to allow for easy identification and a back-up if the label becomes unreadable at some point. Bottles to be prepared as follows:

1. Weigh empty 40 mL VOA bottle,
2. Add 15-20 mL of purge and trap grade methanol to bottle, and
3. Re-weigh sample bottle.

QA/QC Samples

A fundamental step in the method is the ability to track the potential for cross contamination which may lead to erroneous interpretations. To address this issue the following QA/QC samples will be taken.



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1. Trip blanks – VOA filled with 15-20 mL of purge and trap grade methanol that travels in the cooler with samples. (3 per cooler)
2. Equipment blank – VOA filled with 15-20 mL of purge and trap grade methanol and a kimwipe that has been rubbed on the **cleaned** sampling equipment to test the efficacy of the decontamination procedure. (1 every 20 samples)
3. Duplicate Samples – VOA filled with purge and trap grade methanol and rock taken from the same subsample. (1 every 20 samples)
4. Methanol Blank – VOA filled with 15-20 mL of purge and trap grade methanol. These samples should not come in contact with the other samples and should travel in a separate cooler. One sample at the top of the bottle and one at the bottom of the bottle for each bottle.

Rock VOC Subsampling Procedure

- 1) As soon as the core comes to surface, exposure to the elements will be minimized. This will be done by wrapping the rock core in aluminum foil.
- 2) The core will be exposed and photographed to include the entire core length. Typically overhead photos provide the best pictures and two photos may be required to get the entire core.
- 3) The core will be quickly logged to record the location of fractures and lithology changes.
- 4) During this period the location of subsamples for VOCs and physical properties will be chosen. Samples will be chosen based on the purpose and limitations of the investigation. Samples next to a fracture should provide an indication of the contaminant concentration in the fracture water whereas samples farther from a fracture will provide insight into the concentration in the rock matrix. Typically, samples will be taken as pairs, one near a fracture (within 6”) and one away from a fracture (12-18”) and also one on either side of a lithology change.
- 5) Using a wide-faced chisel will break off 1” thick puck shaped pieces of rock. If multiple samples are taken from each core run exposure to the elements will be limited by:
 - a. Wrapping with foil
 - b. Placing in a labeled ziplock bag
 - c. Placed in a cooler with ice packs until the trimming process begins.
- 6) Chip away at the outer rind of rock which has had a greater exposure to heating and the drilling process and select a central portion for the sample to crush.
- 7) Manually crush the central portion and place ~20 grams of crushed rock in a pre-weighed glass VOA bottle containing 20 ml Purge and Trap grade Methanol (if this cannot be obtained HPLC grade will work). Rock particle size will at most 5 mm at the largest dimension and will be be totally immersed in the methanol. Field personnel will insure that the sample vial threads are cleaned of sand particles to avoid sample leakage.



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- 8) Clean all equipment coming into contact with the rock particles.
- 9) Choose physical property subsamples. Typically will select at least three for each lithology type encountered.

Decontamination Procedure

1. Basin 1: Soap/water wash (Alconox with water – can be tap water if source is known to be TCE free). Fully immerse all equipment coming into contact with the rock in this basin and remove all rock particles.
2. Basin 2: Water wash. Fully immerse in clean water rinse. Ideally distilled or deionized water would be used for this step.
3. Basin 3: Wash grade methanol rinse from a 500 mL squeeze bottle. This basin is to catch the methanol rather than an immersion into methanol.
4. Basin 4: Distilled or deionized water rinse from a 500 mL squeeze bottle. This basin is for catching the rinse water.
5. Dry with clean disposable lint free paper towels or if time allows, air dry will also work if you have time.
6. Cleaned equipment should only be handled with clean gloves (Nitrile).

Packaging procedure

1. Teflon tape will be wrapped around the outside of the sample vial where the lid and glass vial meet. This is to provide an indication if the sample vial leaked during transport.
2. Sample will be wrapped with bubble wrap to protect from possible breaks.
3. Three samples will be placed in a zip locking bag.
4. The samples will be placed in a cooler with ice packs and an absorbent pad in case a methanol bottle should break.
5. The chain of custody forms will be placed in a zip lock bag and included with the sample cooler. Copies will be made if field of all chain of custody forms if possible.

Materials

The following materials table lists the materials and equipment necessary for the rock core VOC sampling method.



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Table 1: Materials for rock core sampling

Packaging and Sample transport	Comments
Coolers for samples	Keep samples cool and safe for transportation
Absorbant pads to line coolers	Absorb methanol spill due to broken samples during shipping.
Ice packs	Keep samples cool
VOA Bottles (clear, closed cap)	Holds samples
Labels for Bottles	Unique identifier for sample
Purge and trap grade methanol for samples	Samples go in this
Teflon tape	Goes around lid and top of vial to check for leaks
Nitrile exam gloves	for handling
Bubble wrap	Keep samples safe for transportation
zip locking bags	Keep samples safe for transportation
Decontamination	
Kim Wipes	For wiping sample threads and for the equipment blank
Wash grade methanol	For rinsing samples
Alconox	Soap
4 Basins	To hold decontamination fluids
2 Squeeze bottles	One for methanol, One for distilled/DI water
Rubber gloves	
Sampling	
Chisels	To break samples from core and trim samples
Hammer	5 lb
Crushing container	To smash the rock particles with
Aluminum foil	To cover core as it comes out of the ground and to wrap samples
Zip locking bags	Place foil covered samples in these bags
Measuring tape	To go alongside core
Core Holders	To store core after it has been sampled
Saran Wrap	To wrap physical property samples with
Other	
Analytical balance	for weighing bottles and samples
Tables	For working on
Camera	For photographing the process
Pens/pencils	Sharpies, ink pens
Sampling data sheets	
Binder	to hold data sheets
Dry erase board	for photographs
Dry erase markers	for photographs
Clock or water	To keep track of sample exposure times



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Analytical Method

The rock samples will be analyzed for volatile organic compounds with EPA Methods 8260B. The analytical laboratory has not yet been chosen but is likely to be Columbia Analytical in Kelso, Washington.

References

- Hurley, J. C. 2003, Rock core investigation of DNAPL penetration and persistence in fractured sandstone, Master's thesis, Earth Sciences Department, University of Waterloo.
- Kennel, J.R. 2008, Advances in Rock Core VOC Analyses for High Resolution Characterization of Chlorinated Solvent Contamination in a Dolostone Aquifer
- Meyer, J. R. 2005, Migration of a mixed organic contaminant plume in a multilayer sedimentary rock aquifer system, Master's thesis, Earth Sciences Department, University of Waterloo
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- Turner, C. M. 2001, Origin and behavior of TCE and metolachlor contamination in a fractured dolostone water supply aquifer, Master's thesis, Earth Sciences Department, University of Waterloo.

ATTACHMENT B



DISCRETE FRACTURE NETWORK APPROACH

Overview of the Rock CORE Process Stone Environmental, Inc.

The rock core sampling and analysis which comprise the CORE technology are designed to assess the distribution of chlorinated volatile organic compounds (CVOCs) in fractured bedrock environments. This type of approach is necessary in fractured rock environments where the rock matrix has significant primary porosity. In such settings, a significant portion of the contaminant mass may be found in the matrix porosity as a result of the diffusion of contaminants from the fractures.

Stone Environmental, Inc. provides the CORE technology on a commercial basis under agreement with Professor Beth Parker (University of Guelph) and Professor Tadeusz Gorecki (University of Waterloo). This type of investigation has been performed at sites in the United States and Canada as part of ongoing research projects. Previous investigations have been performed in sedimentary bedrock such as sandstone, shale, and dolomite as well as in granite. The CORE approach was developed by Parker from a literature search for information on such methods used by others, and from previous studies conducted by the University of Waterloo (e.g. Parker and Sterling, 1999; Sterling, 1999; Sterling et al., 2005; Turner, 2001; Hurley, 2003; Meyer, 2005) at a variety of fractured rock sites with chlorinated solvent contamination. The process and equipment have evolved over the course of many research projects, resulting in a high level of data quality and efficiency.

Cores are obtained using an HQ-sized (2.5-inch diameter) triple-tube core barrel system in five-foot runs. A Stone hydrogeologist selects sample locations within the core based on presence of fractures, lithology, weathering and evidence of groundwater and/or DNAPL fluid flow. The hydrogeologist will exercise judgment during sampling to provide an average sample frequency of one sample every 1 to 2 ft. The hydrogeologist then removes thin pieces of the core at the determined depths and wraps and labels them for further processing. Additional samples are also collected for physical property analyses including porosity, bulk density, organic carbon content, chloride diffusion coefficient and matrix permeability. Once the cores have been obtained to the desired depth, the corehole should be sealed with a blank FLUTE liner to prevent cross contamination of the borehole (see Sterling et. al., 2005). The hole can then be further investigated using borehole geophysical techniques and/or equipped with a multi-level monitoring system.

The rock samples are immediately crushed onsite by a second Stone Scientist using a proprietary hydraulic rock crusher that reduces the difficulty and time required to decontaminate the crusher and improves sample integrity by reducing the potential for losses due to volatilization during the crushing process. The system employs a hydraulic press that provides the crushing power necessary to break up the rock samples, and has been used successfully for sedimentary rocks at numerous sites. The core sample is placed in a closed stainless steel crushing cell fitted with o-rings and crushed with a stainless steel piston at pressures as high as 6000 psi. The crushed sample is then extruded from the cylinder directly into a pre-weighed 40 mL VOA vial containing a known volume of purge and trap grade methanol. The amount of air passing by the sample while being crushed is minimized as well as the time required to completely crush the rock fragments into the desired particle size. The stainless steel crushing vessels and associated tools are thoroughly decontaminated following each use. The crushing equipment, balances, methanol dispensers, computers and other equipment are housed in Stone's data collection trucks which serves as a secure work space with lights, heat, air conditioning, electrical power and a variety of tools and equipment. The specialized stainless steel crushing chambers and tools are decontaminated by a third Stone staff member using a 4 stage process.

The crushed samples are carefully packed and are shipped to the Stone facility in Barre, Vermont. The laboratory can also be set up at the site if the data are needed quickly. Upon receipt, the samples are logged in and undergo microwave assisted extraction (MAE). Typical solvent extractions using shaking or sonication require five weeks in order to extract all of the contaminant mass even following crushing. Using MAE, this extraction time is reduced to less than an hour. MAE is known to fully and/or partially destroy several halogenated compounds (i.e. 1,1,2,2-Tetrachloroethane and 1,2-Dibromo-3-chloropropane) and therefore this method should be evaluated for applicability on a site by site basis.

Analysis of the extract typically involves one of two methods:

- 1) A low level gas chromatographic method using microelectron capture detectors (μ -ECD). This GC/ECD method (Gorecka et. al. 2001) is limited to halogenated compounds and involves a cool on-column injection technique in order to achieve method detection limits (MDLs) in the sub-ppb range (given as $\mu\text{g}/\text{kg}$ of rock) for compounds such as trichloroethene (TCE) and tetrachloroethene (PCE) and;
- 2) A mid level method (EPA 8260C) involving the use of a Gas Chromatograph/Mass Spectrometer (GC/MS). This method is more commonly used where the site contaminants include non-halogenated compounds and provides method detection limits of about 20 $\mu\text{g}/\text{kg}$ for the PCE and TCE compounds.

The selection of the method used should be based on the site chemistry and the Data Quality Objectives (DQOs) for the given project. Both methods are conducted under a full quality assurance/quality control (QA/QC) system that is designed to meet the objectives set forth by the EPA's SW846 methodologies.

At the outset of the project, a work plan including a QAPP and standard operating procedures will be prepared. The deliverables will be defined at the project planning stage when the project and data quality objectives are established. A data management program will be specified on the basis of the project objectives.

References

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