Addendum to Remedial Action Optimization Work Plan, Former Tronox Facility, Springfield, Missouri, MOD007129406

PREPARED FOR:	Greenfield Environmental Multistate Trust, LLC, Trustee of the Multistate Environmental Response Trust
PREPARED BY:	Environmental Works Inc.
DATE:	December 12, 2016

1.0 Introduction and Purpose

This Remedial Action Optimization Work Plan Addendum (RAO Work Plan Addendum) was prepared by Environmental Works, Inc. (EWI) on behalf of the Greenfield Environmental Multistate Trust LLC, not individually, but solely in its representative capacity as Trustee for the Multistate Environmental Response Trust (the Multistate Trust) for the former Tronox Facility, Springfield, Missouri (the Site), Resource Conservation and Recovery Act (RCRA) Post Closure Care Permit #MOD007129406.

The purpose of this technical memorandum is to summarize the status of the activities being performed as part of the Missouri Department of Natural Resources (MDNR)-approved Remedial Action Optimization (RAO) Work Plan (RAO Work Plan; EWI, 2016a) and to amend procedures specific to the implementation of the soil vapor (SV) sampling program.

2.0 RAO Work Plan Status Update

On November 29, 2016, the Multistate Trust submitted the Draft Remedial Action Optimization Status Memorandum, Former Tronox Wood Treating Facility, Springfield, Missouri (Draft RAO Status Memorandum; EWI, 2016b) prepared by EWI on behalf of the Multistate Trust. This Draft RAO Status Memorandum (1) summarized the findings and conclusions of the work performed to date in accordance with the RAO Work Plan and (2) presented the recommended next steps to address remaining data gaps based on those findings. Based on verbal and written comments received from MDNR and the Missouri Department of Health & Senior Services (MDHSS), the RAO Status Memorandum was revised to incorporate those comments. The Revised RAO Status Memorandum is included as Attachment 1.

3.0 Basis for Soil-Vapor Sampling Program Modifications

The MDNR-approved RAO Work Plan provided a stepwise process for gathering data for the assessment of the vapor intrusion pathway. This stepwise process was based on a conservative approach using the U.S. Environmental Protection Agency's (EPA) Vapor Intrusion Screening Level (VISL) calculator to develop an initial list of chemicals of potential concern (COPCs) and did not take into consideration petroleum vapor intrusion (PVI) guidance (See the Revised RAO Status Memorandum for the VISL calculator spreadsheets for those locations that exceeded the screening levels).

3.1 Background Analysis of Conditions

The RAO Work Plan provided a stepwise process for gathering data for the assessment of the vapor intrusion pathway. This included the following steps (actions completed are noted):

1. Preliminary screening of the existing data using EPA's VISL calculator to develop initial list of COPCs. (Completed)
2. Install new groundwater monitoring wells within the target area (in the City of Springfield Right-of-Way [ROW]) and sample those wells. (Completed)
3. Input groundwater data into VISL calculator (version 3.5.1, updated July 11, 2016) and evaluate against EPA May 2016 vapor intrusion criteria. (Completed)
4. Results of the VISL screening will guide the necessity and placement of SV wells. (Completed)
5. Based on the VISL results from the newly installed groundwater monitoring wells (SMW-80, SMW-81 and SMW-82), further evaluation of the vapor intrusion pathway is warranted and the collection of SV samples is necessary.
    a. The RAO Work Plan includes the installation of 3 nested SV wells located within 100 feet of the residences. While the RAO Work Plan stated permanent locations, the following is recommended (To be Performed):
        i. Install temporary SV wells to better facilitate vapor collection with no water entry. The installation is the same, but none of the wells will be placed in well vaults. It is likely that these wells can be resampled the spring/summer to account for temporal variability.
        ii. Further characterize the nature and extent of the SV to adequately address impacts, if any, on those living in the neighborhoods directly north and northeast of the Facility.

While the VISL calculator is a conservative approach for the COPCs, this approach, complemented with the PVI assessment below, provides a sound technical basis for evaluating SV in the subsurface and is protective of human health and the environment.

3.2 PVI Screening Process Assessment

The following guidance documents provide the basis of this assessment:

- Interstate Technology and Regulatory Council (ITRC) Petroleum Vapor Intrusion Fundamentals of Screening, Investigation and Management. October, 2014.
    - Applicable PVI at Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), RCRA and Underground Storage Tanks (UST) sites
    - Designed to complement the EPA Office of Underground Storage Tanks (OUST) PVI guidance
- Technical Guide for Addressing Petroleum Vapor Intrusion At Leaking Underground Storage Tank Sites, U.S. Environmental Protection Agency Office of Underground Storage Tanks (OUST), EPA 510-R-15-001. June, 2015.
    - Applicability is primarily UST sites
    - Excerpt from electronic page 9: *This PVI guide focuses on releases of petroleum-based fuels (e.g., gasoline, diesel), including both PHCs and non-PHC fuel additives, from underground storage tanks (USTs) regulated under Subtitle I of the Solid Waste Disposal*

Act of 1984, which are typically located at gas stations. This guide applies to new and existing releases of PHCs and non-PHC fuel additives from leaking USTs and to previously closed sites where the implementing agency has reason to suspect that there may be a potential for PVI. Although EPA developed the PVI guide based on data from typical UST sites, this technical guide may also be helpful when addressing petroleum contamination at comparable non-UST sites.

- OSWER Technical Guide for Assessing and Mitigating the Vapor Intrusion Pathway from Subsurface Vapor Sources to Indoor Air, OSWER Publication 9200.2-154. June, 2015.
    - Applicable to PVI at CERCLA, RCRA and UST sites

The PVI Screening Process and assessment is summarized below and those actions specific to the RAO activities that have been completed actions are noted:

1. Conduct a site characterization investigation and develop a conceptual site model (CSM).
    a. This was previously completed, which led to the implementation of the RAO Work Plan. (Completed)
    b. Based on the RAO Work Plan field investigation results, update the CSM and based on the decision process outlined in the RAO Work Plan implement the next steps (i.e., collect exterior SV samples in the City of Springfield ROW). (To be Performed)
2. Delineate the lateral inclusion zone (guidance recommendation range from >10 feet to <30 feet from the edge of the building).
    a. The approach as originally presented in the RAO Work Plan recommended three SV wells located in the residential street ROW areas within 100 feet of the residences. After further review of the PVI screening guidance documents and to increase the density of coverage within the residential area, it is recommended that a focused "by house" placement be used instead of what was presented in the RAO Work Plan. Figure 1.0, shows the proposed SV sampling locations.
    b. It is acknowledged that there is uncertainty beneath the Clifton Drainage surface depression because there are no samples proposed in that area given issues of access. Recognizing that surface depressions and subsurface features are not always equal and that this is a stepwise process, the Multistate Trust and EWI recommend moving forward with the proposed SV sampling program to be responsive based on the recent results and the expressed concerns of the residences during the September 14, 2016 public meeting.
    c. The proposed SV sampling locations will help to refine the areas of impact, if any, and provide information to make decisions regarding the next steps. (To be Performed)
    d. SMW-80 is located at the southwest end of the Clifton Drainage and across the street from the residential areas. Naphthalene was detected in the dissolved phase at a concentration of 11,000 micrograms per liter (ug/L), representing the highest off-site naphthalene concentration. SMW-82 is located at the far side of the Clifton Drainage, northeast of the residential area, and has a dissolved phase concentration of 3,900 ug/L. These wells effectively "bound" the residential area.
    e. Based on the VISL calculator, the concentrations of naphthalene in groundwater at these wells triggers a greater than 1x10-3 risk and 1x10-4 risk at SMW-80 and SMW-82, respectively. These results are likely an "over prediction" because the VISL calculator does not take into account bio-attenuation of petroleum hydrocarbons.

The depth to water at SMW-80 is 8.8 feet below land surface (bls) and the depth to water at SMW-82 is 3.2 feet bls.

  f. The proposed temporary well locations along West High Street, North Fulbright Avenue, and North Clifton Avenue will be installed using a Geoprobe. These locations will be immediately abandoned upon groundwater sample collection. Depth to water information in these areas will also be collected, as well as lithologic information on clay and chert fragment horizons, to guide the SV sampling program. (To be Performed)

3. Evaluate site for precluding factors (e.g., karst or fractured bedrock, utility lines).
    a. Karst and fractured bedrock exist in this area; thus, the geology and NAPL migration pathways are complex.
    b. The proposed SV sampling program will provide additional information of nature and extent of the contamination. (To be Performed)
4. Determine vertical separation distances.
    a. EPA OUST guidance states: Additional investigation is generally unnecessary if the distance to contamination is greater than (1) 6 feet for dissolved contamination beneath buildings of any size or (2) 15 feet for light non-aqueous phase liquid (LNAPL) if the overlying building has at least one side shorter than 66 feet in length. If the distance to contamination is less than those indicated above, then additional investigation is recommended.
    b. ITRC PVI Guidance states: Several empirical studies have defined vertical screening distances for LNAPL and dissolved-phase sources. As previously noted, there is more uncertainty with the industrial sites because of the relatively small data set of industrial sites in the empirical study. Although the values derived for dissolved-phase and LNAPL sources vary slightly among the studies, they can be conservatively defined as:
        - 5 feet: dissolved-phase sources
        - 15 feet: LNAPL sources (petroleum UST/Aboveground Storage Tanks sites)
        - 18 feet: LNAPL sources (petroleum industrial sites)

       Determine whether the vertical separation distance between the top of the petroleum vapor source and the bottom of the building foundation exceeds these vertical screening distances for either an LNAPL source (see ITRC Guidance Figure 3-5) or a dissolved-phase source (see ITRC Guidance Figure 3-6). If so, then no further evaluation of the PVI pathway is necessary. If not, then further site investigation or vapor control and site management is necessary.
    c. In reviewing the data collected to date, neither condition appears to apply for the area of interest (residential area north and northeast of the Site)
        i. Depths to groundwater range from about 3 feet bls to 11 feet bls.
        ii. Basements have been identified for some of the homes; thus, even if the depth to groundwater is 11 feet bls, the vertical separation distance is likely 6 feet or less.
        iii. NAPL is present at depths less than 15/18 feet bls at SMW-80.
        iv. Depth to water at SMW-81 is about 11 feet and NAPL was not detected; however, there are several homes along West Truman Street with basements.

The ITRC PVI Pathway Evaluation Checklist was completed and is included as Attachment 2.

3.3 Recommended Next Steps Soil Vapor Sampling Program

Given the PVI guidance documents and discussions between the Multistate Trust, MDNR and MDHSS, it is recommended that the following phased approach be implemented:

1. Four Geoprobe borings will be pushed at locations shown on Figure 1.0 to obtain lithologic information, determine the depth to groundwater and to collect groundwater samples for analysis. The lithologic information will confirm the expected soil lithology in the area, the depth to groundwater will guide the SV sample collection, and the groundwater analytical data will further provide information on nature and extent of groundwater impact. The Geoprobe and sample collection will be implemented in accordance with MDNR-approved RAO Work Plan (SOP 2, SOP 3, and SOP 4).
2. Install two monitoring wells along Margaret Street as shown on Figure 1.0 and collected a groundwater sample for laboratory analysis in accordance with the MDNR-approved RAO Work Plan (SOP 6 and SOP 9). Groundwater analytical data will be input into the EPA VISL calculator and the PVI Screening Process will be performed to determine if the vapor intrusion pathway needs to be further evaluated for those homes located along Margaret Street.

3. SV samples will be collected from the locations shown on Figure 1.0, in the City of Springfield ROW, approximately 30 feet from the outside edge of each home or as close as possible depending on the ROW restrictions, and in accordance with SOP 10a and SOP 19 (New SOPs; Attachments 3 and 4, respectively).
    i. These SV sample locations are intended to be temporary SV points. Samples will be submitted to Eurofins Air Toxics laboratory for analysis using EPA Method TO-15 (full scan) as requested by MDNR on December 6, 2016. Benzene, toluene, ethylbenzene, xylenes, and naphthalene (BTEX,N) are the Site-specific COPCs and will be assessed further as part of the vapor intrusion assessment. Naphthalene is considered the "driver compound."
    ii. Target shallow (3 feet bls) and deep (8 feet bls) monitoring points will be installed at each location, generally using the PVI guidance regarding water depth. Sampling depths will be adjusted based on water depth and presence of favorable lithologic horizons with higher permeability, if present. Semivolatile compounds (SVOCs) cannot be analyzed, since the volume of air from Summa® canister is insufficient to achieve the low detection limits needed for screening levels.
    iii. 1-liter Summa® canisters will be used instead of Tedlar® bags to achieve lower detection limits, increase laboratory holding times, and increase the analyte recoveries.
    iv. Oxygen, carbon dioxide and methane will be measured using a 4-gas meter from each SV sampling location to help evaluate bio-attenuation.
    v. SV samples will be submitted for a 3-day turnaround. Data validation will take 5 business days per sample data group (SDG) from the receipt of the SDG/analytical data from the laboratory.

The approach described above will provide information on nature and extent as well as information to make decisions regarding the next steps for the assessment of the vapor intrusion pathway.

The results from SV sampling program outlined in this RAO Work Plan Addendum, will guide decisions regarding the next step and may include:

- Development of a Vapor Intrusion Work Plan for review and approval by MDNR. The Vapor Intrusion Work Plan would include procedures for:
    - Building (includes utility/basement) and chemical surveys
    - Near-slab soil gas
    - Sub-slab soil gas
    - Crawl space air sampling
    - Indoor air sampling

The next steps, if necessary, will be developed through discussions with MDNR and MDHSS.

3.4 Ambient Air Samples

Outdoor air samples will be collected in 1-liter Summa® canisters to verify the presence of site-specific COPCs. Every attempt will be made to collect samples when odors are reported by residents, and a background (upwind) sample will be collected from an area away from the Clifton Drainage. Up to four samples will be collected and analyzed using EPA Method TO-15 (full scan). Samples will be submitted for a 3-day turnaround. Data validation will take 5 business days per sample data group (SDG) from the receipt of the SDG/analytical data from the laboratory.

4.0 Schedule

The following table summarizes the anticipated schedule. This is subject to weather and laboratory delays.

Activity	Starting Date	Completion Data
Temporary Geoprobe Wells and Groundwater Sampling	Monday, December 12, 2016	Tuesday, December 13, 2016
Shallow and Deep Soil Gas Collection	Tuesday, December 13, 2016	Friday, December 16, 2016
Receipt of Analytical Reports	December 16, 2016	December 22, 2016
Data Validation	December 19, 2016	January 6, 2017

5.0 References

EWI, 2016a. Remedial Action Optimization Work Plan, Former Tronox Facility, 2800 West High Street, Springfield, Missouri, RCRA Permit Number M0D007129406, Environmental Works Inc. (EWI), August 8, 2016

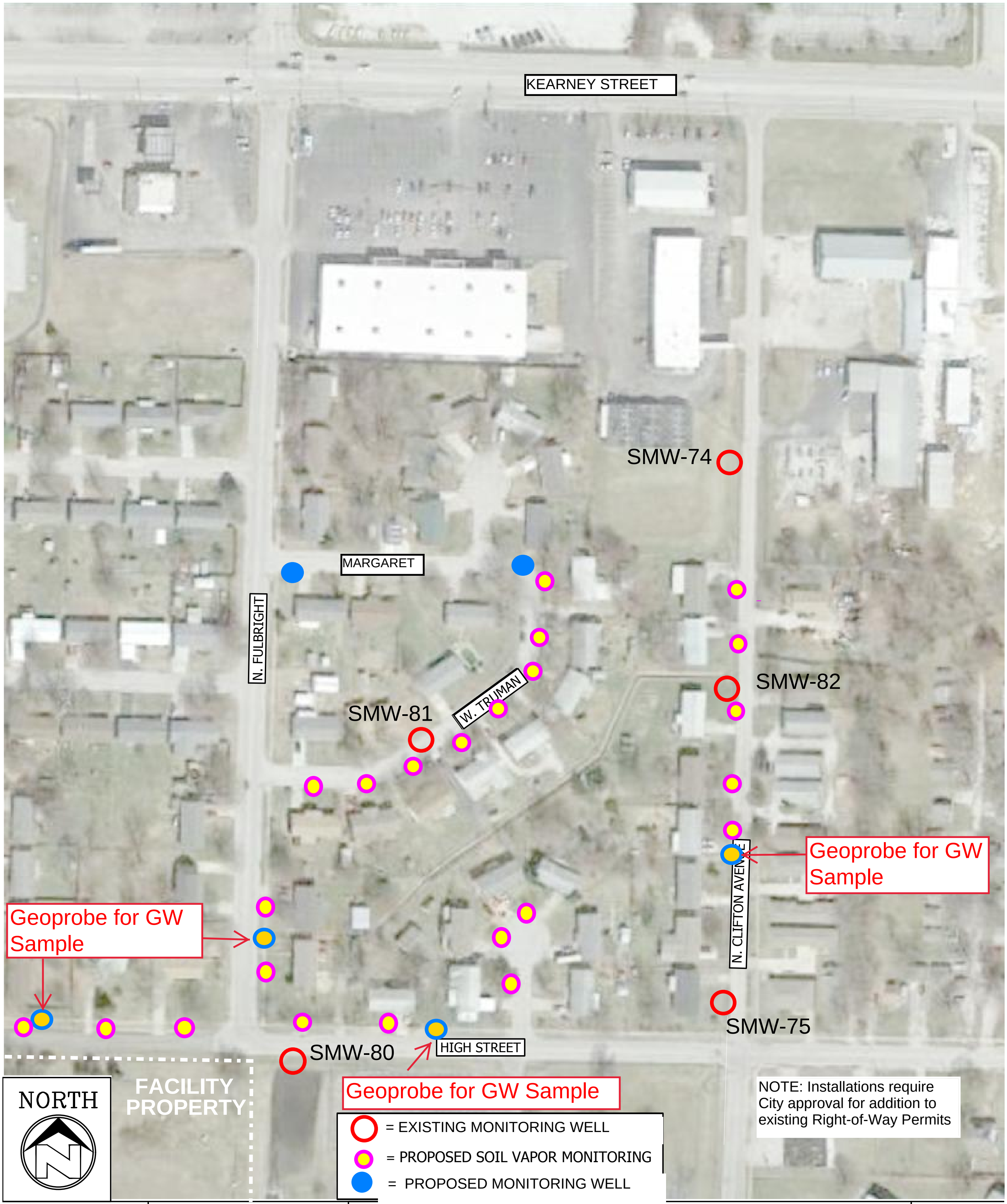
EWI, 2016b. Draft RAO Status Update Memorandum, Former Tronox Facility, 2800 West High Street, Springfield, Missouri, RCRA Permit Number M0D007129406, November 29, 2016.

EPA, 2016. Vapor Intrusion Screening Levels (VISLs). Version 3.5.1. May 2016 RSLs. https://www.epa.gov/vaporintrusion/vapor-intrusion-screening-levels-visls

ITRC, 2014. Interstate Technology and Regulatory Council Petroleum Vapor Intrusion Fundamentals of Screening, Investigation and Management. October, 2014.

EPA, 2015a. Technical Guide for Addressing Petroleum Vapor Intrusion At Leaking Underground Storage Tank Sites, U.S. Environmental Protection Agency Office of Underground Storage Tanks, EPA 510-R-15-001. June, 2015.

EPA, 2015b. OSWER Technical Guide for Assessing and Mitigating the Vapor Intrusion Pathway from Subsurface Vapor Sources to Indoor Air, OSWER Publication 9200.2-154. June, 2015.



NOTE: Installations require City approval for addition to existing Right-of-Way Permits

CHECKED BY:
B. LANNING

E.W.I. # 150683
DRAWN BY: MRB
Jul. 20, 2016

SCALE IN FEET
0 90 180
APPROXIMATE

ENVIRONMENTAL WORKS
1455 E. Chestnut Expressway, Springfield, MO 65802

PROPOSED ROW VAPOR MONITORING
PER HOUSE CLIFTON DRAINAGE

SPRINGFIELD SITE
GREENFIELD MULTISTATE TRUST
2800 W. HIGH STREET
SPRINGFIELD, GREENE COUNTY, MISSOURI

FIGURE
1.0

Attachment 1
RAO Status Memorandum (Revised)

Remedial Action Optimization Status Memorandum Revision 1 (12/12/2016)
Former Tronox Facility, Springfield, Missouri

This status memorandum summarizes the current status of the Remedial Action Optimization (RAO) activities for the former Tronox Facility in Springfield, Missouri (Facility or Site), and has been revised based on December 8, 2016 comments by the Missouri Department of Natural Resources (MDNR) and the Missouri Division of Health and Senior Services (MDHSS). Specific activities performed and reported herein are based on Sections 5.1 through 5.3, 5.4.1, 5.4.2, 5.5, 5.6, and 5.7 of the RAO Work Plan. This memorandum summarizes findings, conclusions, and presents a path forward, and Figures 1.0 through 8.0 are provided for reference. This memorandum is a preliminary submittal in order to provide a status update to MDNR and MDHSS, and conclusions presented in this memorandum may be updated based on new information. The Final RAO Report will be completed after the RAO activities are completed and all data and findings have been evaluated.

Proposed Springfield RAO Field Sampling and Analysis Next Steps Executive Summary

1. Delineate nature and extent of contamination in groundwater and evaluate the vapor intrusion pathway northeast of Facility

    - Identify shallow soil cover areas and verify depth to groundwater to target exposure investigation
    - Collect and analyze shallow groundwater/surface water from groundwater seepage
    - Install “fill-in” monitoring wells in key residential areas where plume extent is not defined
    - Evaluate groundwater data from new monitoring wells using the EPA vapor intrusion screening levels (VISL) calculator to identify locations where chemicals of concern (COCs) exceed the screening levels, thus warranting further evaluation of the vapor intrusion pathway. Perform additional VISL screening of additional groundwater analytical results
    - Collect and analyze ambient air samples from onsite (1 sample), background areas (2 samples), the residential neighborhood located directly to the north of the Facility (2 samples) and the residential neighborhood located to the northeast of the Facility (2 samples)
    - Install and sample shallow and deep soil vapor wells within the residential neighborhoods located directly to the north and northeast of the Facility. Soil vapor wells will be installed in the City of Springfield right-of-way (ROW).
    - For additional details, see the RAO Work Plan Addendum.

2. Determine additional UFZ or SFZ groundwater delineation needs in other areas

    - Coordinate step-out well locations with MDNR and property owners
        - Locations for further UFZ delineation are along the northeast Clifton Drainage outside of the residential area, pending discussion with MDNR
        - Further SFZ delineation would be off-site to the southwest of the Facility
    - Install up to four new monitoring wells at identified locations
        - UFZ locations may be along Kearney Street right-of-way for lateral plume delineation
        - An off-site SFZ well may be installed southwest of the Facility four southwest delineation of this lower hydrogeologic zone

3. Revise the August 18, 2016, Sampling and Analysis Plan, former Tronox Facility, Springfield, Missouri, and RCRA Post Closure Care Permit #MOD007129406 (RCRA Permit) as requested by MDNR. This is anticipated to be submitted no later than Q3-2017 to allow collection and evaluation of sampling data from the new wells from two quarters.

- Perform quarterly sampling of new monitoring wells
- Evaluate appropriate monitoring wells for long-term monitoring
- Identify locations for periodic vapor intrusion monitoring
- Revise Sampling and Analysis Plan and RCRA Permit for revised monitoring issues

TarGOST and Geoprobe Boring Investigation

47 TarGOST borings were completed (please see Figure 1.0). TarGOST borings were completed on the Facility only, due to lack of access to off-site locations – eastern Greene County and southern BNSF property – during TarGOST availability.

- Pumping Center #1 (PC-1, northeast corner): 3 TarGOST with no detections (creosote is in bedrock)
- PC-2 (East border): 6 TarGOST, 2 detections near bedrock (13.9 feet below land surface [ft bls])
- PC-3 (site center): 5 TarGOST with no detections
- PC-4 (site west-center): 2 TarGOST with no detections
- PC-5 (pre-RCRA cell, site south center): 15 TarGOST (including western step-outs), with 10 detections including strongest site TarGOST responses between 4.5 – 8 ft bls.
- PC-7 (East side, BNSF property line): 4 TarGOST, 2 detections with apparent connection north with PC-5 detections
- PC-7 (Drip Track, former production area): 12 TarGOST, 1 detection at 13.4 ft bls

4 Geoprobe borings were completed as follow-up to TarGOST borings with soil samples collected at peak TarGOST responses (note: TarGOST responses are measured as percent of the reference emitter[RE], similar to a PID measurement relative to 100% isobutylene):

- SB-B (PC-2 near TG-47): at 13.9 feet (ft) below ground surface (bls) at 195% TarGOST RE, 17 polycyclic aromatic hydrocarbon (PAH) and 3 benzene, toluene, ethylbenzene, and xylene (BTEX) detections; 8 PAHs exceed EPA Region 3 Screening Levels for Industrial Soil (RSL-Industrial Soil)
- SB-B-2 (Greene County, east of SB-B): at 13 ft bls, 4 detections all below RSL-Industrial Soil
- SB-E (PC-5 near TG-20): at 8 ft bls at 409% TarGOST RE, 19 PAH and 4 BTEX detections, highest overall concentrations; 9 PAHs exceed RSL-Industrial Soil
- SB-F (PC-7, west former production area): at 13.4 ft bls at 225% TarGOST RE, 17 PAH and 4 BTEX detections; 7 PAHs exceed RSL-Industrial Soil
- Overall, chemical concentration patterns generally matched the TarGOST response strength

Preliminary Conclusions: TarGOST results, confirmed by laboratory analytical results, indicate that a large area of creosote appears present within, west, and south of the former pre-RCRA cell in the south-central Facility area at depths up to 8 ft bls. Soil borings and confirmation soil sampling is warranted to define the nature and extent of contamination in this area and to provide data for evaluating remedial options. The area east of PC-2 does not require additional investigation, since soil sample results there reported only 4 detections of COCs at concentrations well below RSL-Industrial Soil.

Source Area Surficial Soil Investigation

Three surface soil samples were collected from former source areas (Landfarm Area, Drip Track Area, and Black Tie Area) to determine whether or not COCs in soil exceeded the RSL-Industrial Soil. Locations are depicted on Figure 2.0.

- SS-1 (south side Drip Track Area near TG-34): at 1.5 ft bls 17 PAH and 4 BTEX detections; 4 PAHs exceed RSL-Industrial Soil levels

- SS-2 (Landfarm Area, south-central at highest historical concentration area): at 1.25 ft bls, 19 PAH and 4 BTEX detections, with 8 PAHs exceeding RSL-Industrial Soil
- SS-3 (Black Tie Area): two aliquots from 1.25 ft bls, 16 PAH and no BTEX detections, one PAH exceeds RSL-Industrial Soil (benzo[a]pyrene) by less than two times RSL
- Several PAHs exceed the RSL-Industrial Soil by one order of magnitude at SS-1. Several PAHs exceed the RSL-Industrial Soil by 2 to 3 orders of magnitude at SS-2.

Conclusions: Concentrations of PAHs in the Landfarm Area have remained elevated; therefore, continued maintenance of the surface cap is required to achieve the established remedial action objectives. Because soil in the Drip Track Area exceeds the RSL-Industrial Soil, additional investigation of the surficial zone is warranted to define nature and extent; collected data would be used to assess potential exposure risk.

New Upper Flow Zone Monitoring Wells

New Upper Flow Zone (UFZ) monitoring wells were installed on the Greene County Highway Department (GCHD) property located east of the Facility (East off-site GCHD), the residential area located southwest of the Facility, and the residential and Clifton Drainage area located northeast of the Facility. All wells were sampled for screening analysis of all Groundwater Protection Standards (GWPS) chemicals.

East Off-Site GCHD Monitoring Wells

Two new monitoring wells were installed on the GCHD property as depicted on Figure 3.0 (please see reference Index Figure).

SMW-77 (south location)

- Bedrock at 10 ft deep, weathered to 15 ft bls
- Total depth 40 ft bls
- No visual presence of creosote impacted soil, no odor, or no PID detections
- Constructed with 20 ft of screen from 20-40 ft bls. The well began producing water.
- Analytical results: 4 detections of PAHs and 2 VOCs, all below GWPS

SMW-78 (north location)

- Bedrock at 15 ft bls, weathered to 20 ft bls
- Diesel-like odor was observed at 15 ft bls (PID reading 28 parts per million [ppm])
- Total depth of 42 ft bls
- No indication of secondary porosity
- Constructed with 20 ft screen from 22 -42 ft bls. The well began producing water, with minor odor observed
- Analytical results: 9 detections of PAHs and 3 VOCs, one PAH above GWPS (phenanthrene).

Conclusions: No further delineation is warranted; however, it is recommended that these new monitoring wells be incorporated into the existing groundwater monitoring program, to include quarterly sampling for one year.

South and Southwest Off-Site BNSF and Residential Monitoring Wells

Two new monitoring wells were installed in City of Springfield ROW locations as depicted on Figure 4.0. Lack of BNSF access for drilling and obstacles from underground utilities prevented drilling the other proposed well locations as identified in the RAO Work Plan.

SMW-79 (north Drury Ave at Atlantic Street location)

- Bedrock at 17 ft bls, minimal weathering horizon
- Total depth 26 ft bls
- No visual presence of creosote impacted soil, no odor, or no PID detections
- Constructed with 7 ft of screen from 19-26 ft bls
- Well has remained dry and has not been sampled

SMW-83 (south location at W. Thoman and Drury Ave)

- Clay and weathered limestone fragments to 15 ft bls, competent bedrock to 20 ft bls
- Increased weathering was observed between 20-29 ft bls; total depth of well is 33.5 ft bls
- Constructed with 25 ft of screen from 8.5 -33.5 ft bls
- Well took several days to produce water and was sampled; 3 estimated PAH detections were reported with one (phenanthrene) slightly over its GWPS (0.2 ug/L vs 0.1 ug/L GWPS)

Preliminary Conclusions: Current results do not indicate an additional delineation need, since SMW-79 is dry and SMW-83 has only one PAH slightly above the GWPS. Additional groundwater sampling is needed to verify groundwater quality. Well SMW-60 located in the south BNSF yard was rehabilitated after damage by BNSF activities for use as a south delineation well, given the overall southward groundwater flow direction from the Facility. SWW-79 will continue to be monitored for presence of water and will be sampled if water appears.

Northeast Off-Site Residential and Clifton Drainage Area Monitoring Wells

Three new monitoring wells were installed in the City of Springfield ROW in the residential neighborhoods located to the northeast of the Facility (see Figures 3.0 and 5.0), and two new monitoring wells were installed further to the northeast along the Clifton Drainage on commercial property (Figure 5.0). Analytical results are summarized in Table 1.0.

SMW-80 (High St. ROW immediately northeast of the Facility corner, see Figure 3.0)

- Bedrock encountered at 12 ft deep, weathered to 24 ft bls
- Total depth of well is 27 ft bls
- Depth to water is 8.8 ft bls
- Creosote DNAPL was was observed in the weathered bedrock and groundwater. A strong creosote-like odor was also observed in both the drill cuttings and the groundwater.
- The well produces water.
- Constructed with 20 ft of screen from 7-27 ft bls.
- Sampled after DNAPL settled with results: 15 detections of PAHs and 4 VOCs, one VOC and 8 PAHs exceed GWPS. Naphthalene concentration is 11,000 ug/L. Well will be resampled to verify results.
- Conducted VISL evaluation of analytical results which showed that benzo(a)anthracene, benzene, ethylbenzene, and naphthalene calculated indoor air concentration exceed the residential carcinogenic exposure level, and naphthalene also exceeds the non-carcinogenic exposure level.

SMW-81 (W. Truman St. ROW, see Figure 5.0)

- Bedrock encountered at 10 ft bls, weathered to 22 ft bls with void horizons 14-19 and 21-22 ft bls
- Total depth of well is 27 ft bls
- Depth to water is 11.4 ft bls

- No significant PID detections, but minor odors observed in both the drill cuttings and the groundwater.
- Constructed with 20 ft of screen from 7-27 ft bls. Well began producing water.
- Analytical results: 17 detections of PAHs and 2 VOCs; 12 PAHs exceed GWPS
- Conducted VISL evaluation of analytical results which showed that benzo(a)anthracene calculated indoor air concentration exceeds the residential carcinogenic exposure level

SMW-82 (N. Clifton Ave ROW, immediately south of surface drainage, see Figure 5.0)

- Bedrock ledge at 6 ft bls, saturated clay below with weathered bedrock to 16 ft bls
- Drilling in shallow unconsolidated produced bubbling from cracks in concrete surface drainage with some sheen (controlled by absorbents)
- At depth, no significant PID readings or odor
- Drilled to 30 ft bls to verify no deeper secondary porosity; bentonite backfill with sand cap to 21 ft bls; constructed with 15 ft of screen from 6-21 ft bls.
- Total depth of well is 21 ft bls
- Depth to water is 3.2 ft bls average
- Abundant water produced; when purged for sampling, odor and minor sheen was observed.
- Analytical results: 17 detections of PAHs and 3 VOCs, 11 PAHs exceed GWPS
- Conducted VISL evaluation of analytical results which showed that ethylbenzene and naphthalene calculated indoor air concentrations exceed both carcinogenic and non-carcinogenic residential exposure levels

SMW-84 (Northeast Clifton Drainage, south Rite-Way Concrete property, see Figure 5.0)

- Bedrock at 12 ft bls, no significant near surface weathering
- Bedding plane voids/fracures from 45 to 55 ft bls with minor PID readings
- Drilled to 60 ft bls to verify no deeper secondary porosity; bentonite backfill with sand cap to 55 ft bls; constructed with 20 ft of screen from 35 -55 ft bls
- Total depth of well is 55 ft bls
- When purged for sampling, DNAPL globules and creosote odor were observed.
- Sampled after DNAPL settled, analytical results: 18 detections of PAHs and 4 VOCs, 11 PAHs exceed GWPS
- Conducted VISL evaluation of analytical results which showed that ethylbenzene and naphthalene calculated indoor air concentrations exceed residential carcinogenic exposure risk and naphthalene also exceeds the residential non-carcinogenic exposure level

SMW-85 (East extension of Clifton Drainage, east of surface ditch, Race Brothers property, see Figure 5.0)

- Bedrock at 10 ft bls
- No apparent fractures or voids; began producing water at 38 ft bls, minor PID readings
- Drilled to 57 ft bls; constructed with 20 ft of screen from 37 -57 ft bls
- Total depth of well is 57 ft bls
- When purged for sampling, a slight creosote-like odor was observed
- Analytical results: 14 detections of PAHs and no VOCs, 9 PAHs exceed GWPS

Figure 6.0 depicts a southwest to northeast cross-section from the northeast Facility corner to SMW-85 in the northeast Clifton Drainage area. The following is noted:

- Topography and bedrock surface both display elevation decrease to the northeast
- Upper weathered bedrock/karst features thin to the northeast, while karst features deepen in

the bedrock proceeding northeast
- DNAPL appears to follow the downward trend of secondary porosity (note occurrences in SMW-80 vs SMW-84, and RW-21 further to the north)
- Groundwater elevations decrease northeastward, with a significant drop past SMW-82. This is likely related to the deepening of karst features (also present at RW-21 to the north).
- The relatively high water level in SMW-82 may be related to the adjacent surface drainage
- During heavy precipitation and recharge, it may be possible for ground water to "back up" southward from the deeper karst system in the northeast. Sufficiently high recharge conditions could cause upward seepage in the area of the Clifton surface drainage in the residential area where conditions similar to SMW-82 exist

Preliminary Conclusions: Contaminant concentrations in groundwater exceeding GWPS are observed along inferred fracture lines following the northeast Clifton Drainage from the Facility. Delineating the nature and extent of contaminated groundwater and the potential for vapor intrusion within the residential areas located to the north and northeast of the Facility is warranted. These additional investigation activities are presented in the RAO Work Plan Addendum. It is recommended that these activities be prioritized.

VISL Evaluation of Groundwater for Vapor Inhalation Risk

The potential for vapor intrusion from off-gassing of UFZ groundwater was initially evaluated by inputting groundwater data from four new impacted wells, SMW-80, SMW-81, SMW-82, and SMW-84, into the EPA VISL calculator. The VISL calculator was used to assess for a residential exposure scenario for both carcinogenic (C) for $1x10^{-6}$ risk and non-carcinogenic (NC) Hazard Quotient=1 risk vapor intrusion standards for SMW-80, SMW-81, and SMW-82 in the residential neighborhood, and the same parameters for commercial exposure for SMW-84 which on industrial property. A memorandum of the findings of the VISL calculations with printouts of the VISL output is attached.

- Based on VISL parameter selection criteria, constituents automatically evaluated are: benzo(a)anthracene, benzene, ethylbenzene, naphthalene, toluene, and xylenes.
- Results show calculated exceedances for each well location:
    - SMW-80: Benzene, ethylbenzene, and naphthalene each exceed residential carcinogenic exposure levels, and naphthalene also exceeds the residential non-carcinogenic exposure level
    - SMW-81: Benzo(a)anthracene exceeds the residential carcinogenic exposure level
    - SMW-82: Naphthalene and ethylbenzene each exceed both carcinogenic and non-carcinogenic residential exposure levels
    - SMW-84: Ethylbenzene and naphthalene each exceed the residential carcinogenic exposure level, naphthalene also exceeds the residential non-carcinogenic exposure levels

Conclusions: Estimated screening levels indicate that groundwater contamination that extends into the residential areas northeast of the Facility has the potential for vapor intrusion exposure to residents. Per the RAO Work Plan, follow-up investigation of potential vapor intrusion exposure is warranted. Activities associated with this follow-up investigation are presented in the RAO Work Plan Addendum.

Secondary Flow Zone Monitoring Wells for Vertical and Horizontal Delineation

New Secondary Flow Zone (SFZ) monitoring wells were installed on-site to evaluate extent of SFZ impact between BMW-10R and BMW-5, downgradient of BMW-5 and BMW-10R, and vertically between the UFZ and SFZ. Wells were sampled for screening analysis of all GWPS chemicals.

SFZ Vertical Delineation Monitoring Wells

Two SFZ and two UFZ monitoring wells were installed as depicted on Figure 7.0 in the main facility area. Analytical results are summarized on Table 1.0.

BMW-12 (northeast of BMW-10R)

- Bedrock encountered at 18 ft deep, weathered to 20 ft bls
- Drilled and set surface casing to 35 ft bls, with abundant water production
- Drilled to 80 ft bls for initial monitoring; no visual, no odor, or PID indicators of impact
- 24 hrs later downhole video indicated multiple horizons of DNAPL entry between 37-75 ft bls, with minor DNAPL accumulating at the bottom
- Continued monitoring indicates slow DNAPL and water production; DNAPL is periodically bailed out
- Extensive vertical length of DNAPL entry horizons indicated potential vertical connection to upper SFZ, so decided to not drill well further and monitor for potential DNAPL recovery.
- Total depth of well is 80 ft bls

SMW-76 (northwest of BMW-10R, intended as downgradient SFZ delineation well)

- Bedrock encountered at 11 ft bls; water-producing void at 18-20 ft bls; creosote-like odor observed
- Drilled to 25 ft bls; constructed with 10 ft of 4-inch diameter screen from 15-25 ft bls; larger screen diameter was used to allow for future recovery options
- Total depth of well is 25ft bls
- Designated well as UFZ well for monitoring
- Analytical results: 17 detections of PAH and 2 BTEX, 11 PAHs exceed GWPS

BMW-13 (northwest of BMW-5, horizontal and vertical SFZ delineation well)

- Bedrock at 12 ft deep, weathered to 15 ft bls
- Drilled and set temporary surface casing to 30 ft bls, drilled bottom hole to 80 ft bls with no indications of impact.
- Limited water at 80 ft bls was sampled for screening analysis
- Analytical results at 80 ft: 9 PAH and 4 BTEX detections, 2 PAH exceed GWPS
- Downhole video showed no secondary porosity, and no DNAPL entry.
- Hole reamed out and casing set and grouted to 82 ft bls, bottom hole drilled to 180 ft bls
- Total depth of well is 180 ft bls
- Downhole video showed weathered secondary porosity zone 143 – 158 ft bls.
- Bottom hole low-flow sampled at 90, 150, 175 ft bls. Analytical results:
  - 90 ft: 11 PAH detections and 4 BTEX, 6 exceed GWPS
  - 150 ft: 11 PAH detections and 4 BTEX, 6 exceed GWPS (similar to 90 ft)
  - 175 ft: 11 PAH detections and 4 BTEX, 6 exceed GWPS (similar to 90 & 150 ft)

BMW-14 (northwest of SMW-76 and BMW-10R, horizontal SFZ delineation well)

- Bedrock at 19 ft bls, no moisture until 41 ft bls
- Drilled and cased to 80 ft bls; drilled bottom hole to 180 ft bls; no visual presence of creosote impacted soil, no odor, or no PID detections

- Total depth of well is 180 ft bls
- Water level at 67 ft bls; low-flow sampled at 107 ft bls
- Analytical results: 2 estimated BTEX detections, no GWPS exceedances

Preliminary Conclusions: Drilling observations, DNAPL occurrence at SMW-12 (and BMW-10R), and horizontal groundwater sampling indicates the potential for vertical migration of DNAPL between the UFZ and upper SFZ in the former production area. While BMW-13 has GWPS exceedances, impacted SFZ groundwater is delineated downgradient by existing well BMW-6. Similarly, BMW-14 delineates SFZ groundwater downgradient of BMW-10R. Southwestern delineation of BMW-10R is pending an access agreement with an off-site property owner. New UFZ well SMW-76 is impacted, and delineated to the south and southwest by PC-7 area wells, and new wells SMW-79 and SMW-83 to the south. It is recommended that SMW-12 remain as a deep UFZ/shallow SFZ monitoring well for potential DNAPL recovery; DNAPL monitoring and recovery is ongoing.

Next Steps for Evaluating the Vapor Intrusion Pathway

Details for evaluating the vapor intrusion pathway and next steps are presented in the RAO Work Plan Addendum.

As an additional aid in evaluating potential exposure in the area of the Facility, Figure 8.0 depicts area businesses and industries surrounding the Facility.

Table 1.0 - INITIAL GROUNDWATER ANALYTICAL DATA - NEW RAO MONITORING WELLS

Former Tronox Facility, Springfield, MO

			SMW-76		**SMW-77**		**SMW-78**		**SMW-80**		**SMW-81**		**SMW-82**		**SMW-83**	
Analyte	Units	**GWPS**	Results	MDL	Results	MDL	Results	MDL	Results	MDL	Results	MDL	Results	MDL	Results	MDL
Acenaphthene	ug/l	1200	150	1	0.16 J	0.11	1.0	0.10	370	2	320	1	470	1.0	N.D.	0.1
Acenaphthylene	ug/l	0.1	6	0.1	N.D.	0.11	N.D.	0.10	18	0.1	3	0.1	1.9	0.10	N.D.	0.1
Anthracene	ug/l	9600	16	0.1	N.D.	0.11	0.70	0.10	14	0.1	61	0.1	22	0.10	N.D.	0.1
Benzo(a)anthracene	ug/l	0.1	36	0.1	N.D.	0.11	N.D.	0.10	0.5	0.1	68	0.1	9.8	0.10	N.D.	0.1
Benzo(a)pyrene	ug/l	0.2	17	0.1	N.D.	0.11	N.D.	0.10	N.D.	0.1	23	0.1	2.6	0.10	N.D.	0.1
Benzo(b)fluoranthene	ug/l	0.1	25	0.1	N.D.	0.11	N.D.	0.10	0.1 J	0.1	33	0.1	5.4	0.10	N.D.	0.1
Benzo(k)fluoranthene	ug/l	0.1	11	0.1	N.D.	0.11	N.D.	0.10	N.D.	0.1	13	0.1	2.1	0.10	N.D.	0.1
2-Chlorophenol	ug/l	0.5	N.D.	0.5	N.D.	0.54	N.D.	0.51	N.D.	0.5	N.D.	0.5	N.D.	0.52	N.D.	0.5
Chrysene	ug/l	0.1	26	0.1	N.D.	0.11	N.D.	0.10	0.4 J	0.1	47	0.1	7.2	0.10	N.D.	0.1
Dibenz(a,h)anthracene	ug/l	0.1	2	0.1	N.D.	0.11	N.D.	0.10	N.D.	0.1	2	0.1	0.32 J	0.10	N.D.	0.1
Dibenzofuran	ug/l	7.9	100	0.5	N.D.	0.54	0.90 J	0.51	270	10	220	5	290	5.2	N.D.	0.5
2,4-Dimethylphenol	ug/l	540	N.D.	0.5	N.D.	0.54	N.D.	0.51	2	0.5	N.D.	0.5	N.D.	0.52	N.D.	0.5
2,4-Dinitrophenol	ug/l	70	N.D.	10	N.D.	11	N.D.	10	N.D.	10	N.D.	10	N.D.	10	N.D.	10
Fluoranthene	ug/l	300	170	1	0.69	0.11	0.15 J	0.10	23	0.1	400	1	83	0.10	0.2 J	0.1
Fluorene	ug/l	1300	100	1	0.15 J	0.11	2.6	0.10	230	2	350	1	300	1.0	N.D.	0.1
Indeno(1,2,3-cd)pyrene	ug/l	0.1	6	0.1	N.D.	0.11	N.D.	0.10	N.D.	0.1	6	0.1	1.3	0.10	N.D.	0.1
2-Methylnaphthalene	ug/l	36	11	0.1	N.D.	0.11	0.28 J	0.10	630	2	43	0.1	470	1.0	N.D.	0.1
Naphthalene	ug/l	20	67	0.1	0.14 J	0.11	0.54	0.10	11,000	20	4	0.1	3,900	10	N.D.	0.1
Phenanthrene	ug/l	0.1	110	1	N.D.	0.11	1.6	0.10	210	2	950	1	390	1.0	0.2 J	0.1
Phenol	ug/l	300	N.D.	0.5	N.D.	0.54	N.D.	0.51	0.5 J	0.5	N.D.	0.5	N.D.	0.52	N.D.	0.5
2-Picoline	ug/l		N.D.	2	N.D.	2.2	N.D.	2.0	N.D.	2	N.D.	2	N.D.	2.1	N.D.	2
Pyrene	ug/l	960	100	1	0.48 J	0.11	0.29 J	0.10	11	0.1	240	1	47	0.10	0.3 J	0.1
Benzene	ug/l	5	N.D.	0.2	0.3 J	0.2	0.6 J	0.2	10	0.2	N.D.	0.2	N.D.	1.0	N.D.	0.2
Ethylbenzene	ug/l	700	1.7	0.2	N.D.	0.2	N.D.	0.2	94	0.2	0.7 J	0.2	13	1.0	N.D.	0.2
Toluene	ug/l	1000	N.D.	0.2	0.4 J	0.2	1 J	0.2	47	0.2	N.D.	0.2	2.6 J	1.0	N.D.	0.2
Total Xylenes	ug/l	10000	3.8	0.2	N.D.	0.2	0.8 J	0.2	310	0.2	2.7	0.2	38	1.0	N.D.	0.2

Notes: **GWPS** = Groundwater Protection Standards

Yellow Highlight = GWPS exceedances

MDL = Minimum Detection Limit

Table 1.0 - INITIAL GROUNDWATER ANALYTICAL DATA - NEW RAO MONITORING WELLS

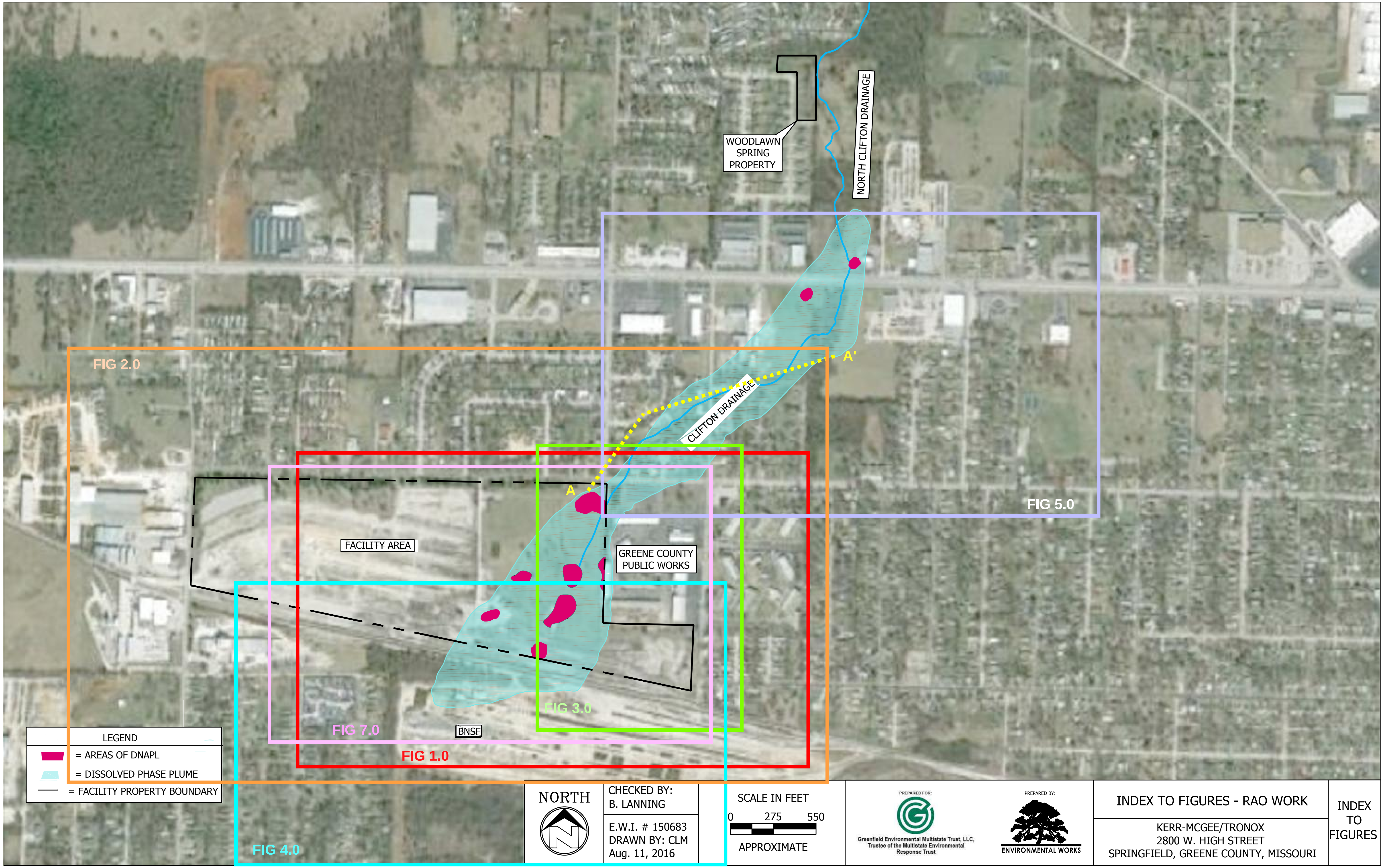
Former Tronox Facility, Springfield, MO

			SMW-84		SMW-85		BMW-13						BMW-14	
Analyte	Units	**GWPS**	Results	MDL	Results	MDL	80-ft	MDL	90-ft	150-ft	175-ft	MDL	107-ft	MDL
Acenaphthene	ug/l	1200	410	1	37	1	0.4 J	0.1	93	58	48	0.1	N.D.	0.11
Acenaphthylene	ug/l	0.1	3	0.1	1 J	1	N.D.	0.1	4	3	2	0.1	N.D.	0.11
Anthracene	ug/l	9600	17	0.1	5 J	1	N.D.	0.1	N.D.	N.D.	N.D.	0.1	N.D.	0.11
Benzo(a)anthracene	ug/l	0.1	2	0.1	6	1	N.D.	0.1	N.D.	N.D.	N.D.	0.1	N.D.	0.11
Benzo(a)pyrene	ug/l	0.2	0.5 J	0.1	6	1	N.D.	0.1	N.D.	N.D.	N.D.	0.1	N.D.	0.11
Benzo(b)fluoranthene	ug/l	0.1	0.7	0.1	9	1	N.D.	0.1	N.D.	N.D.	N.D.	0.1	N.D.	0.11
Benzo(k)fluoranthene	ug/l	0.1	0.3 J	0.1	4 J	1	N.D.	0.1	N.D.	N.D.	N.D.	0.1	N.D.	0.11
2-Chlorophenol	ug/l	0.5	N.D.	0.5	N.D.	5	N.D.	0.5	N.D.	N.D.	N.D.	0.5	N.D.	0.54
Chrysene	ug/l	0.1	1	0.1	5	1	N.D.	0.1	N.D.	N.D.	N.D.	0.1	N.D.	0.11
Dibenz(a,h)anthracene	ug/l	0.1	N.D.	0.1	N.D.	1	N.D.	0.1	N.D.	N.D.	N.D.	0.1	N.D.	0.11
Dibenzofuran	ug/l	7.9	290	5	24	5	N.D.	0.5	91	57	47	0.5	N.D.	0.54
2,4-Dimethylphenol	ug/l	540	1	0.5	N.D.	5	1	0.5	6	8	6	0.5	N.D.	0.54
2,4-Dinitrophenol	ug/l	70	N.D.	10	N.D.	100	N.D.	10	N.D.	N.D.	N.D.	10	N.D.	11
Fluoranthene	ug/l	300	28	0.1	42	1	0.1 J	0.1	4	3	2	0.1	N.D.	0.11
Fluorene	ug/l	1300	230	1	32	1	0.7	0.1	41	26	22	0.1	N.D.	0.11
Indeno(1,2,3-cd)pyrene	ug/l	0.1	0.1 J	0.1	3 J	1	N.D.	0.1	N.D.	N.D.	N.D.	0.1	N.D.	0.11
2-Methylnaphthalene	ug/l	36	540	1	N.D.	1	1	0.1	330	200	160	1	N.D.	0.11
Naphthalene	ug/l	20	5000	5	N.D.	1	58	0.1	6,400	4,000	3,400	10	N.D.	0.11
Phenanthrene	ug/l	0.1	240	1	32	1	0.6	0.1	54	36	27	0.1	N.D.	0.11
Phenol	ug/l	300	1	0.5	N.D.	5	3	0.5	N.D.	N.D.	N.D.	0.5	N.D.	0.54
2-Picoline	ug/l		N.D.	2	N.D.	20	N.D.	2	5 J	5 J	5 J	2	N.D.	2.2
Pyrene	ug/l	960	14	0.1	26	1	0.1 J	0.1	2	2	1	0.1	N.D.	0.11
Benzene	ug/l	5	0.5 J	0.2	N.D.	0.2	1.9	0.2	180	160	150	2.0	0.2 J	0.2
Ethylbenzene	ug/l	700	20	0.2	N.D.	0.2	1.0	0.2	73	51	42	2.0	N.D.	0.2
Toluene	ug/l	1000	5	0.2	N.D.	0.2	2.9	0.2	190	150	130	2.0	0.4 J	0.2
Total Xylenes	ug/l	10000	82	0.2	N.D.	0.2	3.3	0.2	290	200	170	2.0	N.D.	0.2

Notes: **GWPS** = Groundwater Protection Standarc

Yellow Highlight = GWPS exceedances

MDL = Minimum Detection Limit



LEGEND

- = AREAS OF DNAPL
- = DISSOLVED PHASE PLUME
- = FACILITY PROPERTY BOUNDARY

CHECKED BY:
B. LANNING

E.W.I. # 150683
DRAWN BY: CLM
Aug. 11, 2016

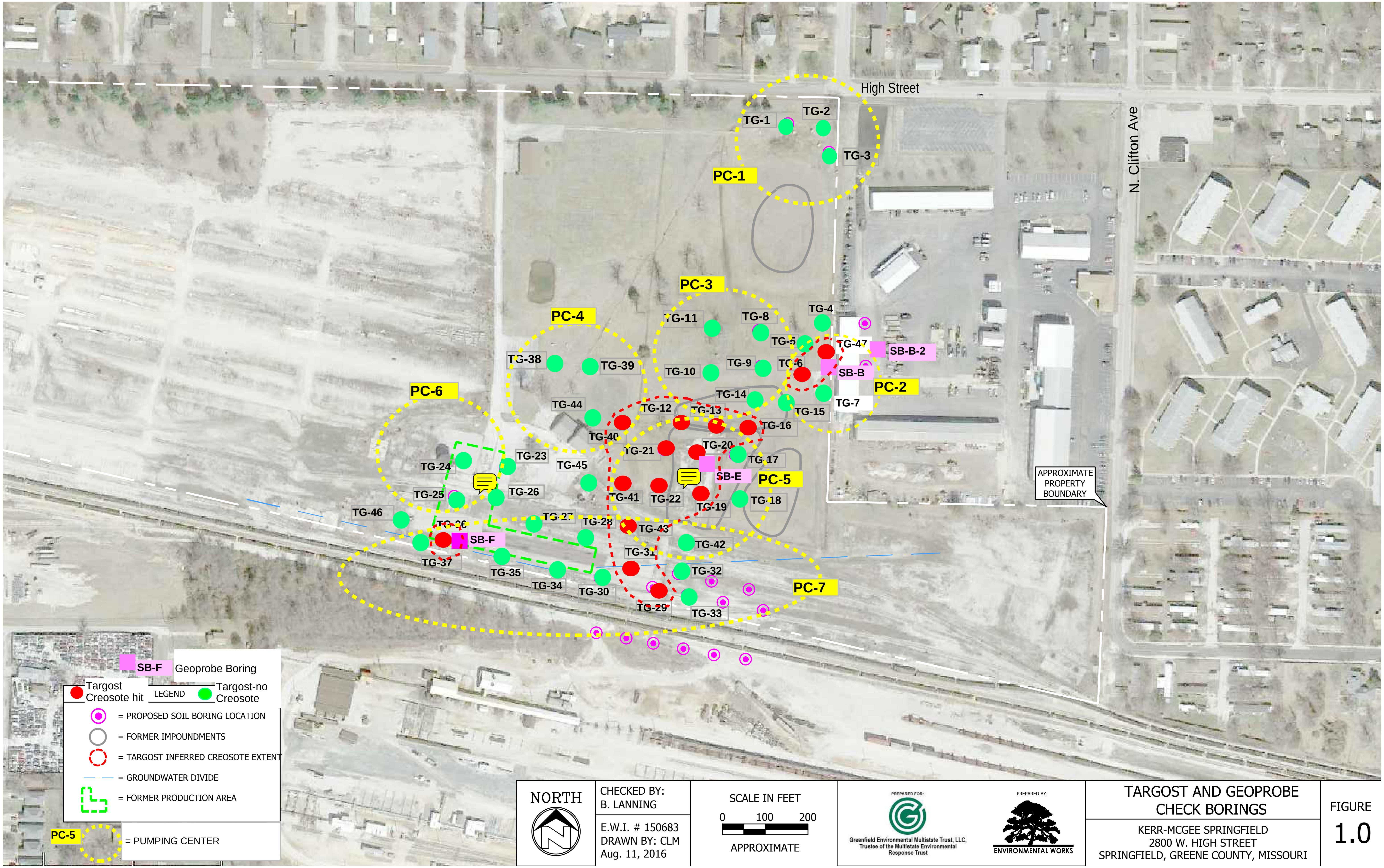
PREPARED FOR:
Greenfield Environmental Multistate Trust, LLC,
Trustee of the Multistate Environmental
Response Trust

PREPARED BY:
ENVIRONMENTAL WORKS

INDEX TO FIGURES - RAO WORK

KERR-MCGEE/TRONOX
2800 W. HIGH STREET
SPRINGFIELD, GREENE COUNTY, MISSOURI

INDEX
TO
FIGURES



NORTH

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B. LANNING

E.W.I. # 150683
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Aug. 11, 2016

SCALE IN FEET
0 100 200
APPROXIMATE

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TARGOST AND GEOPROBE CHECK BORINGS

KERR-MCGEE SPRINGFIELD
2800 W. HIGH STREET
SPRINGFIELD, GREENE COUNTY, MISSOURI

FIGURE
1.0

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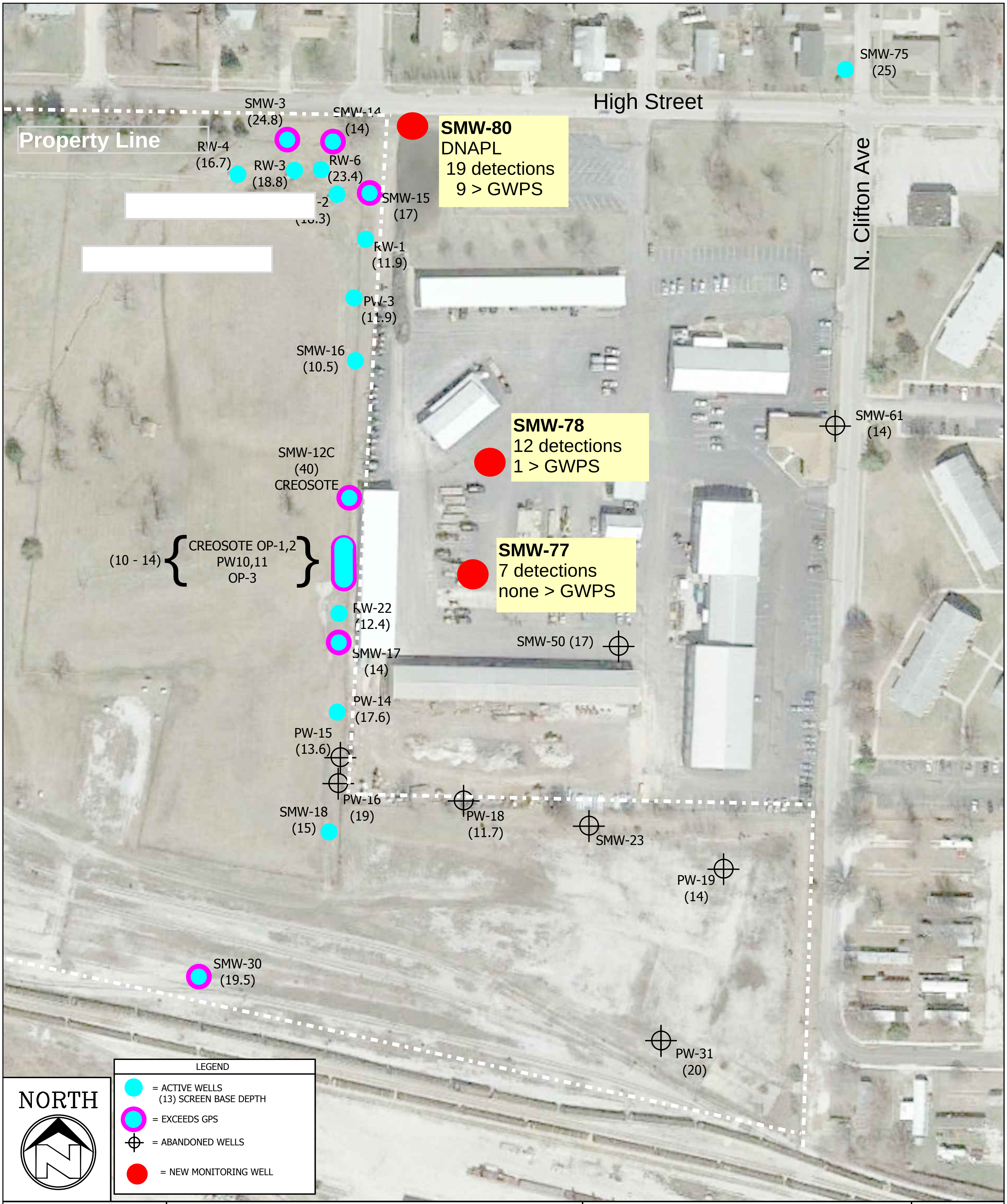
SURFICIAL SOIL BORINGS

FORMER TRONOX FACILITY
2800 WEST HIGH ST.
SPRINGFIELD, GREENE COUNTY, MISSOURI

FIGURE
2.0



SCALE (FEET)
0 1000 2000

EWI# 150683
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Aug. 11, 2016

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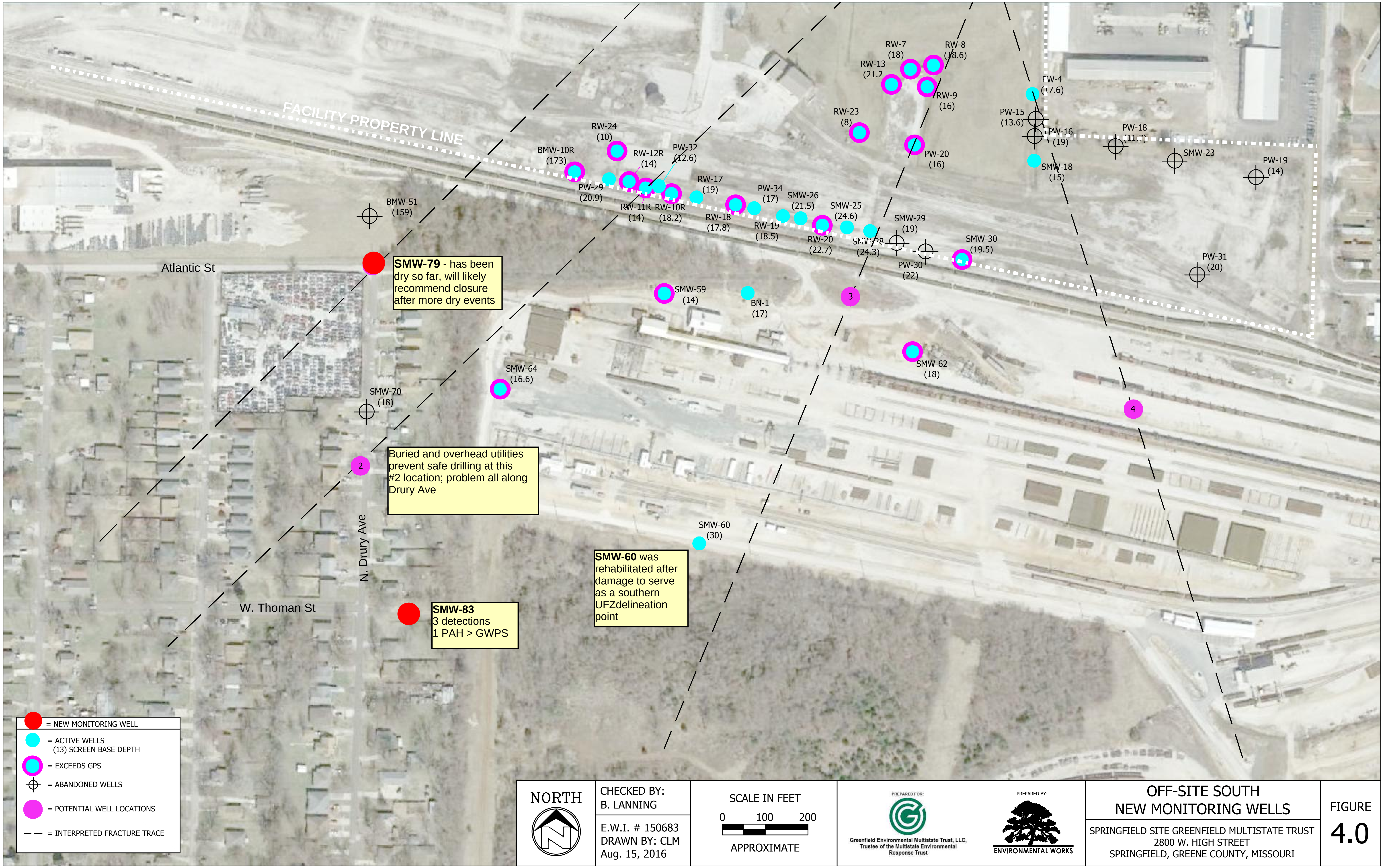
OFF-SITE EAST
NEW MONITORING WELLS

SPRINGFIELD SITE GREENFIELD MULTISTATE TRUST
2800 W. HIGH STREET
SPRINGFIELD, GREENE COUNTY, MISSOURI

FIGURE
3.0

PRELIMINARY - SUBJECT TO REVISION



SMW-79 - has been dry so far, will likely recommend closure after more dry events

Buried and overhead utilities prevent safe drilling at this #2 location; problem all along Drury Ave

SMW-60 was rehabilitated after damage to serve as a southern UFZdelineation point

SMW-83
3 detections
1 PAH > GWPS

NORTH

CHECKED BY:
B. LANNING

E.W.I. # 150683
DRAWN BY: CLM
Aug. 15, 2016

SCALE IN FEET
0 100 200
APPROXIMATE

PREPARED FOR:
Greenfield Environmental Multistate Trust, LLC, Trustee of the Multistate Environmental Response Trust

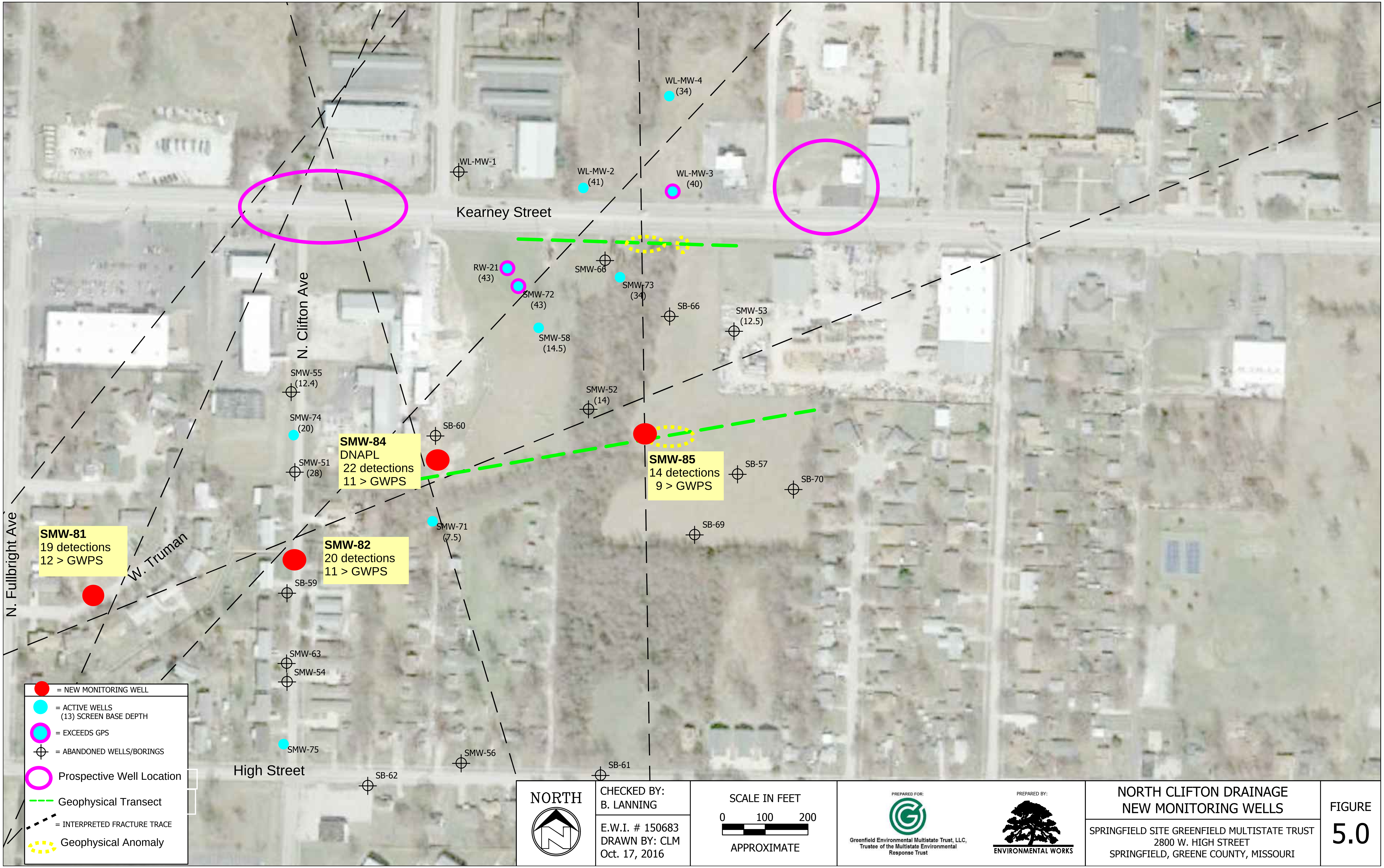
PREPARED BY:
ENVIRONMENTAL WORKS

OFF-SITE SOUTH
NEW MONITORING WELLS

SPRINGFIELD SITE GREENFIELD MULTISTATE TRUST
2800 W. HIGH STREET
SPRINGFIELD, GREENE COUNTY, MISSOURI

FIGURE
4.0

PRELIMINARY - SUBJECT TO REVISION



CHECKED BY:
B. LANNING

E.W.I. # 150683
DRAWN BY: CLM
Oct. 17, 2016

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Greenfield Environmental Multistate Trust, LLC,
Trustee of the Multistate Environmental
Response Trust

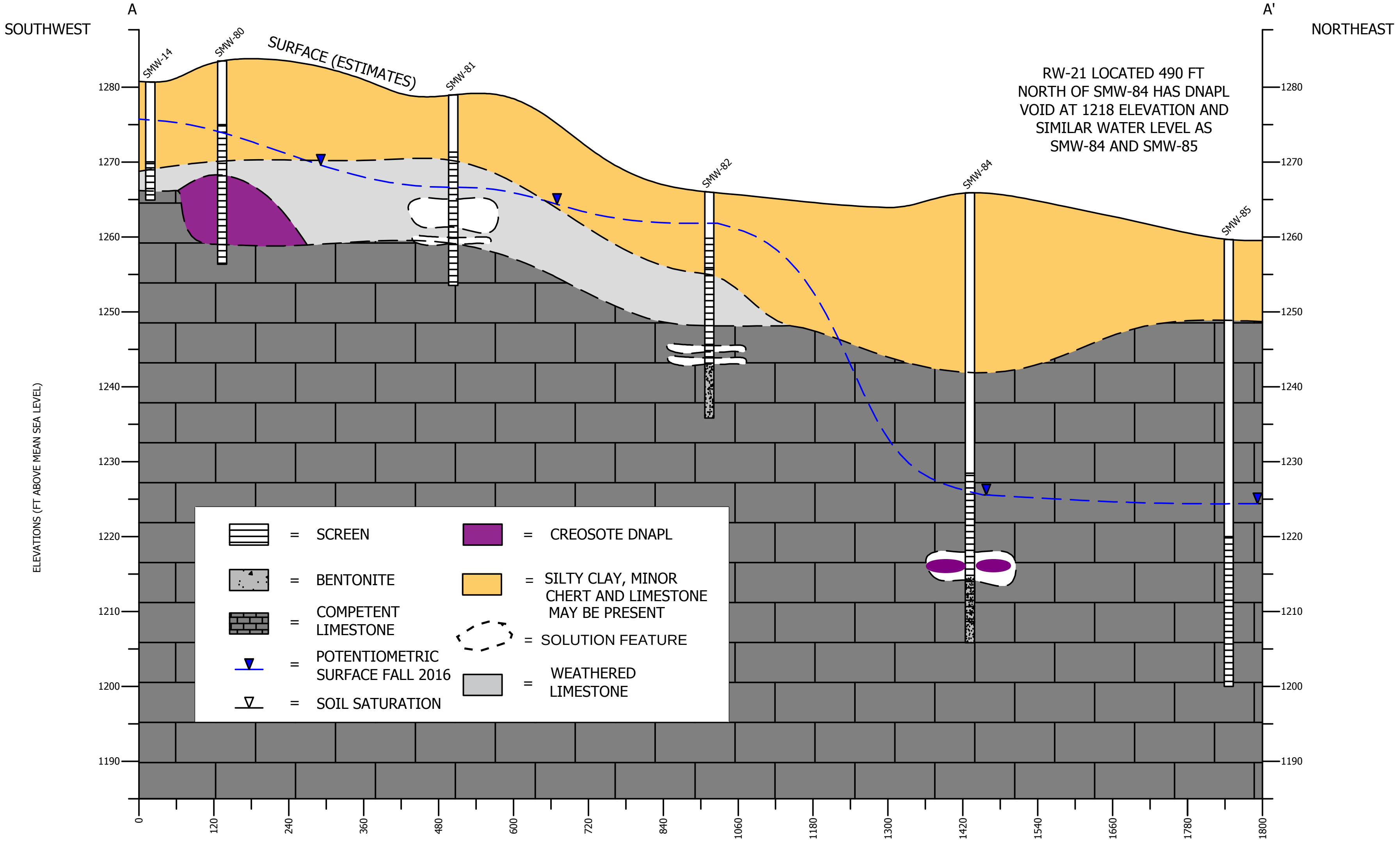
PREPARED BY:
ENVIRONMENTAL WORKS

NORTH CLIFTON DRAINAGE
NEW MONITORING WELLS

SPRINGFIELD SITE GREENFIELD MULTISTATE TRUST
2800 W. HIGH STREET
SPRINGFIELD, GREENE COUNTY, MISSOURI

FIGURE
5.0

PRELIMINARY - SUBJECT TO REVISION



RW-21 LOCATED 490 FT NORTH OF SMW-84 HAS DNAPL VOID AT 1218 ELEVATION AND SIMILAR WATER LEVEL AS SMW-84 AND SMW-85

NORTH

CHECKED BY:
B. LANNING

E.W.I. # 150683
DRAWN BY: JWP
Nov. 21, 2016

HORIZONTAL SCALE IN FEET
0 60 120

APPROXIMATE
VERTICAL SCALE IN FEET
0 5 10

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Trustee of the Multistate Environmental
Response Trust

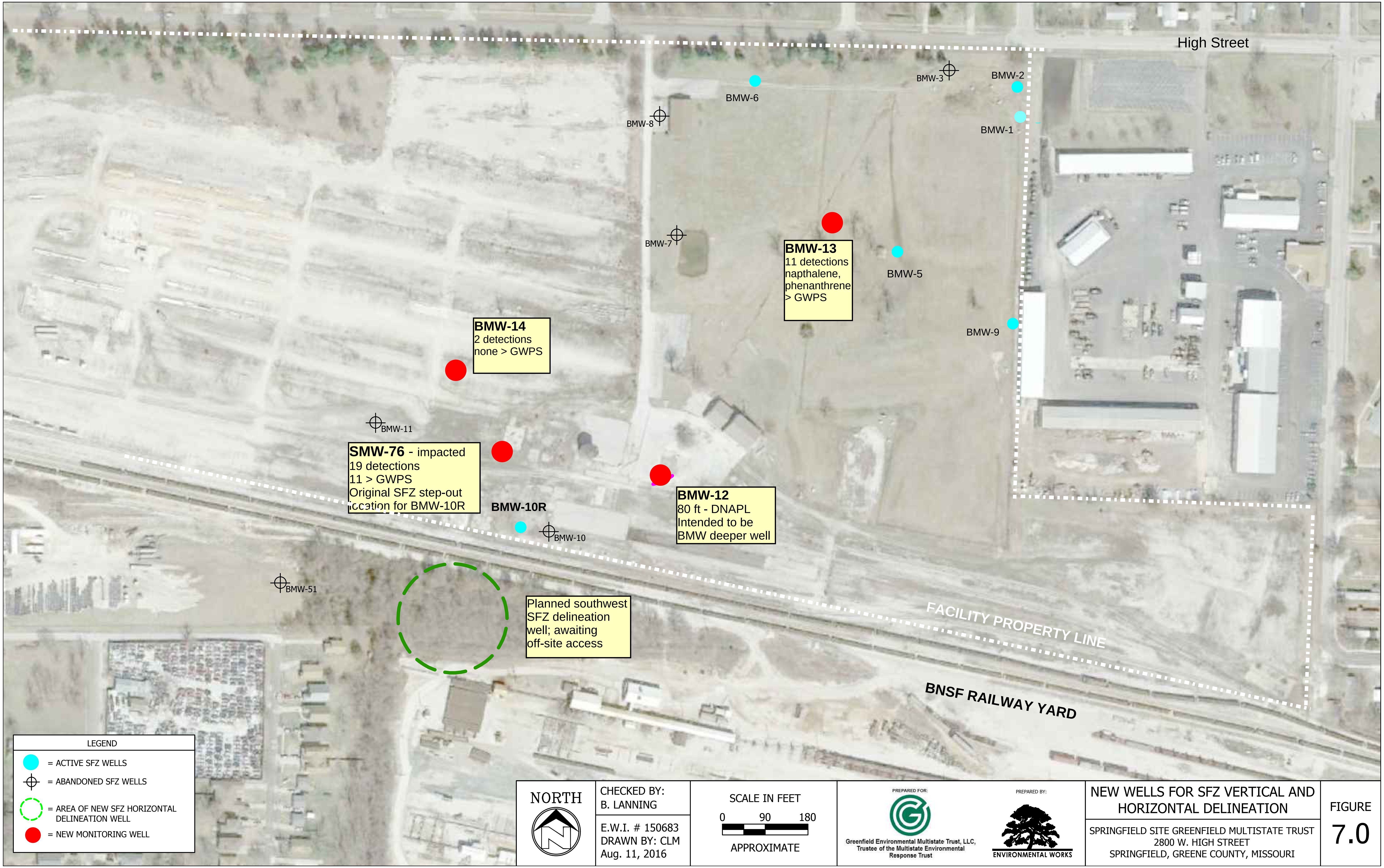
ENVIRONMENTAL WORKS

CROSS SECTION (A-A')

KERR - MCGEE / TRONO X
2800 WEST HIGH ST.
SPRINGFIELD, GREENE COUNTY, MISSOURI

FIGURE
6.0

PRELIMINARY - SUBJECT TO REVISION



BMW-13
11 detections
napthalene,
phenanthrene
> GWPS

BMW-14
2 detections
none > GWPS

SMW-76 - impacted
19 detections
11 > GWPS
Original SFZ step-out
location for BMW-10R

BMW-12
80 ft - DNAPL
Intended to be
BMW deeper well

Planned southwest
SFZ delineation
well; awaiting
off-site access

CHECKED BY:
B. LANNING

E.W.I. # 150683
DRAWN BY: CLM
Aug. 11, 2016

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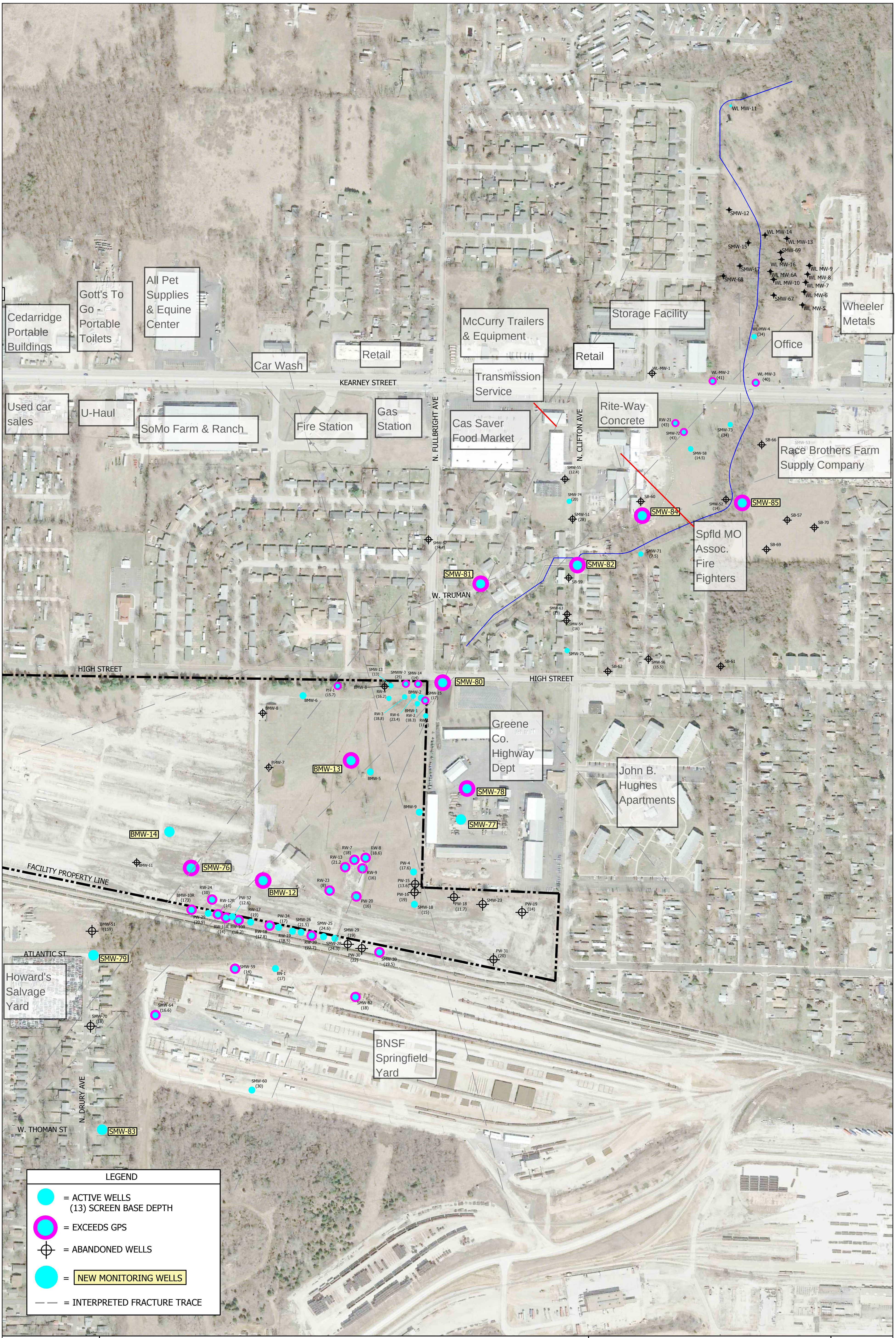
ENVIRONMENTAL WORKS

NEW WELLS FOR SFZ VERTICAL AND HORIZONTAL DELINEATION

SPRINGFIELD SITE GREENFIELD MULTISTATE TRUST
2800 W. HIGH STREET
SPRINGFIELD, GREENE COUNTY, MISSOURI

FIGURE
7.0

PRELIMINARY - SUBJECT TO REVISION



CHECKED BY:
B. LANNING

E.W.I. # 150683
DRAWN BY: JWP
Dec. 9, 2016

NORTH

PREPARED FOR:
Greenfield Environmental Multistate Trust, LLC, Trustee of the Multistate Environmental Response Trust

PREPARED BY:
ENVIRONMENTAL WORKS

0 250 500

AREA AROUND FACILITY

SPRINGFIELD SITE - GREENFIELD MULTISTATE TRUST
2800 W. HIGH STREET
SPRINGFIELD, GREENE COUNTY, MISSOURI

FIGURE
8.0

PRELIMINARY - SUBJECT TO REVISION

VISL Screening for Inhalation Risk from New Monitoring Well Groundwater
Former Tronox Facility, Springfield, Missouri

Groundwater analytical results from the screening samples taken from new off-site wells were input to the U.S. EPA Vapor Intrusion Screening Level (VISL) software as an initial screening of vapor intrusion risk in the residential areas near the Facility. The only data for the new off-site wells thus far are the screening samples that were obtained after the wells were built. Contaminants of concern (COCs) for the facility were selected in VISL, and six of them were chosen for evaluation based on their physical properties. Of the Springfield facility COCs, six (benzo[a]anthracene, benzene, ethylbenzene, naphthalene, toluene, and xylenes) are physically capable of creating vapor intrusion (VI) risks, *and* have toxicity data available to assess health risks. It is important to keep in mind that for some COCs toxicity data for indoor air is not available, even though it is volatile enough to make it to the breathing zone, as is the case with 2-methylnaphthalene. Other standard input parameters the VISL used to forward-calculate VI risk based on analytical groundwater data were:

- Exposure Scenario – Residential
- Target Risk for Carcinogens (TCR) - $1x10^{-6}$
- Target Hazard Quotient for Non-Carcinogens (THQ) – 1
- Average Groundwater Temperature (T_{GW}) – 25^{o} C

Based on data from the 2H16 sampling event, groundwater temperatures range from approximately 20^{o} C to 25^{o}C. Sensitivity analysis reveals that health risk (Cancer Risk [CR] and Hazard Quotient [HQ]) and groundwater temperature are directly related. If T_{GW} increases, so does CR and HQ for each COC. The maximum T_{GW} of 25^{o}C was used in the risk screening to be conservative.

New off-site upper flow zone (UFZ) wells considered for this evaluation are SMW-79, SMW-80, SMW-81, SMW-82, SMW-83, SMW-84, and SMW-85. SMW-84 and SMW-85 are on industrial/commercial properties, but the wells are very close to residential areas so the groundwater data obtained from the wells will be screened using the residential scenario. A summary of VISL evaluation and results is given below. The VISL printouts are included as attachments.

- SMW-79
    - This well has been dry since it was installed, so no analytical data exist.

- SMW-80
    - Visual NAPL (creosote) was observed while drilling this well. After settling, a groundwater sample was carefully collected and analyzed, with data input to the VISL with the following results:
    - Benzene: CR = 6.3E-06 > Target CR 1E-06
    - Ethylbenzene CR = 2.7E-05 > Target CR 1E-06
    - Naphthalene CR = 2.4E-03 > Target CR 1E-06; HQ = 630 > THQ = 1

- SMW-81
    - Benz[a]anthracene: CR = 3.6E-06 > Target CR = 1E-06
    - Acute toxicity data for benzo[a]anthracene is not available, so VISL did not calculate a hazard quotient (HQ) for this COC.
    - All other COCs passed the risk screening (CR<TCR and HQ<THQ)

- SMW-82
    - Naphthalene: CR = 8.5E-04 > TCR = 1E-06; HQ = 2.2E+01 > THQ = 1
        - *Naphthalene exceeded the TCR by 2 orders of magnitude, and the THQ by 1 order of magnitude.*
    - Ethylbenzene: CR = 3.7E-06 > TCR = 1E-06
    - All other COCs passed the risk screening (CR<TCR and HQ<THQ).

- SMW-83
    - Groundwater analytical data from this well have no detections applicable to VISL.

- SMW-84
    - Visual NAPL (creosote) was observed while drilling this well. After settling, a groundwater sample was carefully collected and analyzed, with data input to the VISL with the following results:
    - Ethylbenzene CR = 5.7E-06 > Target CR 1E-06
    - Naphthalene CR = 1.1E-03 > Target CR 1E-06; HQ = 29 > THQ = 1

<u>Recommendation for Groundwater Vapor Intrusion Risk Potential</u>: Estimated indoor air concentrations calculated by VISL screening from input groundwater data exceed residential risk levels at these locations:

- SMW-80 on High Street
- SMW-81 on W. Truman Street
- SMW-82 on N. Clifton Ave
- SMW-84 on Rite-way Concrete commercial property

This indicates that groundwater contamination that extends into the residential areas northeast of the facility has the potential for vapor intrusion exposure to residents. A plan of action to further assess this potential is warranted. Per the RAO Work Plan Addendum, this will involve installation of soil vapor monitoring points near the wells that exceeded the screening levels, and collection of soil vapor data for direct comparison of vapor concentrations to the action levels.

Environmental Works, Inc. will coordinate installing shallow and deep soil vapor monitoring points in the right-of-ways near the subject SMW wells per the RAO Work Plan Addendum. We have contacted Eurofins Laboratory to confirm the appropriate sampling and analytical method(s) for the analytes identified by the VISL evaluation, and are coordinating with the Multistate Trust as to plans and schedule.

Maximum Concentration - Residential Exposure

EPA-OLEM VAPOR INTRUSION ASSESSMENT
Groundwater Concentration to Indoor Air Concentration (GWC-IAC) Calculator Version 3.5.1 (May 2016 RSLs)

Parameter	Symbol	Value	Instructions
Exposure Scenario	Scenario	Residential	Select residential or commercial scenario from pull down list
Target Risk for Carcinogens	TCR	1.00E-06	Enter target risk for carcinogens (for comparison to the calculated VI carcinogenic risk in column F)
Target Hazard Quotient for Non-Carcinogens	THQ	1	Enter target hazard quotient for non-carcinogens (for comparison to the calculated VI hazard in column G)
Average Groundwater Temperature (^{o}C)	Tgw	25	Enter average of the stabilized groundwater temperature to correct Henry's Law Constant for groundwater target concentrations

CAS	Chemical Name	Site Groundwater Concentration Cgw (ug/L)	Calculated Indoor Air Concentration Cia (ug/m^3)	VI Carcinogenic Risk CR	VI Hazard HQ
56-55-3	Benz[a]anthracene	5.0E-01	2.45E-04	2.7E-08	No RfC
71-43-2	Benzene	1.0E+01	2.27E+00	**6.3E-06**	7.3E-02
100-41-4	Ethylbenzene	9.4E+01	3.03E+01	**2.7E-05**	2.9E-02
91-20-3	Naphthalene	1.1E+04	1.98E+02	**2.4E-03**	**6.3E+01**
108-88-3	Toluene	4.7E+01	1.28E+01	No IUR	2.4E-03
1330-20-7	Xylenes	3.1E+02	8.40E+01	No IUR	8.1E-01

Inhalation Unit Risk IUR (ug/m^3)$^{-1}$	IUR Source*	Reference Concentration RfC (mg/m^3)	RFC Source*	Mutagenic Indicator i
1.10E-04	CA			Mut
7.80E-06	I	3.00E-02	I	
2.50E-06	CA	1.00E+00	I	
3.40E-05	CA	3.00E-03	I	
		5.00E+00	I	
		1.00E-01	I	

Notes:

(1) **Inhalation Pathway Exposure Parameters (RME):**

Exposure Scenario	Units	Residential Symbol	Residential Value	Commercial Symbol	Commercial Value	Selected (based on scenario) Symbol	Selected (based on scenario) Value
Averaging time for carcinogens	(yrs)	ATc_R_GW	70	ATc_C_GW	70	ATc_GW	70
Averaging time for non-carcinogens	(yrs)	ATnc_R_GW	26	ATnc_C_GW	25	Atnc_GW	26
Exposure duration	(yrs)	ED_R_GW	26	ED_C_GW	25	ED_GW	26
Exposure frequency	(days/yr)	EF_R_GW	350	EF_C_GW	250	EF_GW	350
Exposure time	(hr/day)	ET_R_GW	24	ET_C_GW	8	ET_GW	24

(2) **Generic Attenuation Factors:**

Source Medium of Vapors	Units	Residential Symbol	Residential Value	Commercial Symbol	Commercial Value	Selected (based on scenario) Symbol	Selected (based on scenario) Value
Groundwater	(-)	AFgw_R_GW	0.001	AFgw_C_GW	0.001	AFgw_GW	0.001
Sub-Slab and Exterior Soil Gas	(-)	AFss_R_GW	0.03	AFss_C_GW	0.03	AFss_GW	0.03

(3) **Formulas**

Cia, target = MIN(Cia,c; Cia,nc)
Cia,c (ug/m3) = TCR x ATc x (365 days/yr) x (24 hrs/day) / (ED x EF x ET x IUR)
Cia,nc (ug/m3) = THQ x ATnc x (365 days/yr) x (24 hrs/day) x RfC x (1000 ug/mg) / (ED x EF x ET)

(4) **Special Case Chemicals**

	Residential Symbol	Residential Value	Commercial Symbol	Commercial Value	Selected (based on scenario) Symbol	Selected (based on scenario) Value
Trichloroethylene	mIURTCE_R_GW	1.00E-06	IURTCE_C_GW	0.00E+00	mIURTCE_GW	1.00E-06
	IURTCE_R_GW	3.10E-06	IURTCE_C_GW	4.10E-06	IURTCE_GW	3.10E-06

Mutagenic Chemicals

The exposure durations and age-dependent adjustment factors for mutagenic-mode-of-action are listed in the table below:

Note: This section applies to trichloroethylene and other mutagenic chemicals, but not to vinyl chloride.

Age Cohort	Exposure Duration	Age-dependent adjustment factor
0 - 2 years	2	10
2 - 6 years	4	3
6 - 16 years	10	3
16 - 26 years	10	1

Mutagenic-mode-of-action (MMOA) adjustment factor 72 This factor is used in the equations for mutagenic chemicals.

Vinyl Chloride

See the Navigation Guide equation for Cia,c for vinyl chloride.

Notation:

I = IRIS: EPA Integrated Risk Information System (IRIS). Available online at: http://www.epa.gov/iris/subst/index.html
P = PPRTV. EPA Provisional Peer Reviewed Toxicity Values (PPRTVs). Available online at: http://hhpprtv.ornl.gov/pprtv.shtml
A = Agency for Toxic Substances and Disease Registry (ATSDR) Minimum Risk Levels (MRLs). Available online at: http://www.atsdr.cdc.gov/mrls/index.html
CA = California Environmental Protection Agency/Office of Environmental Health Hazard Assessment assessments. Available online at: http://www.oehha.ca.gov/risk/ChemicalDB/index.asp
H = HEAST. EPA Superfund Health Effects Assessment Summary Tables (HEAST) database. Available online at: http://epa-heast.ornl.gov/heast.shtml
S = See RSL User Guide, Section 5
X = PPRTV Appendix

EPA-OLEM VAPOR INTRUSION ASSESSMENT
Groundwater Concentration to Indoor Air Concentration (GWC-IAC) Calculator Version 3.5.1 (May 2016 RSLs)

Parameter	Symbol	Value	Instructions
Exposure Scenario	Scenario	Residential	Select residential or commercial scenario from pull down list
Target Risk for Carcinogens	TCR	1.00E-06	Enter target risk for carcinogens (for comparison to the calculated VI carcinogenic risk in column F)
Target Hazard Quotient for Non-Carcinogens	THQ	1	Enter target hazard quotient for non-carcinogens (for comparison to the calculated VI hazard in column G)
Average Groundwater Temperature (^oC)	Tgw	25	Enter average of the stabilized groundwater temperature to correct Henry's Law Constant for groundwater target concentrations

CAS	Chemical Name	Site Groundwater Concentration Cgw (ug/L)	Calculated Indoor Air Concentration Cia (ug/m^3)	VI Carcinogenic Risk CR	VI Hazard HQ

Inhalation Unit Risk IUR (ug/m^3)$^{-1}$	IUR Source*	Reference Concentration RfC (mg/m^3)	RFC Source*	Mutagenic Indicator i

Mut = Chemical acts according to the mutagenic-mode-of-action, special exposure parameters apply (see footnote (4) above).
VC = Special exposure equation for vinyl chloride applies (see Navigation Guide for equation).
TCE = Special mutagenic and non-mutagenic IURs for trichloroethylene apply (see footnote (4) above).
Yellow highlighting indicates site-specific parameters that may be edited by the user.
Blue highlighting indicates exposure factors that are based on Risk Assessment Guidance for Superfund (RAGS) or EPA vapor intrusion guidance, which generally should not be changed.
Pink highlighting indicates VI carcinogenic risk greater than the target risk for carcinogens (TCR) or VI Hazard greater than or equal to the target hazard quotient for non-carcinogens (THQ).

EPA-OLEM VAPOR INTRUSION ASSESSMENT

Groundwater Concentration to Indoor Air Concentration (GWC-IAC) Calculator Version 3.5.1 (May 2016 RSLs)

Parameter	Symbol	Value	Instructions
Exposure Scenario	Scenario	Residential	Select residential or commercial scenario from pull down list
Target Risk for Carcinogens	TCR	1.00E-06	Enter target risk for carcinogens (for comparison to the calculated VI carcinogenic risk in column F)
Target Hazard Quotient for Non-Carcinogens	THQ	1	Enter target hazard quotient for non-carcinogens (for comparison to the calculated VI hazard in column G)
Average Groundwater Temperature (^oC)	Tgw	25	Enter average of the stabilized groundwater temperature to correct Henry's Law Constant for groundwater target concentrations

CAS	Chemical Name	Site Groundwater Concentration Cgw (ug/L)	Calculated Indoor Air Concentration Cia (ug/m^3)	VI Carcinogenic Risk CR	VI Hazard HQ
56-55-3	Benz[a]anthracene	6.8E+01	3.34E-02	**3.6E-06**	No RfC
71-43-2	Benzene	1.0E-01	2.27E-02	6.3E-08	7.3E-04
100-41-4	Ethylbenzene	7.0E-01	2.26E-01	2.0E-07	2.2E-04
91-20-3	Naphthalene	4.0E+00	7.20E-02	8.7E-07	2.3E-02
108-88-3	Toluene	1.0E-01	2.71E-02	No IUR	5.2E-06
1330-20-7	Xylenes	2.7E+00	7.32E-01	No IUR	7.0E-03

Inhalation Unit Risk IUR (ug/m^3)$^{-1}$	IUR Source*	Reference Concentration RfC (mg/m^3)	RFC Source*	Mutagenic Indicator i
1.10E-04	CA			Mut
7.80E-06	I	3.00E-02	I	
2.50E-06	CA	1.00E+00	I	
3.40E-05	CA	3.00E-03	I	
		5.00E+00	I	
		1.00E-01	I	

Notes:

(1) **Inhalation Pathway Exposure Parameters (RME):**

Exposure Scenario	Units	Residential Symbol	Residential Value	Commercial Symbol	Commercial Value	Selected (based on scenario) Symbol	Selected (based on scenario) Value
Averaging time for carcinogens	(yrs)	ATc_R_GW	70	ATc_C_GW	70	ATc_GW	70
Averaging time for non-carcinogens	(yrs)	ATnc_R_GW	26	ATnc_C_GW	25	Atnc_GW	26
Exposure duration	(yrs)	ED_R_GW	26	ED_C_GW	25	ED_GW	26
Exposure frequency	(days/yr)	EF_R_GW	350	EF_C_GW	250	EF_GW	350
Exposure time	(hr/day)	ET_R_GW	24	ET_C_GW	8	ET_GW	24

(2) **Generic Attenuation Factors:**

Source Medium of Vapors		Residential Symbol	Residential Value	Commercial Symbol	Commercial Value	Selected (based on scenario) Symbol	Selected (based on scenario) Value
Groundwater	(-)	AFgw_R_GW	0.001	AFgw_C_GW	0.001	AFgw_GW	0.001
Sub-Slab and Exterior Soil Gas	(-)	AFss_R_GW	0.03	AFss_C_GW	0.03	AFss_GW	0.03

(3) **Formulas**

Cia, target = MIN(Cia,c; Cia,nc)

Cia,c (ug/m3) = TCR x ATc x (365 days/yr) x (24 hrs/day) / (ED x EF x ET x IUR)

Cia,nc (ug/m3) = THQ x ATnc x (365 days/yr) x (24 hrs/day) x RfC x (1000 ug/mg) / (ED x EF x ET)

(4) **Special Case Chemicals**

Trichloroethylene	Residential Symbol	Residential Value	Commercial Symbol	Commercial Value	Selected (based on scenario) Symbol	Selected (based on scenario) Value
	mIURTCE_R_GW	1.00E-06	IURTCE_C_GW	0.00E+00	mIURTCE_GW	1.00E-06
	IURTCE_R_GW	3.10E-06	IURTCE_C_GW	4.10E-06	IURTCE_GW	3.10E-06

Mutagenic Chemicals — The exposure durations and age-dependent adjustment factors for mutagenic-mode-of-action are listed in the table below:

Note: This section applies to trichloroethylene and other mutagenic chemicals, but not to vinyl chloride.

Age Cohort	Exposure Duration	Age-dependent adjustment factor
0 - 2 years	2	10
2 - 6 years	4	3
6 - 16 years	10	3
16 - 26 years	10	1

Mutagenic-mode-of-action (MMOA) adjustment factor 72 This factor is used in the equations for mutagenic chemicals.

Vinyl Chloride — See the Navigation Guide equation for Cia,c for vinyl chloride.

Notation:

I = IRIS: EPA Integrated Risk Information System (IRIS). Available online at: http://www.epa.gov/iris/subst/index.html
P = PPRTV. EPA Provisional Peer Reviewed Toxicity Values (PPRTVs). Available online at: http://hhpprtv.ornl.gov/pprtv.shtml
A = Agency for Toxic Substances and Disease Registry (ATSDR) Minimum Risk Levels (MRLs). Available online at: http://www.atsdr.cdc.gov/mrls/index.html
CA = California Environmental Protection Agency/Office of Environmental Health Hazard Assessment assessments. Available online at: http://www.oehha.ca.gov/risk/ChemicalDB/index.asp
H = HEAST. EPA Superfund Health Effects Assessment Summary Tables (HEAST) database. Available online at: http://epa-heast.ornl.gov/heast.shtml
S = See RSL User Guide, Section 5
X = PPRTV Appendix
Mut = Chemical acts according to the mutagenic-mode-of-action, special exposure parameters apply (see footnote (4) above).
VC = Special exposure equation for vinyl chloride applies (see Navigation Guide for equation).
TCE = Special mutagenic and non-mutagenic IURs for trichloroethylene apply (see footnote (4) above).
Yellow highlighting indicates site-specific parameters that may be edited by the user.
Blue highlighting indicates exposure factors that are based on Risk Assessment Guidance for Superfund (RAGS) or EPA vapor intrusion guidance, which generally should not be changed.
Pink highlighting indicates VI carcinogenic risk greater than the target risk for carcinogens (TCR) or VI Hazard greater than or equal to the target hazard quotient for non-carcinogens (THQ).

Maximum Concentration - Residential Exposure

EPA-OLEM VAPOR INTRUSION ASSESSMENT
Groundwater Concentration to Indoor Air Concentration (GWC-IAC) Calculator Version 3.5.1 (May 2016 RSLs)

Parameter	Symbol	Value	Instructions
Exposure Scenario	Scenario	Residential	Select residential or commercial scenario from pull down list
Target Risk for Carcinogens	TCR	1.00E-06	Enter target risk for carcinogens (for comparison to the calculated VI carcinogenic risk in column F)
Target Hazard Quotient for Non-Carcinogens	THQ	1	Enter target hazard quotient for non-carcinogens (for comparison to the calculated VI hazard in column G)
Average Groundwater Temperature (^{o}C)	Tgw	25	Enter average of the stabilized groundwater temperature to correct Henry's Law Constant for groundwater target concentrations

CAS	Chemical Name	Site Groundwater Concentration Cgw (ug/L)	Calculated Indoor Air Concentration Cia (ug/m^3)	VI Carcinogenic Risk CR	VI Hazard HQ	Inhalation Unit Risk IUR $(ug/m^3)^{-1}$	IUR Source*	Reference Concentration RfC (mg/m^3)	RFC Source*	Mutagenic Indicator i
56-55-3	Benz[a]anthracene	9.8E+00	4.81E-03	5.2E-07	No RfC	1.10E-04	CA			Mut
71-43-2	Benzene	5.0E-01	1.13E-01	3.2E-07	3.6E-03	7.80E-06	I	3.00E-02	I	
100-41-4	Ethylbenzene	1.3E+01	4.19E+00	**3.7E-06**	4.0E-03	2.50E-06	CA	1.00E+00	I	
91-20-3	Naphthalene	3.9E+03	7.02E+01	**8.5E-04**	**2.2E+01**	3.40E-05	CA	3.00E-03	I	
108-88-3	Toluene	2.6E+00	7.06E-01	No IUR	1.4E-04			5.00E+00	I	
1330-20-7	Xylenes	3.8E+01	1.03E+01	No IUR	9.9E-02			1.00E-01	I	

Notes:

(1) **Inhalation Pathway Exposure Parameters (RME):**

Exposure Scenario	Units	Residential Symbol	Residential Value	Commercial Symbol	Commercial Value	Selected (based on scenario) Symbol	Selected (based on scenario) Value
Averaging time for carcinogens	(yrs)	ATc_R_GW	70	ATc_C_GW	70	ATc_GW	70
Averaging time for non-carcinogens	(yrs)	ATnc_R_GW	26	ATnc_C_GW	25	Atnc_GW	26
Exposure duration	(yrs)	ED_R_GW	26	ED_C_GW	25	ED_GW	26
Exposure frequency	(days/yr)	EF_R_GW	350	EF_C_GW	250	EF_GW	350
Exposure time	(hr/day)	ET_R_GW	24	ET_C_GW	8	ET_GW	24

(2) **Generic Attenuation Factors:**

Source Medium of Vapors	Units	Residential Symbol	Residential Value	Commercial Symbol	Commercial Value	Selected (based on scenario) Symbol	Selected (based on scenario) Value
Groundwater	(-)	AFgw_R_GW	0.001	AFgw_C_GW	0.001	AFgw_GW	0.001
Sub-Slab and Exterior Soil Gas	(-)	AFss_R_GW	0.03	AFss_C_GW	0.03	AFss_GW	0.03

(3) **Formulas**

Cia, target = MIN(Cia,c; Cia,nc)

Cia,c (ug/m3) = TCR x ATc x (365 days/yr) x (24 hrs/day) / (ED x EF x ET x IUR)

Cia,nc (ug/m3) = THQ x ATnc x (365 days/yr) x (24 hrs/day) x RfC x (1000 ug/mg) / (ED x EF x ET)

(4) **Special Case Chemicals**

Trichloroethylene	Residential Symbol	Residential Value	Commercial Symbol	Commercial Value	Selected (based on scenario) Symbol	Selected (based on scenario) Value
	mIURTCE_R_GW	1.00E-06	IURTCE_C_GW	0.00E+00	mIURTCE_GW	1.00E-06
	IURTCE_R_GW	3.10E-06	IURTCE_C_GW	4.10E-06	IURTCE_GW	3.10E-06

Mutagenic Chemicals

The exposure durations and age-dependent adjustment factors for mutagenic-mode-of-action are listed in the table below:

Note: This section applies to trichloroethylene and other mutagenic chemicals, but not to vinyl chloride.

Age Cohort	Exposure Duration	Age-dependent adjustment factor
0 - 2 years	2	10
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16 - 26 years	10	1

Mutagenic-mode-of-action (MMOA) adjustment factor 72 This factor is used in the equations for mutagenic chemicals.

Vinyl Chloride

See the Navigation Guide equation for Cia,c for vinyl chloride.

Notation:

I = IRIS: EPA Integrated Risk Information System (IRIS). Available online at: http://www.epa.gov/iris/subst/index.html
P = PPRTV. EPA Provisional Peer Reviewed Toxicity Values (PPRTVs). Available online at: http://hhpprtv.ornl.gov/pprtv.shtml
A = Agency for Toxic Substances and Disease Registry (ATSDR) Minimum Risk Levels (MRLs). Available online at: http://www.atsdr.cdc.gov/mrls/index.html
CA = California Environmental Protection Agency/Office of Environmental Health Hazard Assessment assessments. Available online at: http://www.oehha.ca.gov/risk/ChemicalDB/index.asp
H = HEAST. EPA Superfund Health Effects Assessment Summary Tables (HEAST) database. Available online at: http://epa-heast.ornl.gov/heast.shtml
S = See RSL User Guide, Section 5
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EPA-OLEM VAPOR INTRUSION ASSESSMENT
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CAS	Chemical Name	Site Groundwater Concentration Cgw (ug/L)	Calculated Indoor Air Concentration Cia (ug/m^3)	VI Carcinogenic Risk CR	VI Hazard HQ	Inhalation Unit Risk IUR (ug/m^3)$^{-1}$	IUR Source*	Reference Concentration RfC (mg/m^3)	RFC Source*	Mutagenic Indicator i
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71-43-2	Benzene	5.0E-01	1.13E-01	3.2E-07	3.6E-03	7.80E-06	I	3.00E-02	I	
100-41-4	Ethylbenzene	2.0E+01	6.44E+00	**5.7E-06**	6.2E-03	2.50E-06	CA	1.00E+00	I	
91-20-3	Naphthalene	5.0E+03	8.99E+01	**1.1E-03**	**2.9E+01**	3.40E-05	CA	3.00E-03	I	
108-88-3	Toluene	5.0E+00	1.36E+00	No IUR	2.6E-04			5.00E+00	I	
1330-20-7	Xylenes	8.2E+01	2.22E+01	No IUR	2.1E-01			1.00E-01	I	

Notes:

(1) **Inhalation Pathway Exposure Parameters (RME):**

Exposure Scenario	Units	Residential Symbol	Residential Value	Commercial Symbol	Commercial Value	Selected (based on scenario) Symbol	Selected (based on scenario) Value
Averaging time for carcinogens	(yrs)	ATc_R_GW	70	ATc_C_GW	70	ATc_GW	70
Averaging time for non-carcinogens	(yrs)	ATnc_R_GW	26	ATnc_C_GW	25	Atnc_GW	26
Exposure duration	(yrs)	ED_R_GW	26	ED_C_GW	25	ED_GW	26
Exposure frequency	(days/yr)	EF_R_GW	350	EF_C_GW	250	EF_GW	350
Exposure time	(hr/day)	ET_R_GW	24	ET_C_GW	8	ET_GW	24

(2) **Generic Attenuation Factors:**

Source Medium of Vapors	Units	Residential Symbol	Residential Value	Commercial Symbol	Commercial Value	Selected (based on scenario) Symbol	Selected (based on scenario) Value
Groundwater	(-)	AFgw_R_GW	0.001	AFgw_C_GW	0.001	AFgw_GW	0.001
Sub-Slab and Exterior Soil Gas	(-)	AFss_R_GW	0.03	AFss_C_GW	0.03	AFss_GW	0.03

(3) **Formulas**

Cia, target = MIN(Cia,c; Cia,nc)
Cia,c (ug/m3) = TCR x ATc x (365 days/yr) x (24 hrs/day) / (ED x EF x ET x IUR)
Cia,nc (ug/m3) = THQ x ATnc x (365 days/yr) x (24 hrs/day) x RfC x (1000 ug/mg) / (ED x EF x ET)

(4) **Special Case Chemicals**

Trichloroethylene	Residential Symbol	Residential Value	Commercial Symbol	Commercial Value	Selected (based on scenario) Symbol	Selected (based on scenario) Value
	mIURTCE_R_GW	1.00E-06	IURTCE_C_GW	0.00E+00	mIURTCE_GW	1.00E-06
	IURTCE_R_GW	3.10E-06	IURTCE_C_GW	4.10E-06	IURTCE_GW	3.10E-06

Mutagenic Chemicals

The exposure durations and age-dependent adjustment factors for mutagenic-mode-of-action are listed in the table below:

Note: This section applies to trichloroethylene and other mutagenic chemicals, but not to vinyl chloride.

Age Cohort	Exposure Duration	Age-dependent adjustment factor
0 - 2 years	2	10
2 - 6 years	4	3
6 - 16 years	10	3
16 - 26 years	10	1

Mutagenic-mode-of-action (MMOA) adjustment factor 72 This factor is used in the equations for mutagenic chemicals.

Vinyl Chloride

See the Navigation Guide equation for Cia,c for vinyl chloride.

Notation:

I = IRIS: EPA Integrated Risk Information System (IRIS). Available online at: http://www.epa.gov/iris/subst/index.html
P = PPRTV. EPA Provisional Peer Reviewed Toxicity Values (PPRTVs). Available online at: http://hhpprtv.ornl.gov/pprtv.shtml
A = Agency for Toxic Substances and Disease Registry (ATSDR) Minimum Risk Levels (MRLs). Available online at: http://www.atsdr.cdc.gov/mrls/index.html
CA = California Environmental Protection Agency/Office of Environmental Health Hazard Assessment assessments. Available online at: http://www.oehha.ca.gov/risk/ChemicalDB/index.asp
H = HEAST. EPA Superfund Health Effects Assessment Summary Tables (HEAST) database. Available online at: http://epa-heast.ornl.gov/heast.shtml
S = See RSL User Guide, Section 5
X = PPRTV Appendix

EPA-OLEM VAPOR INTRUSION ASSESSMENT
Groundwater Concentration to Indoor Air Concentration (GWC-IAC) Calculator Version 3.5.1 (May 2016 RSLs)

Parameter	Symbol	Value	Instructions
Exposure Scenario	Scenario	Residential	Select residential or commercial scenario from pull down list
Target Risk for Carcinogens	TCR	1.00E-06	Enter target risk for carcinogens (for comparison to the calculated VI carcinogenic risk in column F)
Target Hazard Quotient for Non-Carcinogens	THQ	1	Enter target hazard quotient for non-carcinogens (for comparison to the calculated VI hazard in column G)
Average Groundwater Temperature (^{o}C)	Tgw	25	Enter average of the stabilized groundwater temperature to correct Henry's Law Constant for groundwater target concentrations

CAS	Chemical Name	Site Groundwater Concentration	Calculated Indoor Air Concentration	VI Carcinogenic Risk	VI Hazard
		Cgw	Cia	CR	HQ
		(ug/L)	(ug/m^3)		

Inhalation Unit Risk	IUR Source*	Reference Concentration	RFC Source*	Mutagenic Indicator
IUR		RfC		
(ug/m^3)$^{-1}$		(mg/m^3)		i

Mut = Chemical acts according to the mutagenic-mode-of-action, special exposure parameters apply (see footnote (4) above).
VC = Special exposure equation for vinyl chloride applies (see Navigation Guide for equation).
TCE = Special mutagenic and non-mutagenic IURs for trichloroethylene apply (see footnote (4) above).
Yellow highlighting indicates site-specific parameters that may be edited by the user.
Blue highlighting indicates exposure factors that are based on Risk Assessment Guidance for Superfund (RAGS) or EPA vapor intrusion guidance, which generally should not be changed.
Pink highlighting indicates VI carcinogenic risk greater than the target risk for carcinogens (TCR) or VI Hazard greater than or equal to the target hazard quotient for non-carcinogens (THQ).

EPA-OLEM VAPOR INTRUSION ASSESSMENT
Groundwater Concentration to Indoor Air Concentration (GWC-IAC) Calculator Version 3.5.1 (May 2016 RSLs)

Parameter	**Symbol**	**Value**	**Instructions**
Exposure Scenario	Scenario	Residential	Select residential or commercial scenario from pull down list
Target Risk for Carcinogens	TCR	1.00E-06	Enter target risk for carcinogens (for comparison to the calculated VI carcinogenic risk in column F)
Target Hazard Quotient for Non-Carcinogens	THQ	1	Enter target hazard quotient for non-carcinogens (for comparison to the calculated VI hazard in column G)
Average Groundwater Temperature (^{o}C)	Tgw	25	Enter average of the stabilized groundwater temperature to correct Henry's Law Constant for groundwater target concentrations

CAS	**Chemical Name**	**Site Groundwater Concentration** Cgw (ug/L)	**Calculated Indoor Air Concentration** Cia (ug/m^3)	**VI Carcinogenic Risk** **CR**	**VI Hazard** **HQ**

Inhalation Unit Risk IUR (ug/m^3)$^{-1}$	**IUR Source***	**Reference Concentration** RfC (mg/m^3)	**RFC Source***	**Mutagenic Indicator** i

Mut = Chemical acts according to the mutagenic-mode-of-action, special exposure parameters apply (see footnote (4) above).
VC = Special exposure equation for vinyl chloride applies (see Navigation Guide for equation).
TCE = Special mutagenic and non-mutagenic IURs for trichloroethylene apply (see footnote (4) above).
Yellow highlighting indicates site-specific parameters that may be edited by the user.
Blue highlighting indicates exposure factors that are based on Risk Assessment Guidance for Superfund (RAGS) or EPA vapor intrusion guidance, which generally should not be changed.
Pink highlighting indicates VI carcinogenic risk greater than the target risk for carcinogens (TCR) or VI Hazard greater than or equal to the target hazard quotient for non-carcinogens (THQ).

Attachment 2
ITRC PVI Pathway Evaluation Checklist

ITRC PVI Pathway Evaluation Checklist

Project Number:	150683	***Contact Name:***	Robert Lanning
Site Name:	Former Tronox Facility	***Contact Phone:***	417-890-9500
Street Address:	2800 W High St		
City, State:	Springfield, MO		

PRELIMINARY INFORMATION

Establishing Site Requirements

Occurrence: Has an unauthorized release of petroleum occurred?	Yes, the release of creosote occurred during historical operations by Kerr-McGee and Tronox.
Emergency response Actions: Was an emergency response required?	No. The site has been in RCRA Corrective Action for over 20 years.
Location of Site: What state is the site located?	Missouri
Regulatory Jurisdiction: What agency(ies) have regulatory jurisdiction for the site?	• Missouri Department of Natual Resources/Hazardous Waste Progam • Missouri Division of Health and Senior Services
PVI Regulatory Requirements: Does the site require evaluation for the PVI pathway?	Yes, through RCRA corrective action. The need for VI pathway evaluation is based on groundwater data screened with the EPA VISL calculator.
Regulatory Guidance: What regulation(s) or guidance(s) are to be followed to address the PVI pathway?	• U.S. EPA RCRA Corrective Action guidance • OSWER Technical Guide for Assessing and Mitigating the Vapor Intrusion Pathway from Subsurface Vapor Sources to Indoor Air (Publication 9200.2-154, June 2015) • ITRC Petroleum Vapor Intrusion Fundamentals of screening, Investigation, and Management (October 2014)
Petroleum Release - What is the predominant type of petroleum released, if known?	Creosote
Other Chemicals: Are non-petroleum volatile chemicals also present?	No
PVI Risk Drivers - What chemical(s) are likely to drive VI regulatory decision(s)?	Benzene, ethylbenzene Naphthalene Benzo(a)anthracene
Media-Specific Screening Criteria: Are there applicable regulatory screening criteria for soil and groundwater for the chemicals of potential VI concern?	Yes

STEP 1

Develop Conceptual Site Model (CSM) for Site Screening

Site Type - For General Site Category: Classify site as either: • **Petroleum UST/AST Sites:** Petroleum UST/AST sites generally include facilities used for vehicle fueling (e.g., gas stations, municipal fleet yards, bus terminals, fire stations, etc.) and commercial/home heating oil tanks. Fuel at these sites are typically stored in USTs, but could be stored in similarly sized ASTs. • **Petroleum Industrial Sites:** Includes: a) bulk fuel terminals, b) refineries, c) exploration and production sites, d) crude oil and product pipelines, and e) former manufactured gas plants.	Industrial Site - former wood treating operations
Petroleum Vapor Source: Determine the type of petroleum vapor source (dissolved-phase or LNAPL) is underlying each building of interest. List buildings and vapor source as appropriate.	Both creosote NAPL and dissolved phase contamination exist in the subsurface below residential and commercial areas, with NAPL likely occuring in residual pockets. Fractures and karst are key migration pathway concerns.
Extent of Source: Can the lateral and vertical extent of the petroleum vapor source in soil and groundwater be determined?	Lateral and vertical limits of impact on-site and off-site have been defined, and delineated on a larger scale than the area of interest for vapor intrusion. Additional step-in monitoring points are planned to further refine impact delineation in primary areas of vapor intrusion potential. Off-site impact primarily occurs within weathered bedrock limestone horizons, with the potential for dissolved phase impact extending into soil horizons from 3 to 9 feet below ground surface
Include or exclude building based on Lateral Inclusion Zone: Is the distance between any current or future building foundations and the edge of petroleum vapor source < 30 ft?	Yes, impacted groundwater, and possibly pockets of NAPL,exist beneath a residential buildings area within 30 feet of buildings.

	Vertical Separation Distance: Determine the vertical separation distance between the bottom of the building foundation and the top of the petroleum vapor source.	The distance between the bottom of building foundations and the surface of shallow groundwater may be less than 11 feet. When the water table is high, local seepage to the surface may occur within the residential area, indicating that homes with basements could at times be in direct contact with groundwater. Karst features that could hold NAPL are expected to be deeper, but likely less than 30 feet deep. Just to the northeast of the Facility, NAPL was detected
	Precluding Factors: Assess presence of factors that would prevent the use of the vertical separation distance screening, such as: • Preferential pathways (natural - e.g., karst or fractured geology or anthropogenic - e.g., sanitary sewers, piping corridors)? • Expand/advancing plume? • Certain fuel types (e.g., lead scavengers or > 10% vol/vol ethanol)? • Certain soil types (e.g., peat or excessively dry soils between the source and the building)?	Additional factors complicate the use of vertical separation distance screening: • Fractures, karst features, and utility corridors are present and likely control contaminant movement. • Off-site NAPL is isolated and largely residual except in immediate areas of new openings such as wells. • On-site pumping networks near the Facility borders are used to control off-site migration of the dissolved phase plume. • No lead scavengers or ethanol are present. • Soil type is clay-rich and expected to inhibit upward vapor movement. • High water table conditions would be an obstacle to vertical horizon vapor screening.
STEP 2	**Evaluate Building for Precluding Factors and Lateral Inclusion**	
	Precluding Factors: Are there factors that prevent the use of the vertical separation distance screening approach?	Factors complicate vertical separation approach rather than prevent use (see above).
	Evaluate buildings that are within 30 ft laterally from the petroleum vapor source (or potentially further if precluding factors are present). List buildings that fall within the 30 ft inclusion zone.	Impacted groundwater underlies buidlings in the area of interest; however, no data collected to date indicate a need for building evacuation. Screening for additional data is planned.
STEP 3	**Conduct Screening With Vertical Separation Distance**	
	Select the appropriate vertical screening distance based on petroleum vapor source and general petroleum site type. • **Dissolved Phase Sources:** Vertical separation distance between the dissolved phase source and the bottom of the building foundation is > 5ft. List buildings using the dissolved source distance.	Dissolved phase source vertical separation may be less than 5 feet. Additional investigation work is planned to determine vertical screening distances.
	• **FOR LNAPL:** Vertical separation distance between top of LNAPL source (in soil or at water table) and bottom of building foundation is: > 15ft (petroleum UST/AST sites) smaller sites, such as a UST or aboveground storage tank (AST) gas station > 18 ft (petroleum industrial sites) larger petroleum industrial site, such as a terminal, refinery, pipeline, or manufactured gas plant (MGP) site. List buildings using the LNAPL source distance.	Known NAPL present is dense vs. light, so likely NAPL vertical separation exceeds 10 feet (about 12 feet at SMW-80). Light NAPL components from weathering/degradation could occur but have not been encountered. Additional investigation is planned to define impact depth in areas of primary vapor intrusion concern.
	Screen Building Using Vertical Separation Distance: Is the building outside the applicable vertical separation distance? List building that fall within their respective vertical screening distances.	Buildings within the residential area may be within the applicable vertical separation distance to vapor sources.
STEP 4	**Conduct Concentration-Based Evaluation Using Existing Data**	
	Compare existing concentration data to applicable vapor intrusion screening criteria (i.e., look-up values) to evaluate whether the pathway can be eliminated. What is the applicable screening criteria, and does the site screen out?	The U.S. EPA VISL calculator was used to screen groundwater data from monitoring wells in the area of interest. Results indicate potential for acute and chronic vapor exposure for benzene, ethylbenzene, naphthalene, and benzo(a)anthracene.
STEP 5	**Selecting and Implementing an Applicable Scenario and Investigative Approach**	
	Applicable site scenario identified. List applicable scenario.	A residential area is adjacent to the former wood treating facility in a downgradient direction along a subsurface karst groundwater migration pathway ("Clifton drainage karst trough"). NAPL and dissolved phase contamination is present beneath the residential area, controlled by fractures and karst, with top of water from about 3 to 11 feet bls. Residences potentially within the impacted area are both slab on-grade and walk-out basements. Isolated surface seeps during times of high precipatation and groundwater recharge are known to occur within the area.
	Design and implement an investigative approach consistent with the applicable site scenario	A phased investigation approach using shallow and deep soil gas sampling has been developed. Soil gas screening will be done for each residence in the area of potential vapor exposure but remain in the public right-of-way. Screening will progess in a step-wise fashion to define specific locations for further VI evaluation (.e.g., near-slab soil gas, followed by sub-slab and indoor air sampling if appropriate.). A VI Work Plan will be prepared and reviewed by MDNR and MDHSS.

STEP 6	**Data Evaluation**	
	Identify any issues with the location of the data	N/A at this time
	Identify any issues with the quality of the data collected	N/A at this time
	Is modeling and the use of BIOVAPOR warranted?	N/A at this time
	• Does current value screening values consider biodegradation?	N/A at this time
	• Are existing lines of evidence sufficient to confidently assess pathway?	N/A at this time
	• Existing data represent future site conditions (such as new construction)?	N/A at this time
	• Vapor bioattenuation observed in soil gas depth profiles?	N/A at this time
	• Did the site fail screening by a little… or a lot? If by a little, model may add value. If by a lot, consider focusing on other lines of evidence first (e.g., vapor	N/A at this time
	Comparison of data to appropriate screening levels	N/A at this time
STEP 7	**Is Additional Investigation Warranted?**	
	Has site been adequately characterized? Questions to consider include the following:	N/A at this time
	• Have the site contaminants been properly delineated?	N/A at this time
	• Has the potential for PVI at all possibly affected buildings been assessed?	N/A at this time
	• Are there sufficient data to reach a vapor control decision at the site?	N/A at this time
STEP 8	**PVI Pathway Completeness**	
	Does the PVI Pathway pose a human health risk?	N/A at this time
	Vapor control strategy to be implemented:	N/A at this time
	• Environmental Remediation	N/A at this time
	• Institutional Control	N/A at this time
	• Mitigation	N/A at this time
	Vapor control strategy has considered various factors such as:	N/A at this time
	• new versus existing buildings	N/A at this time
	• building size	N/A at this time
	• foundation type and condition	N/A at this time
	• soil conditions; high water conditions	N/A at this time
	• the presence of sumps and floor or footing drains	N/A at this time
	Design factors and potential limitations have been considered for the installation of vapor controls?	N/A at this time
	An operation, maintenance, and monitoring (OM&M) plan has been prepared	N/A at this time
	Pathway for closure has been identified	

Attachment 3

SOP No. 10a – Active Soil Vapor Sampling using Summa Canisters

Skills Required:

1) 40-hour HAZWOPER training (if working on hazardous waste sites)
2) Understanding of, and ability to make decisions regarding, site-specific objectives
3) Training in assembly and proper use of sampling equipment
4) Knowledge of EWI and the state of Missouri quality control standards
5) Knowledge of corporate safety requirements and health and safety plan

1.0 OBJECTIVE / APPLICABILITY

This procedure offers a practical approach for the collection of soil gas samples from temporary soil gas probes or from permanently installed soil gas probes, into SUMMA (or equivalent) canisters. Soil gas sample integrity is verified by using a real-time leak checking procedure before taking each sample. This must be done after probe installation and prior to sampling, as well as before each subsequent soil gas sample from permanent probes. This standard operating procedure (SOP) should be used when its application is consistent with the project's data quality objectives (DQOs) and in conjunction with the SOP for the Installation of Soil Gas Sampling Probes. It is the responsibility of the project team to make sure this procedure meets all applicable regulatory standards and receives approval/concurrence from the leading regulatory agency for the project. Vapor intrusion (VI) subject-matter experts (SMEs) should be consulted as needed to address technical, regulatory or field implementation issues associated with the use of this SOP. Only persons trained in the collection of soil gas samples should attempt this procedure.

This SOP should serve as a reference tool and facilitate consistency among Environmental Works, Inc. (EWI) personnel. Soil vapor sampling procedures allow little departure from procedural standards. If site conditions or equipment issues limit adherence to the procedures, any variance needs to be discussed with the project manager and recorded in field notes. The ultimate procedures employed should be documented in field notes and in related reports.

2.0 Project-Specific Considerations

2.1 Soil gas sampling should not be performed until 48 hours after a significant rain event (defined as >1 inch of rainfall).

2.2 It is common practice to both install and remove soil gas probes by the direct push method using equipment specifically designed for this purpose (Geoprobe or equivalent drill rig). Operation of direct-push machinery shall be performed only by trained and licensed personnel. Soil gas probes can also be advanced with a hand tool method (e.g., the AMS Retract-A-Tip system). The hand tool installation method is only applicable to relatively shallow sampling [e.g., up to 10 to 15 feet below ground surface (ft bgs) depending on the soil type].

2.3 Methane and carbon dioxide (CO2) can cause positive bias with a helium leak detector, if a helium leak-check procedure is used as detailed in this SOP. If methane or CO2 are expected or encountered at a site, then it may be necessary to explore different strategies to determine well integrity.

2.4 The subsurface needs time to equilibrate after probe installation; 30 minutes for temporary probes and 24 hours for permanent probes.

2.5 Prior to attempting sampling of soil gas probes, there should be an understanding of subsurface conditions at the site.

2.5.1 Depth to Groundwater – soil gas samples must be collected in the vadose zone (and above the capillary fringe). Depth to groundwater is estimated by collection of water level from nearby wells and from inferences of soil saturation from nearby soil borings. Target sampling depths will be modified (during installation) based on observed soil moisture/water table measurements.

2.5.2 Soil permeability – Fine-grained or tight soils with little permeability pose certain challenges for collection of soil vapor. Care should be taken during purging and sampling so that the vacuum in the sampling system never exceeds 8 inches mercury (inches Hg) or approximately 100 inches water.

3.0 Materials

3.1 Teflon® tubing 1/4-inch outside diameter (OD) sample tubing. Ensure there is enough tubing to use new tubing at each sample location.

3.2 Swagelok® 1/4-inch nut and ferrule sets for connecting the probe tubing to the sampling manifold.

3.3 The helium leak-check equipment (or equivalent), including the enclosure, helium cylinder (high purity helium [NO BALLOON HELIUM]), and helium detector. The enclosure may be provided by the driller or can be constructed from polyvinyl chloride (PVC) pipe.

3.4 60-ml syringes, vacuum gauge, and 3-way valve for purging of the sampling train and vapor tubing.

3.5 Sampling manifold consisting of Swagelok gas-tight fittings with three valves and one vacuum gauge to attach the probe. This manifold must be clean, free of oils, and flushed free of VOCs before use. This is accomplished by flushing three or four volumes of purge gas (ultra-high-purity [UHP] air or nitrogen) through the manifold and associated tubing.

3.6 Swagelok valve (only necessary for extended sampling periods [i.e., greater than 30 minutes] so that the sampling manifold can be disconnected without introducing air into the probe).

3.7 Wrenches (clean and free of contaminants), various sizes as needed for connecting fittings and making adjustments to the flow controller (if field-adjustable). A 9/16-inch wrench fits the 1/4-inch Swagelok fittings, which most canisters and flow controllers have.

3.8 Optional gas sampling bag (e.g., Tedlar bag) (1-L or 3-L) to collect the purged soil gas, so the volume of purged soil gas can be measured and field screening with a MultiRae ® five gas meter, to collect total VOCs, O_2, CO_2 and methane measurements from the subsurface can be performed on the purged gas.

3.9 A MultiRae® or MiniRae® PID Meter may be used for health and safety to ensure breathing zone VOC concentrations remain below levels specified by the health and safety plan. It is also optional to collect field measurements of total VOCs, O_2, CO_2 and methane from the probe or purged soil gas; it may warn the lab if high concentrations are detected so they can dilute the sample before analysis.

3.10 Canister, stainless steel, polished, certified-clean, and evacuated. These are typically cleaned, evacuated, and provided by the laboratory. Canisters from the lab are certified clean through batch cleaning, unless project DQO state otherwise. Cleaning procedures can include using a combination of dilution, heat and high vacuum. A batch is certified by analyzing a percentage of canisters for VOCs and the results are below a stated value (e.g., 0.2 ppbv). If canisters are being used for indoor air sampling and results are needed in parts per trillion by volume, individual certification of site specific target compounds may be required.

3.11 Flow controller or critical orifice, certified-clean, and set at desired sampling rate. These are typically cleaned, set, and provided by the laboratory. Soil gas samples are typically collected in 1 or 6 liter canisters at a flow rate of 200 milliliters per minute (ml/min); however, lesser flow rates may be used in finer grained soils.

4.0 System Set Up

4.1 Acquire all the necessary hardware and sampling equipment. Be sure to place the helium leak-check enclosure over the probe, remove the probe cap, and push the sample tubing through the hole in the enclosure cap before attaching the sampling manifold. It may be necessary to cut off the probe cap with tubing cutters if the hole in the enclosure cap is not large enough to accommodate the ferrule set. The nut and probe cap can be reused once sampling is complete. The ferrule set must be replaced. ***Do not connect the canister at this time***.

4.2 Setup up purging train to adjust for a desired flow rate of 200 ml/min or less. Flow rate measurements should be performed manually by determining the amount of time required to fill a 1-liter gas sampling bag or by timing 60-mL strokes using the syringe.

4.3 If the sample will be collected over a period of time greater than 30 minutes a flow diversion valve should be placed in-line between the probe and the manifold. Once purging has been completed, disconnect the manifold and purge system (syringe etc.) for use at another location making sure there is no loss of purge integrity at the purged location.

4.4 Sampling canisters are evacuated prior to shipment by the laboratory. The vacuum will need to be verified in the field utilizing lab specified instructions for testing.

5.0 Soil Gas Sampling System Leak Checking and Purging Procedure

5.1 Physical Leak Check – Perform a leak check of the sample manifold system:

5.1.1 Make sure the gas probe valve is closed and the sample valve is open.

5.1.2 Open the purge valve and start pulling using the syringe or pump if available. Verify that the flow is 200 ml/min or less.

5.1.3 A leak-free system will be evident by closing off the purge valve, and observing no loss of vacuum within the sampling manifold system for a period of 30 seconds. Repair any leaks prior to sample collection by tightening the fittings on the manifold. Re-test to make the sure the manifold passes the physical leak check before proceeding.

5.1.4 Record the leak check date and time on the Soil Gas Sampling Log.

5.2 System Purge – A purge of the soil gas probe and sampling manifold system is required before taking each sample.

5.2.1 Purging is carried out by pulling soil gas through the system at a rate of 200 ml/min or less for a time period sufficient to achieve a purge volume that equals 3 internal volumes of the in-ground annular space, sample line, and sampling manifold system. When calculating the dead volume, be sure to take into account the inside diameter and length of the Teflon sample tubing, as well as the probe outside diameter and retraction distance for the annular space of temporary probes. For permanent probes, calculate the volume of the annular space using a nominal 30 percent porosity for the sand or glass bead pack. If, during the purge, the vacuum exceeds 8-inches Hg, then reduce the purging rate. The system vacuum must stay below this level at all times to minimize the risk of inducing leaks or altering conditions in the subsurface.

5.2.2 If there is shallow groundwater in the area, carefully watch the tubing as the pump is turned on. If water is observed in the sample tubing, **shut the pump off immediately**. Soil gas collection will not be feasible if the probe is in contact with water.

5.2.3 If the vacuum gauge reads >8 inches Hg during the purge, then close the purge valve and monitor the vacuum in the manifold and probe. If there is no noticeable change in vacuum after a minute, then there is an insufficient amount of soil gas to collect a sample and the vacuum is too great to collect a soil gas sample. Several factors can cause this situation. Consult with the project manager and take corrective action.

5.2.3.1 The soil formation is too "tight" (i.e., high clay or moisture content). Try using a lower flow rate.

5.2.3.2 The soil formation is too tight. Try a different depth or location.

5.2.3.3 With a temporary probe system, the expendable tip may not have released when the drive rod was retracted. Try retracting the probe a little further, or use a long, thin rod to poke the tip loose.

5.2.3.4 If water is visible in the flexible soil gas tubing, **stop the purging immediately**. It is not possible to take a soil gas sample at that depth or location.

5.2.4 At the end of the calculated purge time and after the system is verified to be leak free, close the purge valve. Do not open the purge valve again. Doing so will result in loss of the purge integrity and will require re-purging.

6.0 Sample Collection

6.1 Clean sampling protocols must be followed when handling and collecting samples. This requires care in the shipping, storage, and use of sampling equipment. Cleanliness of personnel who come in contact with the sampling equipment is also important: for example, no smoking, eating, or drinking; no perfumes or deodorants; and no dry-cleaned clothing. Canisters should not be transported in vehicles with gas-powered equipment or fuel cans. Sharpie-type markers should not be used for labeling or note-taking during sampling.

6.2 The air sampling canisters are certified clean and evacuated by the laboratory to ~29 to 30 inches Hg vacuum. Initial canister vacuums that are less than certified by the laboratory are a potential indication of leakage that could affect the accuracy of analytical results. Care should be used at all times to prevent inadvertent loss of canister vacuum. Never open the canister's valve unless the intent is to collect a sample or check the canister vacuum with an attached gauge.

6.3 Verify that the canister has sufficient initial vacuum for sampling. Measure the initial canister vacuum using an external vacuum gauge as described below:

1. Confirm that canister valves are closed (knob should already be tightened clockwise).

2. Remove brass caps from both the sample canister and the purge canister. (Unless using certified media, there is no difference between the two).

3. Attach manifold center fitting to sample canister.

4. Attach purge syringe to the Purge Valve end of the manifold by attaching provided Teflon tubing and compression fittings.

5. Confirm that there is a brass cap secured at the inlet of the manifold creating an air tight train, make sure the manifold valve above the purge canister is open, and quickly open and close the purge canister valve in order to check for leaks. If the needle on the gauge drops, your train is not airtight. In this case, try refitting your connections and/or tightening them until the needle holds steady

6.4 If there is sufficient initial vacuum and no leaks detected, the line is now ready to be sampled. Open the sample canister valve and monitor sampling progress periodically. Gauge readings, rates, times, and helium check readings should be logged accordingly.

1. When the sampling is complete close the valve and replace the brass cap on the canister; record final vacuum of canister (simply read built-in gauge).
2. Fill out canister sample tag (make sure the sample ID and date of collection recorded on the sample tag matches what is recorded on the COC exactly).
3. Return canisters in boxes provided and all parts of the soil gas manifold.
4. Fill out chain-of-custody and relinquish samples properly (it is important to note the canister serial numbers on the chain-of-custody).
5. Place chain-of-custody in box and retain pink copy.

6.5 For permanent probes, replace the probe cap and make sure it is securely in place. For temporary probes, remove the probe and abandon the bore hole.

7.0 Sample Handling and Shipping Procedure

7.2 The canisters should be shipped back to the laboratory in the same shipping container in which they were received. The samples should not be cooled during shipment. DO NOT put ice in the shipping container.

7.3 When packing the canisters for shipment, verify that the valve (just past finger-tight) and valve caps are snug (1/4 turn past finger tight), and use sufficient clean packing to prevent the valves from rubbing against any hard surfaces. Never pack the canisters with other objects or materials that could cause them to be punctured or damaged. Ensure that flow controllers and gauges are separately and adequately wrapped to prevent damage.

7.4 Do not place sticky labels or tape on any surface of the canister.

7.5 Place a custody seal over the openings to the shipping container.

7.6 Make sure to insure the package for the value of the sample containers and flow controllers if corporate card policy does not cover this.

7.7 Ship canisters for overnight delivery. If sampling on a Friday, ensure the laboratory accepts samples on Saturdays.

8.0 Quality Control

8.1 Laboratories supplying canisters must follow the performance criteria and quality assurance prescribed in U.S. Environmental Protection Agency (EPA) Method TO-14/15 for canister cleaning, certification of cleanliness, and leak checking. SOPs are required.

8.2 Laboratories supplying flow controllers must follow the performance criteria and quality assurance prescribed in EPA Method TO-14/15 for flow controller cleaning and adjustment.

9.0 SAFETY

Acute or chronic exposure to chemically-contaminated soil or water could result in bodily injury. Routes of exposure include inhalation, ingestion, and dermal contact. Consult the appropriate chemical material safety data sheet (MSDS) before mobilization so that proper PPE and monitoring are planned and implemented.

Conduct an on-site safety meeting each day before the start of field work utilizing a Tailgate Safety Meeting form. Review safety hazards (e.g. high-traffic areas, exposure to chemicals, alertness to heavy equipment, PPE, health monitoring, severe weather conditions and emergency procedures). Soil vapor wells can be located within a parking lot or drive of an active commercial facility: remember to make yourself as visible as possible by donning all appropriate PPE and using cone/barricades to segregate yourself from potential traffic hazards. Take appropriate action if personnel are injured on-site per EWI policy guidance.

When working with potentially hazardous substances, follow the United States Environmental Protection Agency (US EPA), Occupational Safety and Health Administration (OSHA), EWI Corporate Health and Safety Plan, and site-specific health and safety plan.

10.0 REFERENCES

The following documents may be reviewed for further information appropriate to this SOP.

- Hartman, B., 2006, How to Collect Reliable Soil-Gas Data for Risk-Based Applications-Specifically Vapor Intrusion, Part 4: Updates on Soil-Gas Collection and Analytical Procedures*, LUSTLine Bulletin* 53, September, 2006.
- U.S. Environmental Protection Agency, 2015, OSWER Technical Guide for Assessing and Mitigating the Vapor Intrusion Pathway from Subsurface Vapor Sources to Indoor Air, June, 2015.
- U.S. Environmental Protection Agency, 2002, Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils (Subsurface Vapor Intrusion Guidance), November 2002.
- http://www.eurofinsus.com/media/161448/guide-to-air-sampling-analysis-2014-06-27_revised-logos.pdf

- Environmental Works, Incorporated, Corporate Health and Safety Plan
- Site Specific Health and Safety Plan

Environmental Works, Inc. SOP No. 10a

Active Soil Vapor Sampling Using Summa Canisters

ATTACHMENTS

Soil Vapor Sampling Log

Example Chain of Custody

Eurofins Air Toxics, Inc. Guide to Air Sampling 6/27/14

SOIL GAS SAMPLING FORM

Client Code: ____________________ **Job Code:** ____________________ **Date:** ____________________

Samplers: ____

Sample ID: ____

Summa ID: ____

Weather: **Temp:** __________ **Wind:** __________ **Barometric Pressure Start/End:** ____________________

Purge Start Time: __________ **End Time:** __________ **Volume Extracted:** __________

Initial Screening

TIME	Helium	Oxygen (%)	CO_2	Methane (%)	VOCs (total)

Sample Start Time: __________ **End Time:** __________

Summa Start Pressure: __________ **End Pressure:** __________

Tracer Gas Used: __________ **Leak Detection Passed:** __________

Field Measurements

Time	Vacuum Pressure Reading		Comments

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For courier service / sample drop off information, contact us26_sales@eurofinsus.com or call us.

WO # / LAB USE ONLY

CHAIN OF CUSTODY RECORD

DATE: ____________________

PAGE: __________ OF __________

LABORATORY CLIENT:

ADDRESS:

CITY: STATE: ZIP:

TEL: E-MAIL:

CLIENT PROJECT NAME / NUMBER:

P.O. NO.:

PROJECT CONTACT:

SAMPLER(S): (PRINT)

TURNAROUND TIME (Rush surcharges may apply to any TAT not "STANDARD"):

☐ SAME DAY ☐ 24 HR ☐ 48 HR ☐ 72 HR ☐ 5 DAYS ☐ STANDARD

☐ COELT EDF

GLOBAL ID:

LOG CODE:

SPECIAL INSTRUCTIONS:

REQUESTED ANALYSES

Please check box or fill in blank as needed.

LAB USE ONLY	SAMPLE ID	SAMPLING		MATRIX	NO. OF CONT.	Unpreserved	Preserved	Field Filtered	☐ TPH(g) ☐ GRO	☐ TPH(d) ☐ DRO	TPH ☐ C6-C36 ☐ C6-C44	TPH ____	BTEX / MTBE ☐ 8260 ☐ ____	VOCs (8260)	Oxygenates (8260)	Prep (5035) ☐ En Core ☐ Terra Core	SVOCs (8270)	Pesticides (8081)	PCBs (8082)	PAHs ☐ 8270 ☐ 8270 SIM	T22 Metals ☐ 6010/747X ☐ 6020/747X	Cr(VI) ☐ 7196 ☐ 7199 ☐ 218.6				
		DATE	TIME																							

Relinquished by: (Signature)	Received by: (Signature/Affiliation)	Date:	Time:
Relinquished by: (Signature)	Received by: (Signature/Affiliation)	Date:	Time:
Relinquished by: (Signature)	Received by: (Signature/Affiliation)	Date:	Time:

06/02/14 Revision

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Guide to Air Sampling

Canisters and Bags

- Soil Gas
- Vapor Intrusion
- Property Redevelopment
- Ambient Air Monitoring
- Indoor Air Quality
- Waste-to-Energy

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Always Air. Always Accurate.

Eurofins Air Toxics, Inc.
Guide to Whole Air Sampling – Canisters and Bags

Revision 6/27/14

Contents

Section 1.0 Introduction

Eurofins Air Toxics Inc. presents this guide as a resource for individuals engaged in air sampling. Air sampling can be more involved than water or soil sampling due to the reactivity of chemical compounds in the gas matrix and sample interaction with the equipment and media used. Ensuring that air samples are collected properly is an important step in acquiring meaningful analytical results. This guide is not a substitute for experience and cannot sufficiently address the multitude of field conditions. Note that this guide is intended for projects involving whole air sampling of volatile organic compounds (VOCs) in canisters and Tedlar® bags. Eurofins Air Toxics provides the "Guide to Sorbent-Based Sampling - Volatiles and Semi-Volatiles" for other types of sampling.

1.1 Whole Air Sampling of VOCs

There are three general ways to collect compounds in a gas phase sample. A sampler may collect the gas sample in a container, actively pump the vapor through a sorbent tube, solution or filter, or rely on passive sample collection onto a sorbent bed. This guide focuses on collecting a sample in the most common air sampling containers, Summa canisters and bags. The sample may be collected in the container either passively, relying on an evacuated canister to drive the sample collection, or actively using a pump to fill the container. The container is subsequently sealed and transported to the laboratory for analysis. The sample is referred to as a "whole air sample" and the compounds remain in the gas matrix inside the container.

As a general rule, whole air sampling is appropriate when target compounds are chemically stable and have vapor pressures greater than 0.1 torr at 25°C and 760mm Hg (EPA standard ambient conditions). Performance of a given compound in a whole air sample is dependent upon its chemical properties, the matrix of the sample, and the degree of inertness of the sample container.

1.2 Choosing Between Canisters and Bags

Table 1.2 compares the features and performance of Summa canisters and bags. Summa canisters or similarly treated canisters are rugged containers designed to provide superior inertness and extended sample storage times. Evacuated canisters also do not require a sampling pump for sample collection. By contrast, bags require a sample pump, but can be purchased inexpensively in bulk, require little preparation or cleaning, and take up little space prior to use. Unlike canisters, bags are typically not appropriate for ppbv-level VOC measurements due to their background artifacts and short hold-times. Over time, low molecular weight gases can diffuse through the bag material while chemicals with lower vapor pressures can condense on the bag surface thereby compromising analyte recoveries. Call your Project Manager at 800-985-5955 if you have questions regarding the appropriate sampling media.

Table 1.2 Comparison of Canisters to Bags

	Canisters	Bags
Type of Sampling	Passive (vacuum)	Active (pump required)
Media Hold Time	Up to 30 days recommended	Indefinite
Hold Time to Analysis	Up to 30 days	Up to 3 days
Surface Inertness	Excellent	Fair
Cleanliness	Batch or 100% certified to ppbv/pptv levels	Some VOCs present in the ppbv range
Sampling Application	Ambient air, soil/landfill gas	Soil/landfill gas, stationary sources, SVE systems
Rule of Thumb	"ppbv device"	"ppmv device"
Advantages	Inertness, hold time, ruggedness, no pump	Purchase/shipping cost, availability, convenience

Section 2.0 Canisters and Associated Media

This section provides a description of air sampling canisters, practical considerations for sampling, and step-by-step instructions for collecting grab and integrated samples. Photographs illustrate the correct way to assemble the various sampling components. Tables provide detailed information on many operational factors that ultimately influence the quality of the data obtained from a canister sample.

2.1 Introduction to Canisters

An air sampling canister is a container for collecting a whole air sample. A canister may be spherical or cylindrical and is constructed of specially treated stainless steel. The canister is prepared for sampling by evacuating the contents to a vacuum of approximately 29.9 inches of Mercury (in Hg). Opening the stainless steel bellows valve allows the air sample to enter the canister. Flow controllers can be utilized to restrict the flow and allow for collection at a desired flow rate or over a desired range. When the sample has been collected, the valve is closed and the canister is returned to the laboratory. Canisters range in volume from less than 1 liter (L) to 6 L. In general, 6 L canisters are used to collect ambient air samples and samples requiring time integration greater than 2 hours. One liter canisters are typically used for taking high concentration (i.e., greater than 5 ppbv) samples not requiring time integration such as soil vapor.

2.1.1 Summa Canister

A Summa canister is a stainless steel container that has had the internal surfaces specially passivated using a "Summa" process. This process combines an electropolishing step with a chemical deactivation step to produce a surface that is nearly chemically inert. A Summa surface has the appearance of a mirror: bright, shiny and smooth. The degree of chemical inertness of a whole air sample container is crucial to minimizing reactions with the sample and maximizing recovery of target compounds from the container. Eurofins Air Toxics maintains a large inventory of Summa canisters in 1 and 6 L volumes.

2.1.2 Canister Certification

Eurofins Air Toxics provides two types of canister cleaning certification, batch and 100%, depending upon the requirements of the project. The batch certification process is most appropriate for routine ambient air applications and high concentration applications such as soil vapor and landfill gas monitoring. The batch certification process begins by cleaning a set of canisters using a combination of dilution, heat and high vacuum. The cleaning batch is certified by analyzing a percentage of canisters for approximately 60 VOCs using GC/MS. The batch meets cleaning requirements if the target compound concentrations are below 0.2 ppbv. Alternatively, the 100% certification (i.e., individual certification) process is typically required for ambient and indoor air applications driven by risk assessment or litigation requiring pptv (parts per trillion by volume) sensitivity. If 100% certification is required, canisters are individually certified for a client-specific list of target compounds using GC/MS. When the 100% certified canisters are shipped, the analytical documentation demonstrating that they are free of the target compounds down to the project reporting limits is emailed to the client. When sampling with certified media, it is important to note that all media is certified as a train and must be sampled as such (i.e., a particular flow controller goes with a particular canister and is labeled as such).

Specify whether your project requires batch or 100% canister certification.

2.1.3 Canister Hold Time

Media Hold Time: Unlike water and soil environmental samples, which are collected in single-use, disposable vials and jars, air samples are collected in reusable summa canisters. Eurofins Air Toxics requires that canisters be returned within 15 days of receipt to effectively manage our inventory and to insure canisters meet performance requirements in the field. Evacuated canisters have a finite timeframe before the canisters naturally lose vacuum during storage. Using canisters beyond 15 days increases the risk of having unacceptable initial vacuum at the start of sampling.

Sample Hold Time: EPA Method TO-15 cites a sample hold time of up to 30 days for most VOCs. Several non-routine compounds, such as bis(chloromethyl)ether, degrade quickly and demonstrate low recovery even after 7 days. Reactive sulfur compounds such as hydrogen disulfide and methyl, ethyl, and butyl mercaptan are not amenable to storage in stainless steel summa canister, and either fused silica lined (FSL) canisters or Tedlar bags are required for sample collection.

2.2 Associated Canister Hardware

Associated hardware used with the canister includes the valve, brass cap, particulate filter and vacuum gauge. (Flow controllers are covered in detail in section 3.2.)

2.2.1 Valve

An industry standard 1/4" stainless steel bellows valve is mounted at the top of the canister. The valve maintains the vacuum in the canister prior to sampling and seals the canister once the sample has been collected. No more than a half turn by hand is required to open the valve. Do not over-tighten the valve after sampling or it may become damaged. A damaged valve can leak, possibly compromising the sample. Some canisters have a metal cage near the top to protect the valve.

To protect the valve and provide secure connections in the field, a replaceable fitting is attached to all canisters. As threads wear and require replacement, new fittings can be installed at the laboratory prior to shipping to the field. You will need a 1/2" wrench to secure the fitting while connecting or removing the required equipment to the canister.

2.2.2 Brass Cap

Each canister comes with a brass cap (i.e., Swagelok 1/4" plug) secured to the inlet of the valve assembly. The cap serves two purposes. First, it ensures that there is no loss of vacuum due to a leaky valve or a valve that is accidentally opened during handling. Second, it prevents dust and other particulate matter from damaging the valve. The cap is removed prior to sampling and replaced following sample collection.

Always replace the brass cap following canister sampling.

2.2.3 Particulate Filter

Particulate filters should always be used when sampling with a canister. Separate filters are provided to clients taking a grab sample, and filters are built into the flow controllers for clients taking integrated samples. The 2 micron filter is a fritted stainless steel disk that has been pressed into a conventional Swagelok adapter. This device has a relatively high pressure drop across the fritted disk and restricts the flow into the canister even when sampling without a flow controller. Table 2.2.3 lists the typical fill time for a grab sample using a 2 micron particulate filter.

Table 2.2.3 Grab Sample Fill Times for Canisters

CANISTER VOLUME	2 micron filter
6 L	<5 minutes
1 L	<1 minute

2.2.4 *Fittings*

All fittings on the sampling hardware are 1/4” Swagelok, and a 9/16” wrench is used to assemble the hardware. A 1/2” wrench is also required to tighten fittings onto a union connector. Compression fittings should be used for all connections. Never use tube-in-tube connections. It is critical to avoid leaks in the sampling train. Leaks of ambient air through fittings between pieces of the sampling train will dilute the sample and cause the canister to fill at a faster rate than desired. Eurofins Air Toxics can provide the necessary fittings and ferrules if requested.

2.2.5 *Vacuum Gauge*

A vacuum gauge is used to measure the initial vacuum of the canister before sampling, and the final vacuum upon completion. A gauge can also be used to monitor the fill rate of the canister when collecting an integrated sample. Eurofins Air Toxics provides 2 types of gauges. For grab sampling, a test gauge checks initial and final vacuums only and is not to be sampled through. For integrated sampling a gauge is built into the flow controller and may be used for monitoring initial and final vacuums, as well as monitoring the fill rate of the canister. Both gauges are considered to be rough gauges, intended to obtain a relative measure of vacuum change. Accuracy of these field gauges are generally on the order of +/-5 in Hg. Individuals with work plans that outline specific gauge reading requirements are strongly encouraged to purchase and maintain their own gauges in the field. In special cases, a laboratory-grade, NIST-traceable vacuum gauge can be provided upon request.

The vacuum gauges that are routinely provided are intended as a rough gauge measurement device (+/-5 in Hg accuracy).

Section 3.0 Sampling with Canisters

There are two basic modes of canister sampling: grab and integrated. A grab sample is taken over a short interval (i.e., 1-5 minutes) to provide a point-in-time sample concentration, while an integrated sample is taken over a specified duration or utilizing a specified flow rate. In both modes the canister vacuum is used to draw the sample into the canister. This is commonly referred to as passive canister sampling. Sections 3.1 and 3.2 detail procedures for grab and integrated sampling, and section 3.3 provides procedures specific to soil vapor collection.

Regardless of the type of canister samples collected, the following rules apply:

- DO NOT use canister to collect explosive substances, radiological or biological agents, corrosives, extremely toxic substances or other hazardous materials. It is illegal to ship such substances and you will be liable for damages.
- ALWAYS use a filter when sampling. NEVER allow liquids (including water) or corrosive vapors to enter canister.
- DO NOT attach labels to the surface of the canister or write on the canister; you will be liable for cleaning charges.
- DO NOT over tighten the valve, and remember to replace the brass cap.
- IF the canister is returned in unsatisfactory condition, you will be liable for damages.
- DO NOT make modifications to the equipment connections and/or use Teflon tape unless approved by the laboratory.
- AND, if you have any questions or need any support, our experienced project management team is just a phone call away at 800-985-5955.

Use a 9/16” and 1/2” wrench to tighten Swagelok connections on the canister sampling train.

3.1 Grab Sampling Using Canisters

The most common hardware configuration used to take a grab sample is to simply attach a particulate filter to the canister inlet. A particulate filter is shown in section 2.2.3 and is used to prevent particulate matter from fouling the valve and entering the canister.

3.1.1 Step-By-Step Procedures for Canister Grab Sampling

These procedures are for a typical ambient air sampling application; actual field conditions and procedures may vary.

Before you get to the field:

1. Verify contents of the shipped package (e.g., chain-of-custody, canister, particulate filter, and gauge – if requested).
2. Make sure you include a 9/16” and 1/2” wrench in your field tool kit.
3. Verify the gauge is working properly.
4. Verify the initial vacuum of canister as described in the following section:

- **Verify Initial Vacuum of the Canister**: Prior to shipment, each canister is checked for mechanical integrity. However, it is still important to check the vacuum of the canister prior to use. Eurofins Air Toxics recommends doing this before going to the field if possible. The initial vacuum of the canister should be greater than 25 in Hg. If the canister vacuum is less than 25 in Hg, ambient air may have leaked into the canister during storage or transport and the sample may be compromised. Contact your Project Manager if you have any questions on whether to proceed with sample collection. If sampling at altitude, there are special considerations for gauge readings and sampling (see Section 5.2). The procedure to verify the initial vacuum of a canister is simple but unforgiving.

1. Confirm that valve is closed (knob should already be tightened clockwise).
2. Remove the brass cap.
3. Attach gauge.
4. Attach brass cap to side of gauge tee fitting to ensure a closed train.
5. Open and close valve quickly (a few seconds).
6. Read vacuum on the gauge.
7. Record gauge reading on "Initial Vacuum" column of chain-of-custody.
8. Verify that canister valve is closed and remove gauge.
9. Replace the brass cap.

When ready to sample:

1. Confirm that valve is closed (knob should already be tightened clockwise).
2. Remove brass cap.
3. Attach particulate filter to canister.
4. Open valve 1/2 turn (6 L canister normally takes less than 5 minutes to fill).
5. Close valve by hand tightening knob clockwise.
6. Verify and record final vacuum of canister (repeat steps used to verify initial vacuum). For grab samples, the ending vacuum is typically close to ambient pressure (0 in Hg).
7. Replace brass cap.
8. Fill out canister sample tag (make sure the sample ID and date of collection recorded on the sample tag matches what is recorded on the COC exactly).
9. Return canister in box provided.
10. Return sample media in packaging provided.
11. Fill out chain-of-custody and relinquish samples properly (it is important to note the canister serial numbers on the chain-of-custody).
12. Place chain-of-custody in box and retain pink copy.
13. Tape box shut and affix custody seal (if applicable) across flap.
14. Ship accordingly to meet method holding times.

Return all equipment used or unused to the laboratory. Unreturned canisters and associated hardware will result in additional charges as outlined in the media agreement.

3.2 Integrated Sampling with Canisters and Flow Controllers

As an alternative to an "instantaneous" grab sample, an air sample collected at a controlled rate is referred to as an integrated sample. Flow controllers or flow restrictors are devices which provide sample collection at a desired flow rate and/or sampling interval. By using a flow controller at a specified flow rate, air samples can provide information on average compound concentrations over a defined period. For example, an 8- or 10-hour integrated sample can be used to determine indoor air quality in the workplace. Similarly, a 24-hour integrated sample may be collected to determine residential exposure to indoor or outdoor air sources. In addition to using a flow controller for time-integrated sample collection, a flow controller may be required for soil gas collection to restrict the vacuum applied to the soil and pore water and to collect a representative sample with minimal intrusion of ambient air.

Eurofins Air Toxics provides two general types of flow controllers: mass flow controllers and critical orifice devices. Both devices are driven by differential pressure between ambient conditions and vacuum in the canister.

3.2.1 *Mass Flow Controller*

A mass flow controller employs a diaphragm that actively compensates to maintain a constant mass flow rate over the desired time period. As the differential pressure decreases, the flow rate decreases and the diaphragm responds by opening up to allow more air to pass through to maintain a stable flow rate. Mass flow controllers are calibrated in the laboratory to provide flow rates suitable for durations up to 24 hours. Durations greater than 24 hours are possible, however, performance of the flow controller is less reliable due to the low flow rates required.

3.2.2 *Critical Orifice Devices*

Eurofins Air Toxics has two types of critical orifice controllers – “capillary column” and “frit pressed”. Both types restrict the flow rate and the canister fill rate decreases as the canister fills to ambient pressure. These controllers are suitable for applications not requiring constant flow rate over the sampling period such as soil vapor collection or at sites in which temporal variability of VOCs is not expected. Critical orifice devices can cover intervals from 0.5 to 12 hours and flow rate from 10 to 250 ml/min. The “capillary column” device (also known as the Blue Body Flow Controller) restricts air flow by forcing the sample to enter a capillary column of minute radius. The flow rate is a function of the length of inert capillary column. The frit pressed device has a critical orifice machined to meet a set flow rate.

3.2.3 *Sampling Interval and Flow Controller Setting*

When you request canisters and flow controllers from Eurofins Air Toxics, you will be asked for the flow rate (soil vapor) or sampling interval (ambient air), and the flow controllers will be pre-set prior to shipment. The flow rate is set at standard atmospheric conditions (approximately sea level and 25°C). If samples will be collected at elevation or at ambient temperatures significantly different than 25°C, the canister will fill faster or slower depending on sample conditions. If you specify unusual sample conditions at the time of project set-up, we can set the flow controller accordingly. (See Section 5.2 for a discussion of collecting a sample at elevation.) Mass flow controllers should not be utilized for source or process samples in which the collection point is under vacuum or pressure. Please discuss these specific non-standard field conditions with your Project Manager at the time of project set-up.

Table 3.2.3 Flow Rates for Selected Sampling Intervals (mL/min)

Sampling Interval (hrs)	**4 min.**	**0.5**	**1**	**2**	**4**	**8**	**12**	**24**
6 L Canister	NA	167	83.3	41.7	20.8	11.5	7.6	3.8
1 L Canister	167	26.6	13.3	6.7	-	-	-	-

Note: Target fill volumes for 6 L and 1 L canisters are 5,000 mL and 800 mL, respectively.

3.2.4 *Final Canister Vacuum and Flow Controller Performance*

For time-integrated sample collection using a mass flow controller, the final vacuum of a canister should ideally be approximately 5 in Hg or greater. The flow rate will remain constant as the canister fills and will start to decrease as the canister vacuum approaches

5 in Hg. At this point, the differential pressure between the canister and ambient air is not sufficient to maintain the set flow rate. Because of normal fluctuations in the flow rate due to changes in field temperature and pressure, the final vacuum typically ranges between 3 and 10 in Hg.

- **If the residual canister vacuum is greater than 10 in Hg** (i.e., more vacuum), the actual flow rate is lower than the set point and less sample volume is collected. When the canister is pressurized prior to analysis, the pressurization dilution will be greater than normal. This will result in elevated reporting limits.
- **If the residual canister vacuum is near ambient pressure** for a time-integrated sample, the canister filled faster than calibrated. Once the vacuum decreases below 5 in Hg, the flow rate begins to decrease from its set point. This scenario indicates that the sample is weighted toward the first portion of the sampling interval. The sampler cannot be certain the desired sampling interval was achieved before the canister arrived at ambient conditions. Although the actual sampling interval is uncertain, the canister still contains a sample from the site.

Table 3.2.4 Relationship between Final Canister Vacuum, Volume Sampled, and Dilution Factor (6 L Canister)

Final Vacuum (in Hg)	0	2.5	5	7.5	10	12.5	15	17.5	20
Volume Sampled (L)	6	5.5	5.4	5	4	3.5	3	2.5	2
Dilution Factor*	1.34	1.46	1.61	1.79	2.01	2.30	2.68	3.22	4.02

*Canister pressurized to 5 psig for analysis

$$\textbf{Final Reporting Limit} = \text{Method Reporting Limit} \times \text{Dilution Factor (Canister Pressurization)} \times \text{Dilution Factor (Sample Analysis)}$$

$$\textbf{Dilution Factor (Canister Pressurization)} = \frac{\text{Final Pressure}}{\text{Receipt Pressure}} = \frac{14.7\text{ psig} + \text{Final Pressure (psig)}}{14.7\text{ psig}\left[\dfrac{1-\text{Receipt Vacuum (in Hg)}}{29.9\text{ in Hg}}\right]}$$

3.2.5 Considerations for Integrated Sampling with Canisters

Collecting an integrated air sample is more involved than collecting a grab sample. Sampling considerations include verifying that the sampling train is properly configured, monitoring the integrated sampling progress, and avoiding contamination.

- **Avoid Leaks in the Sampling Train**: A leak in any one of these connections means that some air will be pulled in through the leak and not through the flow controller. (Follow the leak check step #4 in 3.2.6).
- **Verify Initial Vacuum of Canister:** See Section 3.1.1 for instructions on verifying initial canister vacuum. A separate gauge is not necessary as both the mass flow controllers and critical orifice flow controllers have built-in rough gauges.
- **Monitor Integrated Sampling Progress**: When feasible, it is a good practice to monitor the progress of the integrated sampling during the sampling interval. The volume of air sampled is a linear function of the canister vacuum. For example, when using a 24-hour mass flow controller, at a quarter of the way (6 hours) into a 24-hour sampling interval, the canister should be a quarter filled (1.25 L) and the gauge should read approximately 6 in Hg lower than

the starting vacuum (~22 in Hg). More vacuum indicates that the canister is filling too slowly; less vacuum means the canister is filling too quickly. If the canister is filling too slowly, a valid sample can still be collected (see Section 3.2.4). If the canister is filling too quickly because of a leak or incorrect flow controller setting, corrective action can be taken. Ensuring all connections are tight may eliminate a leak. It is possible to take an intermittent sample; the time interval need not be continuous.

- **Avoid Contamination**: Flow controllers should be cleaned between uses. This is done by returning them to the laboratory.
- **Caution When Sampling in Extreme Temperatures**: Field temperatures can affect the performance of the mass flow controllers. Laboratory studies have shown that flow rates can increase slightly with decreasing temperatures. A flow rate increase of approximately 10% is expected when sampling at field temperatures of 5 to 10°C.

3.2.6 Step-by-Step Procedures for Integrated Sampling

These procedures are for a typical ambient air sampling application; actual field conditions and procedures may vary.

Before you get to the field:

1. Verify contents of the shipped package (e.g., chain-of-custody, canister, and flow controller)
2. Make sure you include a 9/16" and 1/2" wrench in your field tool kit.
3. Verify the gauge is working properly
4. Verify the initial vacuum of canister (section 3.1.1)

When ready to sample:

1. Confirm that valve is closed (knob should already be tightened clockwise).
2. Remove brass cap from canister.
3. Attach flow controller to canister. The flow controller is securely attached if the flow controller body does not rotate.
4. Place the brass cap at the end of the flow controller creating an air tight train, and quickly open and close the canister valve in order to check for leaks. If the needle on the gauge drops, your train is not airtight. In this case, try refitting your connections and/or tightening them until the needle holds steady.
5. Once the sample train is airtight remove the brass cap from the flow controller and open the canister valve a ½ turn.
6. Monitor integrated sampling progress periodically.
7. Verify and record final vacuum of canister (simply read built-in gauge).
8. When sampling is complete, close valve by hand tightening knob clockwise.
9. Detach flow controller and replace brass cap on canister.
10. Fill out canister sample tag (make sure the sample ID and date of collection recorded on the sample tag matches what is recorded on the COC exactly).
11. Return canisters and associated media in boxes provided. **Failure to return all of the provided equipment will result in a replacement charge as outlined in the media agreement.**
12. Fill out chain-of-custody and relinquish samples properly (it is important to note the canister serial numbers on the chain-of-custody).
13. Place chain-of-custody in box and retain pink copy.
14. Tape box shut and affix custody seal at each opening (if applicable).
15. Ship accordingly to meet method holding times.

3.3 Soil Gas Sample Collection

Canisters can be used for the collection of soil vapor by attaching the sampling train to the soil gas probe. Typically, a critical orifice flow controller is used to minimize the applied vacuum in order to minimize partitioning of VOCs from the soil or pore water to the soil vapor. Additionally, lower flow rates help to minimize the intrusion of ambient air into the soil vapor probe. In general, time-integration is not required for soil gas samples; however, there may be exceptions to this rule of thumb. For example, some regulatory guidance documents recommend concurrent indoor air and sub-slab soil vapor collection over a

24-hour period. This means that a mass flow controller calibrated for a 24-hour sample would be required for the sub-slab as well as the indoor air sample.

3.3.1 Canister to probe connection – Tubing

Collection of a soil gas sample requires the use of tubing to connect the soil gas probe to the sample train. Teflon FEP tubing is recommended based on its low background and its inertness. Alternative tubing can be used if shown to meet data quality objectives. Please note that Low Density Polyethylene or flexible Tygon tubing is not recommended due to VOC adsorption during sample collection. Teflon tubing is provided by the laboratory upon request at the time of order. A charge based on the length will be assessed. It is important to store the tubing away from VOC sources during storage and transport to the site to minimize contamination.

3.3.2 Canister to probe connection –Fittings

To connect the tubing to the canister sampling train, a Swagelok fitting and a pink ferrule are used. The position of the ferrule is key to ensure the fitting is securely connected to the canister. See the figure below for the correct positioning and connection. The pink ferrule is flexible and cannot be over-tightened.

3.3.3 Leak Check Compounds Considerations

To determine whether ambient air is introduced into soil gas sample, a leak check may be used. Leak check compounds may be liquid or gaseous tracers. Liquid compounds are challenging to use effectively in the field and can be introduced into the sample due to improper handling in the field, erroneously indicating a leak in the sampling train. Liquid tracers such as isopropanol should never be directly applied to connections in the sampling train. Rather, the liquid is carefully applied to a cloth and placed near the connection or on the ground next to the probe. Great care must be used in the field to insure the liquid tracer is not handled during sampling train assembly or disassembly. Even a trace amount of a liquid tracer on a glove used to replace a canister brass cap can contaminate the sample. Liquid leak check compounds can interfere with the analytical runs, and even small leaks may result in analytical dilution and raised reporting limits when measuring ppbv target compound levels.

Gaseous tracers such as helium are typically used with shroud placed over the sampling equipment and/or borehole. To quantify the leak, the concentration of the tracer gas in the shroud should be measured.

Specify the leak check compound planned for your soil gas sampling event and record on the COC.

3.3.4 Step-by-Step Procedures for Soil Vapor Sampling

These procedures are for a typical soil vapor sampling application; actual field conditions and procedures may vary. Please consult your specific regulatory guidance for details.

Before you get to the field:

1. Verify contents of the shipped package (e.g., chain-of-custody, canister, tubing, fittings, and flow controller).
2. Make sure you include a 9/16” and 1/2” wrench in your field tool kit.
3. Verify the gauge is working properly.
4. Verify the initial vacuum of canister.

Prior to vapor collection:

- **Purge tubing adequately**. A long length of tubing has significant volume of “dead air” inside. Without purging, this air will enter the canister and dilute the sample. Consider using a handheld PID/FID to confirm that you have purged the tubing and are drawing sample air through the tubing. A standard rule of thumb is to utilize 3 purge volumes prior to sample collection. However, under certain circumstances, purge volumes of 1 to 10 may be appropriate. Please review your regulatory guidance and your site specific conditions in determining the appropriate purge volumes.
- **Don’t sample water**. If moisture is visible in the sample tubing, the soil gas sample may be compromised. Soil gas probes should be at an appropriate depth to avoid reaching the water table. Additionally, subsurface vapor should not be collected immediately after measurable precipitation.

When ready to sample:

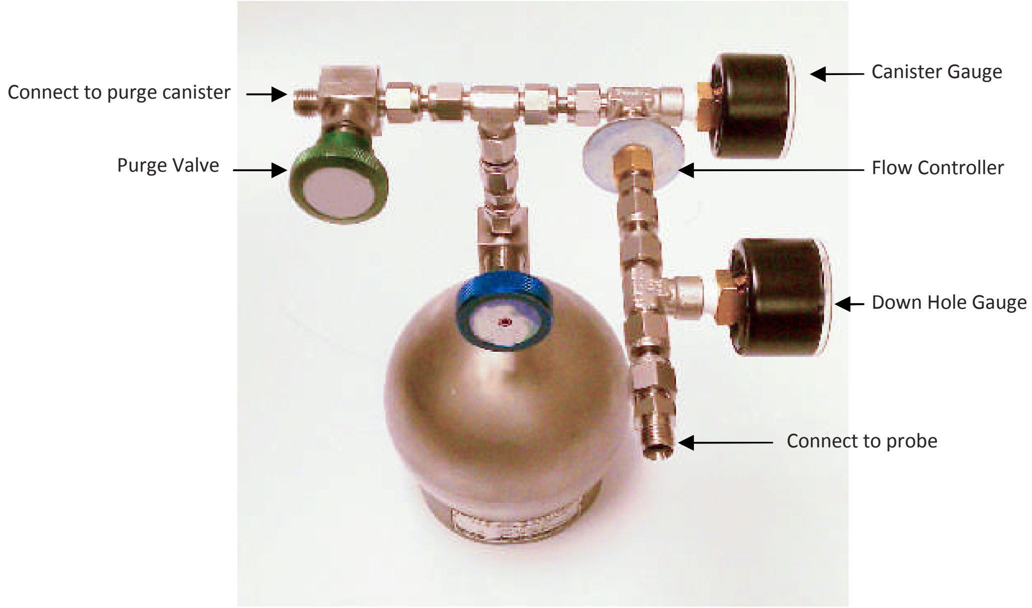
1. Confirm that valve is closed (knob should already be tightened clockwise).
2. Remove brass cap from canister.
3. Attach flow controller to canister if needed. The flow controller is securely attached if the flow controller body does not rotate. (Note: The frit-press flow controller and 1 L canister may be pre-assembled by the laboratory.)
4. Place the brass cap at the end of the flow controller creating an air tight train, and quickly open and close the canister valve in order to check for leaks. If the needle on the gauge drops, your train is not airtight. In this case, try refitting your connections and/or tightening them until the needle holds steady.
5. Once the sample train is airtight remove the brass cap from the flow controller and attach the probe tubing to the flow controller using the pink ferrule and Swagelok nut. (See 3.3.2 for proper positioning of the ferrule.)
6. Once the probe line has been purged and appropriate leak check measures have been implemented, open the canister valve a ½ turn.
7. Verify and record final vacuum of canister (simply read built-in gauge).
8. When canister fills to the desired end vacuum, close valve by hand tightening knob clockwise.

   Please note: Some projects require residual vacuum of approximately 5 in Hg at the end of sample collection even if time-integrated samples are not required. The residual vacuum serves to provide a check of the integrity of the canister during transport to the laboratory to insure no leaks occurred during shipment. A field vacuum reading similar to the lab receipt vacuum reading demonstrated that no leak occurred.

9. Detach tubing and flow controller and replace brass cap on the canister.
10. Fill out canister sample tag (make sure the sample ID and date of collection recorded on the sample tag matches what is recorded on the COC exactly).
11. Return canisters and associated media in boxes provided. **Failure to return all of the provided equipment will result in a replacement charge as outlined in the media agreement.**
12. Fill out chain-of-custody and relinquish samples properly (it is important to note the canister serial numbers on the chain-of-custody).
13. Place chain-of-custody in box and retain pink copy
14. Tape box shut and affix custody seal at each opening (if applicable)
15. Ship accordingly to meet method holding times

3.4.4 Collecting Soil Gas Samples with Sampling Manifolds

If required, Eurofins Air Toxics can provide a sampling manifold to assist with leak checking the sampling train, purging the sampling line, and monitoring the vacuum applied to the soil gas bore hole during sample collection. The manifold is shown below:



The 'Down Hole Gauge', located prior to the flow restrictor, is a vacuum gauge that monitors the vacuum applied to the soil gas probe. Because this is not a flow meter but a measure of pressure/vacuum, the gauge should read at zero if there is sufficient flow from the soil. If the gauge begins to read a vacuum, then the flow is being restricted. Low flow, high vacuum conditions can be encountered when sampling in low permeability soil. The 'Canister Gauge', in line after the flow controller and prior to the purge canister, is a vacuum gauge that indicates to the sampler whether or not the canister is filling properly at the expected rate. This setup enables the sampler to evaluate the lithologic conditions at the site and determine if a valid soil gas sample is being taken. Finally, when duplicate samples are required, the manifold can be used as a duplicate sampling "T" by simply replacing the purge canister with another sample canister.

There are several options to use as a purge vacuum source to attach to the purge valve connection – a Summa canister, sampling pump or sampling syringe. The below instructions assume a Summa canister will be used as a purge volume source since other sources are generally provided by the client.

When ready to sample:

Leak Check Test

1. Confirm that canister valves are closed (knob should already be tightened clockwise).

2. Remove brass caps from both the sample canister and the purge canister. (Unless using certified media, there is no difference between the two).

3. Attach manifold center fitting to sample canister.

4. Attach purge canister to the Purge Valve end of the manifold by attaching provided Teflon tubing and compression fittings.

5. Confirm that there is a brass cap secured at the inlet of the manifold creating an air tight train, make sure the manifold valve above the purge canister is open, and quickly open and close the purge canister valve in order to check for leaks. If the needle on the gauge drops, your train is not airtight. In this case, try refitting your connections and/or tightening them until the needle holds steady.

Purging

6. Once the sample train is airtight remove the brass cap from the manifold inlet, connect the tubing from the sample port using a compression fitting and open the purge canister valve, 1/2 turn.

7. Monitor integrated sampling progress periodically. *Please note, because the purge canister is inline after the flow restrictor the line will not purge faster than at a rate of 167 ml/min.

8. Once the desired purge volume is met close both the manifold valve and the purge canister valve by hand tightening the knobs clockwise.

9. If sampling at multiple locations, the purge canister can be disconnected from the manifold and used to begin purging the next sample location without compromising the sample train.

Sampling

10. The line is now ready to be sampled. Open the sample canister valve and monitor sampling progress periodically.

11. When the sampling is complete close the valve and replace the brass cap on the canister; record final vacuum of canister (simply read built-in gauge).

12. Fill out canister sample tag (make sure the sample ID and date of collection recorded on the sample tag matches what is recorded on the COC exactly).

13. Return canisters in boxes provided and all parts of the soil gas manifold. **Unreturned media will result in a replacement charged assessed as described in the media agreement**.

14. Fill out chain-of-custody and relinquish samples properly (it is important to note the canister serial numbers on the chain-of-custody).

15. Place chain-of-custody in box and retain pink copy.

16. Ship accordingly to meet method holding times.

Section 4.0 Sampling with Bags

This section provides a description of the types of air sampling bags, selecting the right bag for your application, practical considerations for sampling, and step-by-step instructions for collecting a grab sample. Photographs illustrate the correct way to assemble the various sampling components.

4.1 Introduction to Bags

Air sampling bags are containers used to collect whole air samples for landfill gas, soil gas and stationary source applications. Bags can be constructed from various materials which can differ in terms of stability characteristics and cleanliness. In general, air sampling bags are best suited for projects involving analysis of compounds in the ppmv range. They can be used to collect sulfur compounds, but only if the fittings are non-metallic (e.g., polypropylene, Teflon®, or Nylon).

Air sampling bags are equipped with a valve that allows for filling. Sample collection requires a pressurized sampling port, a low flow rate pump or a lung sampler. The bag expands as the vapor sample is pulled in. When the target volume of the sample is collected, the valve is closed and the bag is returned to the laboratory. Bag materials should be selected based on the specific application. Common air sampling bags include Tedlar film and FlexFoil. Eurofins Air Toxics maintains a limited inventory of air sampling bags in 1 L, 3 L and 5 L volumes.

4.1.1 Tedlar® Film

Tedlar® is a trade name for a polyvinyl fluoride film developed by DuPont Corporation in the 1960's. This patented fluoropolymer has been used in a wide variety of applications including protective surfacing for signs, exterior wall panels and aircraft interiors. Tedlar® film is tough yet flexible and retains its impressive mechanical properties over a wide range of temperatures (from well below freezing to over 200°F). Tedlar® exhibits low permeability to gases, good chemical inertness, good weathering resistance and low off-gassing.

Tedlar® bags may be used to collect samples containing common solvents, hydrocarbons, chlorinated solvents, sulfur compounds, atmospheric and biogenic gases and many other classes of compounds. Compounds with low vapor pressures such as Naphthalene are not appropriate for Tedlar bags as recovery is very low even under short sample storage times. Low molecular compounds such as Helium and Hydrogen can diffuse through the Tedlar bag material resulting in poor storage stability.

4.1.2 Tedlar® Bag Suppliers and Re-use

Compounds commonly detected from analyzing new Tedlar® bags include methylene chloride, toluene, acetone, ethanol, 2-propanol, phenol, and dimethylacetamide. While levels of these common artifacts are typically in the ppbv range, the cleanliness of bags can vary significantly between vendors, and purchasing bags directly from an unknown vendor should be avoided. Once the Tedlar® bag is used for sample collection, the surface has been exposed to moisture and possible VOCs. It may irreversibly adsorb many VOCs at the low ppbv level. A series of purges with certified gas may not remove the VOCs from the surface. Consider your data quality objectives to determine whether re-using Tedlar® bags is appropriate.

4.1.3 Hold Time for a Tedlar® Bag

The media hold time for a Tedlar® bag is indefinite if stored out of sunlight in a cool, dry location.

The sample hold time to analysis varies by method and compound. See Table 4.1.3 for recommended sample storage times for commonly requested parameters.

Table 4.1.3 Recommended Maximum Sample Storage Times for Tedlar® Bags

Analytical Method	Chemical Class	Storage Time
ASTM D5504	Suite of sulfur compounds including Reactive Sulfur compounds (Hydrogen sulfide, Methyl mercaptan)	24 hours
ASTM D1946 ASTM D1945	Atmospheric and natural gases: CO, CO2, CH4, C2-C5 hydrocarbons (He and H_2 not recommended)	Up to 3 days
Modified TO-14A, TO-15, TO-3, TO-12	Volatile Organic Compounds (VOCs)	Up to 3 days

4.1.4 FlexFoil Bags

FlexFoil bags are made from an opaque and flexible material with 4-ply construction resulting in high physical strength to minimize rupture and leakage and low permeability to provide good stability for low molecular weight compounds. FlexFoil bags are ideal for target compounds such as Hydrogen and Helium and can be used for the suite of atmospheric and natural gas components. While the reactive sulfur compounds, Hydrogen Sulfide and Methyl Mercaptan, show good stability over 24 hours in FlexFoil bags, other sulfur compounds demonstrate low recovery. Table 4.1.4 summarizes the compounds and the hold times amenable to FlexFoil bags.

Table 4.1.4 Recommended Maximum Sample Storage Times for FlexFoil Bags

Analytical Method	Chemical Class	Storage Time
ASTM D5504	Hydrogen sulfide, Methyl mercaptan only Not recommended for full sulfur list.	24 hours
ASTM D1946 ASTM D1945	Atmospheric and natural gases Full List	Up to 3 days

4.2 Air Bag Sampling

Using a bag to collect an air sample normally involves “active” sampling, unlike an evacuated canister that can be filled “passively” by simply opening the valve. There are two methods commonly used to fill a bag: a pump or a lung sampler.

- **Sampling with a Pump**: The most common method for filling a bag is to use a small pump with low flow rates (50-200 mL/min) and tubing to fill the bag. Eurofins Air Toxics, Inc. does not provide pumps but pumps may be rented from equipment providers or purchased from manufacturers such as SKC or Gilian.
- **Sampling with a Lung Sampler**: A “lung sampler” may be used to fill a bag. Although a little more complicated than simply using a pump, the main advantage to using a lung sampler to fill a bag is that it avoids potential pump contamination.

A bag with attached tubing is placed in a small airtight chamber (even a 5-gallon bucket can work) with the tubing protruding from the chamber. The sealed chamber is then evacuated via a pump, causing the bag to expand and draw the sample into the bag through the protruding tube. The sample air never touches the wetted surfaces of the pump. Eurofins Air Toxics does not provide lung samplers, but they can be rented from equipment suppliers or purchased by manufacturers such as SKC Inc.

4.2.1 Considerations for Bag Sampling

Some considerations for collecting a bag sample:

- **Fill the bag no more than 2/3 full**: Allow for possible expansion due to an increase in temperature or decrease in atmospheric pressure (e.g., the cargo hold of a plane)
- **Keep the Tedlar® bag out of sunlight**: Tedlar® film is transparent to ultraviolet light (although opaque versions are available) and the sample should be kept out of sunlight to avoid any photochemical reactions
- **Protect the bag**: Store and ship the bag samples in a protective box at room temperature. An ice chest may be used, but DO NOT CHILL
- **Fill out the bag label**: It is much easier to write the sample information on the label before the bag is inflated. Make sure to use a ball-point pen, never a Sharpee or other marker which can emit VOCs.
- **Provide a “back-up” bag**: Consider filling two bags per location in the rare occasion that a defective bag deflates before analysis. The “hold” sample does not need to be documented on the Chain-of-Custody and should have an identical sample ID to the original sample indicating that it is the “hold” sample
- **Avoid Contamination**: Care should be taken to avoid contamination introduced by the pump or tubing. Begin sampling at locations with the lowest compound concentrations (e.g., sample the SVE effluent before the influent). Decontaminate the pump between uses by purging with certified air for an extended period; better yet, use a lung sampler. Use the shortest length possible of Teflon® tubing or other inert tubing. DO NOT REUSE TUBING. If long lengths of tubing are used, consider purging the tubing with several volumes worth before sampling. If you are concerned about sampling for trace compounds, you shouldn’t be using a Tedlar® bag (see Section 1.2)
- **Don’t Sample Dangerous Compounds in a Bag**: Do not ship any explosive substances, radiological or biological agents, corrosives or extremely hazardous materials to Eurofins Air Toxics. Bag rupture during transit to the laboratory is possible and the sampler assumes full liability.

4.2.2 Step-by-Step Procedures for Bag Sampling (Pump)

Note: These procedures are for a typical stationary source (e.g., SVE system) sampling application; actual field conditions and procedures may vary.

Before you get to the field:

1. Verify contents of the shipped package (e.g., chain-of-custody, bag, and tubing/fittings – if requested).
2. Verify pump cleanliness and operation (Eurofins Air Toxics does not provide pumps).

When ready to sample:

3. Purge sample port.
4. Attach new Teflon® tubing from sample port or probe to low flow rate pump.
5. Purge tubing.
6. Fill out bag sample tag.
7. Attach additional new Teflon® tubing from the pump outlet to the bag valve.
8. Open bag valve.
9. Collect sample (FILL NO MORE THAN 2/3 FULL).
10. Close bag valve by hand tightening valve clockwise.
11. Return filled bags in a rigid shipping container (DO NOT CHILL).
12. Fill out chain-of-custody and relinquish samples properly.
13. Place chain-of-custody in box and retain pink copy.

14. Tape box shut and affix custody seal (if applicable) across flap.
15. Ship first overnight or priority overnight to meet method holding times.

Expedite delivery of air sampling bags to the laboratory for analysis.

Section 5.0 Special Sampling Considerations

This section provides recommendations for the collection of field QC samples such as field duplicates. Considerations for sampling at altitude, sampling SVE ports and using sample cylinders are presented.

5.1 Field QC

To measure accuracy and precision of the field activities, project plans often include field duplicates, field blanks, ambient blanks, trip blanks and/or equipment blanks.

5.1.1 Field Duplicate

A field duplicate is a second sample collected in the field simultaneously with the primary sample at one sampling location. The results of the duplicate sample may be compared (e.g., calculate relative percent difference) with the primary sample to provide information on consistency and reproducibility of field sampling procedures. Due to the nature of the gas phase, duplicate samples should be collected from a common inlet. The configuration for collecting a field duplicate includes stainless steel or Teflon® tubing connected to a Swagelok "T". If integrated samples are being collected and the sample duration is to be maintained, the sample train should be assembled as follows: each canister should have a flow controller attached, then the duplicate sampling T should be attached to the flow controllers. If the collection flow rate from the sample port is to be maintained then the duplicate sampling T should be connected to the canisters; then the flow controller is connected to the inlet of the sampling T.

Alternatively, if the project objective is to assess spatial or temporal variability, then field duplicates may be deployed in close proximity (ambient air sampling) or samples may be collected in succession (soil vapor).

5.1.2 Field Blank

A field blank is a sample collected in the field from a certified air source. Analysis of the field blank can provide information on the decontamination procedures used in the field. Clean stainless steel or Teflon® tubing and a certified regulator should be used. It is imperative that individually certified canisters (the sample canister and the source canister/cylinder, if applicable) be used to collect a field blank.

5.1.3 Ambient Blank

An ambient blank is an ambient air sample collected in the field. It is usually used in conjunction with soil gas or stationary source (e.g., SVE system) sampling. Analysis of the ambient blank can provide information on the ambient levels of site contaminants. It is recommended that an individually certified canister be used to collect an ambient blank.

5.1.4 Trip Blank

When sampling for contaminants in water, the laboratory prepares a trip blank by filling a VOA vial with clean, de-ionized water. The trip blank is sent to the field in a cooler with new sample vials. After sampling, the filled sample vials are placed back in the cooler next to the trip blank and returned to the laboratory. Analysis of the trip blank provides information on decontamination and sample handling procedures in the field as well as the cleanliness of the cooler and packaging.

When sampling for compounds in air, a trip blank provides little, if any, of the information above. A trip blank canister can be individually certified, evacuated, and sent to the field in a box with the sample canisters. Since the valve is closed and the brass cap tightened, it is questionable if the trip blank canister contents are ever “exposed” to sampling conditions. The trip blank VOC concentrations essentially provide information regarding the cleanliness and performance of the trip blank canister. Results cannot necessarily be applied to the associated field sample canisters accompanying the trip blank. **Eurofins Air Toxics does not recommend collecting a trip blank for air sampling.**

5.2 Considerations for Sampling at Altitude

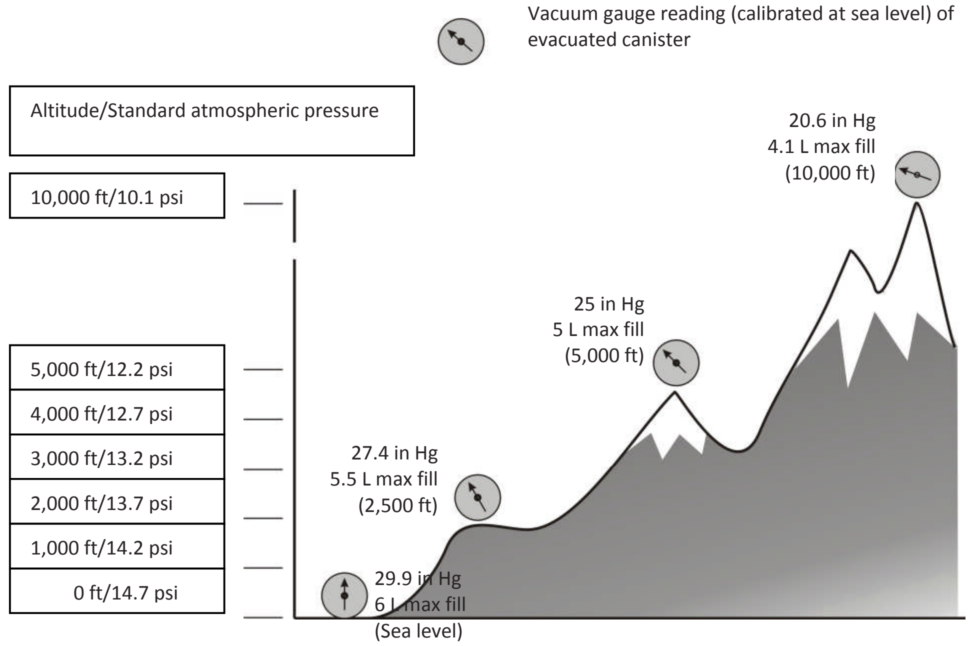
Sampling at altitudes significantly above sea level is similar to sampling a stationary source under vacuum in that target fill volumes may be difficult to achieve. The figure to the right illustrates the relationship between increasing altitude and decreasing atmospheric pressure. Ambient conditions in Denver at 5,000 ft altitude are quite different from ambient conditions at sea level. Canister sampling is driven by the differential pressure between ambient conditions and the vacuum in the canister.

There is less atmospheric pressure in Denver and 5 L is the maximum fill volume of standard air assuming the canister is allowed to reach ambient conditions (i.e., final gauge reading of 0 in Hg). Theoretically, if you sample high enough (e.g., in space), no sample would enter the canister because there is no pressure difference between the evacuated canister and ambient conditions. To fill a canister to 6 L in Denver, you would need to use an air pump.

Sampling at altitude also affects gauge readings. The gauges supplied by Eurofins Air Toxics, Inc. (see Section 2.2.4) measure canister vacuum relative to atmospheric pressure and are calibrated at approximately sea level. Before sampling at altitude, the gauges should be equilibrated (see Section 3.1). But even after equilibrating the gauge, verifying the initial vacuum of a canister at altitude is misleading. In Denver at 5,000 ft, expect the gauge to read 25, not 29.9 in Hg. You do not have a bad canister (i.e., leaking or not evacuated properly). The canister is ready for sampling and the gauge is working properly.

Rule of Thumb: For every 1,000 ft of elevation, the gauge will be off by 1 in Hg and the fill volume will be reduced by 1/5 L.

If you have questions about sampling at altitude, please call your Project Manager at 800-985-5955.



5.3 Considerations for SVE/LFG Collection System Sampling

There are some additional sampling considerations for collecting grab samples (canister or bag) from a Soil Vapor Extraction (SVE) system or landfill gas (LFG) collection system. The general challenge with these samples arises from the need to employ a length of tubing to direct the landfill gas or process air to the canister or bag. Tubing introduces the potential for contamination and diluting the sample.

- **Use inert tubing**. Teflon® tubing is recommended. Tubing with an outer diameter of ¼" works best with the fittings on the particulate filter. (See Section 3.3.1).
- **Do not reuse tubing**.
- **Purge tubing adequately**. A long length of tubing has significant volume of "dead air" inside. Without purging, this air will enter the canister and dilute the sample. Consider using a handheld PID/FID to confirm that you have purged the tubing and are drawing sample air through the tubing.
- **Avoid leaks in the sampling train**. Leaks of ambient air through fittings between pieces of the sampling train (e.g., tubing to particulate filter) will dilute the sample.
- Always use compression fittings for all connections; never use tube in tube connections.
- **Purge the sample port**. A sample port on an SVE system or LFG collection system can accumulate solids or liquids depending upon the location of the port in the process and the orientation of the port. An influent sample port located upstream of a filter or moisture knock-out can be laden with particulates or saturated with water vapor. Heavy particulate matter can clog the particulate filter and foul the canister valve. It is important to prevent liquids from entering the canister. A sample port oriented downward may have liquid standing in the valve. Purge the sample port adequately before connecting the sampling train.
- **Consider the effects of sampling a process under vacuum or pressure**. When collecting a grab sample from a stationary source such as an SVE system or LFG collection system, some sample ports may be under vacuum or pressure relative to ambient conditions. When the sample port is under vacuum, such as the header pipe from the extraction well network, it may be difficult to fill the canister with the desired volume of sample. A vacuum pump may be used to collect a canister grab sample from a sample port under considerable vacuum. See the related discussion on sampling at altitude in Section 5.2. When the sample port is under pressure, such as the effluent stack downstream of the blower and treatment system, you may inadvertently pressurize the canister. Only a DOT-approved sample cylinder should be used to transport pressurized air samples (see Section 5.4). Under no circumstances should a Summa canister be pressurized more than 15 psig. Bleed off excess pressure by opening the valve temporarily while monitoring the canister with a pressure gauge.

5.4 Considerations for Sample Cylinder Sampling

Sample cylinders, also known as "sample bombs", are DOT-approved, high pressure, thick-walled, stainless steel cylinders with a valve at each end. They were intended for collecting a pressurized sample for petroleum gas applications. Sample cylinders differ from sample canisters in that they do not have a Summa-passivated interior surface and are not evacuated prior to shipment. Sample cylinders are not suitable for analysis of hydrocarbons at ppbv levels. Sample cylinders can be used for analysis of natural gas by ASTM D-1945 and calculation of BTU by ASTM D-3588. Eurofins Air Toxics assumes that clients requesting a sample cylinder have a pressurized process and sample port with a built-in gauge and 1/4" Swagelok fitting to attach to the sample cylinder. Eurofins Air Toxics has a limited inventory of 500 mL sample cylinders that are particularly suited for landfill gas collection systems (i.e., LFG to energy applications). This section provides step-by-step procedures for sampling with a sample cylinder.

Inform the lab during project set up if hazardous samples (e.g. high Hydrogen Sulfide concentrations) will be collected to verify the lab can safely handle the samples.

Step-by-Step Procedures for Sample Cylinder Sampling

These procedures are for a typical stationary source sampling application and actual field conditions; procedures may vary. Follow all precautions in the site Health and Safety Plan when dealing with a pressurized sample port and sample cylinder. Follow required DOT guidelines for packaging and shipping.

1. Verify contents of the shipped package (e.g., chain-of-custody, sample cylinder, particulate filter).
2. Verify that gauge on sample port is working properly.
3. Purge sample port.

4. Remove brass caps on either end of cylinder.
5. Attach particulate filter to upstream valve.
6. Attach filter/cylinder assembly directly to the sample port.
7. Open both valves 1/2 turn.
8. Allow sample air to flow through sample cylinder (approximately 10 L for a 500 mL cylinder).
9. Close downstream valve of sample cylinder by hand tightening knob clockwise.
10. Allow sample cylinder to pressurize to process pressure (max 100 psig).
11. Close upstream valve of sample cylinder and sample port.
12. Detach filter/cylinder assembly from sample port and remove particulate filter.
13. Replace brass caps.
14. Fill out sample cylinder sample tag.
15. Fill out chain-of-custody and relinquish samples properly.
16. Include the chain-of-custody with the samples and retain pink copy.
17. Pack, label, and ship according to DOT regulations.

Follow DOT regulations for packaging and shipping hazardous samples.

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Attachment 4

SOP No. 19 – Installation of Temporary Soil Vapor Monitoring Points for Non-Tank Sites

ENVIRONMENTAL WORKS INC.	**Standard Operating Procedure (SOP)**	**Issue Date:** **Updated:** *12/12/2016*
Procedure No. 19 Installation of Temporary Soil Vapor Monitoring Points for Non-Tank Sites		**Technical Reference: Jason Smith** Page: 1 of 6

Skills Required:

1) 40-hour HAZWOPER training (if working on hazardous waste sites)
2) Understanding of, and ability to make decisions regarding, site-specific objectives
3) Training in assembly and proper use of sampling equipment
4) Knowledge of Environmental Works, Inc. (EWI) and the state of Missouri and EPA quality control standards
5) Knowledge of corporate safety requirements and health and safety plan

1.0 OBJECTIVE / APPLICABILITY

This standard operating procedure (SOP) is recommended as a practical approach for the installation of soil gas sampling probes where the intent is to collect a grab sample of subsurface gases. A common use of this SOP is during vapor intrusion assessments associated with subsurface volatile organic compound (VOC) contamination. This SOP should be used when its application is consistent with the project's data quality objectives (DQOs) and in conjunction with the *SOP for the Active Soil Vapor Sampling Using Tedlar® Bags (SOP #10) or Active Soil Vapor Sampling Using Summa Canisters (SOP #10a)*. The project team is responsible for ensuring this procedure meets all applicable regulatory standards and receives approval/concurrence from the leading regulatory agency for the project. This SOP should serve as a reference tool and facilitate consistency among EWI personnel. Only persons trained in the installation of soil gas probes should attempt this procedure.

2.0 Project-Specific Considerations

2.0 As with all intrusive site work, a utility clearance should be performed prior to mobilization. It may also be necessary to acquire permits and site access.

2.1 Soil gas sampling should not be performed until 48 hours after a significant rain event (defined as >1 inch of rainfall).

2.2 It is common practice to install soil gas probes using a drill rig (e.g., Geoprobe). Operation of such machinery shall be performed only by trained and licensed personnel. Soil gas probes can also be advanced with a hand tool method (e.g., the AMS Retract-A-Tip system). The hand tool installation method is only applicable to relatively shallow sampling (e.g., up to 10 to 15 feet below ground surface [ft bgs] depending on the soil type. Gravel or dense clay layers may make the hand tool installation method impracticable).

2.3 Prior to installing soil gas probes there should be an understanding of subsurface conditions at the site such as:

2.3.1 Depth to Groundwater – soil gas samples must be collected in the vadose zone (and above the capillary fringe). Depth to groundwater is estimated by collection of water level from nearby wells and from inferences of soil saturation from nearby soil borings. Target sampling depths will be modified based on observed soil moisture/water table measurements.

2.3.2 Soil permeability

- Additional consideration is needed if attempting to collect soil gas from cohesive, such as clays.
- Target depths may be modified to include horizons of chert fragments, if present near the target horizon as they may offer more permeability for soil gas

2.4 Select the probe interval length – typically probe sample intervals are 1 foot including probe length and sand pack; however, smaller or larger intervals may be selected depending on the project's DQOs.

2.5 Selecting the probe interval.

2.5.1 The top of the soil gas probe should be at least 3 ft bgs to avoid short circuiting with outdoor air. If there is impermeable ground cover (e.g., concrete, asphalt), shallower sampling depths may be considered. In general, target depths are 3 ft and 8 ft bgs knowing that the sample interval includes the probe length and the sand pack.

2.5.2 The bottom of the soil gas probe must be above the capillary fringe. Depths will be modified based on observations of moisture or measurements of the water table depth.

2.5.3 Due to increasing pressure with depth, one may encounter more challenging conditions for installation.

2.5.4 Sampling at multiple depths at each sample location (or a subset of the locations) should be considered to obtain a vertical profile of soil gas conditions if the vadose zone height is long enough. Typically the bottom of a probe should be approximately 5 feet from the top of the probe beneath it; however, if this is not possible, a minimum of 3 feet separation is needed. Multi-depth probes can be installed in one hole by starting with the deepest depth interval and then continuing upward.

3.0 EQUIPMENT/MATERIALS

- Geoprobe Systems® soil gas implant method (the equipment below is typically supplied by the drilling subcontractor)

- Drive rods – 1.25-inch outer diameter (OD) drive rods
- Expendable drive points – steel or aluminum 1.1-inch OD
- Geoprobe Systems ® implants- Several screen lengths are available (nominal 2-inch, 6-inch, 14-inch 21-inch) but for discrete intervals required in vapor intrusion investigations, a nominal 2 -inch screen is typically recommended.
- Probe tubing - 1/4-inch OD Teflon ® tubing
- Probe cap (to seal the tubing during equilibration) – Swagelok part number SS-400-C
- Silica sand to create a permeable layer around the probe screen.
- Bentonite to seal the hole from above the screen to the ground surface.
- Electrical tape
- MultiRae ® five gas meter, or equivalent for health and safety monitoring during drilling and to collect O_2, CO_2 and methane measurements from the subsurface.

Additional Pre-Installation Considerations

- The soil gas probes and equipment must be decontaminated prior to use. Steam cleaning is the preferred method of decontamination; however, a three-stage decontamination process consisting of a wash with a non-phosphate detergent, a rinse with tap water and a final rinse with distilled water may be used. The equipment should be allowed to dry before use. Once decontaminated, the probes must be shown to be free of contaminants. At a minimum, a suitably sensitive organic vapor meter should be used for this purpose. Any probe that does not pass decontamination should not be used.
- Handle and store decontaminated soil gas probes in a manner that prevents contamination.
- Inspect each gas probe assembly for wear and faulty parts. Replace probe tips, o-rings, adapters, and probe rods as needed. New parts and parts in good working condition greatly reduce the chances of ambient air leaking into the soil gas sample, which would require re-installation of the probe.

5.0 Soil Gas Implant Installation

5.1 Assemble the drive point holder, implant anchor/drive point, and drive rod. Drive the rod to the desired bottom screen depth (e.g., for a probe screened from 5.5 ft to 5 feet bgs, the rod should be driven to 5.5 ft). Do not disengage the drive point at this time.

5.1 Attach the 1/4-inch Teflon ® tubing to the probe screen. Use enough tubing so that at least 2 feet will be left above ground. Make sure that the tubing does not spin on the probe screen; if it does, it will not be possible to screw the probe screen into the drive point/anchor. Electrical tape can be used to secure the tubing to the screen. Plug the exposed end of the tubing with the probe cap.

5.2 Remove the drive head and thread the probe screen (Geoprobe Systems ® implant) and tubing down the inside of the drive rod. Once the implant reaches the drive point, turn the tubing counterclockwise with a gentle downward force to thread the screen into the drive point/anchor. Test that the screen is seated by gently pulling up on the tubing. It is very important to ensure that the screen is seated before moving on to the next step.

5.3 Retract the drive rod 12 inches while pushing down on the Teflon ® tubing. This is to ensure that as the rod is being removed while the anchor/drive point and implant stay at depth.

5.4 Thread the tubing through a funnel and place the funnel on top of the drive rod. Determine the volume of sand needed to fill the space around the screen plus an additional 6-inch space above the screen. Remove the cap placed over the end of the tubing. Pour the sand into the funnel and down the inside diameter of the drive rod. Use the Teflon ® tubing to stir the sand pack and ensure the material descends all the way down to the bottom. Do not pull on the tubing. Note: Failure to remove the cap during this step can result in bridging of the sand pack (due to air displacement issue) and therefore an insufficient filter pack around the screen.

5.5 Lift the drive rod up and pour 1 foot of granular bentonite above the sand pack.

5.6 Fill the remaining hole to about 1 foot from the ground surface with hydrated bentonite.

5.7 Wait at least 30 minutes for temporary probes and 24 hours for permanent probes 24 hours before sampling. This ensures that the subsurface has time to equilibrate. Follow the proper sampling procedures as presented in the SOP #10 or SOP #10a.

5.8 When calculating air volume, use the internal volume of the Teflon ® tubing, the internal volume of the screen, and the volume of the sand pack (assume 30 percent porosity).

5.9 After sampling, remove the sampling tube shall be pulled and repair the ground surface to match its original condition.

5.0 References

- Hartman, B., 2006, How to Collect Reliable Soil-Gas Data for Risk-Based Applications-Specifically Vapor Intrusion, Part 4: Updates on Soil-Gas Collection and Analytical Procedures*, LUSTLine Bulletin* 53, September, 2006.
- U.S. Environmental Protection Agency, 2002, Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils (Subsurface Vapor Intrusion Guidance), November 2002.
- Environmental Works, Incorporated, Corporate Health and Safety Plan
- Site Specific Health and Safety Plan

Environmental Works, Inc. SOP No. 19

Installation of Temporary Soil Vapor Monitoring Points for Non-Tank Sites

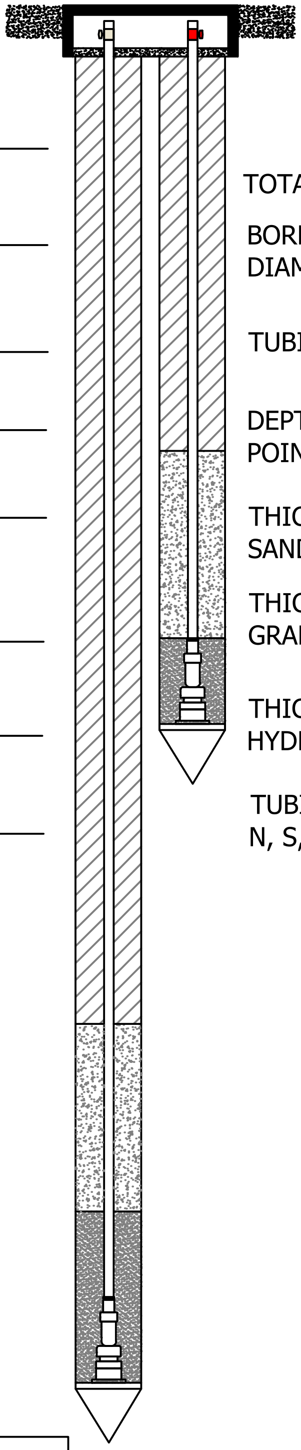
ATTACHMENT

Soil Vapor Well Construction Log

NESTED SOIL VAPOR WELL DIAGRAM

PROJECT NAME: ____________________ SOIL VAPOR WELL: __________ PROJECT NUMBER: ____________________

LAND SURFACE ______________



DEEP SV WELL

TOTAL DEPTH: ____________________

BOREHOLE DIAMETER: ____________________

TUBING OD: ____________________

DEPTH OF SV POINT: ____________________

THICKNESS OF SAND PACK: ____________________

THICKNESS OF GRANULATED BENTONITE: ____________________

THICKNESS OF HYDRATED BENTONITE: ____________________

TUBING LOCATED N, S, E, W, IN VAULT: ____________________

SHALLOW SV WELL

TOTAL DEPTH: ____________________

BOREHOLE DIAMETER: ____________________

TUBING OD: ____________________

DEPTH OF SV POINT: ____________________

THICKNESS OF SAND PACK: ____________________

THICKNESS OF GRANULATED BENTONITE: ____________________

THICKNESS OF HYDRATED BENTONITE: ____________________

TUBING LOCATED N, S, E, W, IN VAULT: ____________________

LOGGED BY: ______________

DRILLED BY: ______________

DATE: ______________

TIME: ______________

KEY

▩ = GROUND SURFACE

▨ = HYDRATED BENTONITE

▦ = SAND PACK

░ = GRANULATED BENTONITE

⊽ = SOIL VAPOR POINT

🟥 = RED VALVE (USED FOR SHALLOW VAPOR WELL)

□ = VALVE

NOT-TO-SCALE

ENVIRONMENTAL WORKS

1[illegible]55 E. [illegible], Springfield, MO 65802