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December 22, 2017

Michael Stroh
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Superfund Section
Hazardous Waste Program
Missouri Department of Natural Resources
P.O. Box 176
Jefferson City, MO 65102-0176

Re: Revised Soil Gas Investigation Work Plan
Former Hulett Lagoon Site
Camdenton, Missouri

Dear Mr. Stroh:

On behalf of Hamilton Sundstrand, Geosyntec Consultants, Inc. is pleased to submit the attached revised Soil Gas Investigation Work Plan for the Former Hulett Lagoon Site in Camdenton, Missouri (Work Plan). The original October 18, 2017 Work Plan was revised based on the Missouri Departments of Natural Resources (MDNR) and Health and Senior Services (MDHSS) comments of November 15, 2017. The revisions to the Work Plan are consistent with Hamilton Sundstrand's December 4, 2017 responses to these comments.

Please don't hesitate to contact me if you have any questions, or would like me to send the revised Work Plan to any other parties.

Sincerely,
Geosyntec Consultants, Inc.

David J. Folkes, PE (CO)
Senior Principal

Attachment

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Prepared for:

Hamilton Sundstrand

Soil Gas Investigation Work Plan

Former Hulett Lagoon

Prepared by:

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engineers | scientists | innovators

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SOIL GAS INVESTIGATION WORK PLAN

Former Hulett Lagoon
Camdenton, Missouri

Revised December 22, 2017

Prepared for:

Hamilton Sundstrand

Prepared by:

Geosyntec Consultants, Inc.
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TABLE OF CONTENTS

Page

TABLE OF CONTENTS I

LIST OF TABLES II

LIST OF FIGURES III

LIST OF APPENDICES IV

1. INTRODUCTION 1

2. BACKGROUND INFORMATION 2

   2.1 Site Setting 2
   2.2 Former Lagoon Operations and Decommissioning 2
   2.3 Previous Investigations 3
   2.4 Current Investigation 3

3. INVESTIGATION APPROACH 4

   3.1 Investigation Objective 4
   3.2 Soil Gas Screening Levels 4
   3.3 Initial Soil Gas Sampling Locations 5
   3.4 Additional Soil Gas Sampling Locations 5
   3.5 Evaluation of Temporal Variability 6
   3.6 Lines of Evidence 7
   3.7 Ability and Limitations of Investigation Approach 7

4. INVESTIGATION PROCEDURES 9

   4.1 Access and Permitting 9
   4.2 Utility Clearance 9
   4.3 Soil Gas Probe Installation and Sampling 9
      4.3.1 Drilling and Probe Installation 9
      4.3.2 Soil Gas Sample Collection 10
   4.4 Soil Gas Sample Analysis 12
   4.5 Quality Assurance/Quality Control 13
   4.6 Investigative Derived Waste 13

5. SCHEDULE AND REPORTING 15

6. REFERENCES 16

LIST OF TABLES

Table 1 VISLs for Compounds of Concern

Table 2 Soil Gas Sample Requirements

LIST OF FIGURES

Figure 1 Site Location Map

Figure 2 Initial Soil Gas Probe Locations

Figure 3 Hypothetical Example of Step-Out Procedure

Figure 4 Potential Decision Matrix

Figure 5 Soil Gas Probe Construction Details – Shallow

Figure 5 Soil Gas Probe Construction Details – Deep

LIST OF APPENDICES

Appendix A – Initial Conceptual Site Model

Appendix B – Standard Operating Procedures

Appendix C – Quality Assurance Project Plan

1. INTRODUCTION

This Soil Gas Investigation Work Plan (Work Plan) presents procedures for evaluating the potential presence of volatile organic compounds (VOCs), specifically trichloroethene (TCE), 1,1,-dichloroethene (DCE), and cis-1,2-dichloroethene (cDCE), in subsurface materials at the former Hulett Lagoon (the former lagoon), and the potential for VOCs, if any, to partition into soil gas and migrate toward nearby structures. The former lagoon is located approximately 1000 feet northeast of the former Modine Manufacturing, Inc. facility at 221 Sunset Drive in Camdenton, Missouri ("Facility"), as shown in Figure 1. The investigation approach and procedures presented in this Work Plan are consistent with those recommended in the U.S. Environmental Protection Agency (EPA) Technical Guide for Assessing and Mitigating the Vapor Intrusion Pathway from Subsurface Vapor Sources to Indoor Air (EPA, 2015).

The following sections of this Work Plan present background information pertinent to the investigation (Section 2); the proposed approach to the investigation, including initial sample locations and step-out procedures (Section 3); field and laboratory procedures (Section 4); the investigation schedule and reporting (Section 5); and references (Section 6).

2. BACKGROUND INFORMATION

This section presents information on the site setting, former lagoon operations and decommissioning, and the results of previous soil and groundwater investigations in the former lagoon vicinity. More detail is provided in the initial Conceptual Site Model (CSM) in Appendix A.

2.1 Site Setting

The former lagoon is located within a low-lying, wooded area approximately 1000 feet northeast of the Facility (Figure 1). The former lagoon property is owned by the City of Camdenton, Missouri. The current ground surface elevation at the former lagoon is approximately 930 to 940 feet above mean sea level (amsl). Multi-family residential buildings are located approximately 150 feet north and single-family homes are located approximately 250 feet south, 300 feet west, and 200 feet southwest of the former lagoon boundaries.

The former lagoon is now an open field covered with grass and a few small trees and shrubs. Dolomite bedrock is overlain by approximately 4 to 12 feet of silt and clay-textured soil in the immediate vicinity of the former lagoon, increasing in thickness (up to 55 feet) as the ground rises to the north and south (SECOR, 2008).

The first saturated groundwater zone, encountered in the dolomite bedrock at a depth of greater than 100 feet below ground surface[1] at the former lagoon, is a sporadic and discontinuous perched zone, hydraulically separated from a deeper, more extensive aquifer by argillaceous intervals in the dolomite (SECOR, 2008).

2.2 Former Lagoon Operations and Decommissioning

The former lagoon was an above-grade sewage lagoon operated by the City of Camdenton from 1961 through 1989, when it was decommissioned by removing accumulated sludge, removing inlet and outfall structures, and regrading the former lagoon area using material from the excavation sidewalls (SECOR 2004, 2008). During a portion of the period of operation, wastes from the Facility were discharged to the former lagoon.

[1] Groundwater elevations in perched zone wells have typically ranged from 817 to 828 feet amsl at and in the vicinity of the former lagoon (SECOR, 2004).

2.3 Previous Investigations

Investigations by the Missouri Department of Natural Resources (MDNR) and Hamilton Sundstrand in the 1990s and early 2000s, respectively, indicated that VOCs were present in soil and groundwater in and around the former lagoon (MDNR, 1999 and SECOR, 2003). VOC detections within the former lagoon footprint were limited to 4 of 25 locations sampled by MDNR and Hamilton Sundstrand, as summarized on Figure 2. TCE and cDCE were the only two VOCs detected in the soil, at concentrations ranging from 120 to 9,500 parts per billion (ppb) and 110 to 650 ppb, respectively. No soil remedial action was considered necessary based on these results (SECOR, 2003). TCE and cDCE were also detected in monitoring wells installed in the perched zone (at a depth of greater than 100 feet below the former lagoon) near the former lagoon (MW-5, MW-8, and MW-25). TCE concentrations in wells on the south side of the former lagoon ranged from 99 to 560 ppb in MW-5 and from 252 to 550 in MW-8 between 2006 and 2008. cDCE was less than 30 ppb in both wells over the same period. TCE and cDCE concentrations in MW-25, on the north side of the former lagoon, ranged from 474 to 1,200 ppb and 29 to 74 ppb, respectively, from late 2007 through 2008 (Stantec, 2009).

A feasibility study and remedial actions since the remedial investigation in 2003 have focused on protecting municipal drinking water supplies in the deep aquifer by pumping from a former water supply well known as the Mulberry Municipal Well (SECOR, 2004, 2008).

2.4 Current Investigation

In August 2017, MDNR asked Hamilton Sundstrand to determine if the former lagoon could be a source of potential VOC vapors. This Work Plan is intended to characterize the nature and extent of VOC vapors, if any, in and around the former lagoon, and to determine whether there is a need for further vapor intrusion investigations associated with the former lagoon.

3. INVESTIGATION APPROACH

This Work Plan is based on an initial CSM (see Appendix A) and site-specific data quality objectives (see Appendix C), as recommended by EPA (2015). The investigation is intended to characterize the nature and extent of potential VOCs in soil gas due to migration in the vadose zone associated with the former lagoon.

The following sections describe the proposed investigation objectives, the EPA VI screening levels (VISLs), procedures for characterizing the nature and extent of VOC migration in the vadose zone associated with the former lagoon, quarterly monitoring of potential VOC concentrations in soil gas associated with the former lagoon, and the lines of evidence that will be considered during data evaluation.

3.1 Investigation Objective

The objectives of this investigation include characterizing the nature and extent of potential VOCs in soil gas in both space and time due to migration, if any, associated with the former lagoon; establishing a site-specific VI inclusion zone[2], if necessary, based on observed soil gas migration behavior; and, if necessary, determining whether any occupied or potentially occupied buildings are located within the VI inclusion zone associated with the former lagoon, as recommended by EPA (2015). If VOCs are detected in soil gas at concentrations exceeding the EPA Residential VISL set forth in Table 1 of the Work Plan, Hamilton Sundstrand will prepare and submit without delay a work plan to evaluate the potential for VI in any buildings, if any, determined to be within the VI inclusion zone associated with that sample. Assessment of the potential for VI in any buildings within the VI inclusion zone associated with the former lagoon would be based on this work plan, if necessary. If no buildings are located within the VI inclusion zone associated with the former lagoon, soil gas sampling will be repeated over the subsequent three quarters to evaluate the potential for changes in the concentration and extent of VOCs in soil gas, if any, over time. The need for further action would be based on evaluation of multiple lines of evidence, as discussed below.

3.2 Soil Gas Screening Levels

If detected, the soil gas VOC concentrations, specifically TCE, will be compared to the residential EPA VI Screening Level (VISL) values for sub-slab and exterior soil gas, based on a

[2] EPA (2015) notes that VI inclusion zones have often been based on a distance of 100 feet laterally and vertically from VOC vapor sources, but recommends determining a site-specific distance based on the results of investigations.

target risk of 1 x 10^{-5} for carcinogens and a target hazard quotient of 1 for non-carcinogens (EPA, 2016). Currently, EPA does not have a VISL for cDCE (EPA, 2016). VISLs for the compounds of concern at the former lagoon are shown in Table 1. EPA indicates that the VI pathway is unlikely to be complete when "near source" soil gas concentrations are below VISLs. At the same time, exceedance of the VISLs does not necessarily mean that the VI pathway is complete, or that indoor air target concentrations are exceeded (EPA, 2015, 2016).

3.3 Initial Soil Gas Sampling Locations

Characterization of the nature and extent of potential VOCs in soil gas associated with the former lagoon will be based on sampling and analysis of soil gas according to the sample collection and analytical procedures described in Section 4. Soil gas samples will be collected at nominal depths of 5 feet and 10 feet below ground surface to represent typical foundation depths for slab-on-grade or crawl space and basement homes, respectively, unless bedrock is encountered at shallower depths. The depth to bedrock (clay thickness) varies from approximately 4 to 12 feet in the immediate vicinity of the former lagoon, increasing as the ground rises to the north and south (see initial CSM, Appendix A).

The initial soil gas samples will be collected from soil gas probes installed at an approximate 50-foot spacing around the perimeter of the former lagoon (see Figure 2). As a result, any location with elevated VOC concentrations at the edge of the former lagoon will be within 25 feet of a soil gas probe.

One of the initial soil gas probes will be installed close to monitoring well MW-5, where VOC concentrations in the perched groundwater zone (at a depth of greater than 100 feet below the former lagoon) have been elevated during past investigations. Additionally, one of the soil gas probes will be installed at the approximate location of the former inlet pipe located at the southwest corner of the former lagoon. Because of the depth of the perched groundwater zone, any VOCs detected in the vadose zone soil gas at the edge of the former lagoon are more likely to be due to residual levels in the soil or weathered bedrock; nevertheless, the soil gas probes will also reflect VOC contributions from the perched groundwater zone, if any.

3.4 Additional Soil Gas Sampling Locations

Soil gas samples will be analyzed in the field using a mobile laboratory (see Section 4), so that additional soil gas probes can be installed, as needed, during the same field event. Replicate samples will be collected at a rate of 1 in 5 samples (20%) and submitted to a fixed-base

laboratory for comparison to mobile laboratory results for quality control purposes (see Section 4.5).

Three additional soil gas probes[3] will be installed approximately 50 to 100 feet[4] beyond any initial location where a TCE VISL is exceeded, as shown by the hypothetical example in Figure 3. If TCE is detected below the VISL, but other VOCs (e.g., DCE, cDCE or vinyl chloride) are detected, we will evaluate the concentration levels to determine if additional step-out soil gas probes are necessary (e.g., if the VISLs for other VOCs are exceeded). In general, we will attempt to minimize step-out distances beyond 100 feet, but access restrictions, including dense forest, may require installation of probes at greater step-out distances.

The investigation will continue to step out from the former lagoon following the above procedure until the extent of potential VOCs, in particular TCE, exceeding VISLs associated with the former lagoon is characterized.

To assess the degree of variability of VOC concentrations in soil gas over a short distance, at two locations where VOCs are detected, Hamilton Sundstrand will conduct High Volume Sampling (HVS), to evaluate the change in VOC concentrations with increasing purge volume. One of these locations is anticipated to be where the former inlet pipe discharged to the former lagoon. Soil gas will be extracted at a constant vacuum and flow rate will be measured to estimate the radius of influence of the test over time. Photoionization detector (PID) readings will be made at regular intervals, and samples will be collected and analyzed by the mobile laboratory at the beginning (the original sample), middle, and end of the test. This approach was developed by McAlary, et al. (2010) specifically to evaluate changes in soil gas concentrations with distance, along with other information related to soil air permeability and transmissivity.

3.5 Evaluation of Temporal Variability

Soil gas VOC concentrations can vary over time due to changes in soil temperature, soil moisture, barometric pressure, and long-term depletion of source mass. The resulting temporal variability is likely limited at the former lagoon because of the relatively low diffusivity of the

[3] Note that if VISLs are exceeded in adjacent initial soil gas probes, some of the additional soil gas probes may serve two of the initial soil gas probes.

[4] Step-out distances will range from approximately 50 to 100 feet, depending on the distance to the nearest buildings in the step-out direction. In general, shorter (e.g., 50 foot) step-out distances will be employed when buildings are closer, and longer (e.g., 100 foot) step-out distances will be employed when buildings are farther away. Hamilton Sundstrand believes that this approach will rapidly extend the investigation area, if needed, while providing good areal coverage closer to buildings. The actual step-out distances may also be controlled by access.

clay soils, which limits the rate of VOC mass flux and resultant changes in concentration over time. Nevertheless, soil gas samples will be collected for three additional quarters following the initial sampling event to evaluate temporal variability and the resultant impact, if any, on the extent of VOC concentrations above VISLs.

3.6 Lines of Evidence

EPA and most state and industry VI guidance documents recommend that the potential for VI be based on multiple lines of evidence (e.g., EPA, 2015; ITRC, 2007). Several lines of evidence have already been considered during preparation of the initial CSM (Appendix A) and scoping of this investigation. The lines of evidence that will be considered when evaluating the results of this soil gas investigation include, but are not necessarily limited to:

- Former lagoon operations and decommissioning procedures
- Soil and bedrock geology
- Hydrogeologic conditions including depth to groundwater
- Soil, soil gas, and groundwater data at and near the former lagoon
- Soil gas data from this investigation
- Building locations, proximity, type
- Preferential vapor migration pathways
- Climate and meteorological conditions during sampling events
- Temporal variability

A potential decision matrix or flow chart illustrating the investigation approach is shown in Figure 4.

3.7 Ability and Limitations of Investigation Approach

As indicated in the Quality Assurance Project Plan (QAPP) provided in Appendix C, the principal objectives of the QAPP pertain to the collection of data that are sufficient to evaluate the possible presence and concentration of constituents in the media of interest, in this case, VOC concentrations in soil gas around the former lagoon.

The investigation approach proposed in this Work Plan was developed to assess whether soil gas exceeding action levels is migrating from the former lagoon, rather than characterizing the nature of any potential soil gas volume (e.g., mean concentrations, variance). Therefore, the probability that the proposed sampling scheme adequately characterizes the potential extent and, therefore, determines whether any buildings are within the VI inclusion zone, is the statistical parameter of

concern. If step-out soil gas sampling indicates that a building could fall within the VI inclusion zone, then the nature and extent of soil gas concentrations in the immediate building vicinity will become the objective. Thus, the subsequent VI evaluation work plan, if necessary, would address this sampling goal.

We also note that the HVS discussed in Section 3.4 will provide information regarding the variability of concentrations over short distances, and the four quarters of soil gas sample collection described in Section 3.5, will provide a statistical measures of the spatial temporal variability of the boundary of any soil gas concentrations above VISLs.

4. INVESTIGATION PROCEDURES

Investigation activities will be completed according to the procedures described below.

4.1 Access and Permitting

Prior to mobilization, site access will be secured and a City of Camdenton Right-Of-Way (ROW) permit for performing drilling activities will be obtained, if required, to complete the proposed scope of work near the former lagoon.

4.2 Utility Clearance

Prior to mobilization to the former lagoon, Missouri One Call will be contacted to locate known public utilities near the proposed soil gas probe locations. Additionally, a private utility location service may be contacted to scan for subsurface utilities using ground-penetrating radar (GPR) if the potential for private underground services appears significant. Proposed soil gas probe locations may be relocated based on the results of the utility clearance process.

4.3 Soil Gas Probe Installation and Sampling

Soil gas probe installation, construction, and sampling procedures are identified below.

4.3.1 Drilling and Probe Installation

Soil gas probes will be advanced using a direct-push drill rig. Borehole soil cores will be logged by an experienced field technician and recorded on borehole logs. Soil samples will be collected by continuous samplers from ground surface to the total depth of each borehole and will be logged for visual descriptions and screened for the presence of organic vapors utilizing a PID and recorded at one-foot intervals in parts per million (ppm) on borehole logs. Shallow and deep soil gas probes will be installed in separate, adjacent boreholes.

Shallow soil gas probes will be installed at a depth of approximately four to five feet below ground surface (ft bgs) using 1/4-inch Nylaflow® tubing connected via speed-fit fitting to a six-inch-long, ¼-inch diameter stainless steel sampling screen. Deep soil gas probes will be installed at a depth of approximately nine to ten ft bgs using the same materials. A filter pack consisting of clean sand or glass beads will be placed in the annulus to a height of approximately three inches above the screen. Granular bentonite will be placed and wetted in two lifts of approximately three inches each above the filter pack and then a thick slurry of powdered

bentonite and water will be added to seal the remainder of the borehole annulus to ground surface. The top of each soil gas probe will be fitted with a valve to maintain an air-tight seal.

As reported in the Remedial Investigation Summary Report (SECOR, 2003), in June 2000, a total of 15 soil borings were advanced via Geoprobe® within the footprint of the former lagoon. All borings were advanced until meeting refusal within the upper (weathered) dolomite bedrock. Depths of refusal ranged from 4.5 ft bgs in GP-8 to 11.5 ft bgs in GP-14. Therefore, the actual depth of each soil gas probe may be modified in the field during advancement of the soil borings.

Shallow and deep soil gas probe construction details are shown in Figures 5 and 6, respectively. A copy of the Soil Gas Probe Installation Standard Operating Procedure (SOP) is provided in Appendix B. A copy of the borehole log form is provided in Appendix C.

4.3.2 Soil Gas Sample Collection

Soil Gas Probe Purging – Moderate to High Permeability Soils
After soil gas probe installation, the soil gas probes will be allowed to rest for at least 2 hours and when practical, for 24 hours[5], then purged by removing a minimum of one liter of soil gas. Purging will be completed at a flow rate of 200 milliliters per minute (mL/min) or less using a lung box and Tedlar® bag, then screened with a PID for VOCs and a GEM 2000 landfill gas meter for oxygen, carbon dioxide and methane (O2/CO2/CH4). During purging and sampling, a vacuum gauge will be attached to the sampling train. If a flow rate of 100 mL/min cannot be sustained at the maximum applied vacuum of 100 inches of water column ("WC), purging will be stopped and low permeability soil gas purging and sampling measures will be implemented as described in the following section.

If the permeability is sufficient to allow reasonable flow rates, soil gas will be screened for PID and O2/CO2/CH4 field measurements for a minimum of three successive Tedlar® bag samples to confirm stable readings prior to collection of a sample for mobile laboratory analysis.

To ensure the collection of representative soil gas samples, each soil gas probe will be leak tested by placing a small plastic shroud filled with a minimum concentration of 10% helium (He) to serve as a tracer. During purging activities, soil gas will be screened for the presence of He using a MDG-2002 helium detector to determine if there are leaks in the sampling train. If He concentrations >1% of the shroud concentration are observed in the purged soil gas, the soil gas

[5] EPA (2015) recommends 2 hours for driven probes and 24 hours for probes installed using augers.

probe seal will be checked and/or enhanced to reduce the infiltration of ambient air into the probe and another purge sample collected. If He concentrations of less than 1% of the shroud concentration are observed, stabilized soil gas readings will be recorded.

Once the integrity of the sampling train has been established, soil gas samples will be collected for mobile laboratory analysis as described below.

Soil Gas Probe Purging – Low Permeability Soils
If low permeability sampling measures are encountered during soil gas purging or sampling, the following alternative approaches will be implemented, in succession if required, to facilitate sample collection:

1. A modified purging and sampling procedure will be implemented based on a study conducted by McAlary and others (McAlary, et al., 2009). Once the vacuum threshold (i.e., vacuum of 100”WC is obtained and it is determined that a flow rate of 100 mL/min is not sustainable), the probe valve will be closed to allow the vacuum to dissipate and to allow soil gas to slowly enter the sand pack and tubing from the surrounding soils. When the vacuum dissipates, the probe valve will be reopened, and another aliquot of sample collected. This procedure will be repeated until the soil gas probe is adequately purged and sampled. In this manner, probes can be appropriately purged and enough sample volume can be collected for analysis.

2. A new soil gas probe will be installed at an adjacent location within a more permeable lithology, if such exists. Standard soil gas purging and sampling procedures will be implemented. If low flow or no flow conditions are encountered, the modified purging and sampling procedure (identified in Step 1 above) will be implemented.

3. A new soil gas probe will be installed with a sand pack larger than traditional size. Standard soil gas purging and sampling procedures will be implemented. If low flow or no flow conditions are encountered, the modified purging and sampling procedure (identified in Step 1 above) will be implemented.

A copy of the typical Soil Gas Sampling SOP is provided in Appendix B. A copy of the soil gas sampling form is provided in Appendix C.

4.4 Soil Gas Sample Analysis

Mobile Laboratory

Following soil gas probe purging, soil gas samples will be collected for mobile laboratory analysis using Pace Analytical Mobile Lab Services (PACE), a Missouri certified mobile laboratory. Soil gas samples will be collected utilizing a SKC Inc., 500 ml Tedlar bag® (or other suitable containers) provided by PACE at a flow rate of 200 ml/min or less. PACE will be utilized to provide real-time laboratory analysis of soil gas samples to guide the installation of additional, "step-out" soil gas probes. The mobile lab will perform soil gas analysis utilizing EPA Method 8260[6] with nominal reporting limits (RLs) of 20 ug/m^3 for TCE, DCE, and cDCE with method detection limits (MDLs) for TCE and DCE of 5.4 and 5.8 ug/m^3, respectively. (both below the VISLs for sub-slab and exterior soil gas). Currently, EPA does not have a VISL for cDCE (EPA, 2016). Analytical results from both shallow (5 ft bgs) and deep (10 ft bgs) soil gas probes will be evaluated in real time and compared to current EPA VISLs.

Based on the results of mobile laboratory analysis, if required, additional "step-out" soil gas probes will be installed as described in Section 3.4..

Proposed soil gas analytical procedures, sample containers, and analytical methods are shown on Table 2. A copy of the typical Soil Gas Sampling SOP is provided in Appendix B. A copy of the soil gas sampling form is provided in Appendix C.

Fixed-Base Laboratory

To confirm mobile laboratory results, soil gas samples will be collected from 20% of the new soil gas probes (minimum of 2 samples) and submitted to a fixed-base laboratory for confirmation VOC analysis. To ensure that the full range of observed VOC concentrations are captured, sample locations will be selected so that the soil gas probes with the highest and lowest observed VOC concentrations are sampled during confirmation sampling. Soil gas samples will be collected following the same purging and leak testing procedures describe above. Soil gas samples will be collected utilizing 200 mL/min flow controllers and 1 liter Summa canisters for

[6] EPA SW-846 Method 8260 also lists the air matrix (inter alia) as being a viable medium (e.g., Method 8260 Section 1.1 and Section 1.2). In addition, Section 1.2. of the method reads "For air samples, Method 5041 provides methodology for desorbing volatile organics from trapping media (Methods 0010, 0030, and 0031). In addition, direct analysis utilizing a sample loop is used for sub-sampling from Tedlar® bags (Method 0040)." PACE Analytical Mobile Lab Services used Method 8260B to develop an air-specific Method 8260, for use in soil gas studies, for lower concentrations (approx. 4 – 8 parts per billion by volume (ppbv) range). The method uses Method 8260 GC/MS technology for compound separation, identification, and quantification, and uses two sample preparation techniques: direct injection and solid-phase micro-extraction (SPME). In both techniques, the GC/MS is operated in SIM mode, and typical Method 8260 surrogates and internal standards are used for quantification.

VOC analysis by EPA Method TO-15. Additionally, during this process, the mobile laboratory will be utilized to analyze a second sample from which the results can be compared to the initial results to assess "repeatability" of VOC concentrations.

During soil gas sampling, ambient air samples will be collected at the same time as soil gas near the former lagoon. One ambient air sample will be collected per day from a representative/upwind location and analyzed for VOCs by EPA Method 8260 to provide information on potential background levels of compounds of concern due to ambient air.

4.5 Quality Assurance/Quality Control

This investigation Work Plan has been prepared consistent with the data quality objectives included in the Quality Assurance Project Plan provided in Appendix C.

The field instruments used to ensure that the concentrations of VOCs, O2, CO2 and CH4 in the purge gas have stabilized before collecting a sample for laboratory analysis will be calibrated according to manufacturer's instructions, and calibration checks will be performed at the beginning and end of each field day throughout the monitoring program. A He shroud will also be used to detect any leaks in the sampling train. If the He concentration does not exceed 1% of the minimum concentration of He in the shroud, then the sampling setup will be considered suitable for sample collection.

Prior to deployment to the site, sample canisters and air flow regulators will be cleaned and blank checked according to EPA Method TO-15 standards by the laboratory. For QA/QC purposes, duplicate and replicate samples will be collected at a rate of one per every five mobile laboratory samples. All Summa canisters and flow controllers will be batch certified by the laboratory.

Standard laboratory quality control tests and procedures will be conducted pursuant to EPA Method requirements. All soil gas sample data will be reviewed, validated, and verified in terms of their ability to satisfy quality assurance requirements.

4.6 Investigative Derived Waste

The drilling rods will be decontaminated before initial use and between boreholes. The drilling equipment and tooling will be steam-cleaned or brushed with a decon-solution to remove any residual soil or aquifer material. The decontamination fluids and soil cuttings from the direct-

push borings will be placed in separate 55-gallon drums for management by Hamilton Sundstrand in accordance with applicable local, state, and federal regulations.

5. SCHEDULE AND REPORTING

The soil gas investigation will begin within 30 days of approval of this Work Plan by MDNR, access, contractor schedules, and weather permitting. The initial soil gas probes around the perimeter of the former lagoon will be installed and soil gas samples collected and analyzed within one week of mobilization of drilling and mobile laboratory equipment to the field, access and weather permitting.

Initial investigation (including step-out samples, if needed) mobile laboratory and fixed-base laboratory analytical results will be submitted to MDNR within 45 days of receipt of all final data, to allow time for data verification and validation.

Hamilton Sundstrand will submit a technical report to MDNR within 15 business days of submitting the laboratory data, which will include a description of the field and lab procedures, a discussion of data quality, and tabular and map view summaries of the results. More detailed lines of evidence evaluation of the potential for VI will be included in the final technical report, as discussed below.

This schedule assumes that no buildings are found to be located within the 100 foot VI inclusion zone after the initial investigation; if any buildings are found to be located within the 100 foot VI inclusion zone, Hamilton Sundstrand will submit a VI evaluation work plan for any structure of concern without delay. The goal of the VI evaluation work plan, if required, would be to assess the potential for indoor air to exceed VISLs due to migration of soil gas from the former lagoon, based on a phased or step-wise process beginning with exterior soil gas samples and screening levels, and rapidly progressing to sub-slab soil gas and indoor air tests as necessary. The VI evaluation work plan will provide data quality objectives, standard operating procedures consistent with EPA (2015), and a discussion of the step-wise process.

Quarterly monitoring of the soil gas probes will be conducted for three quarters (resulting in 4 consecutive quarters of data) following the investigation. The laboratory analytical results for each quarter will be submitted to MDNR within 45 days of receipt of final data following data verification and validation.

A final technical letter report, including an updated CSM and evaluation of multiple lines of evidence, will be submitted to MDNR within 90 days of receipt of final data following the last quarter of sampling.

6. REFERENCES

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TABLES

TABLE 1

Vapor Intrusion Screening Levels for Compounds of Concern
Former Hulett Lagoon, Camdenton, Missouri

Analyte[1]	Toxicity Basis[2]	EPA VISL[3,4]	Laboratory (RL / MDLs)[5]	
		Target Sub-Slab and Exterior Soil Gas Conc.	Mobile Lab (Method 8260)	Fixed-Base Lab (Method TO-15)
Tetrachloroethene	C	1,400	20 / 5.1	9.0 / 3.4
Trichloroethene (TCE)	C	70	20 / 5.4	7.1 / 2.7
1,1-Dichloroethene (DCE)	C	7,000	20 / 5.8	5.3 / 2.0
Cis-1,2-Dichlorothene (cDCE)	---	No Inhalation Toxicity Info	20 / 6.2	5.3 / 2.0
Trans-1,2-Dichloroethene (tDCE)	---	No Inhalation Toxicity Info	20 / 7.1	5.3 / 2.0
Vinyl Chloride	C	56	20 / 4.0	3.4 / 1.3

Notes:
1) TCE and cDCE have been historically detected in soil and/or groundwater samples collected at or near the former Hulett Lagoon. TCE, DCE, and cDCE are considered the primary compounds of concern. Additional volatile compounds commonly reported with TCE and cDCE are provided for reference.
2) C=Carcinogenic; --- = Not Available.
3) EPA Vapor Intrusion Screening Levels (VISLs) presented in micrograms per cubic meter (ug/m^3).
4) EPA Residential Exposure Scenario (TR=1E-05, HQ=1), July 2016.
5) Estimated mobile and fixed-base laboratory reporting limit (RL) and method detection limit (MDL). Detections between the RL and MDL will be reported and flagged by the laboratory with a “J” qualifier to indicate that these are estimated results. Presented in ug/m^3.

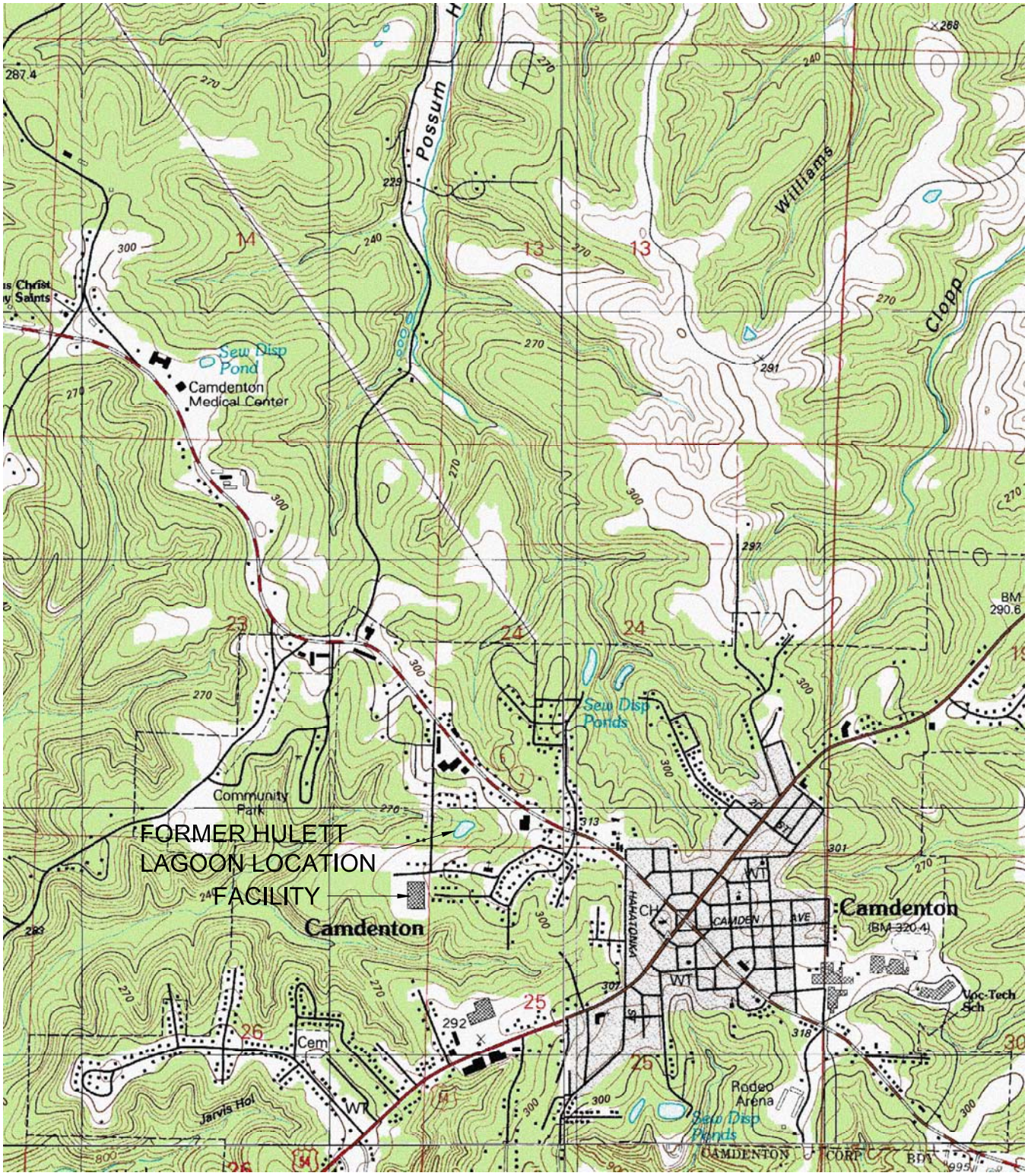
TABLE 2

Soil Gas Sample Requirements[1]
Former Hulett Lagoon, Camdenton, Missouri

Laboratory Type	EPA Method	Sample Container Type	Minimum Sample Volume	Purge/Sample Collection Rate	Preservative	Holding Time
Mobile Laboratory	8260	SKC, Inc. Tedlar Bag	500 ml	< 200 ml/min	None, Cool 4°C	3 Days
Fixed-Base Laboratory	TO-15	Summa Canister	1 L	< 200 ml/min	None	30 Days

Notes:
1) Soil gas sample requirements may change based on mobile or fixed-base laboratory requirements.

FIGURES



N

0 2000' 4000'

SCALE IN FEET

SITE LOCATION MAP
FORMER HULETT LAGOON
HAMILTON SUNDSTRAND
CAMDENTON, MISSOURI

Geosyntec consultants

FIGURE 1

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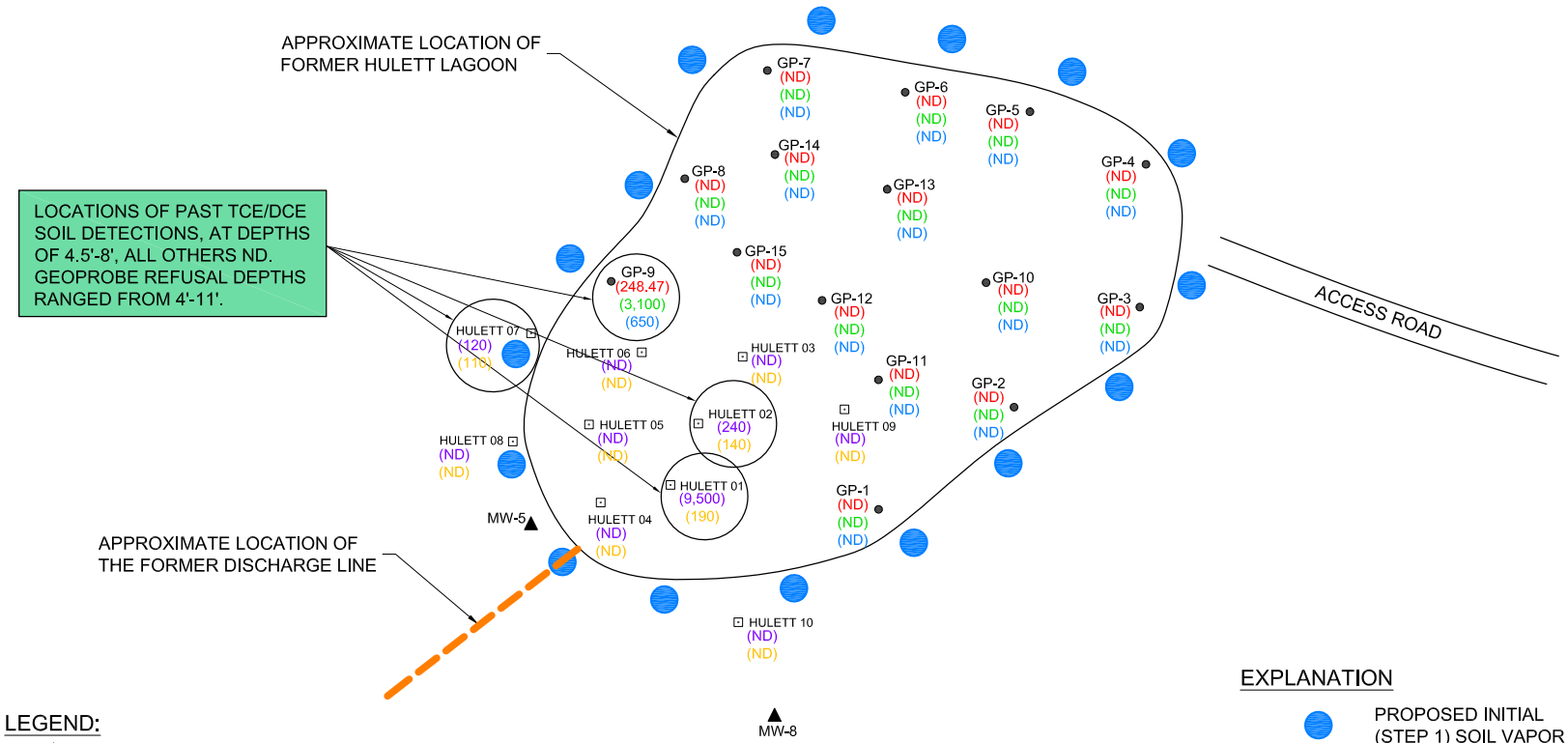
DECEMBER 2017

R:\2_INACTIVE GEOSYNTEC PROJECTS\GEOSYNTEC\MEM1501\SHEET FILES\SITE LOCATION MAP -FIGURE1



LEGEND:

- ▲ MONITORING WELL LOCATION
- ● SECOR SOIL BORING LOCATION, JUNE 2000
- ⊡ MDNR SOIL BORING LOCATION, JANUARY 1999
- (248.47) TCE CONCENTRATIONS IN µg/L, MOBILE LABORATORY - SECOR
- (3,100) TCE CONCENTRATIONS IN µg/kg, FIXED BASE LABORATORY - SECOR
- (650) DCE CONCENTRATIONS IN µg/kg, FIXED BASE LABORATORY - SECOR
- (9,500) TCE CONCENTRATIONS IN µg/kg, MDNR
- (190) TCE CONCENTRATIONS IN µg/kg, MDNR
- (ND) = NOT DETECTED

NOTE:

1. A SOIL VAPOR PROBE WILL BE LOCATED AT THE FORMER DISCHARGE LINE DISCHARGE LOCATION.

SOURCE: MDNR 1999 AND SECOR 2003.

EXPLANATION

● PROPOSED INITIAL (STEP 1) SOIL VAPOR PROBE LOCATIONS

N

0 100' 200'

SCALE IN FEET

INITIAL SOIL VAPOR PROBE LOCATIONS
FORMER HULETT LAGOON
HAMILTON SUNDSTRAND
CAMDENTON, MISSOURI

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FIGURE 2

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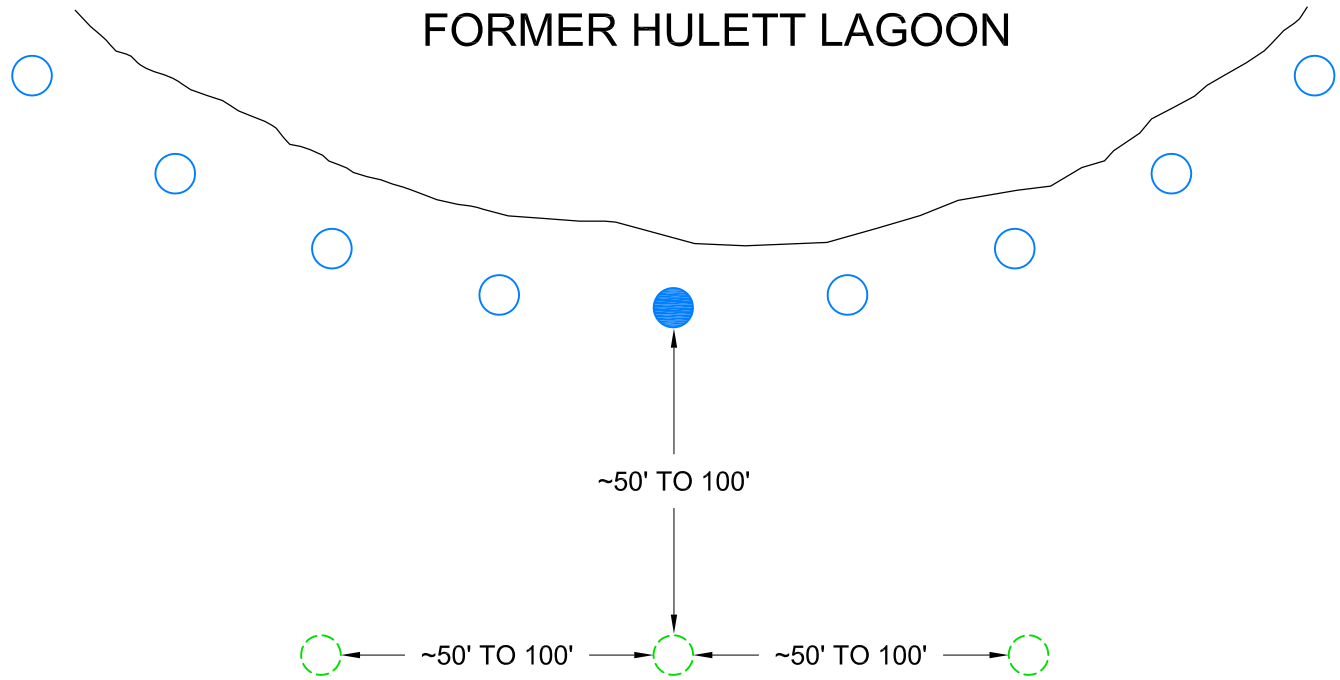
R:\2_INACTIVE GEOSYNTEC PROJECTS\GEOSYNTEC\MEM1501\SHEET FILES\FIGURES 2-3-4-5-APPA



EXPLANATION

- STEP 1 SAMPLE ≤ VISL
- STEP 1 SAMPLE > VISL
- STEP 2 SAMPLE LOCATIONS (BIASED TOWARD RESIDENTIAL BUILDINGS IF APPLICABLE)

NOTES:

1. STEP-OUT DISTANCES WILL RANGE FROM APPROXIMATELY 50 TO 100 FEET, DEPENDING ON THE DISTANCE TO THE NEAREST BUILDINGS IN THE STEP-OUT DIRECTION. IN GENERAL, SHORTER (E.G., 50 FOOT) STEP-OUT DISTANCES WILL BE EMPLOYED WHEN BUILDINGS ARE CLOSER, AND LONGER (E.G., 100 FOOT) STEP-OUT DISTANCES WILL BE EMPLOYED WHEN BUILDINGS ARE FARTHER AWAY. ACTUAL STEP-OUT DISTANCES MAY ALSO BE CONTROLLED BY ACCESS.

2. STEP 3 LOCATIONS, IF NEEDED, WOULD FOLLOW SAME RATIONALE.

HYPOTHETICAL EXAMPLE OF
STEP-OUT PROCEDURE
FORMER HULETT LAGOON
HAMILTON SUNDSTRAND
CAMDENTON, MISSOURI

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FIGURE 3

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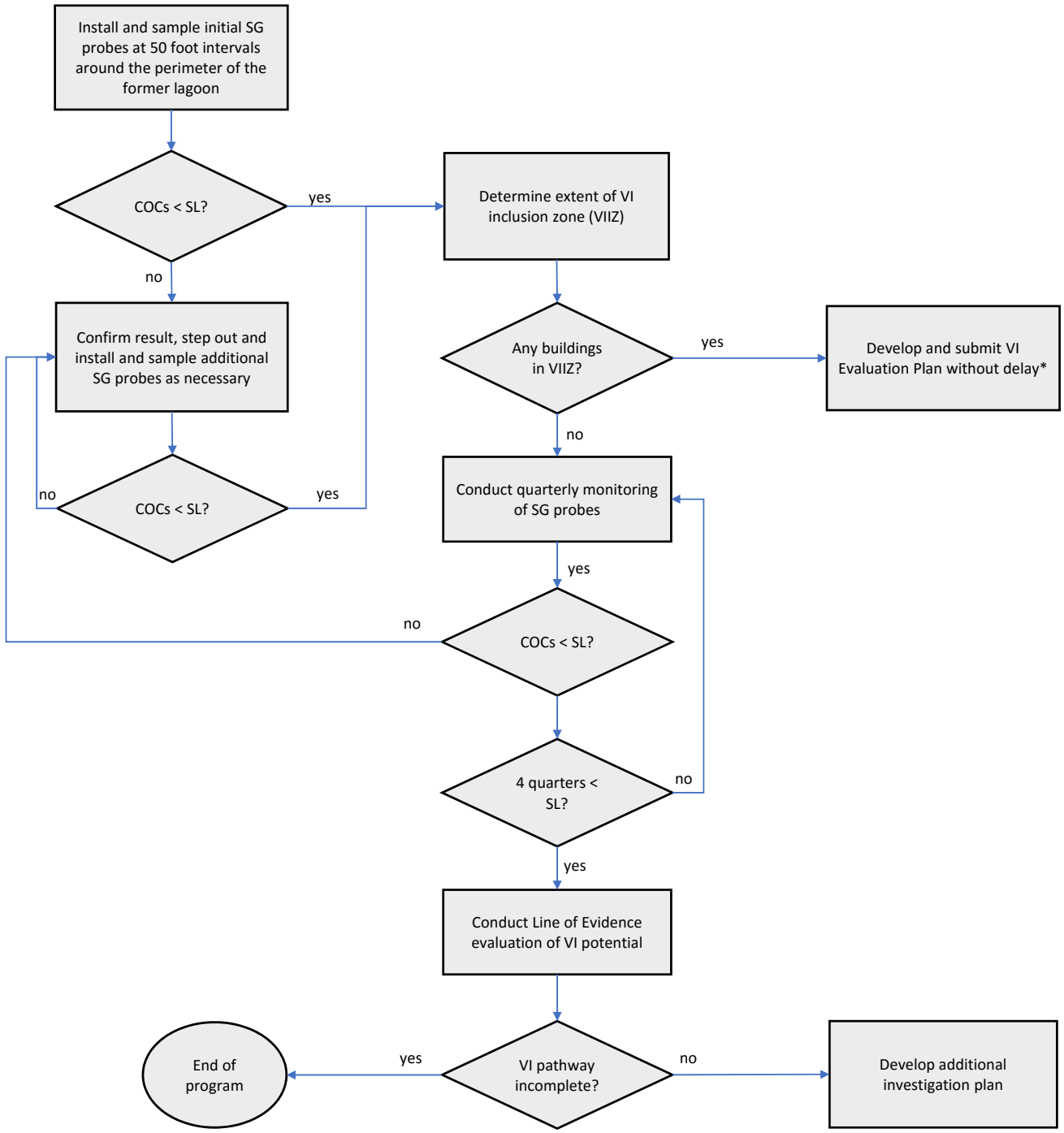
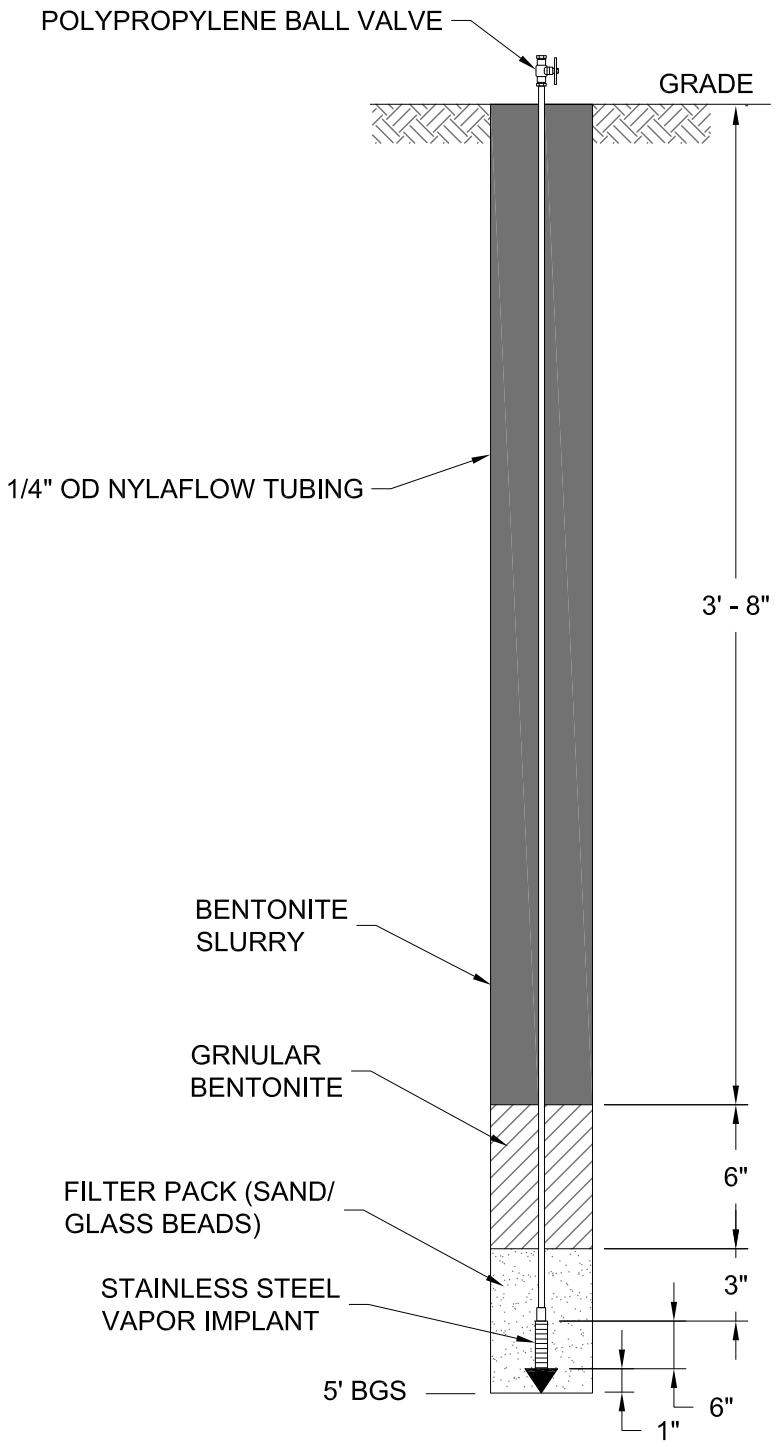


Notes:

SG	soil gas
SL	screening level (VISL)
VI	vapor intrusion
*	If any sampling event shows results above screening levels and this results in any buildings being within the VIIZ, a VI Evaluation Plan will be submitted without delay.

Figure 4. Potential Decision Matrix



SOIL GAS PROBE
CONSTRUCTION DETAILS - SHALLOW
FORMER HULETT LAGOON
HAMILTON SUNDSTRAND
CAMDENTON, MISSOURI

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FIGURE 5

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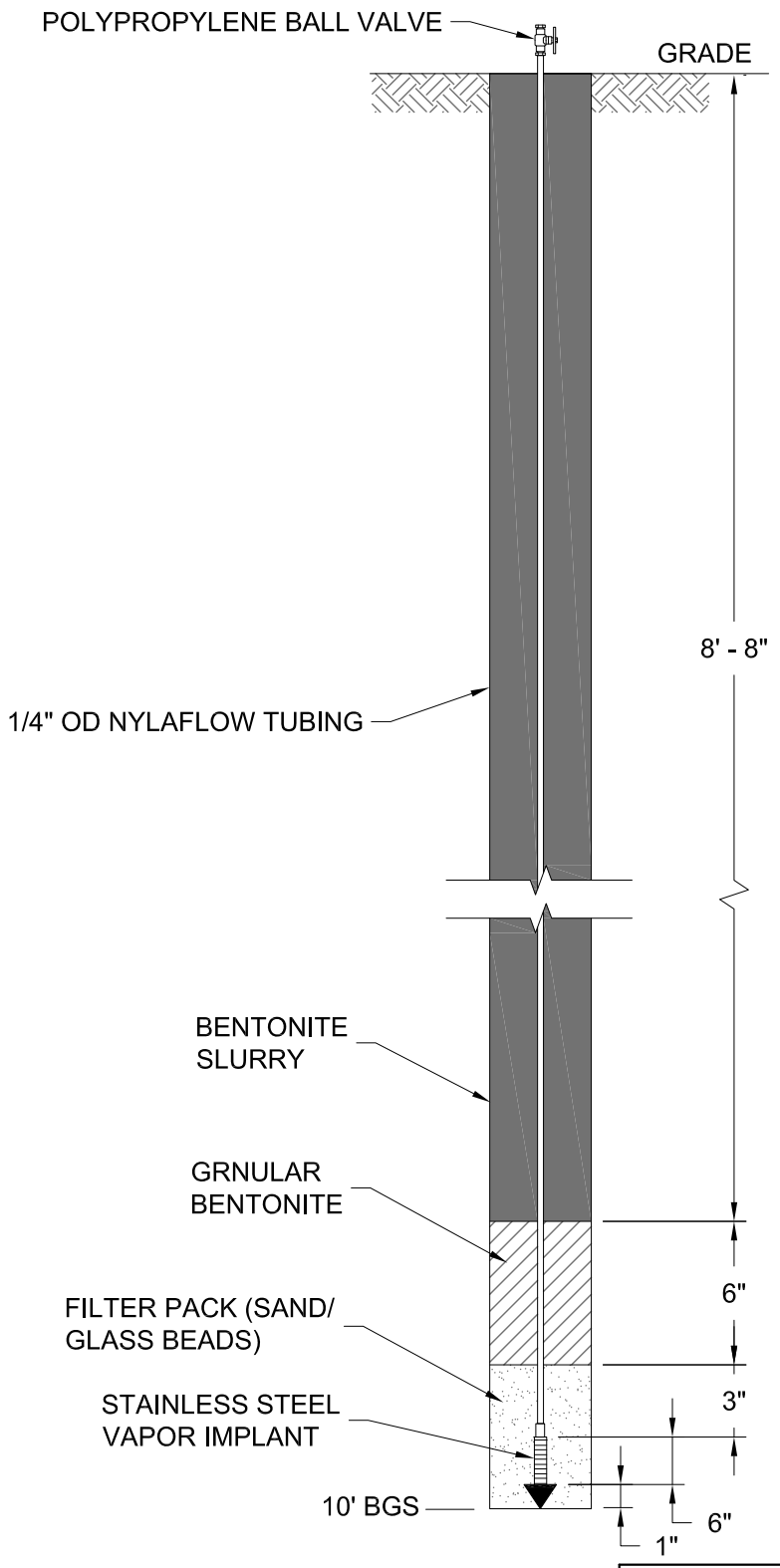

SOIL GAS PROBE
CONSTRUCTION DETAILS - DEEP
FORMER HULETT LAGOON
HAMILTON SUNDSTRAND
CAMDENTON, MISSOURI

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FIGURE 6

PROJECT NO: MEM1501 | DECEMBER 2017

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APPENDIX A

INITIAL CONCEPTUAL SITE MODEL

Table of Contents

1. INTRODUCTION 1
   1.1 Site Setting 1
   1.2 Former Lagoon Operations and Decommissioning 2
2. POTENTIAL SOURCES OF VOCS AT THE FORMER LAGOON 2
   2.1 VOCs in Soil 2
   2.2 VOCs in Bedrock 2
   2.3 VOCs in Groundwater 3
3. VOC MIGRATION PATHWAYS AND MECHANISMS 3
   3.1 VOC Source Zone 3
   3.2 VOC Migration in the Vadose Zone 4
   3.3 VOC Migration into Buildings 5
   3.4 Preferential Pathways 6
   3.5 Temporal Variability 7
4. POTENTIAL RECEPTORS 8
5. DATA GAPS 8
6. REFERENCES 9

List of Figures

A-1 Location Map

A-2 Conceptual Cross-Section

A-3 Results of Soil Investigations at Former Hulett Lagoon

1. INTRODUCTION

This document presents an initial conceptual site model (CSM) for the former Hulett Lagoon (former lagoon) in Camdenton, Missouri (Figure A-1). A CSM provides a general description of the source(s) of volatile organic compounds (VOCs) that may be present in soil gas, the potential soil gas migration pathway and transport mechanisms, the potential for VOCs in soil gas to enter existing or future buildings, and the potential receptors (EPA, 2015, ITRC, 2007). This initial CSM is based on existing information and identifies data gaps to be filled during future investigations. The CSM will then be refined based on the new data, as appropriate.

The following subsections describe the former lagoon setting and historic lagoon operations and decommissioning. Subsequent sections describe the potential sources of VOCs that may be present in soil gas at the former lagoon (Section 2), potential VOC migration pathways in the vadose zone (Section 3), potential receptors of any VOC vapors from the former lagoon (Section 4), current data gaps (Section 5), and references (Section 6).

1.1 Site Setting

The site of the former lagoon is located within a low-lying, wooded area approximately 1000 feet northeast of the former Modine Manufacturing, Inc. facility at 221 Sunset Drive (the Facility), as shown on Figure A-1. The former lagoon is now an open field covered with grass and a few small trees and shrubs. The current ground surface elevation at the former lagoon is approximately 930 to 940 feet above mean sea level (amsl). The ground surface rises to the north, east, and south, and declines to the west along a small drainage (Figure A-2).

The former lagoon is underlain by dolomite bedrock, which is covered by approximately 4 to 12 feet of fine-grained soil in the immediate vicinity of the former lagoon, increasing in thickness (up to 55 feet) as the ground rises to the north and south (SECOR, 2008).

The first saturated groundwater zone below the former lagoon, encountered in the dolomite bedrock at a depth of approximately 110 feet below ground surface,[1] is described as a sporadic and discontinuous perched zone, hydraulically separated from a deeper, more extensive aquifer by argillaceous intervals in the dolomite (SECOR, 2008).

[1] Groundwater elevations in perched zone wells have typically ranged from 817 to 828 feet amsl at and in the vicinity of the former lagoon (SECOR, 2004).

1.2 Former Lagoon Operations and Decommissioning

The former lagoon was an above-grade sewage lagoon with clay berms operated by the City of Camdenton from 1961 through 1989. Wastes from the Facility, including trichloroethene (TCE), were discharged to the former lagoon during a portion of its period of operation. The City decommissioned the former lagoon in 1990 by removing accumulated sludge, removing the inlet and outfall structures, and regrading the lagoon area using clayey soils from the berms and excavation sidewalls (SECOR 2004, 2008).

2. POTENTIAL SOURCES OF VOCS AT THE FORMER LAGOON

Although the wastewater and sludge that accumulated on the bottom of the former lagoon were removed at the time of decommissioning in 1990, it is possible that residual VOCs may remain in soil, bedrock, and perched zone groundwater at the former lagoon, as discussed below.

2.1 VOCs in Soil

Soil samples were collected at the former lagoon site by the Missouri Department of Natural Resources (MDNR) and Hamilton Sundstrand in the 1990s and early 2000s, respectively. TCE was detected at 3 of the 25 boring locations, as summarized on Figure A-3 (SECOR, 2003). TCE and 1,2-cis-dichloroethene (DCE), a breakdown product of TCE, were detected in the soil at concentrations ranging from 240 to 9,500 parts per billion (ppb) and 140 to 650 ppb, respectively, at depths of ranging from 4 to 9 feet below ground surface (bgs).

These data suggest that some TCE-contaminated soil may have been mixed with clean soil during regrading of the former lagoon. No soil remedial action was considered necessary at the time, based on the above results (SECOR, 2003); nevertheless, these small pockets of contaminated soil could act as local sources of TCE and DCE in the soil gas phase.

2.2 VOCs in Bedrock

Wastewater may have seeped from the former lagoon during its period of operation, potentially resulting in residual levels of TCE and DCE in the underlying bedrock that could act as sources of TCE and DCE to soil gas in the vadose zone.

2.3 VOCs in Groundwater

Seepage of wastewater from the former lagoon may have impacted groundwater in the perched zone, at a depth of approximately 110 feet bgs. Between 2006 and 2008, TCE concentrations in wells on the south side of the former lagoon ranged from 99 to 560 ppb in MW-5 and from 252 to 550 in MW-8, while DCE has been less than 30 ppb in both wells over the same period (Stantec, 2009). TCE and DCE concentrations in MW-25, on the north side of the former lagoon, ranged from 474 to 1,200 ppb and 29 to 74 ppb from late 2007 through 2008 (ibid). Based on the relatively consistent TCE concentration levels over time, concentrations today are likely of the same order of magnitude. Therefore, the perched groundwater below the former lagoon may be a source of TCE and DCE in soil gas above the water table. The potential for vapor intrusion (VI) impacts, however, is unlikely given the depth of the groundwater and other factors, as discussed in Section 3.

3. VOC MIGRATION PATHWAYS AND MECHANISMS

The following sections describe the potential VI pathway at the former lagoon, including 1) the VOC source zones; 2) the VOC migration pathway in the vadose zone; 3) potential VOC migration pathways into buildings; 4) the potential impacts of preferential pathways on VOC migration, and 5) the potential for temporal variability.

3.1 VOC Source Zone

The results of prior investigations indicate that a few pockets of VOC-impacted[2] soil may be present at the former lagoon (Figure A-3). Some of the VOCs adsorbed to the soil will partition to the soil gas phase, based on their relative affinity to the solid, water, and soil gas phases. At equilibrium, the relative concentrations in each phase are described by the following equation (EPA, 2004):

$$C_{source} = \frac{H'_{TS}\, C_R\, \rho_b}{\theta_w + K_d \rho_b + H'_{TS}\, \theta_a} \qquad [1]$$

where C_{source} is the soil gas concentration, H'_{TS} is the Henry's Law partition coefficient between the water and gas phase (at the in-situ soil temperature), C_R is the soil concentration, ρ_b is the soil density, θ_w is the water-filled soil porosity, K_d is the soil to water partition coefficient (and equal

[2] Although the principal VOC of concern is TCE, and detections in groundwater and soil have generally been limited to TCE and DCE, we will use the more generic VOC term for efficiency.

to K_{OC} x f_{OC}), θ_a is the air-filled soil porosity, K_{OC} is the soil organic carbon partition coefficient, and f_{OC} is the fraction of natural organic carbon in the soil.

The parameter of concern in Equation 1 is the soil gas concentration, or C_{source}. No VOC soil gas concentrations are currently available for the former lagoon site. While soil gas concentrations can, in theory, be calculated knowing soil and soil moisture concentrations, along with values for the other parameters shown, direct measurements of soil gas concentration will provide more accurate and reliable values of the parameter of concern.

3.2 VOC Migration in the Vadose Zone

VOCs principally migrate in the soil gas phase by a process known as diffusion, where the VOC molecules move in the soil gas from areas of high VOC concentration (e.g., the source zone) to areas of low VOC concentration (e.g., areas adjacent to the source zone, or the ground surface). It should be noted that VOC diffusion typically occurs in the subsurface without any significant soil gas movement, although soil gas can flow close to buildings, as discussed below.

The rate of VOC diffusion in soil gas is determined by Fick's Law:

$$E = A\,(C_{source}-C_L)D_{eff}/L \qquad [2]$$

where E is the rate of VOC mass migration due to diffusion, A is the cross-sectional area through which the VOCs are diffusing, C_{source} and C_L are the VOC concentrations in the soil gas at the source and any distance L from the source, and D_{eff} is the effective diffusivity of the soil or bedrock (EPA, 2004). In other words, VOC mass flux across a unit area of soil or bedrock is equal to the VOC concentration gradient times the diffusivity of the soil or bedrock (i.e., its resistance to diffusion).

In general, fine-grained and moist soils or bedrock will be more resistant to VOC diffusion and have lower D_{eff} values (EPA, 2004). The soils at the former lagoon are described as clay, silty clay, or sandy clay, and are often moist (SECOR, 2003). Similarly, the dolomite bedrock matrix likely has small effective (i.e., connected) porosities, and several intervals within the vadose zone at the former lagoon are described as argillaceous (i.e., clayey) and moist (ibid).

Therefore, most of the VOC diffusion would be likely to occur through small joints or fractures in the rock, which will be more permeable than the intact rock but will also represent a smaller cross-sectional area of transport (i.e., the cross-sectional area comprised of fractures will be a

small percentage of the total area). Therefore, relatively slow rates of mass migration due to diffusion are also expected in the bedrock portion of the vadose zone.

In summary, any VOCs in soil gas at the edge of the former lagoon, either in the clay soils or in the underlying bedrock, will tend to diffuse laterally away from the source materials, and upward toward the ground surface (the shortest distance to areas of lowest concentration), as shown in Figure A-2. Concentrations will decrease with distance, according to Fick's Law of Diffusion (no diffusion would occur without a concentration gradient). As a result, VOC concentrations are expected to be highest in the former lagoon footprint, and decrease with distance from the former lagoon.

Soil gas concentrations (C_{SV}) above dissolved VOCs in the perched zone can be estimated by the following equation (EPA, 2004, 2015):

$$C_{SV} = H'_{TS} C_W \qquad [3]$$

where H'_{TS} is the temperature-dependent Henry's Law Constant, as before, and C_W is the VOC concentration dissolved in groundwater. Note that this equation is not applied to soil moisture or pockets of water in the vadose zone above the water table, where soil concentrations may dominate and Equation 1 should be used.

In most cases, however, soil gas concentrations will reduce substantially above the groundwater table due to diffusion across the capillary fringe (EPA, 2004), so that the VOC concentrations driving diffusion in soil gas through the overlying vadose zone are lower than indicated by Equation 2.

Although EPA (2015) recommends site-specific evaluation of horizontal and vertical screening distances, it notes that groundwater sources deeper than 100 feet are often screened from further VI evaluation (EPA, 2015). This is because distances greater than 100 feet result in smaller diffusion gradients. Argillaceous (clayey) and wet intervals observed within the dolomite strata would also reduce the rate of diffusion and potential for VI. This is consistent with the results of VI investigations at several homes, where sub-slab soil gas concentrations were well below the TCE action level for mitigation and commonly below detection (CH2M, 2017a).

3.3 VOC Migration into Buildings

To the extent that any VOCs from the former lagoon diffuse as far as any buildings (located 150 feet or greater from the former lagoon, as discussed in Section 4), VOCs may continue to diffuse

into the building through cracks or other openings in the foundations (EPA, 2015). In some cases, negative building pressures can cause soil gas to be pulled into the building (ibid). Negative building pressures may occur due to a sudden drop in outdoor barometric pressure, operation of exhaust fans, wind effects, and/or heating of the building during cold weather, also called the "stack effect" (ibid).

Indoor air concentrations due to VI are a function of the concentration in the soil gas below the building (e.g., the sub-slab soil gas concentration), the rate of VOC diffusion and/or soil gas flow into the building (i.e., the rate that VOC mass enters the building), and the volume of diluting air over the same time period (i.e., the volume of the building times the air exchange rate). Indoor and outdoor sources of VOCs (background sources) can also contribute to the indoor air concentration (ITRC, 2007, EPA, 2015, and others).

If VOC molecules due to subsurface sources enter a building, EPA (2015) considers the VI pathway to be complete. The resultant VOC concentrations, however, may or may not be above concentrations of concern or require further action (ibid).

3.4 Preferential Pathways

Preferential pathways are generally considered to be natural or anthropogenic subsurface features that significantly increase the rate of VOC migration (i.e., the mass flux) above rates normally observed (EPA, 2015, ITRC, 2007). Typical underground utilities, such as sanitary sewers and storm sewers, may increase VOC mass flux to some degree, but usually not above rates commonly seen at VI sites (and reflected in empirical databases that support generic screening levels and attenuation factors) (ibid, Folkes, 2016). Of greatest concern are "atypical" preferential pathways that directly connect the source of vapors to buildings by advective pathways that bypass the diffusion component of most VI pathways (Folkes, 2016).

To the extent that geologic features, such as bedrock bedding planes or more permeable strata, enhance horizontal diffusion of vapors beyond the perimeter of the former lagoon, these would not be atypical preferential pathways (to the extent that migration rates and distances would still be within ranges normally observed for higher permeability/diffusivity materials). The Soil Gas Investigation Work Plan for the Former Hulett Lagoon Site (Geosyntec, 2017) (Work Plan) will address the potential for enhanced migration along natural geologic features by beginning at the edge of the former lagoon and stepping out as far as necessary to define the VI inclusion zone, if any. Regardless of the horizontal extent of soil gas migration in natural geologic features, the highest concentrations in shallow soils would be expected to occur closer to the former lagoon

and decrease with distance from the former lagoon. In addition, the thickness of the silt and clay deposits overlying bedrock generally increases with distance from the former lagoon, decreasing vertical diffusion gradients and soil gas flux, all else being equal. The potential for smaller scale geologic variability in natural formations should be addressed by the close spacing of the soil gas samples; i.e., 50 feet around the former lagoon, and 50 to 100 feet in step-out samples (50 feet closer to buildings). Further, high volume sampling will be conducted in two locations to evaluate short distance variability in soil gas concentrations. Nevertheless, step-out sampling will be focused in any areas that appear to exhibit preferential soil gas migration based on investigation results.

To the extent that more permeable backfill material is present near the former lagoon, e.g., associated with the former discharge line from the Facility, or other pipelines that may have entered the former lagoon, soil gas may diffuse along the backfill more readily than in the surrounding native soils. However, the resultant VOC flux and potential impact on buildings, if any, would be limited by the small cross-sectional area of the backfill. The locations of any former pipelines near the former lagoon will be identified to the extent practicable through historic City records and other available information, and the Work Plan will locate soil gas probes near these locations.

No current atypical pathway (e.g., open conduit) has been identified at the former lagoon at this time. Therefore, screening levels and buffer zone distances that are based on upper bound observations from other sites where migration is controlled by diffusion through subsurface materials should still be applicable. This condition will be re-evaluated if atypical preferential pathways between the former lagoon and buildings are identified during the investigation.

3.5 Temporal Variability

VOC source concentrations, rates of diffusion, rates of soil gas entry into buildings, and degree of dilution within the building can all vary over time, resulting in variations in indoor air concentrations over time. Some of these variations can occur rapidly over the short term (building ventilation rates and pressure levels), while others tend to have seasonal (temperature) or long term (natural attenuation or remediation of sources) trends.

Based on low permeability/diffusivity soils at the former lagoon, lack of preferential pathways that might result in atypical vapor migration rates, and the results of VI investigations at several residential homes in the area (CH2M, 2017a), VOC concentrations along the VI pathway are expected to vary within normal ranges and reflect typical seasonal behavior.

4. POTENTIAL RECEPTORS

Multi-family residential buildings are located approximately 150 feet north of the former lagoon boundary, while single-family homes are located approximately 250 feet to the south, 300 feet west, and 200 feet southwest of the former lagoon. Some homes have basements, while others have slab-on-grade and/or crawl-space construction. A number of these structures have already been tested by Modine for VI impacts related to other potential sources of VOCs. The results of these investigations have been submitted to MDNR (e.g., CH2M, 2017a).

5. DATA GAPS

The attached Work Plan has been designed to address the following data daps identified by the initial CSM.

- The nature and magnitude of VOC concentrations in soil gas adjacent to the former lagoon, if any.
- The extent of VOC concentrations in soil vapor due to lateral migration from the former lagoon, if any.
- The extent of the VI inclusion zone, based on the extent of VOCs in soil gas above screening levels and a reasonable buffer zone distance.

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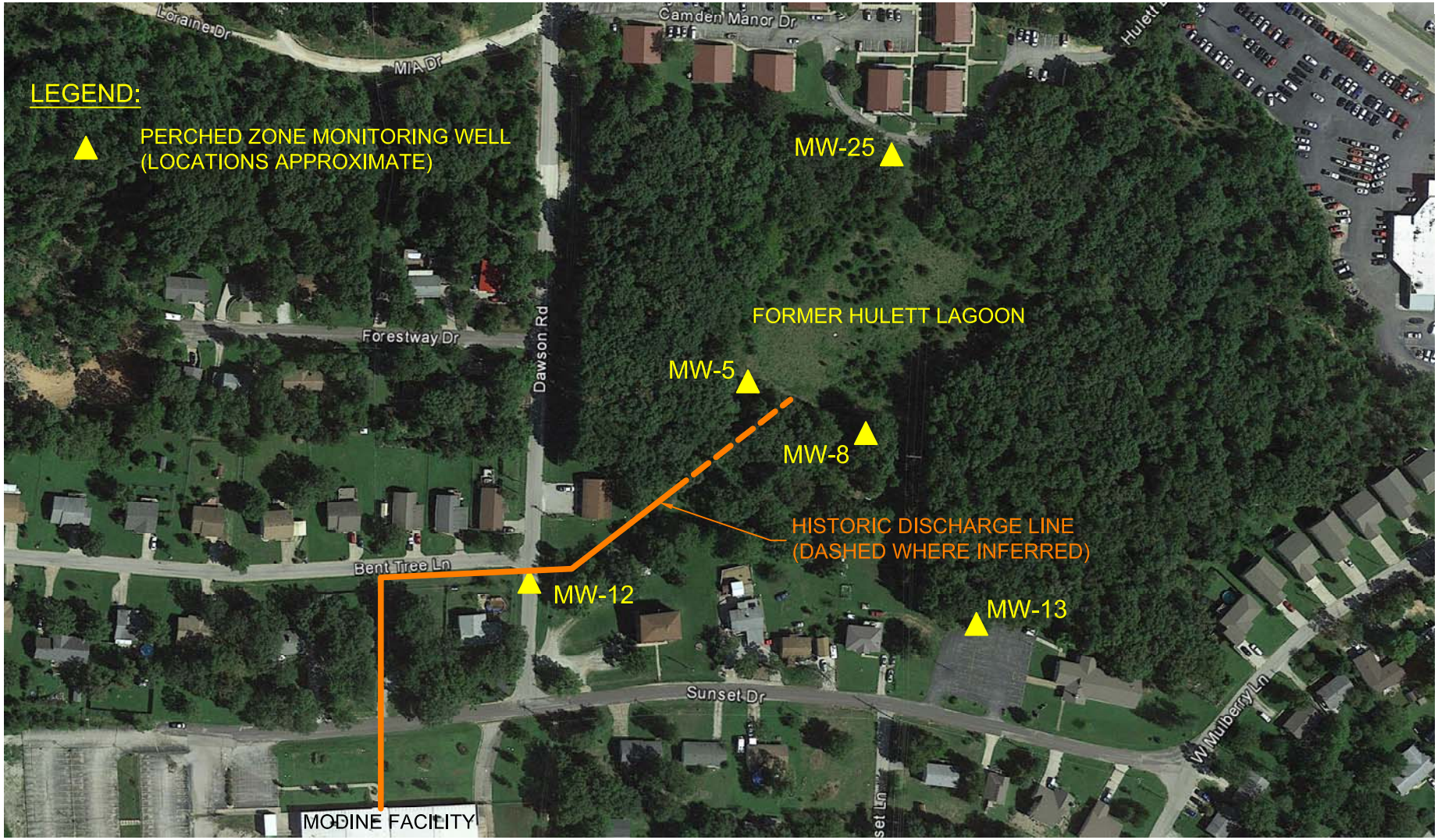

N

0 200' 400'

SCALE IN FEET

LOCATION MAP
FORMER HULETT LAGOON
HAMILTON SUNDSTRAND
CAMDENTON, MISSOURI

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FIGURE A-1

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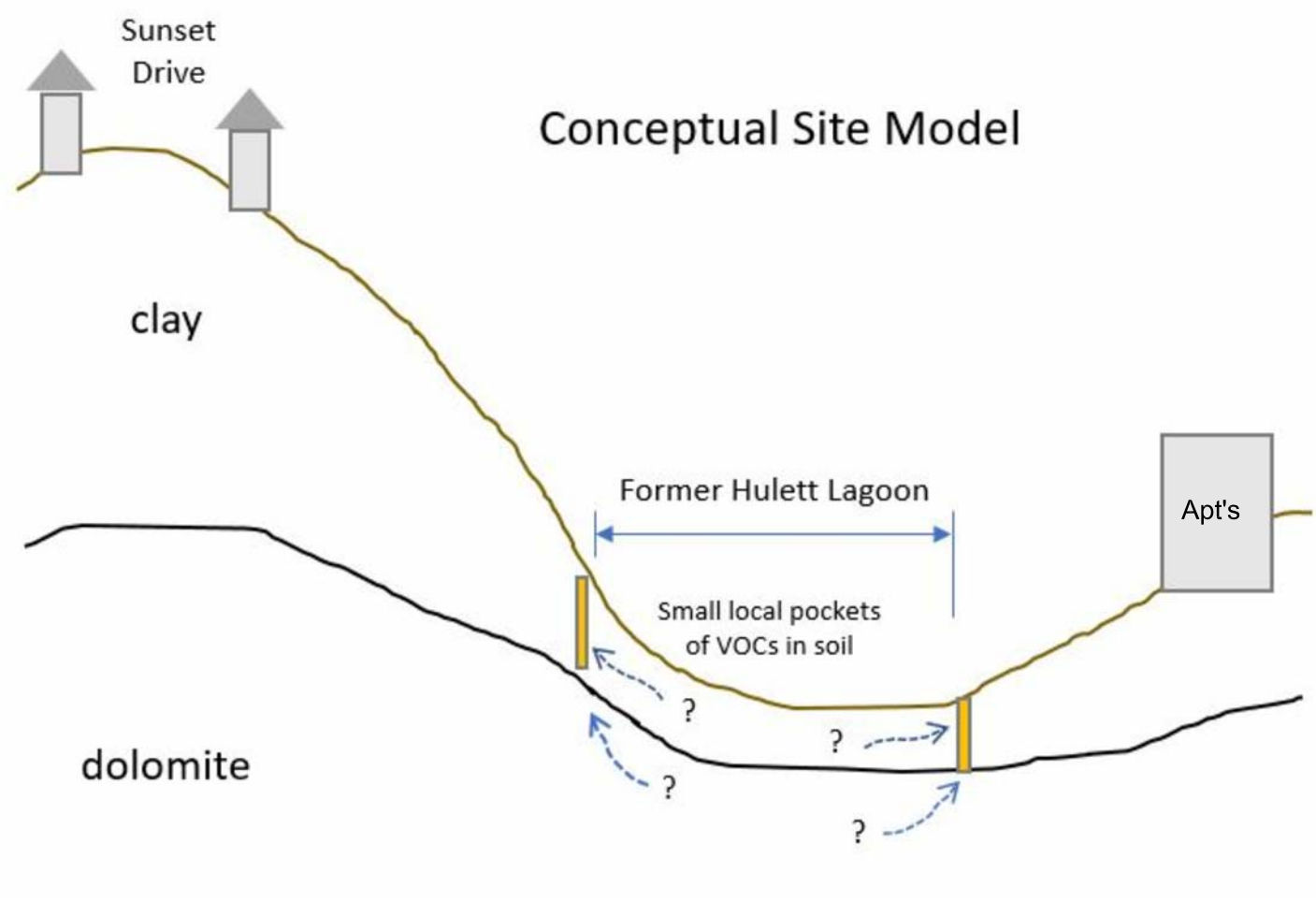
R:\2_INACTIVE GEOSYNTEC PROJECTS\GEOSYNTEC\MEM1501\SHEET FILES\FIGURES 2-3-4-5-APPA



Explanation

Potential VOC diffusion in vapor phase

Proposed perimeter soil vapor probe

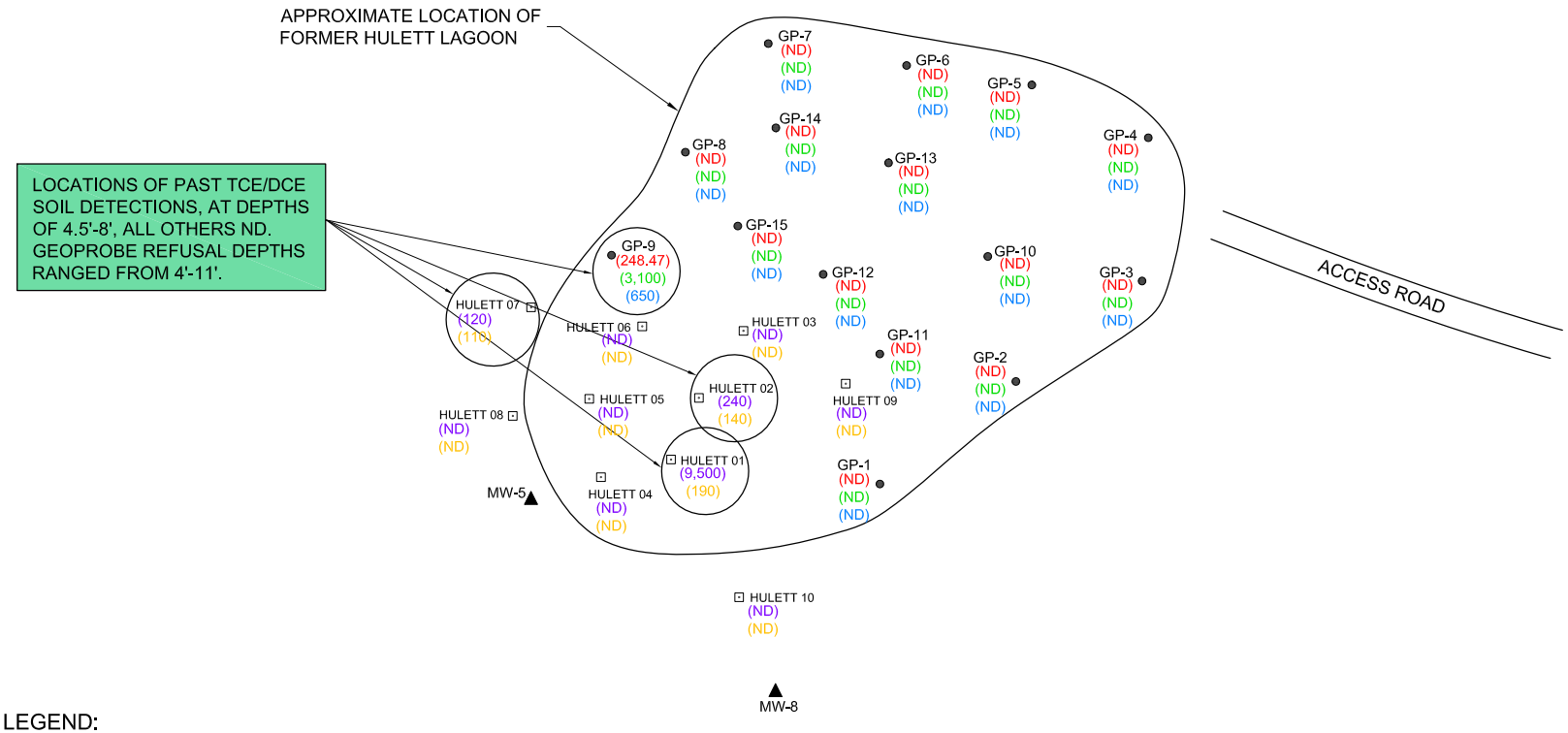
CROSS-SECTION
FORMER HULETT LAGOON
HAMILTON SUNDSTRAND
CAMDENTON, MISSOURI

Geosyntec consultants

FIGURE
A-2

PROJECT NO: MEM1501 | DECEMBER 2017

R:\2_INACTIVE GEOSYNTEC PROJECTS\GEOSYNTEC\MEM1501\SHEET FILES\FIGURES 2-3-4-5-APPA



LEGEND:

▲	MONITORING WELL LOCATION
●	SECOR SOIL BORING LOCATION, JUNE 2000
⊡	MDNR SOIL BORING LOCATION, JANUARY 1999
(248.47)	TCE CONCENTRATIONS IN µg/L, MOBILE LABORATORY - SECOR
(3,100)	TCE CONCENTRATIONS IN µg/kg, FIXED BASE LABORATORY - SECOR
(650)	DCE CONCENTRATIONS IN µg/kg, FIXED BASE LABORATORY - SECOR
(9,500)	TCE CONCENTRATIONS IN µg/kg, MDNR
(190)	TCE CONCENTRATIONS IN µg/kg, MDNR
	(ND) = NOT DETECTED

SOURCE: MDNR 1999 AND SECOR 2003.

N

0 100' 200'

SCALE IN FEET

TCE & DCE CONCENTRATIONS IN SOIL
FORMER HULETT LAGOON
HAMILTON SUNDSTRAND
CAMDENTON, MISSOURI

Geosyntec consultants

FIGURE A-3

PROJECT NO: MEM1501 | DECEMBER 2017

R:\2_INACTIVE GEOSYNTEC PROJECTS\GEOSYNTEC\MEM1501\SHEET FILES\FIGURES 2-3-4-5-APPA

APPENDIX B

STANDARD OPERATING PROCEDURES

SUGGESTED OPERATING PROCEDURE
SOIL GAS PROBE INSTALLATION
Geosyntec Consultants, Inc.

1 INTRODUCTION

This suggested operating procedure (SOP) describes the design and methods for the installation of soil gas probes of sufficient quality to assess potential human health risks due to subsurface vapor intrusion to indoor air and subsequent inhalation exposures.

2 SOIL GAS PROBE DESIGN AND INSTALLATION

2.1 Compliance with Site Dig Permits and Utility Clearances

Site specific permits may be required prior to subsurface activities. Necessary permits will be secured in advance of any drilling activities. Underground utilities (water, sewer, electricity, gas, cable, telephone, etc.) will be reviewed prior to drilling.

2.2 Soil Coring via GeoProbe®

Soil core will be collected with a GeoProbe® direct push system (or equivalent). This method minimizes the disturbance to the geologic materials surrounding a soil gas probe subsequently installed in the core-hole. A 2-inch diameter core barrel will be used, since this provides sufficient core volume for field screening, geologic logging, and selected laboratory analyses (if required).

2.3 Geologic Logging

Soil cores will be photographed and inspected to record details of the color, texture, moisture, density, cohesion, plasticity, staining, and odor.

2.4 Soil Samples for Analysis of Physical Properties (if required)

After geologic logging of the soil core, soil samples will be collected for laboratory analysis of moisture content, grain-size distribution, porosity and bulk density by laboratory methods:

Soil Moisture Content: ASTM D2216
Grain Size: ASTM D422
Porosity: API RP40
Bulk density: API RP40

Samples will be selected to represent each distinct geologic layer. The number of samples to be collected will be determined by the geologist after inspection of the soil core and consideration of the degree of heterogeneity in the geologic materials.

2.5 Soil Gas Probe Installation

Each soil gas probe will consist of ¼-inch diameter Nylaflow® or Teflon® tubing connected with a compression fitting to a ¼-inch-diameter stainless steel sampling point. Probes will be installed inside the borehole and a sand filter pack will be placed in the annulus to a height of 6 inches above the top of the screen. Granular bentonite will be placed in two lifts of 3 inches above the filter pack and hydrated with a small amount of distilled water after each lift. A thick slurry of powdered bentonite and water will be added to seal the remainder of the borehole annulus to ground surface. The top of the probe will be fitted with a compression-fit brass or stainless steel ball valve to maintain an air-tight seal between installation and sampling. Permanent probes will be completed with a traffic rated flush mount protective casing.

3 DOCUMENTATION

Field documentation will include the following information:

- name and number of project;
- name of field personnel;
- date and time of sampling event;
- list of the primary activities performed;
- identification of probes drilled and installed;
- relevant information (weather, attendees, equipment problems, departures from standard procedures and the reasons and responses) observed throughout the day;
- field instrument information and calibration data (includes time and reading for each instrument calibration check; and
- volume of probe dead space volume for each soil gas probe.

SOIL GAS PROBE CONSTRUCTION

Geosyntec consultants

Probe ID _____ **Site Location** _____

Project Name _____ **Field Personnel** _____

Project Number _____ **Recorded By** _____

Permit Number _____ **Drilling Contractor** _____

Installation Date(s) _____ **Driller** _____

Drilling Method _____ ☐ **Temporary Soil Gas Probe**

Borehole Diameter _____ ☐ **Permanent Soil Gas Probe**

Materials Used

Pipe/Tubing : Diameter _____ cm/inches
Construction _____
☐ Nylaflow Tubing
☐ Other _____

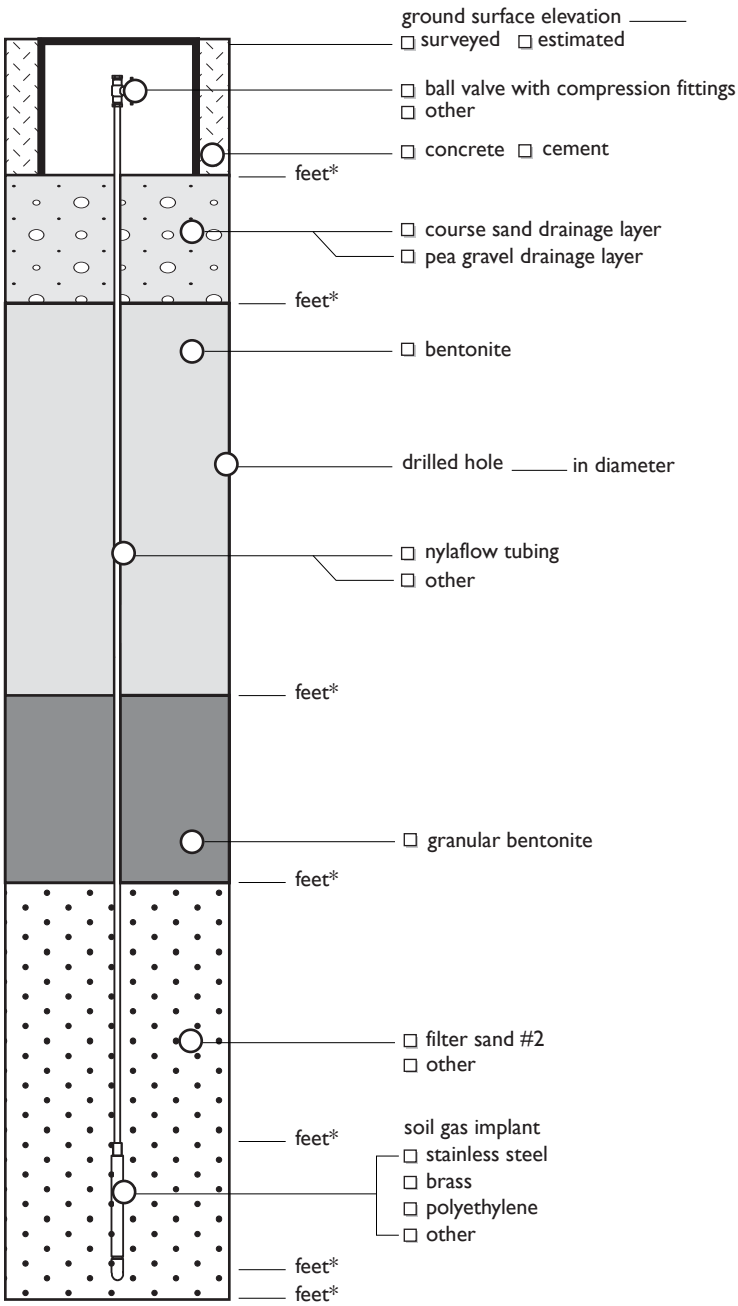
Soil Gas Implant : Length _____ cm/inches
Diameter _____ cm/inches

Construction
☐ Stainless Steel
☐ Brass
☐ Polyethylene
☐ Other _____

Surface Fitting: ☐ Ball valve with compression fittings
☐ Other _____

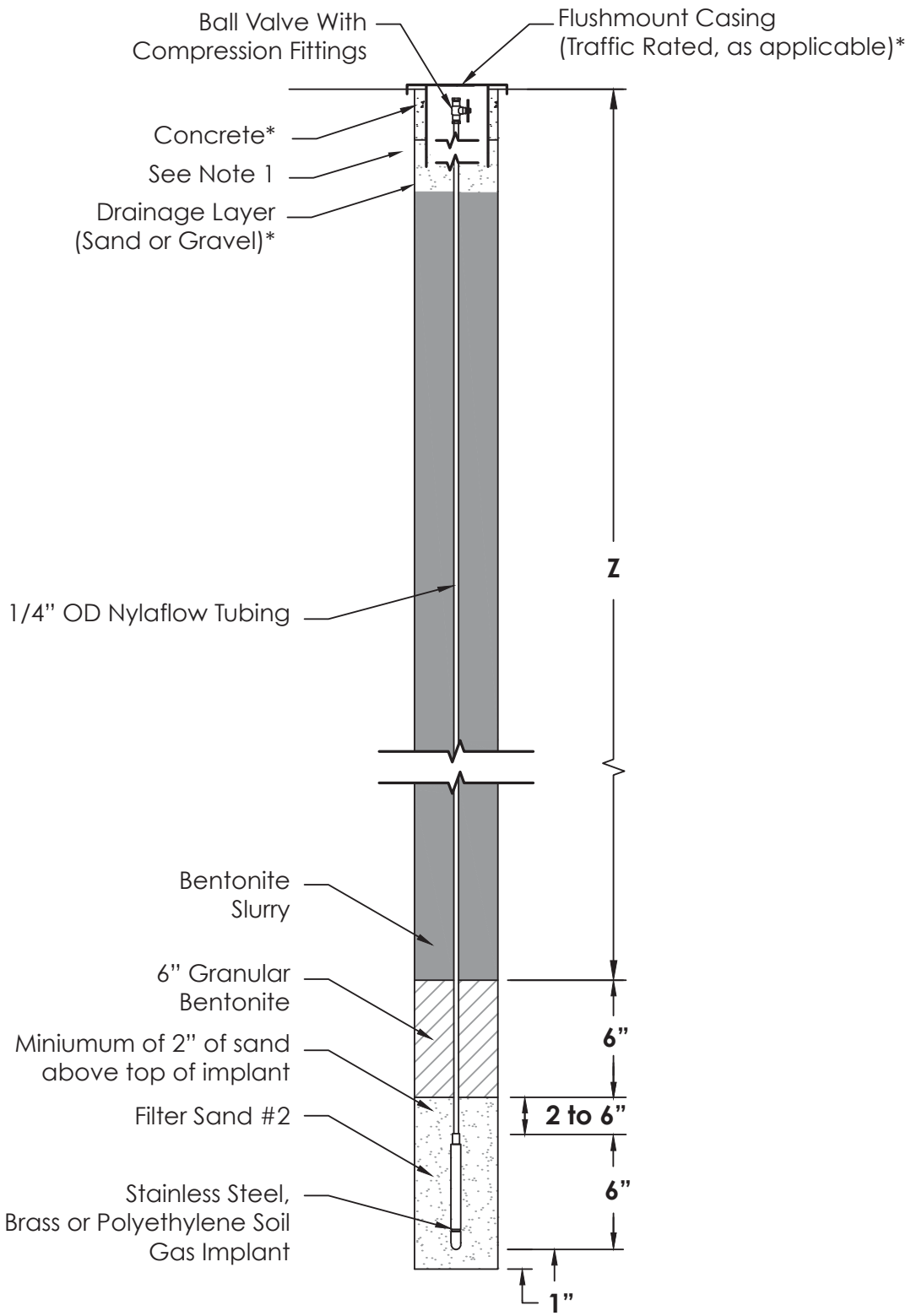
Protective Casing: ☐ Flush mount
☐ Above grade
Length _____ cm/inches
Stickup _____ cm/inches
Construction ☐ Cast Aluminum
☐ Cast Steel
☐ Other _____

Casing Installation: Depth _____ cm/inches
Diameter _____ cm/inches



* *Depth Below Ground Surface*

Soil Gas Probe Construction 2016_TR0254.ai



Notes:

1. Nylaflow tubing can be up to 30 centimeters longer at surface in order to facilitate sampling. Tubing must be coiled up and stored in road box sampling events.

* - for permanent soil gas probes only

Soil Gas Probe Detail

Geosyntec consultants

Guelph | December 2016

Figure 1

Temporary Soil Gas Probe Detail_TR0254.ai

SUGGESTED OPERATING PROCEDURE

SOIL GAS SAMPLING

Geosyntec Consultants, Inc.

Last revision: December 2009

1 INTRODUCTION

This suggested operating procedure (SOP) describes the methods for sampling sub-slab and soil gas probes of sufficient quality to assess potential human health risks due to subsurface vapor intrusion to indoor air and subsequent inhalation exposures.

2 VACUUM SHUT-IN LEAK TEST

The sampling equipment will be assembled as shown in Figure 2, and will be checked for leaks by conducting a "shut-in" test prior to purging. Valves V-1 and V-3 will be closed (valves V-2 and V-4 open) and then the lung box and Tedlar® bag will be used to exert a vacuum on the sampling train (80 - 100 inches of water [in-H_2O]). Valve V-2 will then be closed and the vacuum observed for at least 60 seconds to ensure it does not dissipate.

If the test indicates a leak, the connections should be disconnected and carefully reconnected one at a time until the leak is fixed. The leak test must be repeated until all leaks have been fixed.

3 HELIUM LEAK TEST

After the "shut –in" test, a Tedlar bag will be attached to the tubing inside the lung-box and the lid of the lung box will be secured. V-2 will remain closed while the valve under the shroud (V-1 and V-4) will be opened and the shroud filled with helium (10 to 30%). The minimum and maximum concentrations of helium observed in the shroud during the collection of each Tedlar bag sample will be recorded. The lung box will be turned on and V-2 opened to begin purging. The Tedlar bag will fill at flow rate constrained by the flow controller, typically about 200 mL/min. The time to fill the Tedlar bag should be recorded. The Tedlar bag will visibly fill inside the lung box. As it approaches ¾ full, valve V-2 will be closed and the lung box will be turned off.

The lid of the lung box will be opened, the valve on the Tedlar bag closed, and the Tedlar bag removed from the lung box. The Tedlar bag will be connected to the helium meter and the stabilized reading will be recorded.

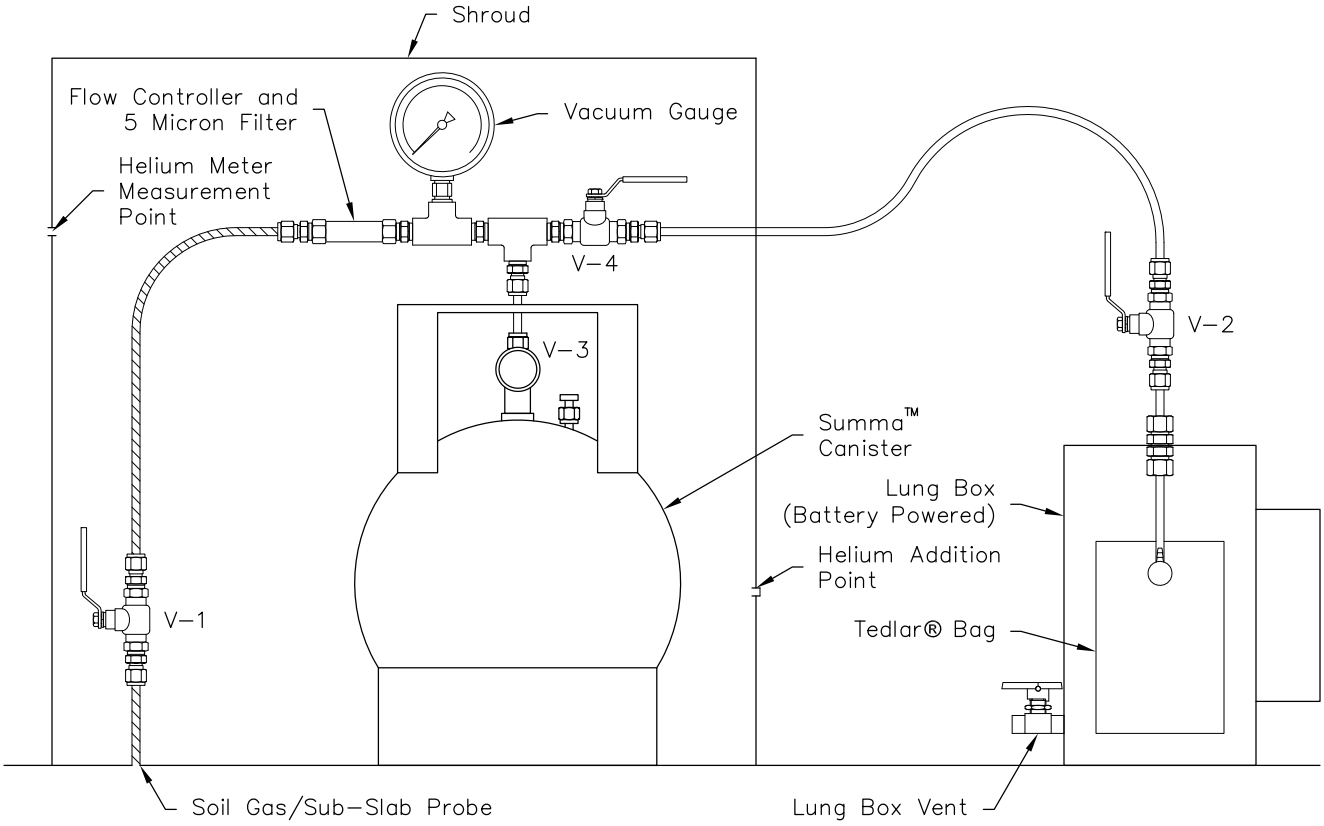
If the concentration of helium in the Tedlar bag is greater than 5% of the concentration in the shroud, the probe seal and fittings should be checked to determine the location of the leak. Once the leak has been fixed, resume purging and field screening. The purging and field screening procedure will be repeated for a minimum of three sets of readings.

4 SUMMA CANISTER LEAK TEST

Valve V-1 and V-4 will be closed and then valve V-3 (summa canister valve) will be opened to induce a vacuum on the sample train. The vacuum in the sample train will be observed for a short duration (30 seconds) to ensure it does not dissipate as a final check that the sample train does not contain any leaks. Valve V-1 will then be opened and the sample collection time recorded. The vacuum gauge on the Summa canister should be monitored and closed when the residual vacuum in the canister is about 5 in Hg.

5 EQUIPMENT BLANK

The equipment blank is collected by connecting a Summa canister to a fully assembled soil gas probe (screen, tubing, and valve) prior to installation via Swagelok fittings through a 200 milliliter per minute (mL/min) flow controller. The Summa canister valve is opened to draw the contents of the tubing and outdoor air into the canister through the probe tip and Swagelok valve.



Legend

New Nylaflow® Tubing

Non–Dedicated Tubing

Soil Gas Purging and Sampling Assembly

Geosyntec consultants

Guelph | July 2009

Figure **2**

P:\PRJ\Marketing-Sales\Indoor Air Quality\SOPs\AutoCAD Figures\Soil Gas Sampling Assembly.dwg

APPENDIX C

QUALITY ASSURANCE PROJECT PLAN

Prepared for

Hamilton Sundstrand

QUALITY ASSURANCE PROJECT PLAN

Former Hulett Lagoon

Camdenton, Missouri

Prepared by:

Geosyntec consultants

engineers | scientists | innovators

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Project Number: MEM1015

Revised December 22, 2017

QUALITY ASSURANCE PROJECT PLAN

Former Hulett Lagoon
Camdenton, Missouri

Revised December 22, 2017

Prepared for:

Hamilton Sundstrand

Prepared by:

Geosyntec Consultants, Inc.
Greenwood Village, Colorado

TABLE OF CONTENTS

1.0 PROJECT MANAGEMENT 1
1.1 Project Background 1
1.2 Responsible Personnel and QAPP Distribution 1
1.2.1 Responsible Personnel 1
1.2.2 QAPP Distribution 3
1.3 Authorized Laboratories 3
1.4 Quality Assurance Objectives 4
1.5 Competency and Training 10
1.6 Documentation and Records 10
1.6.1 Field Notebooks 10
1.6.2 Field Reporting Forms 11
2.0 MEASUREMENTS AND DATA ACQUISITION 12
2.1 Standard Operating Procedures 12
2.1.1 Drilling 12
2.1.2 Soil Vapor Sampling 13
2.1.3 Ambient Air Quality Sampling 15
2.1.4 Aqueous Sample Collection 15
2.1.5 Equipment Decontamination 15
2.1.6 Investigation Derived Wastes 16
2.2 Sample Handling and Custody Requirements 16
2.2.1 Sample Handling 17
2.2.2 Sample Custody Documentation 17
2.3 Analytical Parameter Requirements 18
2.4 Quality Assurance/Quality Control Requirements 18
2.4.1 Laboratory QA/QC Requirements 18
2.4.2 Field QA/QC Requirements 18
2.5 Equipment Inspection, Maintenance and Calibration Requirements 22
2.6 Inspection and Acceptance Criteria for Supplies and Consumables 22
3.0 DATA VALIDATION AND USABILITY 23
3.1 Data Verification and Validation Requirements 23
3.1.1 Data Validation Procedures 23
3.1.2 Laboratory Data Verification 25
3.2 Usability/Reconsiliation With Data Quality Objectives 27
3.2.1 Comparison to Measurement Criteria 28
3.3 Overall Assessment of Environmental Data 31
4.0 CORRECTIVE ACTION 32
4.1 Field Corrective Action 32
4.2 Corrective Actions Taken by the Analyst 32
4.3 Corrective Action During Data Validation and Data Assessment 33
5.0 REFERENCES 34

LIST OF FIGURES

Figure 1.1 Organizational Chart 2

LIST OF TABLES

Table 1.1 Authorized Laboratories 5
Table 1.2 Data Quality Objectives 7
Table 2.1 Anticipated Analytical Methods 19
Table 2.2 Anticipated Analyte List 19
Table 2.3 Typical Field QA/QC Sampling Requirements 20
Table 3.1 Laboratory Verification Parameters 26

LIST OF APPENDICES

Appendix A Field Forms

1.0 PROJECT MANAGEMENT

This Quality Assurance Project Plan (QAPP) was developed by Geosyntec Consultants (Geosyntec) in accordance with United States Environmental Protection Agency (EPA) guidance and the Missouri Department of Natural Resources (MDNR) Quality Management Plan for work conducted at the former Hulett Lagoon located approximately 1000 feet northeast of the Modine Manufacturing, Inc. facility at 221 Sunset Drive in Camdenton, Missouri.

1.1 PROJECT BACKGROUND

Information on the site setting, former lagoon operations and decommissioning, and the results of previous soil and groundwater investigations in the former lagoon vicinity are provided in the Soil Gas Investigation Work Plan (Work Plan; Geosyntec, 2017). This QAPP was developed as Appendix C to the Work Plan and contains quality assurance (QA) and quality control (QC) procedures for the sampling and analysis of soil gas[1].

1.2 RESPONSIBLE PERSONNEL AND QAPP DISTRIBUTION

The organizational structure of the project and distribution of the QAPP are addressed in this section.

1.2.1 Responsible Personnel

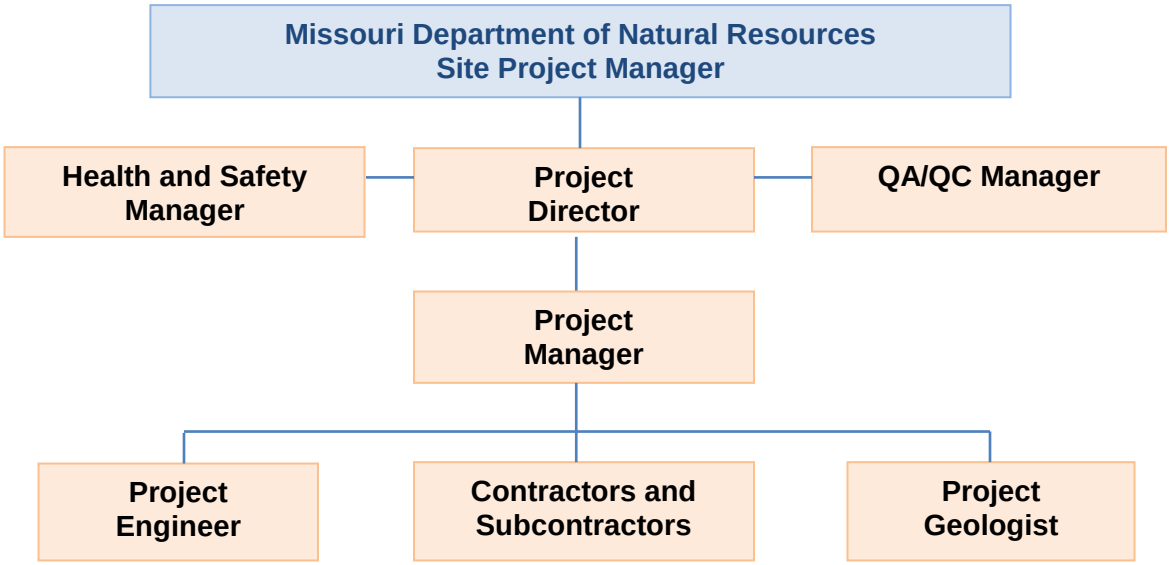
An organizational chart, presented as Figure 1.1, identifies each position in the project team and the individual currently occupying that position. The responsibilities for each position are also summarized in this section.

MDNR Site Project Manager

The MDNR Site Project Manager (MDNR Site Manager) is the individual assigned by the MDNR to a specific project as the primary regulatory contact. This person is familiar with project procedures and requirements. The MDNR Site Manager is authorized to review, approve, approve with modifications, or deem unacceptable, requisite deliverables, and to perform oversight activities as necessary.

[1] The terms “soil gas” and “soil vapor” or “vapor” are used interchangeably in guidance and the literature.

Figure 1.1: Organizational Chart



Geosyntec Project Director

The Geosyntec Project Director has the overall responsibility for ensuring that the assigned activities and deliverables meet applicable MDNR objectives and the quality standards outlined in this QAPP. Specifically, the responsibilities of the Geosyntec Project Director include:

- Communication and coordination with the MDNR Site Manager and Hamilton Sundstrand; and
- Review of project work and deliverables.

Investigation Project Manager

The Investigation Project Manager is responsible for ensuring that all work is conducted in conformance with this QAPP. Specifically, the responsibilities of the Investigation Project Manager include:

- Ensure that the QA, Health and Safety, and Task Manager roles are assigned and being properly performed;
- Monitoring and reporting project progress;
- Management of the investigation team and subcontractors to ensure unified, productive project accomplishments; and
- Review of investigation work product and deliverables.

Health and Safety Manager

The Health and Safety Manager is responsible for ensuring that field personnel and subcontractors comply with the Site-Specific Task Hazard Analyses (THAs) and Health and Safety Plans (HASPs) and any Contractor-developed HASPs.

QA/QC Manager

The QA/QC Manager is responsible for ensuring that all field and laboratory work is conducted in compliance with this QAPP. This individual, or his or her designee, performs both scheduled and random reviews and audits of work activities for conformance with this QAPP and MDNR requirements, and reports directly to the Investigation Project Manager on the outcome of reviews and audits and the status of any corrective action required to address QA deficiencies.

Project Engineer and Project Geologist

These individuals function under the general direction and supervision of the Investigation Project Manager and are responsible for the day-to-day implementation of specific tasks and the preparation of specific deliverables. These individuals will perform general supervisory functions for individual project tasks, ensuring their completion in a timely manner which conforms to MDNR requirements.

Contractors and Subcontractors

Contractors and Subcontractors, to be selected by the Investigation Project Manager, are responsible for conducting work associated with site investigations and implementing approved remedies. During remedy design, Contractors and Subcontractors may provide information on construction procedures and capabilities, construction concerns, available material specifications, and may perform constructability reviews.

1.2.2 QAPP Distribution

All project personnel are to receive and are required to read a copy of the most recent version of the QAPP. A record acknowledging the individual's agreement to follow the procedures and policies contained in the QAPP will be retained for all project personnel.

1.3 AUTHORIZED LABORATORIES

The laboratories authorized to perform analyses on environmental samples are identified in Table 1.1. Additional Missouri-certified laboratories may be authorized subsequent to this QAPP and any

such laboratories will be added to Table 1.1 in future revisions of this QAPP. The identified laboratories are authorized to subcontract analytical work as necessary, with the approval of the Investigation Project Manager. All authorized laboratories are National Environmental Laboratory Accreditation Program (NELAP) certified. Any subcontracted analytical work will meet or exceed the quality objectives described in Section 1.4.

1.4 QUALITY ASSURANCE OBJECTIVES

Work conducted under this contract may include soil gas probe or well installation, sampling programs, and chemical analyses of soil vapor. The sampling and analysis programs will incorporate the following QA elements:

- Sampling programs designed to obtain sufficient data to determine levels of constituents of interest in media of interest;
- The use of sample collection and handling procedures that will ensure the representativeness and integrity of the samples;
- An analytical program designed to generate definitive data of sufficient quality and sensitivity to meet the project objectives; and
- Data deliverables that will allow verification and validation of the data and reproducibility of the reported results.

The design of the sampling programs will be based on the EPA's Data Quality Objective (DQO) process (EPA, 2006), a multi-step, iterative process that ensures that the type, quantity, and quality of environmental data used in decision-making is appropriate for its intended application.

TABLE 1.1

AUTHORIZED LABORATORIES

Authorized Laboratory[2]	Aqueous	Soil Vapor	Ambient Air
Centek Laboratories Syracuse, NY Phone: (315) 431-9730 www.centeklabs.com		X	X
Pace Analytical ECCS Mobile Lab Services Madison, Wisconsin Phone: (608) 221-8700 www.eccsmobilelab.com		X	
ESC Lab Sciences Mt. Juliet, TN Phone: (800) 767-5859/(615) 758-5858 www.esclabsciences.com	X		
Eurofins Air Toxics, Inc. Folsom, CA Phone: (800) 985-5955 www.eurofinsus.com/environment-testing/laboratories/eurofins-air-toxics		X	X
H&P Mobile Geochemistry, Inc. Carlsbad, CA Phone: (800) 834-9888 www.handpmg.com		X	
Pace Analytical Services, Inc. Nationwide – headquartered in: Minneapolis, MN Phone: (612) 607-1700 www.pacelabs.com	X		X

[2] The Investigation Project Manager may authorize additional laboratories in addition to the laboratories listed in Table 1.1.

The overall process for establishing the DQOs will be to:

- State the problem;
- Identify the decision;
- Identify inputs to the decision;
- Define study boundaries;
- Develop a decision rule;
- Specify decision error limits; and
- Optimize the study design.

Systematic planning is a science-based, common-sense approach designed to ensure that the level of documentation and rigor of effort in planning is commensurate with the intended use of the information and available resources. DQOs are a key component of systematic planning and play a central role in the systematic planning process (EPA, 2015)

Table 1.2 summarizes the steps in the DQO process, the purpose of each step, and the application for vapor intrusion at the site.

The principal objectives of the QAPP pertain to the collection of data that are sufficient to evaluate the possible presence and concentration of constituents in the media of interest. Therefore, the quality of the data gathered in this project can be defined in terms of the following elements: precision, accuracy, representativeness, completeness, comparability, and sensitivity (PARCCS). These elements are discussed below.

Precision

Precision is a measure of the degree to which two or more measurements are in agreement. Field precision is assessed through the collection and measurement of field duplicates. Precision will be measured through the calculation of relative percent difference (RPD). Precision in the laboratory is assessed through the calculation of RPD for duplicate samples, either as matrix spike/matrix spike duplicates (MS/MSDs), laboratory control spike/laboratory control spike duplicate samples (LCS/LCSD) or as laboratory duplicates, depending on the method. Duplicate collection frequency and RPD acceptance criteria are detailed in Section 3.0.

TABLE 1.2

DATA QUALITY OBJECTIVES

DQO Step	Purpose of the DQO Step	Application for Vapor Intrusion at the Site
1. State the Problem	Summarize the problem (e.g., the monitoring hypothesis, the investigation objective(s)) for which new environmental data will be collected or modeling or analysis will be performed.	VOCs may be present in soil gas at the former Hulett Lagoon site (former lagoon). If so, these VOCs may have migrated in soil gas toward nearby buildings, resulting in the potential for vapor intrusion if VOC concentrations in soil gas exceed EPA residential, exterior soil gas Vapor Intrusion Screening Levels (VISLs).
2. Identify the Decisions	Identify the decision that will be supported by the new data, modeling or analysis.	1. Determine the extent of VOCs in soil gas above VISLs due to migration from the former lagoon. 2. Determine an appropriate buffer zone distance, nominally 100 feet but to be adjusted based on site-specific conditions (the combined areas will define the "VI inclusion zone"). 3. Determine whether any buildings are within the VI inclusion zone.
3. Identify the Inputs to the Decisions	Identify the information needed to support the decision, including data gaps that warrant collection of new information.	Soil gas will be collected at nominal depths of 5 and 10 feet below ground surface at locations around the lagoon (except where refusal in bedrock occurs at a shallower depth). If necessary, soil gas samples will be collected at additional step-out locations until the extent of the VOC soil gas concentrations exceeding VISLs is characterized.
4. Define the Boundaries of the Study	Specify the spatial and temporal aspects of the environmental media or endpoints that the data are to represent to support the decision.	The spatial boundaries of the study area consist of the former lagoon and adjacent areas where VOCs in soil gas exceed VISLs due to migration from the former lagoon. Soil gas probes will be sampled for three additional quarters to evaluate temporal variability.
5. Develop a Decision Rule	Develop a logical "if…then" statement that defines the conditions that will inform the decision-maker to choose among alternative decisions.	If soil gas concentrations at a sampling location exceed one or more VISLs, then three additional locations approximately 100 feet further from the former lagoon will be sampled. This "step-out" procedure will be followed until the area exceeding VISLs has been characterized. If buildings are found within the site-specific VI inclusion zone, then additional vapor intrusion investigations will be required at these buildings. If no buildings are located with the VI inclusion zone, then the need for further action, if any, will be based on an evaluation of multiple lines of evidence per EPA (2015).

DQO Step	Purpose of the DQO Step	Application for Vapor Intrusion at the Site
6. Specify Tolerable Limits on Decision Errors	Specify acceptable limits on decision errors, which are used to establish performance goals for limiting uncertainty in the analysis.	Soil gas samples will be collected at 50-foot intervals around the former lagoon to ensure migrating VOCs are detected. Analytical limits of detection will be less than risk-based VISLs for compounds of concern based on a target risk of 1×10^{-5} for carcinogens and a target hazard quotient of 1 for non-carcinogens. Laboratory analyses will meet EPA method requirements for accuracy, precision, and repeatability.
7. Optimize the Design for Obtaining Data	Identify the most resource-effective sampling and analysis design for generating the information needed to satisfy the DQOs.	A mobile laboratory will be utilized to provide real-time laboratory analysis of soil gas samples to guide the installation of additional “step-out” soil gas probes, if required. At least 1 in 5 samples will be split with a fixed-base laboratory to ensure adequate data quality.

Accuracy

Accuracy is the degree of agreement between the observed value and an accepted reference or true value. Accuracy in the field is assessed through the use of trip blanks and equipment rinsate blanks and through the adherence to all sample handling, preservation, and holding time requirements. Trip blanks and equipment rinsate blank collection frequency and acceptance criteria are detailed in Section 3.0. Laboratory accuracy is assessed through the analysis of MS/MSDs, laboratory control samples, surrogates, and the subsequent determination of percent recoveries (%Rs). Accuracy is also assessed through the analysis of method blanks. Accuracy control limits are detailed in Section 3.0. Full analyte spikes are required for LCS and MS/MSD samples which include at a minimum all of the constituents of concern.

Representativeness

Representativeness is the extent to which the sampling design adequately reflects the environmental conditions of the site. The data will be considered representative of the site if all sampling and analysis activities are conducted according to the workplans and this QAPP.

Additionally, see Section 3.7 of the Work Plan (Geosyntec, 2017), which discusses the ability and limitations of the investigation approach to collect representative data that meet project goals.

Completeness

Completeness is a measure of the amount of valid data obtained from a measurement system compared to the amount that was expected to be obtained under normal conditions. "Normal conditions" are defined as the conditions expected if the sampling plan was implemented as planned. Field completeness is a measure of the number of valid samples obtained during all sampling for the project. The field completeness objective for the program is greater than 90 percent.

Laboratory completeness is a measure of the amount of valid measurements obtained from all the measurements taken in the project. The laboratory completeness objective is greater than 95 percent.

Comparability

Comparability expresses the confidence with which one data set can be compared to another data set measuring the same property. Comparability is ensured through the use of established and approved analytical methods, consistency in the basis of analysis (wet weight, volume, etc.), consistency in

reporting units, and analysis of standard reference materials. By using standard sampling and analytical procedures, data sets will be comparable.

Sensitivity

Sensitivity refers to the minimum magnitude at which analytical methods can resolve quantitative differences among sample concentrations. If the minimum magnitude for a particular analytical method is sufficiently below an action level or risk screening criterion, then the method sensitivity is deemed sufficient to fully evaluate the dataset with respect to the desired reference values.

Sensitivity of analytical data is demonstrated by the laboratory reporting limits (RLs). The target RLs for the constituents to be analyzed will be detailed in the workplans. The target RLs will be selected in order to support quantitation below the project action limits. Detections between the RL and method detection limit (MDL) will be reported and flagged by the laboratory with a "J" qualifier to indicate that these are estimated results. The laboratory will use its most recent detection limit study results to report analytical results.

Alternative analytical methods will be evaluated if the need arises, and the QAPP will be amended, if necessary.

1.5 COMPETENCY AND TRAINING

Personnel will be deemed competent for assigned tasks by education and/or experience. Requirements for special certifications, registrations, and/or training (e.g., health and safety training, etc.) will be addressed in separate task-specific documents (i.e., HASP). All field staff meet 29 Code of Federal Regulations (CFR) 1910.120.

1.6 DOCUMENTATION AND RECORDS

Documentation and records that are typically generated as part of field activities are described in this section.

1.6.1 Field Notebooks

Information pertinent to a field investigation, monitoring, or implementation activity and to the review of applicable results will be recorded in a bound field notebook with consecutively numbered pages. Entries made in the field notebook will be made in waterproof ink. If required, corrections

will consist of line-out deletions which are to be initialed and dated. Information typically documented in a field notebook may include:

- Author's name, title and signature;
- Date and time of entry;
- Names and responsibilities of field crew members;
- Details of sampling locations, including sketches, as appropriate;
- Date and time of sample collection;
- Sample identification and description;
- Details of any required procedural deviations, such as sampling or schedule changes;
- Calibration or maintenance of field equipment;
- Required or miscellaneous field observations; and
- Weather conditions.

Field investigations and sampling situations vary widely, and actual site conditions are sometimes not fully anticipated at the time of workplan preparation. However, information recorded in the field notebook should be sufficient to allow an adequate reconstruction of events, if necessary. The field notebook will be kept in the team member's possession or in a secure place during the investigation and will become a part of the permanent project file.

1.6.2 Field Reporting Forms

Examples of applicable field reporting forms are included in Appendix A. Entries made on field reporting forms will be made in waterproof ink. If required, corrections will consist of line-out deletions which are to be initialed and dated. The following field reporting forms are included in Appendix A, and may be used as needed:

- Borehole Log
- Soil Gas Probe Construction
- Soil Gas Probe Measurements
- Photographic Record Log
- Meter Calibration
- Daily Field Report
- Inventory of Containerized Material

2.0 MEASUREMENTS AND DATA ACQUISITION

Procedures and protocols for recording field measurements and collecting environmental samples are detailed in this section.

2.1 STANDARD OPERATING PROCEDURES

Standard operating procedures (SOPs) related to anticipated field activities are summarized below and provided in Appendix B of the Work Plan (Geosyntec, 2017). Additional SOPs for field activities that have not yet been identified will be developed as necessary, and will be incorporated into this QAPP by reference or revision.

2.1.1 Drilling

Prior to drilling activities, Missouri One Call will be contacted to locate known public utilities near the proposed drilling locations and applicable access and permitting will be obtained. Soil borings typically will be advanced by hollow stem auger (HSA), solid stem auger (SSA), and/or direct-push (e.g., GeoProbe®) techniques. When possible, the smallest diameter core barrel appropriate for the task should be used to minimize the disturbance to geologic materials surrounding the borehole. Standard split spoon samplers or continuous coring devices may be used while drilling, as necessary. When split spoon samplers are used, blow counts will be recorded for each 6-inch increment/interval to document soil density. Drill cuttings will be inspected and described for intervals not sampled by split spoon or continuous coring devices. Soils recovered from split spoon samplers, continuous coring devices, or drill cuttings will be described by an experienced geologist or engineer. Soil samples may be screened for the presence of volatile organic compounds (VOCs) or other gasses utilizing a clean, calibrated photo-ionization meter (PID) that is capable of reading in parts per million (ppm) or parts per billion (ppb) which may be rented, provided by the client, or owned by the field team, and results will be recorded on borehole logs or in a field notebook. An example borehole log form is included in Appendix A.

Drilling and sampling equipment will be decontaminated prior to and between uses as described in Section 2.1.5. Drill cuttings, unused soil samples, and decontamination water will be containerized or otherwise secured pending the results of analyses designed to evaluate appropriate management options (Section 2.1.6).

2.1.2 Soil Vapor Sampling

Soil vapor samples are typically collected from small diameter borings. Soil vapor samples may be analyzed by mobile laboratory services in the field or delivered to a fixed-base laboratory for analysis.

Sampling Point Installation

Boreholes will be advanced under the oversight of project personnel, at locations selected by the field lead and approved by the Investigation Project Manager, from ground surface to approximately five or ten feet below ground surface (bgs) using a direct-push rig (i.e. Geoprobe® or equivalent). Upon completion of drilling activities, and using freshly-gloved hands, each soil vapor probe assembly will be immediately placed into the borehole by drilling personnel. Soil vapor probes will be constructed using 0.25-inch inner diameter by 6-inch long, stainless steel screens connected to 0.25-inch outer diameter Nylaflow® tubing. Screens will be placed at the desired sampling depth (typically in the middle of the sampling zone, described below) and the tubing extended up the center of the borehole to approximately six inches above ground surface and fitted with an air-tight valve. Screens will be placed in the soil vapor sampling zone (typically one foot in length), but may be adjusted based on soil stratigraphy and moisture content. Stainless-steel screens will be centered within each sampling zone and the annulus surrounding each screen backfilled with approximately one foot of clean silica sand (or glass beads, 60 – 120 sieve size) or to a height of approximately two inches above the screen, at minimum. Granular bentonite will be placed and wetted in two lifts of approximately three inches each (six inches total) above the filter pack and then a thick slurry of powdered bentonite and water will be added to seal the remainder of the borehole annulus to approximately six to eight inches below ground surface. The top of each soil gas probe will be fitted with a valve to maintain an air-tight seal. If required, a 5-inch diameter flush-mount well vault will be set in concrete around the top of each soil vapor probe tube to minimize infiltration of water or outdoor air.

To minimize the potential for cross-contamination during investigation activities, the ends of each length of soil vapor probe tubing will be capped and tubing placed inside an air-tight storage bag or container and kept away from hydrocarbons and truck exhaust. Tubing will remain capped, except during soil vapor probe installation, and will be stored inside the cab of the field vehicle. Stainless-

steel probe screens will be kept in an air-tight container until installation to avoid contamination. An example soil gas probe construction form is included in Appendix A.

Soil Vapor Sample Collection

Soil vapor samples will be collected in the field using current state of the art procedures. Soil vapor probes will not be disturbed for a minimum of two hours and when practical, for 24 hours before sampling, then purged by removing a minimum of one liter (1-L) of soil gas. Purging will be completed at a flow rate of 200 milliliters per minute (mL/min) or less using a lung box and Tedlar® bag, then screened with a PID for VOCs and a GEM 2000 landfill gas meter for oxygen, carbon dioxide and methane (O2/CO2/CH4). If the permeability is sufficient to allow reasonable flow rates, soil gas will be screened for PID and O2/CO2/CH4 field measurements for a minimum of three successive Tedlar® bag samples to confirm stable readings prior to collection of a sample for mobile laboratory analysis.

To ensure the collection of representative soil gas samples, each soil gas probe will be leak tested by placing a small plastic shroud filled with a minimum concentration of 10% helium to serve as a tracer. An air-tight seal of hydrated bentonite or foam will be placed on the ground surface around the edge of the shroud where it contacts the ground. During purging activities, soil gas will be screened for the presence of helium using a MDG-2002 helium detector to determine if there are leaks in the sampling train. If helium concentrations >1% of the shroud concentration are observed in the purged soil gas, the soil gas probe seal will be checked and/or enhanced to reduce the infiltration of ambient air into the probe and another purge sample collected. If helium concentrations of less than 1% of the shroud concentration are observed, stabilized soil gas readings will be recorded. Once the integrity of the sampling train has been established, soil gas samples will be collected for analysis utilizing an SKC Inc., 500-mL Tedlar® bag at a flow rate of 200 mL/min or less. The mobile laboratory uses a gas chromatography-mass spectrometry (GC/MS) and will perform soil vapor analysis for select VOCs using EPA Method 8260 with nominal RLs of 20 micrograms per cubic meter ($\mu g/m^3$).

For a fixed base laboratory, samples may be collected in 1-L SUMMA canisters with regulators set for a flow rate of 200 mL/min, following the procedures established by EPA Method TO-15. An example soil gas probe measurement form is included in Appendix A.

2.1.3 Ambient Air Quality Sampling

Ambient air samples may be collected at the same time as soil vapor samples to provide information on potential background levels of compounds of concern due to ambient air. Typically, one ambient air sample is collected per day from a representative/upwind location in a SKC Inc., 500 mL Tedlar® bag at a flow rate of 200 mL/min or less and analyzed for select VOCs by EPA Method 8260. The sample collection location, time and date will be recorded in the field notebook.

2.1.4 Aqueous Sample Collection

To insure proper decontamination procedures, field rinsate blanks may be collected daily, at minimum. Following equipment decontamination, new distilled/deionized water will be poured into or on decontaminated equipment and aqueous samples will be collected by holding a sample bottle with a freshly gloved hand in the center of flow. Field rinsate blanks will be properly preserved, stored on ice, and shipped under chain of custody documentation to a fixed base lab to be analyzed for select VOCs by EPA Method 8260.

2.1.5 Equipment Decontamination

Equipment decontamination procedures are dependent on the type of equipment. Further, the use of dedicated and disposable equipment (e.g., tubing) is advantageous in that it may eliminate a need for equipment decontamination prior to and between uses, and field rinsate blanks.

The following procedures are typical:

- Physically clean the equipment. For large equipment (e.g., drilling augers, continuous samplers), spraying with high-pressure and (if necessary) high-temperature water provides sufficient decontamination.
- For small equipment (e.g., hand auger, split spoons, etc.), more aggressive procedures, such as those listed below, will also be used:
    - Wash with a solution of detergent and potable/distilled/deionized water.
    - Triple-rinse with distilled or deionized water.
- Decontaminated equipment should be allowed to air dry and, unless it will be re-used again later that day or the next day, wrapped and/or stored appropriately for later use.

Equipment decontamination procedures will be specified as necessary in task-specific workplans.

2.1.6 Investigation Derived Wastes

Investigation derived wastes (IDW) will be managed in accordance with all applicable local, state and federal laws and regulations. IDW may include environmental media, such as drill cuttings and decontamination waters, and solid wastes, such as used tubing or valves and personal protective equipment. The types and estimated amounts of IDW will be described in task-specific work plans. Additionally, it is our understanding that Hamilton Sundstrand will be the generator of any IDW and will provide signatures for any required manifests and disposal forms.

Drill cuttings/soil cores may have significant levels of chemicals of concern (e.g., trichloroethene, cis-1,2-dichloroethene), and will be visually inspected for the presence of non-aqueous phase liquids (NAPLs) and field screened with a PID to measure organic vapor concentrations at each borehole location. Soils exhibiting NAPL or elevated organic vapor concentrations will be segregated and containerized separately from soils not exhibiting these properties to facilitate characterization and minimize disposal costs. Cuttings will be placed into 55-gallon drums, labeled as pending waste determination, and stored at a location designated by Hamilton Sundstrand.

Decontamination water will be visually inspected for the presence of NAPL. Waters that exhibit an oily sheen will be segregated and containerized separately from waters not exhibiting an oily sheen to facilitate characterization and minimize disposal costs. Decontamination and purge water will be placed into 55-gallon drums, labeled as pending waste determination, and stored at a location designated by Hamilton Sundstrand.

Other IDW (e.g., disposable gloves, used tubing/valves, etc.) will be bagged and placed into a waste container at the direction of Hamilton Sundstrand.

An inventory of each day's IDW will be recorded in a bound field book and/or on appropriate field forms. The inventory will reference the date and area of generation and be provided to Hamilton Sundstrand for its use in the proper management of the IDW.

2.2 SAMPLE HANDLING AND CUSTODY REQUIREMENTS

Details on sampling handling and chain of custody requirements are provided in the following subsections.

2.2.1 Sample Handling

Samples will be packaged and preserved in a manner prescribed by the applicable analytical method (Section 2.3). Method-specific holding time requirements will be observed.

2.2.2 Sample Custody Documentation

Sample Labels

Sample containers will be labeled. Labels will be completed with waterproof ink. Clear packaging tape may be applied over the completed label, as necessary, to prevent it from loosening, degrading, or smudging. Information common to sample labels includes:

- Sample number or designation;
- Equipment identification;
- Site or project name;
- Sample collection date and time;
- Preservative and filtration status;
- Analytes requested; and
- Sampler's name or initials.

Chain of Custody Forms

Samples will be recorded chronologically on chain of custody forms. Entries to chain of custody documents will be made in waterproof ink. The chain of custody document(s) will be placed in a zippered plastic bag and enclosed in the sample shipping container. The sample shipping container will be custody-sealed as described below.

Custody Seals

Custody seals are used to assure the integrity of samples from the time the samples are collected and logged into the chain of custody system until the samples are received by analytical laboratory personnel. Samples will be delivered or shipped to the laboratory in appropriate shipping containers. The shipping container will be custody-sealed in a manner which requires the destruction of the seal at the time of opening whenever a third-party delivery service is used. Such shipping containers will also be taped shut, with a layer of clear packaging tape placed over the custody seal to minimize the likelihood of accidental destruction during shipping and handling.

2.3 ANALYTICAL PARAMETER REQUIREMENTS

Anticipated parameters are listed in Table 2.1 as are the requirements for field preparation, container type and volume, and holding times. Requirements for analytical parameters not included in Table 2.1, if any, will be addressed in task-specific workplans and incorporated into this QAPP by reference or revision. The anticipated analyte list is provided in Table 2.2.

2.4 QUALITY ASSURANCE/QUALITY CONTROL REQUIREMENTS

Typical quality assurance/quality control (QA/QC) requirements are summarized in the following sections.

2.4.1 Laboratory QA/QC Requirements

Authorized laboratories (Section 1.3) will analyze environmental samples in accordance with appropriate EPA methods. QA/QC requirements and corrective action procedures are developed by each laboratory in accordance with EPA method requirements and each laboratory's internal SOPs and quality assurance plans. Laboratory QA/QC results will be reviewed as part of the data validation process (Section 3.2).

2.4.2 Field QA/QC Requirements

Typical field QA/QC sampling requirements are summarized in Table 2.3. The rationale for specific field QA/QC sampling requirements is discussed below. The results of field or trip blanks analyses will not be used to correct data. If contaminants are found in blanks, the source of the contamination should be identified and corrective action, possibly including resampling, should be initiated.
QA/QC requirements and corrective action procedures are developed by each provider in accordance with each provider’s internal SOPs and QA plans. Such SOPs and QA plans will be reviewed as part of the data validation process (Section 3.2).

TABLE 2.1

ANTICIPATED PARAMETERS AND SAMPLE PREPARATION REQUIREMENTS

Parameter	Medium	Volume	Container	Filtration	Preservative	Holding Time
VOCs	Aqueous	2 @ 40 mL	Glass/Teflon-lined cap	None	HCl, Cool 4°C	14 Days
VOCs	Ambient Air, Soil Vapor	500 mL	Tedlar® Bag	N/A	None, Cool 4°C	3 Days
VOCs	Ambient Air, Soil Vapor	1 L	SUMMA Canister	N/A	None	30 Days

N/A – Not applicable

TABLE 2.2

ANTICIPATED ANALYTE LIST

Analyte	Aqueous	Soil Vapor	Ambient Air
1,1-Dichloroethene	X	X	X
Cis-1,2-Dichloroethene	X	X	X
Tetrachloroethene	X	X	X
Trans-1,2-Dichloroethene	X	X	X
Trichloroethene	X	X	X
Vinyl Chloride	X	X	X

TABLE 2.3

TYPICAL FIELD QA/QC SAMPLING REQUIREMENTS

QA/QC Sample	Frequency of Sample Collection			
	Aqueous	**Solids**	**Soil Vapor**	**Ambient Air**
Trip Blank (VOCs Only)	1 per sampling event[1]	None	None	None
Equipment or Rinsate Blank	1 per day of borehole drilling	1 per day when collecting soil samples	None	None
Duplicate	1 per 20 samples[1]	None	1 per 10 samples (fixed base lab) 1 per 5 samples (mobile lab)[2]	None
Replicate	1 per 20 samples[1]	None	1 per 10 samples (fixed base lab) 1 per 5 samples (mobile lab)[2]	None

Note: [1]Required when aqueous samples (not including field equipment or rinsate blanks) will be analyzed for volatile organic constituents. Not to exceed 72 hours in the field.
[2]At least two samples will be collected and analyzed per scheduled sampling event.

Aqueous and Solids QA/QC Samples

The use of dedicated, disposable sampling equipment may be specified for aqueous sample collection to minimize or eliminate the need for equipment decontamination and the preparation of field (equipment) rinsate blanks. Nonetheless, the following field QA/QC samples may still be required per the applicable workplan.

Trip Blanks

Trip blanks are containers of organic-free water prepared by the laboratory for transport into the field for the duration of a sampling event. However, no trip blank should be allowed to stay in the field for an extended period. Therefore, a 72-hour maximum holding period has been established for trip

blanks prepared for aqueous sampling events. If aqueous sampling extends beyond a 72-hour event (3 days), more than one trip blank will be required.

Rinsate Blanks

Field rinsate blanks are prepared to assess the decontamination of reusable sampling equipment. Aqueous field rinsate blanks will be prepared at a rate of one per day, per sampler, per drilling or sampling technique when the required drilling or sampling involves the use of reusable equipment.

Field Duplicates

Field duplicates are used to assess the degree of variability apparent due to both sampling technique and laboratory procedures by evaluating representative samples obtained from the same medium, collected sequentially from the same location, and are submitted to the same lab for analysis. Field duplicate samples of soil vapor, for example, include the collection of one sample immediately followed by the collection of a second (duplicate) sample. Solids/soils are inherently non-homogenous and are subject to natural variations in composition and texture across small distances; therefore, field duplicates will not be collected during solid/soil evaluations.

Field Replicates (Splits)

Typically, field replicates are two or more samples split from an original container or sampling device in a manner which assures that the splits are the same in all respects, assuming the original sample is relatively homogenous. Replicate samples will be analyzed by the same analytical procedures at different laboratories to assess the variability between the laboratories. Soils are inherently non-homogenous and it is not possible to prepare representative splits of a solid/soil sample in the field; therefore, field replicates will not be prepared for solid/soil samples.

Soil Vapor and Ambient Air QA/QC Samples

A mobile laboratory blank will be prepared by the laboratory and analyzed prior to initiating the day's sampling to ensure that adequate decontamination has been achieved. If required, field (equipment) blanks will be prepared by drawing a sample of ambient air through the sample collection system (i.e., vacuum pump, tubing, etc.).

Field Duplicates

Field duplicates consist of two canister samples collected simultaneously and side by side. In the case of soil vapor samples for the mobile laboratory, sequential Tedlar® bag samples will be

collected. Field duplicates are prepared to evaluate sampling technique and laboratory procedures through the analysis of representative samples obtained from a relatively homogenous medium.

Field Replicates

For soil vapor sample collection using both a mobile and fixed-base laboratory, replicate samples may be collected sequentially in separate containers (i.e., Tedlar® bag for mobile laboratory and SUMMA canister for fixed-base laboratory) and submitted to the fixed base laboratory to confirm mobile laboratory results.

2.5 EQUIPMENT INSPECTION, MAINTENANCE AND CALIBRATION REQUIREMENTS

Field and laboratory instrumentation must be calibrated prior to use. Laboratory instruments must be calibrated with calibration blanks and standards following EPA SW-846, EPA 600/4-79-020, EPA/625/R-96/010b, etc., as appropriate. Divergence from acceptable benchmark criteria, defined by method-specific protocol and instrument type, requires correction before analysis can begin. Calibration blank and instrument performance standard check results must be recorded in the instrument logbook, which will also contain evaluation procedures, benchmark criteria and maintenance records. Standard Reference Materials from the National Institute of Standards and Technology, the EPA, or other certifiable sources should be obtained and analyzed to assess and ensure the accuracy of the measured parameter.

The PID, GEM, Helium and other meters used will be calibrated daily using methods outlined in the User Manual according to manufacturer's requirements. A meter calibration form is included in Appendix A.

2.6 INSPECTION AND ACCEPTANCE CRITERIA FOR SUPPLIES AND CONSUMABLES

Supplies and consumables specified for use in approved workplans or remedy designs will be obtained from reputable vendors. Field personnel or Task Managers, as appropriate, will confirm the specifications and quality of the supplied materials.

3.0 DATA VALIDATION AND USABILITY

The following sections describe the data validation process used at the Site. Data will be validated in accordance with National Functional Guidelines for Data Review (EPA, 2016).

The following sections describe the QA activities that will be performed to ensure that the collected data are scientifically defensible, properly documented, of known quality, and meet project objectives. Two steps are completed to ensure that project data quality needs are met:

- Data Verification/Validation
- Data Usability Assessment

3.1 DATA VERIFICATION AND VALIDATION REQUIREMENTS

Field and laboratory results will be verified and validated in accordance with the specifications presented in this section. Analytical results will be maintained in an electronic format when possible to eliminate transcription errors. Data that are hand entered into an electronic format will be proofed as necessary to guard against transcription errors.

Analytical data will be verified and validated in terms of its ability to satisfy the data quality objectives for accuracy, precision and completeness specified by the associated workplan and the analytical laboratory. Conditions requiring the invalidation of analytical data (i.e., elimination from future use) are rare, as noted in the following sections. However, conditions necessitating the flagging of data are more common and will be evaluated based on the criteria that follow. Qualified data are valid and usable in every way, but are flagged to alert the user that special care may apply to their use in interpretations.

3.1.1 Data Validation Procedures

Documentation Reviews

One in twenty samples will be tracked through the field logbook and/or other field reporting forms, chain of custody documents, and laboratory confirmation sheets (or executed chain of custody form) to ensure that there are no errors or discrepancies. If an error or discrepancy is found, the entire data group will be checked and all questionable data that cannot be assured to be free of quality concerns will be appropriately flagged or invalidated. Data will be evaluated if the origin of the sample is in

doubt (e.g., sample numbers appear to be switched from one document to another). Errors will be noted and initialed on the raw data forms, but not altered or erased. In such cases, a single line will be drawn though the error and the correct entry will be written immediately beside the error, along with the validator's initials and the date.

Field logbooks and/or field reporting forms will be checked for calculation errors and proper field procedures for one in twenty samples. If an error is found, the entire data package will be checked. The Investigation Project Manager or their designee will use professional judgment to assess whether an error affects the quality or usability of data. Where quality may be affected, the data will be appropriately flagged. Where errors cannot be corrected or quality assured, data may be invalidated subject to professional judgment, and MDNR approval.

All samples will be analyzed within the required holding time limits specified in SW-846 or the appropriate reference. For example, the holding time for VOCs in water or soil is 14 days for preserved samples and 7 days for unpreserved samples. Aqueous samples will be preserved in accordance with applicable EPA method specifications. Samples not analyzed within specified holding time limits, and/or not appropriately preserved, will be invalidated unless professional judgment dictates that flagging would be more appropriate (e.g., consistent with historic observations), subject to MDNR approval.

Field QA Sample Review

The preparation of trip and field blanks is required when sampling various media (refer to Table 2.3). Flagging is not required when fewer trip blanks or field blanks than required are collected, but a QA memo will be placed in the project file and the incident will be noted in the data transmittal for the sampling event. However, the sample results associated with contaminated trip blanks (i.e., samples collected after the trip blank's preparation) or field blanks (i.e., samples collected prior to the field blank's preparation) will be flagged if the blank's concentration exceeds 10% of the sample's concentration. Further, sample results may be invalidated if the blank concentration exceeds 50% of the sample concentration (subject to professional judgment and MDNR approval). Data will not be flagged if the sample concentration is below the reporting limit, regardless of the blank concentration, because the sample is obviously not cross-contaminated. Sample concentrations will not be corrected by subtracting blank concentrations.

Field duplicates are successive (rather than split) samples intended to assess variations due to sample collection, handling or analysis. It is recognized that natural variations in the environment can cause significant variations in concentrations. Field replicates (splits) are related to two or more samples split from a single collection device or container. Field replicates are submitted to different laboratories for analysis, and are intended to assess variations in laboratory performance. Field duplicate and replicate concentrations should agree with one another as described below:

Relative Concentration Relationship	Criterion
Concentrations < 5 Times the Reporting Limit	± Reporting Limit
Concentrations > 5 Times the Reporting Limit	RPD (± 30%)

The Relative Percent Difference (RPD) is calculated with the following equation:

$$RPD\ (\%) = (S1-S2)/[(S1+S2)/2] * 100$$

where: S1 and S2 are the two duplicated values, or the highest and lowest values if more than two sample duplicates are analyzed.

Duplicate and replicate sample results that do not meet the above criteria and are not consistent with historical results will be qualified. Flagging is not required when fewer field duplicates or replicates than required are collected, but a QA memo will be placed in the project file and the incident will be noted in the data transmittal for the sampling event.

3.1.2 Laboratory Data Verification

Laboratory data reports will be reviewed for appropriate QA/QC procedures and data qualifiers. Applicable EPA analytical methods (e.g., SW-846, TO-15) encourage laboratories to develop in-house QA/QC limits, and require adherence to in-house limits for data reporting, flagging and corrective actions. Verification of appropriate laboratory qualifiers will be conducted during data validation in accordance with the criteria presented in Table 3.1.

Although it is the laboratory's responsibility to ensure that its results meet minimum internal QA/QC standards and are properly flagged, the data validation process will also include the following checks:

- Ensure that the required quality control tests (i.e., Table 3.1) were performed at the required frequency. If quality control results cannot be obtained from the laboratory, all associated data will be appropriately qualified.
- Ensure that initial calibration verification and reference sample test results were within laboratory-specified control limits. Data associated with initial calibration verification or reference standards outside of control limits will be invalidated.
- Confirm that the laboratory properly qualified the data.

TABLE 3.1

LABORATORY VERIFICATION PARAMETERS

Method	Parameter	Frequency	Criterion[2]
8000D[1]	Method Blanks (MB)	1 in 20 samples	<MDL
	Initial Calibration Verification (ICV)	Daily	±15-20%[3]
	Continuing Calibration Verification (CCV)	1 in 10 samples	±20%
	Reference Samples	1 in 10 samples	70-130%
	Matrix Spike (MS) and Duplicate pair or MS/Matrix Spike Duplicate (MSD) pair	1 in 20 samples	70-130%
	Laboratory Control Sample (LCS) or LCS/ Laboratory Control Sample Duplicate (LCDS) pair	1 in 20 samples	70-130%
	Surrogate Recovery	Each Field Sample	In-House[3]
TO-15	MB	1 in 20 samples	<MDL
	ICV/CCV	Daily	±30-40%[3]
	Instrument Performance Check	Daily	90-110%
	LCS or LCS/LCSD pair	1 in 20 samples	70-130%
	Surrogate Recovery	Each Field Sample	In-House[3]

Notes: [1]Applicable to EPA 8000-series Methods (e.g., 8260).
[2]Numerical criteria, where presented, is based on SW-846 and TO-15 guidance. In-house acceptance criteria are preferred by EPA, and will be used for verification assessments in each category during data validation.
[3]Compound-specific.

3.2 USABILITY/RECONSILIATION WITH DATA QUALITY OBJECTIVES

This section describes how the verified/validated project data will reconcile with the project DQOs, how data quality issues will be addressed and how limitations on the use of the data will be reported and handled. The purpose of this section is to indicate the methods that will ensure that the data collected for this investigation falls in line with the DQOs as described in Section 1.4 of this QAPP. To meet these DQOs, a combination of quantitative and qualitative evaluations will be used to check the quality of the data. These procedures will be used by the laboratory, in generating the data, and by the Data Validator, in the evaluation of the data for ultimate use in accordance with the associated workplan.

The data generated must meet the data user's needs as defined in the project DQOs. The primary objectives for assessing the usability of the data are to ensure (1) data are representative of conditions at the Site; (2) data meet the project reporting RL requirements; and (3) data are of the quality needed in order to meet the overall objective of the workplan.

Results for QC samples, including field and laboratory blanks, spikes, and duplicates will be evaluated using the equations described below to determine the validity and usability of the data. In addition, the data will be reviewed for indications of interferences to results caused by sample matrices, contamination during sampling, contamination in the laboratory, and sample preservation and storage anomalies (i.e., sample holding time or analytical instrument problems).

Data will be qualified for precision and accuracy by the Data Validator. The Data Validator will apply the standard data validation qualifiers to data to indicate the level of uncertainty in the associated result. In general, data that are left unqualified, data qualified "U" (non-detected), data qualified "J" (including J+ and J-) (detected as an estimated result), and data qualified "UJ" (non-detected at an estimated detection RL) are considered valid and usable for project objectives within the limitations of the qualification. Data that are qualified "R" (rejected), due to severe exceedances of QC requirements, will be considered invalid and unusable for making project decisions.

3.2.1 Comparison to Measurement Criteria

Precision Assessment

The RPD, as a measure of variability between the matrix spike and matrix spike duplicate or sample and matrix duplicate (laboratory duplicates), and field duplicates, will be calculated to compare to precision and representativeness DQOs.

In the event of precision results that do not meet the measurement performance criteria established for this project the results will be inspected to determine if the reduced precision can be attributed to sampling techniques (field duplicates) or sample contamination (field and laboratory blanks). If precision has been determined to be affected by sampling or contamination the data users must decide how to use data near the project action limits that may be affected. Data of reduced precision might be usable with appropriate acknowledgement of the uncertainty associated with results that are near action levels.

Accuracy Assessment

Accuracy, as a measure of bias, will be evaluated based on the percent recoveries (%Rs) of the MS/MSD samples, surrogates, ISs, LCS, and initial and continuing calibration check samples. These QC results will be compared to the project measurement performance criteria for accuracy.
The increase in concentration of the analyte observed in the spiked sample, due to the addition of a known quantity of the analyte, compared to the reported value of the same analyte in the unspiked sample determines the %R.

Percent recoveries for spiked samples and QC are determined using the following equation:

$$\% R = \frac{\text{(Result in Spiked Sample - Result in Original Unspiked Sample) x 100}}{\text{Known Amount of Spike Added}}$$

Percent recoveries for LCS are determined using the following equation:

$$\% R = \frac{\text{Result for constituent in LCS x 100}}{\text{True Value of the LCS}}$$

Additionally, field and laboratory blanks will be used to evaluate whether field or laboratory procedures represent a possible source of contamination in the samples (bias). Unmonitored contamination can allow false positive results to be reported and treated as true sample components

when, in fact, they are not. This type of error will adversely affect the accuracy of the reported results. Several types of blanks, including field blanks, method blanks, and instrument blanks, will be used in this project as described in Section 2.4.2.

In general, the procedure for assessing blank samples for potential contamination is as follows.

- Tabulate blank constituent results.
- Identify blank samples for which constituents are reported above the MDLs.
- If no constituents are detected above the instrument or MDLs in any blanks, the associated data are reported unqualified and no blank actions are taken.
- If constituents are detected above instrument or MDLs in the blanks, the associated sample constituent results may be qualified during data validation. This qualification may result in the negation of results at raised RLs due to blank actions.

Thus, potential false results will be reported with elevated reported limits. These elevated limits will be recognized in the data available for the end user. Bias that does not meet the limits of the measurement criteria objectives will be indicated by the results of LCS, MS, calibration, and surrogate analyses. Bias indicated by these measurement criteria objectives will need to be evaluated to determine the effect on the use of the data. High bias on nondetect results, results that are well below action levels or well over action levels, may have little effect on the use of the data. Low bias for results that are well below the action levels or well over the action levels may have little effect on the use of the data. For results near the action levels with a high or low bias or indeterminate bias, the data will need to be reviewed carefully to establish if the data are usable for the intended purposes. Sample reanalysis, analysis of archived material, and/or recollection of the sample may be appropriate depending on criticalness of the missing data, logistical constraints, cost, and schedule.

Completeness Assessment

Completeness is the ratio of the number of valid sample results to the total number of results planned for collection. The goal of this program is to generate valid, usable data. However, in environmental sampling and analysis, some data may be lost due to sampling location logistics, field or laboratory errors, or matrix effects that may cause the rejection of results for some constituents. The overall completeness goal of collection of valid data is 90% for the field and 95% for analytical data. The

Data Validator will assess the completeness of the overall data generation against the project goals of a minimum of 90% as valid and usable results. Valid and usable results are defined as those that are not rejected during validation (e.g., due to severe holding time or spike recovery noncompliances) or during the overall assessment (e.g., improper sampling technique). Following completion of the sampling, analysis, and data validation, the percent completeness will be calculated and compared to the DQOs using the following equation.

$$\% \text{ Completeness} = \frac{\text{Number of valid/usable results obtained} \times 100}{\text{Number of valid/usable results planned}}$$

If this goal is not met, data gaps may exist that will require evaluation to determine the effect on the intended use of the data. Sample reanalysis, analysis of archived material, and/or recollection of the sample may be appropriate depending on criticalness of the missing data logistical constraints, cost, and schedule.

Sensitivity

Sensitivity is evaluated by verifying that laboratory RLs meet the target RLs stated in the workplans. The failure to calibrate with a standard at the laboratory RL or the presence of excessive dilutions may result in elevated detection limits. The effect of these elevated limits will need to be reviewed in light of the historical data and project action levels to determine if adequate information is available to satisfy the DQOs.

Representativeness

Representativeness expresses the degree to which data accurately and precisely represent a characteristic of a population, parameter variations at a sampling point, a process condition, or an environmental condition within a defined spatial and/or temporal boundary. Representativeness is dependent upon the proper design of the sampling program and will be satisfied by ensuring that the workplan and QAPP are followed and that proper sampling techniques are used. In designing the sampling program, media of interest will be specified.

Representativeness in the laboratory is ensured by using the proper analytical procedures, appropriate methods, meeting sample holding times, and analyzing and assessing field duplicate samples. The sampling network will be designed to provide data representative of the site. During development of

sampling plan, consideration will be given to past site processes and uses, existing analytical data, physical setting and processes, and media of interest. The rationale of the sampling network will be discussed in detail in the workplan.

Comparability

Comparability in the field is dependent on the use of standard sample collection method and will be satisfied by ensuring that the workplan SOPs are followed such that proper sampling techniques and sample handling protocols are followed. This should result in data sets that are comparable between field teams and sampling rounds.

Comparability in the laboratory is dependent on the use of established and approved analytical methods, consistency in the basis of analysis (wet weight, volume, etc.), consistency in reporting units, and analysis of standard reference materials. By using standard sampling and analytical procedures, data sets will be comparable.

3.3 OVERALL ASSESSMENT OF ENVIRONMENTAL DATA

Data assessment will involve data evaluation and usability to determine if the data collected are of the appropriate quality, quantity, and representativeness to the project decision. This evaluation will be performed by the Investigation Project Manager in concert with other users of the data. The QC results associated with each analytical parameter for each matrix type will be compared to the objectives presented in this QAPP. Data generated in association with QC results meeting these objectives and/or the data validation criteria will be considered usable. Data that do not meet the objectives and/or the data validation criteria might still be usable. This assessment may require various statistical procedures to establish outliers, correlations between data sets, adequate sampling location coverage, etc., in order to assess the effect of qualification or rejection of data. The effect of the qualification of data or loss of data deemed unacceptable for use, for whatever reason, will be discussed and decisions made on corrective action for potential data gaps.

4.0 CORRECTIVE ACTION

This section describes processes by which needed corrective actions are identified and implemented.

4.1 FIELD CORRECTIVE ACTION

Corrective action in the field may be needed when the sample frequency is changed (i.e., more/fewer samples, sample locations other than those specified in the QAPP, etc.), or when sampling procedures and/or field analytical procedures require modification, etc. due to unexpected conditions. The field team may identify the need for corrective action. The Task Managers will approve the corrective action and notify the Investigation Project Manager. The Investigation Project Manager will approve the corrective measure. The Task Managers will ensure that the field team implements the corrective action.

Corrective actions will be implemented and documented in the field record book. Documentation will include:

- A description of the circumstances that initiated the corrective action;
- The action taken in response;
- The final resolution;
- Any necessary approvals; and
- Effectiveness of corrective action.

No staff member will initiate corrective action without prior communication of findings through the proper channels.

If at any time a corrective action issue is identified which directly impacts the project DQOs, the MDNR Site Manager will be notified as soon as possible and in advance of any significant project changes.

4.2 CORRECTIVE ACTIONS TAKEN BY THE ANALYST

Corrective actions to be taken by analytical laboratory personnel vary with the analysis being conducted, the matrix and effects of any interfering factors, and with the laboratory responsible for completing the work. These corrective action issues are managed internally by the laboratory in

accordance with method requirements, the laboratory's QAPP and its internal operating procedures. At a minimum, however, laboratories conduct the QA/QC evaluations described below. Results falling outside the laboratory's internal QA/QC ranges should be flagged by the laboratory, and described in its case narrative.

Errors, deficiencies, deviations, or laboratory events or data that fall outside of established acceptance criteria should be investigated. In some instances, corrective action may be needed to resolve the problem and restore proper functioning to the analytical process. The investigation of the problem and any subsequent corrective action taken should be documented.

QC Check Samples

If a result is outside the limits, the test will be repeated, as necessary, or the associated sample results will be appropriately flagged.

Lab Duplicates

If a result is outside the limits, the test will be repeated, as necessary, or the associated sample results will be appropriately flagged.

Fortifications, a.k.a. spikes

If a result is outside the limits, the test will be repeated, as necessary, or the associated sample results will be appropriately flagged.

4.3 CORRECTIVE ACTION DURING DATA VALIDATION AND DATA ASSESSMENT

The need for corrective action may be identified during either data validation or data assessment. Potential types of corrective action may include resampling by the field team or reinjection/reanalysis of samples by the laboratory. These actions are dependent upon the ability to mobilize the field team and whether the data to be collected are necessary to meet the required QA objectives. If the Data Validator or data assessor identifies a corrective action situation that impacts the achievement of the project objectives, the Investigation Project Manager will be responsible for informing the appropriate personnel, including the MDNR Site Manager.

5.0 REFERENCES

EPA, 1999. Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air, Second Edition, Compendium Method TO-15, Determination of Volatile Organic Compounds (VOCs) in Air Collected in Specially-Prepared Canisters and Analyzed by Gas Chromatography/Mass Spectrometry (GC/MS). EPA/5625/R-96/010b. January 1999.

EPA, 2001. Requirements for Quality Assurance Project Plans, EPA QA/R5. March 2001.

EPA, 2006. Guidance on Systematic Planning Using the Data Quality Objectives Process, EPA QA/G-4. February 2006.

EPA, 2014. SW-846 Method 8000D, Revision 4, Determinative Chromatographic Separations. July 2014.

EPA, 2015. Office of Solid Waste and Emergency Response Technical Guide for Assessing and Mitigating the Vapor Intrusion Pathway from Subsurface Vapor Sources to Indoor Air, OSWER Publication 9200.2-154, June.

EPA, 2016. National Functional Guidelines for Superfund Organic Methods Data Review. Office of Superfund Remediation and Technology Innovation, Washington, D.C. OSWER 9355.0-132, EPA 540-R-014-002. September 2016.

Geosyntec, 2017. Soil Gas Investigation Work Plan, Former Hulett Lagoon. October 17, 2017.

MDNR, undated. Quality Management Plan for Missouri Department of Natural Resources, Air and Land Protection Division, Geological Survey and Resource Assessment Division, and Water Protection and Soil Conservation Division.

APPENDIX A

FIELD FORMS

BOREHOLE LOG

CLIENT _____
PROJECT LOCATION _____
PROJECT NO. _____

BH NO. _____
PAGE _____ OF _____

NORTH	DRILLER		DATE START
EAST	RIG		DATE FINISH
GRD ELEV.	BITS	FLUIDS	TOTAL DEPTH
TOC ELEV.	LOGGED BY		WATER DEPTH

SAMPLE TYPES:

CT Cuttings
SS Split Spoon
DC Dry Core
WS Wash
NX NX Core
CS Continuous Sampler
Other: _____

SAMPLER SPECIFICATIONS:

Length _____
O.D. _____
I.D. _____
Material _____
Liner _____
Other _____

DEPTH (FT.)	BIT / CASING	SAMP NO.	SAMP TYPE	RECOV. FT/FT	BLOWS per 6"	SYM	SURFACE CONDITION: _____ SOIL/ROCK DESCRIPTION	SOIL VAPOR PID ☐ FID ☐ BG	HS	Core

LOCATION SKETCH	DENSITY: GRANULAR:		COHESIVE:		PROPORTIONS:		REMARKS/WEATHER
	0–10	Loose	0–4	Soft	0–10%	Trace	
	10–30	Med Dense	4–8	Med Stiff	10–20%	Little	
	30–50	Dense	8–15	Stiff	20–35%	Some	
	>50	Very Dense	15–30	Very Stiff	35–50%	And	

LOG STATUS:

PRELIMINARY: _____ FINAL: _____

Geosyntec consultants

R:\Drawings\STD\Borelog6.dwg Friday, November 08, 2013 11:30:41 AM

SOIL GAS PROBE CONSTRUCTION

Geosyntec consultants

Probe ID _____ **Site Location** _____

Project Name _____ **Field Personnel** _____

Project Number _____ **Recorded By** _____

Permit Number _____ **Drilling Contractor** _____

Installation Date(s) _____ **Driller** _____

Drilling Method _____ ☐ **Temporary Soil Gas Probe**

Borehole Diameter _____ ☐ **Permanent Soil Gas Probe**

Materials Used

Pipe/Tubing : Diameter _____ cm/inches
Construction _____
☐ Nylaflow Tubing
☐ Other _____

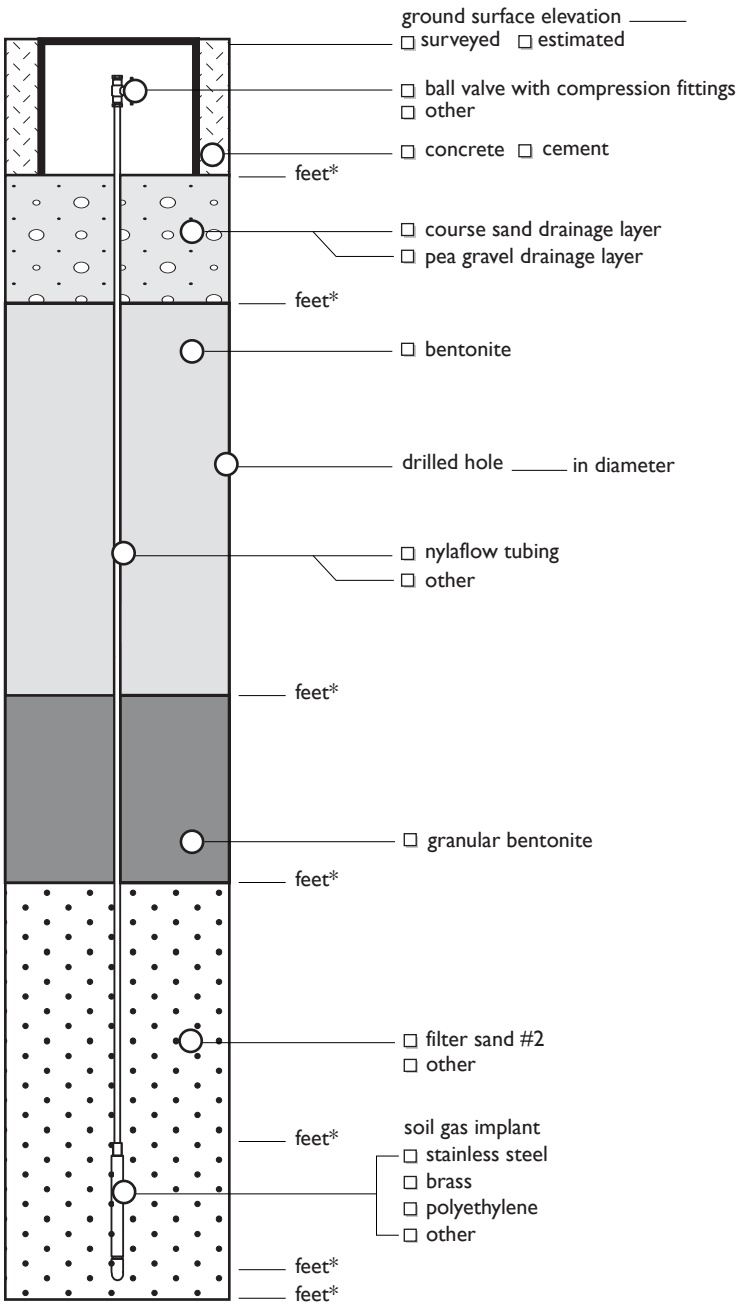
Soil Gas Implant : Length _____ cm/inches
Diameter _____ cm/inches

Construction
☐ Stainless Steel
☐ Brass
☐ Polyethylene
☐ Other _____

Surface Fitting: ☐ Ball valve with compression fittings
☐ Other _____

Protective Casing: ☐ Flush mount
☐ Above grade
Length _____ cm/inches
Stickup _____ cm/inches
Construction ☐ Cast Aluminum
☐ Cast Steel
☐ Other _____

Casing Installation: Depth _____ cm/inches
Diameter _____ cm/inches



* *Depth Below Ground Surface*

Soil Gas Probe Construction 2016_TR0254.ai

SOIL GAS PROBE MEASUREMENTS

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① Project Name: _____ Probe No.: _____ ☐ Sub-slab probe ☐ Soil gas probe

Date: _____ Project Number: _____ Mini Rae 2000 Serial No.: _____ Lamp: 10.6 / 11.7 eV

Site Location: _____ Landtech GEM 2000 Landfill Gas Meter Serial No. M: _____

Weather: _____ MDG 2002 Helium detector Serial No.: _____

Field Personnel: _____ Tracer Gas: ☐ Helium ☐ Other _____

Recorded By: _____

② Surface Type: ☐ Asphalt ☐ Concrete ☐ Grass ☐ Other_____

Surface Thickness _____ inches/centimeters ☐ Unknown
(i.e., asphalt or concrete)

③ 1 Casing Volume

☐ Sub-slab <0.1 L

Soil gas probe _____ (L)

④ Initial Vacuum (prior to pumping) _____ in. H_2O

⑤ Shut in test prior to pneumatic test completed,____ in. H_2O held for ___ seconds.

⑥ Start of Pneumatic Test: _____

Elapsed Time (min.)	Pump Flow Rate (LPM)	Well Head Vacuum in. H_2O
	0.1	
	0.2	
	0.5	

⑦ Field tubing blank reading (ppm_v) completed? ☐Yes ☐No PID Reading _____ ppm_v

⑧ Shut in test prior to purging completed? Yes ☐ No ☐

⑨ Purging

Date	Start Time	End Time	Elapsed Time (min.)	Bag Volume (L)	Purge Rate (LPM)	Cumulative Volume (L)	CH_4 (%)	CO_2 (%)	O_2 (%)	Tracer Gas: Shroud (%) Min	Tracer Gas: Shroud (%) Max	Tracer Gas: Sample (ppm_v, %) (circle one)	VOCs by PID (ppm_v)

⑩ Helium concentration in field screened samples is less than 5% of minimum concentration in the shroud? ☐ Yes ☐ No

Note: 1% helium = 10,000 ppm_v

⑪ Shut in test prior to sample collection completed? Yes ☐ No ☐

⑫ Sample Collection

Date	Time	Sample ID	Summa Canister ID	Flow Controller #	Vacuum Gauge #	Initial Vacuum (in. Hg)	Final Vacuum (in. Hg)

Comments:

SGP measurements - pneumatic testing.ai

GEOSYNTEC CONSULTANTS
Photographic Record

Client:	**Project Number:**
Site Name:	**Site Location:**

[Photograph ID/Number]	
Date:	
Direction:	
Comments:	

[Photograph ID/Number]	
Date:	
Direction:	
Comments:	

METER CALIBRATION

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Project Name:_____ **Date:**_____ **Recorded By:**_____ **Page**_____ **of** _____

Project Number:_____ **Weather:** _____ **PrimaryActivities:**_____

PIDs

Serial Number		Ambient Air (ppm)	100ppm Isobutylene (ppm)
	Initial Time:		
	Final Time:		
	Initial Time:		
	Final Time:		
	Initial Time:		
	Final Time:		
	Initial Time:		
	Final Time:		

GEMs

Serial Number		Ambient Air			Calibration Gas			Ambient Air		
		CH_4(%)	CO_2(%)	O_2(%)	CH_4(%)	CO_2(%)	O_2(%)	CH_4(%)	CO_2(%)	O_2(%)
	Initial Time:									
	Final Time:									
	Initial Time:									
	Final Time:									
	Initial Time:									
	Final Time:									
	Initial Time:									
	Final Time:									

NOTES:

Personnel Signature:_____ **Date:**_____

Meter Calibration.xl

DAILY FIELD REPORT

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Project Name: _____ Date: _____ Page ___ of ___

Project Number: _____ Primary Activities: _____

Field Personnel: _____ _____

_____ _____

Recorded By: _____ _____

Weather: _____

Time	Description of activities - location of work, work performed, equipment & personnel used, incidental information

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INVENTORY OF CONTAINERIZED MATERIAL

Project Name _____ Comments _____

Project Number _____

Date _____

Field Personnel _____

Recorded By _____

Drum Number	Accum. Date	Waste Type	Depth Interval	Corresponding GeoSyntec Sample #	Date GeoSytnec Sample Analyzed	Waste Classification	Date of Transfer

DrumTracking.ai