APPENDIX A

LABORATORY QUALITY ASSURANCE MANUALS AND STANDARD OPERATING PROCEDURES

Appendix A Table 1. Analytical Laboratory Summary
Integrys Business Support, LLC
Former MGP Sites
USEPA Region 5
CERCLA Docket Nos. V-W-'06-C-847, V-W-'07-C-869, and V-W-'07-C-877

	Analytical Laboratory[1]							
Analysis[2]	**Columiba Analytical Services, Inc.**	**Woods-Hole Group**	**Pace Analytical Services, Inc.**	**New Age/Landmark**	**Test America**	**Microbac Laboratories, Inc.**	**STAT Analysis Corporation**	**TriMatrix Laboratories, Inc.**
Soil/Sediment Matrices								
Volatile Organic Compounds								
BTEX	X	X	X	X		X	X	X
Trimethylbenzenes[3]	X	X	X	X		X	X	X
Semi-Volatile Organic Compounds								
34 PAHs[4]	X	X	X	X		X	X	X
20 PAHs[5]	X	X	X	X		X	X	X
Phenols[6]	X	X	X	X		X	X	X
Inorganics[7]	X	X	X	X		X	X	X
TOC	X	X	X	X		X	X	X
Soot Carbon		X						
Water Matrix								
Volatile Organic Compounds								
BTEX	X	X	X			X	X	X
Trimethylbenzenes[3]	X	X	X			X	X	X
Semi-Volatile Organic Compounds								
20 PAHs[5]	X	X	X			X	X	X
Phenols[6]	X	X	X			X	X	X
Inorganics[7]	X	X	X		X	X	X	X
Available Cyanide						X	X	X
TOC	X	X	X			X	X	X
Fate and Transport Parameters[8]			X					X

Notes:

1. Laboratory Quality Assurance Manuals are in Appendix A.
2. Analysis to be performed using methods provided on Multi-Site QAPP Tables 2 through 5.
3. Trimethylbenzenes include 1,2,4-trimethylbenzene and 1,3,5-trimethylbenzene.
4. 34 PAHs include the parent and alkalayted or chain PAHs, for sediment samples only.
5. 20 PAHs include the parent PAHs.
6. Phenols inlcude 2,4-dimethylphenol, 2-methylphenol, 4-methylphenol, and phenol.
7. Inorganics may include aluminum, antimony, arsenic, barium, cadmium, chromium, copper, total cyanide, iron, lead, manganese, mercury, nickel, selenium, silver, vandium, and zinc.
8. Fate and Transport Parameters may include: alkalinity (bi-carb), alkalinity (carb), ammonia, dissolved organic content, nitrate, sulfate, sulfide, ferrous iron, total dissolved solids, and total organic content.

X - indicates the laboratory may be selected to analyze environmental samples for parameters marked.

BTEX = benzene, toulene, ethylbenzene, and total xylenes.

PAHs = polynuclear aromatic hydrocarbons

TOC = total organic carbon

APPENDIX B

DATA VALIDATOR AND RISK ASSESSOR QUALIFICATIONS

APPENDIX B1

MAKUEHL CO.

Marcia A. Kuehl

Marcia Kuehl is an environmental chemist and manager with over 25 years of experience in laboratory analysis, environmental data collection, quality assurance and data assessment. She was involved in the early development of the EPA Contract Laboratory Program and subsequent data validation protocols. Currently, Ms. Kuehl is the President/Owner of an environmental consulting firm, the MAKuehl Company. Ms. Kuehl performs and manages the multiple tasks of data validation, laboratory and field audits and assists engineering firms in Quality Assurance Project Plans (QAPP) and Data Quality Objectives (DQO) development.

Ms. Kuehl's educational background is in chemistry, with environmentally focused graduate research in the maternal transfer of PCBs conducted while pursuing her Master's of Environmental Arts and Sciences (M.E.A.S.) degree. In order to conduct this research, she was responsible for developing the analysis method, statistical design and quality assurance program to provide defensible data. This experience was invaluable in her QA role at U.S. EPA. She recently completed her M.S. in Environmental Science and Policy thesis titled "Polychlorinated Biphenyl Congener Patterns in Lake Michigan Mass Balance Study Biota".

Ms. Kuehl has written and reviewed **technical guidance** documents during and after her tenure at EPA. Ms. Kuehl was involved in establishing the DQOs for the Region V Dioxin study with Dow Chemical, and was subsequently asked to join the National Dioxin QA Task Force. The first protocols for EPA regional data validation of Contract Laboratory Program (CLP) were written by Ms. Kuehl, and her involvement in the CLP technical caucuses dates from their inception. Ms. Kuehl developed the DQO process that Donohue and Associates followed for its assigned EPA Region V ARCS contract RI/FS investigations.

Ms. Kuehl has provided for **implementation of QA programs** through her creation of laboratory QA programs for the EPA Central Regional Laboratory and two commercial laboratories. Ms. Kuehl led all scoping meetings involving environmental measurements to guide staff in appropriate DQO selection. Field Sampling Plans as well as Quality Assurance Project Plans were either written or reviewed by her for all federal lead projects.

Ms. Kuehl has proven **skills in communicating** technical information to professionals and the public. She has conducted training for attorneys, geologists, and engineers in the principles of environmental QA from the DQO process through sample collection, analysis and evaluation. Ms. Kuehl has trained EPA subcontractors and state environmental personnel in data validation, statistics, and writing QAPPs. Integrating these subcontractors into project teams and monitoring the quality of their work was her responsibility. Ms. Kuehl has presented technical issues and findings at national and regional meetings of the American Chemical Society, American Society for Quality Control,

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Water Environment Federation, American Institute of Chemical Engineers and the EPA.

Ms. Kuehl has had over 24 years experience in **conducting on-site audits** of environmental laboratories. She has audited over 15 laboratories providing analytical data under contract to the EPA Contract Laboratory Program, and an additional 14 laboratories that provided analytical data in support of remedial activities and RCRA monitoring programs. She has audited EPA ORD and industrial laboratories conducting ultra-trace level analyses for polychlorinated dibenzofurans and polychlorinated dibenzodioxins for the EPA National Dioxin Study. Most recently she has audited eight federal, state, university and commercial laboratories providing ultra-trace level analyses of congener specific PCBs for the EPA Lake Michigan Mass Balance Study and the seven contract laboratories for the Hudson River Contaminant Assessment Reduction Program. She has been retained by several laboratories to conduct "pre-audits" of them prior to their EPA and/or State audits, and she provides several engineering firms with "capacity and capability" audits of laboratories they are considering for large monitoring projects. She has also worked with a laboratory decertified by the State of Wisconsin in correcting deficiencies and successfully re-applying for certification.

Ms. Kuehl has **implemented automated data verification processes**. As QC Coordinator for the Lake Michigan Mass Balance study, she was responsible for review of all of the organic contaminant data in air, water, sediment and biota. As data was submitted to the EPA, she reviewed each spreadsheet for compliance with the electronic data standard reporting format and the researchers Measurement Quality Objectives. Data was then converted for loading into the data verification program, Research Data Management Quality Control System (RDMQ) developed by Environment Canada. She conducted data verification through RDMQ by the QC Coordinator, and resolved data quality and reporting issues with the laboratory. She worked with Booz Allen & Hamilton to create an automated data verification program for the PCB, pesticide, PNA, dioxin/furan and metals data collected for the Hudson River Contaminant Assessment Reduction Program.

Ms. Kuehl has **validated analytical data** for over 25 years, beginning in the infancy of the EPA Contract Laboratory Program in 1980. She was one of the EPA representatives that met quarterly with the CLP laboratory community and EPA research chemists to refine both the reporting and technical requirements of the CLP from 1980-1984. During her career she has validated data from Superfund sites, RCRA RFI sites and DOD sites for over 10,000 samples. Since 1995, she has validated PCB data for over 2,500 samples collected from the Fox River for the DNR, engineering firms and the paper industry.

Ms. Kuehl's involvement and input into the field of environmental quality assurance are documented and known to her peers. The experience and knowledge Ms. Kuehl holds will enable her to provide data validation support to NRT.

APPENDIX B2

EXPONENT

Exponent™

Statement of Qualifications

Environmental Risk Assessment Consulting Services for Wisconsin Public Service Corporations, Peoples Gas Light and Coke Company, and North Shore Gas Company Former Manufactured Gas Plant Sites

Prepared for

Integrys Business Support LLC
Chicago, Illinois

Exponent®

Statement of Qualifications

Environmental Risk Assessment Consulting Services for Wisconsin Public Service Corporations, Peoples Gas Light and Coke Company, and North Shore Gas Company Former Manufactured Gas Plant Sites

Prepared for

Integrys Business Support LLC
Supply Chain Services
700 N. Adams
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Prepared by

Exponent
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Alexandria, VA 22314

August 2007

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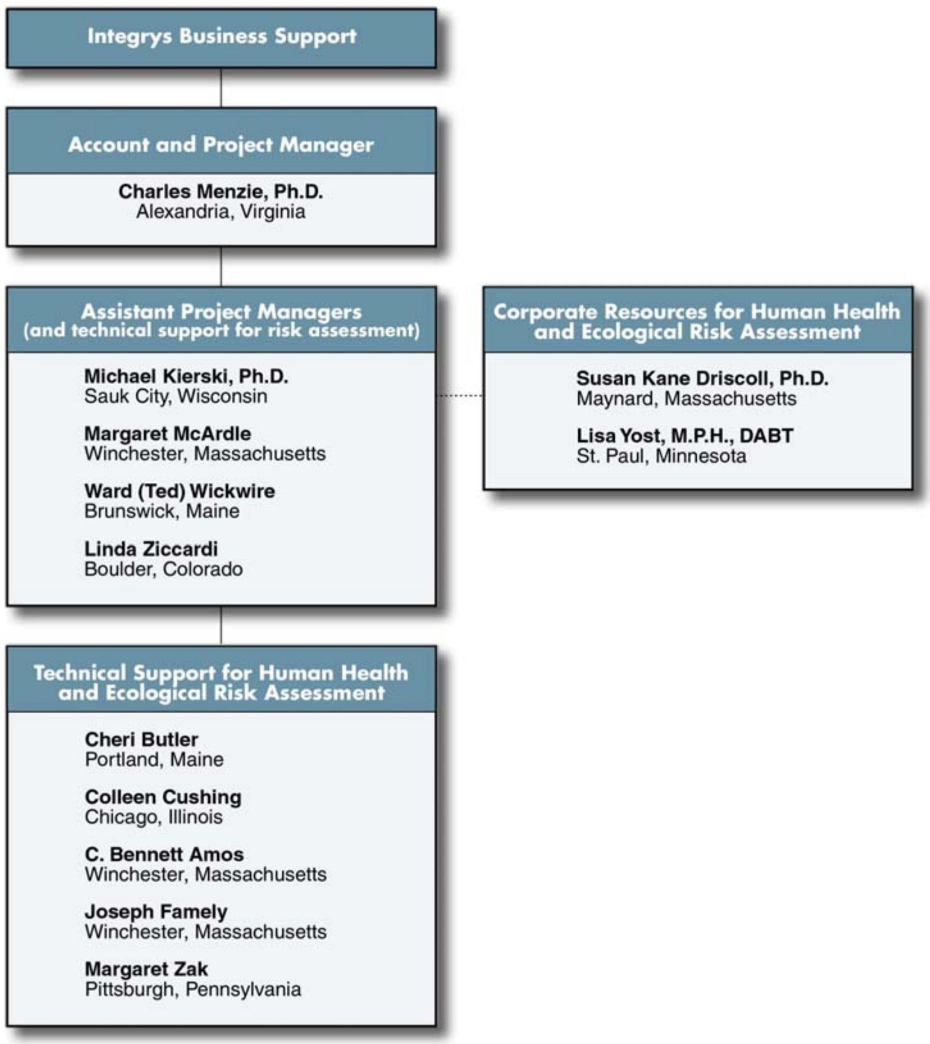
Project Team and Organization Chart

Exponent's Project Team is shown in the organization chart below. The Account and Project Manager will be Dr. Charles Menzie, who is nationally recognized as a leader in the field of human health and ecological risk assessment and has a unique combination of experience with both upland and aquatic environments. He has worked on all risk issues at MGP sites and has worked on more than 40 MGP sites throughout his career. He will use his breadth of experience to assist Integrys to develop streamlined and cohesive approaches to be implemented across MGP sites. This will reduce costs associated with coordinating the many elements of a project. This will also make it possible to conceptualize strategies that can lead to the most cost-effective approaches for sites. Dr. Menzie will be supported by Exponent staff with extensive MGP experience. Collectively this team will be able to efficiently complete the work and deliver the type of support services that Integrys Business Support, LLC (IBS) and the agencies need to support decisions.



Dr. Menzie will assign assistant managers to each site to help him with the day to day management and execution of the risk assessment project. However, he will be the main contact for Integrys on all of the MGP sites and the main point of contact with the remedial investigation companies and regulatory agencies. Each of the assistant project managers has 10 or more years of risk assessment experience and some, like Dr. Kierski, have worked in the field for 20 years on numerous MGP sites. Many of the assistant managers have extensive experience with USEPA Region 5, State of Wisconsin, and Illinois risk assessment staff.

The assistant project managers will not only perform day to day management of the projects, but will be technical resources on the MGP site that they work on. These assistant managers will be able to draw upon technical support staff to complete the risk assessment tasks at each MGP site. In addition, they will be able to draw on other corporate resources for specialized support including strategy support and specialized technical input. Dr. Susan Kane Driscoll will be available to assist with issues related to the bioavailability of PAHs in sediment and provide peer reviews of the ecological risk assessments. Ms. Lisa Yost will be available to assist with strategy on human health risk assessment issues and provide peer reviews of the human health component of risk assessments. Resumes for team members are provided in Attachment 1.

Exponent staff work well within virtual teams where staff can be in their respective locations and contribute productively to the project. The main regulatory interface will be between Dr. Charles Menzie and the USEPA, WDNR, and IEPA staff. Dr. Kierski will be the main support for Dr. Menzie on the MGP sites in Wisconsin and Illinois, as he is centrally located within the footprint of the sites. He will accompany Dr. Menzie on the site visits and disseminate the information to other assistant managers and technical staff. This will allow Exponent to cost-effectively evaluate multiple sites as they begin the remedial investigation process.

Project Team Publications

A list of published papers, conference presentations, and research related to characterization of MGP sites and/or sediments prepared by the project team members is provided in Attachment 2.

Case Histories

Exponent has selected six cases studies to show the breadth of risk assessment experience we have. These case studies showcase past MGP experience, and USEPA-led NPL and RCRA site experience. We have included a case study about the work in which we are presently assisting WPSC and NRT within the Superfund Alternatives Site (SAS) program as this seems most applicable to Integrys' needs. We have highlighted the cost efficiencies or technical innovation that was used to achieve client-specific goals or objectives.

Table 1, which follows the case histories, identifies the proposed Integrys project team members who worked on the project and their role, the scope of services for each project, and the total fees invoiced to the client for those services. Table 2 presents representative experience of Exponent staff at MGP sites throughout the country.

Multi-site Risk Assessment Framework Document and Work Plan Support for the Wisconsin Public Service Corporation Manufactured Gas Plant Sites

Client: Natural Resource Technology, Inc.

Location: WPSC MGP sites in Wisconsin

Project Description: Exponent is assisting NRT on behalf of the Wisconsin Public Service Corporation (WPSC) in the development of a multi-site risk assessment framework (RAF) for six WPSC MGP sites. This RAF was prepared in accordance with the statement of work (SOW) attached to the Settlement Agreement and Administrative Order on Consent for the conduct of remedial investigations and feasibility studies (RI/FS) between WPSC and USEPA. In addition, Exponent is currently assisting NRT and WPSC with the development of site-specific remedial investigation work plans on two of the six MGP sites (i.e., Stevens Point and Manitowoc) that are covered by the Agreement with USEPA.

The RAF provides a consistent streamlined approach for performing baseline risk assessments (BLRA) at the six sites covered by the Settlement Agreement, and is designed to be consistent with USEPA risk assessment guidance. NRT, WPSC, and Exponent, through a series of working meetings with USEPA staff (and sometimes WDNR staff), have negotiated an RAF approach that meets each party's needs, but is streamlined in nature. While the RAF document uses a streamlined approach whenever possible, it also incorporates the ability to use the latest advancements in assessing risks at sediment contaminated sites (e.g., the incorporation of measurements of black carbon in sediments). During the negotiation process, Exponent staff supported NRT and WPSC in a strategy development meeting to educate USEPA on the pros and cons of using specific methods for evaluating the bioavailability of PAHs in sediment. In addition, we introduced the concept of defining zones of sediment from the latest USEPA sediment management guidance, which was incorporated into the RAF document. The RAF was developed with an adaptive management approach built into the process so that lessons learned and information gained from earlier sites will be used to guide site-specific evaluations for subsequent sites. This adaptive management approach may involve refinements in habitat evaluations, the collection of site-specific data, the manner in which risks are characterized, and the use of risk-related information in management decisions.

The RAF process has been incorporated into the Stevens Point and Manitowoc Site-Specific Work Plan documents. At both sites, the process will be used to extensively limit the need for further risk assessment in the upland portions of the site as a result of past remedial actions and the results of site-specific habitat evaluations. For example, at the Manitowoc site the habitat evaluation was used to propose no need for evaluation of ecological risks in the upland site area because of the lack of sufficient ecological habitat.

The RAF process includes the following concepts:

- Use of an adaptive management approach so that lessons learned on early sites can be applied to later sites.
- Consideration of background conditions when evaluating site-related risks at each site.
- Upfront site visits (including qualitative habitat evaluations) during the remedial investigation work plan development to focus remedial investigation needs and the site-specific risk assessment approach.
- More detailed habitat assessments of the river during the remedial investigation to focus the ecological risk assessment on appropriate receptors and collect information important for evaluating different remedial solutions.
- Use of a streamlined human health and ecological risk assessment process for the upland media whenever possible, and additional levels of evaluation only as needed.
- Human health exposure evaluations for the river environment are tailored to the specific characteristics of the river at each site. For example, where water is too deep for human contact with sediment, this exposure pathway is eliminated.
- River investigations for the ecological evaluations are tailored to each site and use state of the art sediment characterization techniques coupled with sediment toxicity testing to evaluate potential ecological risks and to define different risk zones.

Support for Development of Risk-Based Methods to Assess Potential Impact of PAHs in Sediments at MGP Sites

Client: Electric Power Research Institute

Location: Various

Exponent staff have conducted a series of projects for EPRI, focused on the development of a risk-based approach for assessing potential impact of PAHs in sediments at MGP sites.

We wrote a chapter titled "Assessing Ecological Risks of PAH-Contaminated Sediments" in the *Sediments Guidance Compendium* published by EPRI. The *Sediments Guidance Compendium* provides a comprehensive review of key issues pertaining to the management, assessment, and cleanup of contaminated sediments at former MGP sites. Our chapter lays out the current thinking regarding the planning, conduct and use of ecological risk assessments for decision making for PAH-contaminated sediments in the United States. Topics covered in the chapter include: developing management goals; tiered assessment programs; conceptual models specific to PAH-contaminated sediments; developing assessment endpoints; multiple lines of evidence methods; developing work plans and sampling plans; PAH-specific issues associated with bioaccumulation and the food web; methods used to describe, characterize, or model risk; and how risk assessment information is, should, or could be used to inform decision-making.

We also conducted a number of research projects that focused on improving our understanding of the bioavailability and toxicity of sediment-associated PAHs to aquatic organisms. One of the goals of this work was to demonstrate that current draft sediment quality guidelines for PAH mixtures are overly conservative predictors of toxicity at MGP sites. In the first project, we compiled available data from various MGP sites on concentrations of PAHs in sediment and associated levels of sediment toxicity in laboratory tests. The data were used to validate an approach that can be used to develop site-specific remediation goals at MGP sites. In subsequent projects, we field-tested approaches that can be used to assess the bioavailability and toxicity of PAHs in sediments. Sediment samples that were collected from four former MGP sites were analyzed for a suite of parent and alkylated PAHs, as well as for "black carbon." Black carbon, which can include tars, pitch, and soot, is an operationally defined class of sediment organic carbon that has been shown to reduce the bioavailability of PAHs in sediment.

Salem Harbor Area Former MGP Sites

Client: National Grid (Formerly Massachusetts Electric Company)

Location: Salem Harbor, Massachusetts

Project Description: Working for National Grid (formerly Massachusetts Electric Company), Exponent staff developed a comprehensive assessment at a former manufactured gas plant (MGP) site in Salem, Massachusetts. Part of the project involved a multi-media ecological and human health risk characterization at the coastal MGP. Initial studies focused on assessing the impact of an *in situ* bioremediation application. Our scientists designed and employed a biomonitoring survey to assess the health of the benthic communities over a 6-year period following bioremedial activities. In addition, we designed and completed a site risk characterization. The project also included the development of a complex scope of work covering a variety of human receptors, terrestrial wildlife, and coastal marine wildlife. The assessment was applied to industrial, wetland, scrub-shrub, intertidal, and estuarine habitats.

The human health risk assessment considered current and future site uses as well as potential risks to residents bordering the cove. Exposure pathways included direct contact, incidental ingestion, and vapor intrusion. A spatially-explicit approach was used to define upland zones that contributed to the risk and that could be addressed through targeted remediation. Exponent scientists have developed methods for evaluating risks associated with vapor intrusion at MGP sites and those approaches were successfully applied at this site.

To support the ecological assessment, our staff designed a multi-media field sampling program that was used to delineate zones of risk in the aquatic environment. This is similar to the approach that Exponent presented in the RAF and discussed with Mary Logan of USEPA Region 5. Exponent also developed a means of screening terrestrial habitats to determine whether they should be included or excluded from formal assessment. At this site, they were excluded as they did not meet critical criteria.

This work involved a field program designed and implemented by Exponent staff. This included the collection of sediment for chemical analysis and toxicity testing, assessment of benthic community health, analysis of bioaccumulation, as well as visual analysis of habitat types. The design of studies is based on experience at numerous MGP sites and was tailored to the appropriate measures. A terrestrial habitat survey and screening assessment were also completed. Lines of evidence were integrated in a weight of evidence approach to reach an understanding of potential risks and risk drivers at the site. The human health and ecological assessment results were used to narrow of the focus of remedial alternatives. As with many other MGP sites, Exponent staff successfully demonstrated that bioavailability of PAH compounds to human receptors and ecological receptors was substantially reduced. Exponent staff were able to demonstrate that the area where risks were present was considerably less than the zones where MGP-related contaminants were elevated. Through application of multiple lines of evidence, areas with highly weathered MGP-related chemicals were demonstrated to present a low potential risk to ecological receptors. The project required close integration with a broad project team involving two engineering firms and two clients.

For the same client, Exponent staff conducted another Massachusetts Contingency Plan (MCP) ecological risk assessment in the same area, and again we were able to delineate risk zones. We developed a field program and conducted an ecological risk assessment under the MCP for a portion of the Bass River in Beverly, Massachusetts, potentially affected by a former MGP site. We sampled surface water and sediment for chemical analysis, sediment for toxicity testing (using the amphipod *Ampelisca abdita*), and benthic organisms for benthic community analysis. We applied a weight-of-evidence approach (sediment triad) to evaluate potential ecological risk in the sediment. We worked closely with the site engineer to apply our findings to the remedial strategy.

Former Messer Street MGP Site

Client: Northeast Utilities Service Company

Location: Laconia, New Hampshire

Project Description: A human health and ecological risk assessment was designed and conducted to assess risk from PAHs and other contaminants associated with a former MGP on the Winnipesaukee River in Laconia, New Hampshire. There was potential exposure of human and ecological receptors to PAHs from coal tars discharging to the river at discrete points, from tarry sediments, and from PAH-contaminated sediment and surface water. The risk assessment followed New Hampshire Department of Environmental Services policy in addressing potential risk to humans from exposure to sediment, surface water, and ingestion of fish from the river. The human health risk assessment assessed exposure to swimmers using the river, boaters using a local boat ramp, recreational anglers eating fish from the river, and individuals exposed to sediment along the riverbanks. Ecological exposures included exposure to contaminated sediments, tarry areas, and fish and invertebrates as a food source to higher trophic levels. Fieldwork included:

- Sampling of fish and shellfish for fillet and whole body concentrations of PAHs
- Sediment toxicity testing
- Sediment benthic community analyses
- Evaluation of sediment PAH concentrations.

Information generated from the sampling and analysis was evaluated using a weight of evidence protocol to assess ecological risk, following New Hampshire's guidance on ecological risk assessment. The ecological risk assessment also incorporated New Hampshire's use of readily apparent harm to assess ecological risk.

The risk assessment identified potential human health risks for swimmers exposed to surface water in the Winnipesaukee River and for anglers consuming fish from the river. The risk assessment also identified potential ecological risk to receptors in the Winnipesaukee River. Specifically, in certain locations in the river, there was potential ecological risk to sediment dwelling invertebrates, which are an important food source for local fish species. We worked closely with engineers and geologists from Haley and Aldrich, Inc. to develop a map of zones of readily apparent harm and to incorporate the results of the risk assessment into a remedial action plan. The plan as implemented included risk-based decisions for guiding the extent and type of remedial action. We also provided risk communication materials.

After completion of remedial activities at the site, we developed and implemented a post-remediation performance monitoring plan to assess whether the remedial goals for human health and ecological receptors have been achieved. Post-remediation monitoring for human health included the re-evaluation of human health risks based on two consecutive years of post-remediation fish fillet and surface water data. Fish tissue and surface water data were collected in 2002, approximately one year after completion of remedial activities, and were used in the first post-remediation risk assessment. The second round of fish tissue and surface water samples was collected the following year, and was used in the second post-remediation risk assessment. Post-remediation monitoring of benthic invertebrates began two years following remedial activities, to allow the benthic community time to be re-established. Based on the 2002 post-remediation data and updated toxicity information, no significant risks were identified for a swimmer exposed to surface water in the Winnipesaukee River or for an angler consuming fish from the Winnipesaukee River. The post-remediation evaluation for the benthic community is on going, and is being conducted every other year.

Tools for Streamlining Ecological Risk Assessments at RCRA Corrective Action Facilities

Client: General Motors

Location: USEPA Region 5

Project Description: General Motors (GM) has approximately 100 sites subject to corrective action under the Resource Conservation and Recovery Act (RCRA) in EPA Region 5 (Illinois, Indiana, Michigan, Minnesota, Ohio, and Wisconsin). These sites include assembly plants, parts plants, plating operations, and foundries. Most facilities tend to be bounded by urban areas, with all or most of the property developed in some capacity (e.g., parking lots, buildings, process areas). However, some facilities also include relatively large undeveloped areas such as woodlands or fields.

As GM's ecological risk consultant, Exponent has been supporting GM in working collaboratively with EPA Region 5 to develop a set of tools that can be used at RCRA corrective action sites to enhance the efficiency of the ERA process. The risk assessment tools are designed to streamline the ecological risk assessment (ERA) process by early identification and refinement of areas of concern and application of a consistent set of receptors, assessment and measurement endpoints, and toxicity reference values (TRVs). The overall objective of the streamlining process is to develop standardized approaches to and tools for ERA that enhance the usefulness of data for risk-based decision-making, while remaining consistent with EPA guidance.

Exponent identified the following key areas where performance of ERA during RCRA facility investigations (RFIs) could be improved:

- Assessment of the habitat characteristics of man-made features in an industrial context
- Consistency in selection of assessment and measurement endpoints and toxicity reference values (TRVs).

Habitat Assessment: The site investigation process under RCRA corrective action proceeds along a path of identifying contamination, investigating its nature and extent, and implementing corrective actions (if needed) for individual areas of interest (AOIs). At many sites, there are dozens of individual AOIs. Many AOIs are inside buildings, underneath concrete slabs, or are industrial structures, and thus clearly provide no habitat for typical ecological receptors. In other cases, there may be undeveloped areas such as wooded lots, wetlands, or fields that were not identified as AOIs because they were never subjected to any facility-related activity. There are not likely to be complete exposure pathways for ecological receptors in AOIs that provide no habitat—thus it is clearly inefficient to perform a chemical screening in these areas. Similarly, there are not likely to be complete exposure pathways in areas where there have been no releases of hazardous substances, and it would not be appropriate to require sampling and screening in these areas. However, some site features may provide resources for ecological receptors and may present complete exposure pathways as a result of documented releases or facility history.

A habitat assessment matrix was developed to enable risk assessors to 1) eliminate areas from further consideration in an ERA if documentation was sufficient to demonstrate that there were no complete exposure pathways, and 2) focus subsequent steps of the analysis by providing the basis for developing a contextually appropriate conceptual site model. The habitat assessment matrix is designed for use during a habitat characterization.

Endpoint and TRV Selection: Exponent has also improved the efficiency and predictability of the ERA process for GM by developing and employing standard sets of assessment endpoints and TRVs for selected receptors and substances. Standardizing these facets of the risk assessment frees risk assessors and risk managers—especially in cases where a single organization has a large number of sites within any given EPA region—from having to "reinvent the wheel" at each site. For example, a substantial level of effort is typically spent in developing the documentation needed to support the selection of receptors, exposure parameters, and TRVs. *A priori* agreement on the literature base, data interpretation, and rationale for determining these risk assessment variables also results in more efficient review by risk managers by precluding the need for much debate on technical issues. EPA Region 5 agreed on the application of a standard list of receptors that are likely to occur in the urban settings in the general EPA Region 5 ecoregion. Consistent with ERA guidance, these receptors are also expected to be maximally exposed and sensitive to substances that commonly occur at sites. Exposure parameters were developed for these receptors from references commonly used in risk assessments. The list of receptors is not necessarily all-inclusive, and both parties agree to consider other receptors as appropriate on a site-by-site basis. TRVs were developed based on the most current toxicological literature for the most common substances of concern . Whenever possible, source studies are selected that report effects of chronic dietary exposure on survival, growth, or reproduction. Potential source studies are also screened for ecological relevance of study design, test species, and chemical form. The most sensitive relevant endpoint available is selected. TRVs are expressed as a daily dietary dose, and are calculated from dietary exposure endpoints. The list of TRVs is also not necessarily all-inclusive, and both parties agree to consider alternative TRVs as appropriate, in particular if a change is warranted based on new information in the toxicology literature.

Risk-Based Decision Support Tools to Support the Dredged Material Management Program

Client: U.S. Army Corps of Engineers, Waterways Experiment Station

Location: Various

Project Description: Exponent staff have provided technical support for risk-based decision-making for the U.S. Army Corps of Engineers (Corps) Dredged Material Management Program. This includes developing models for evaluating uncertainty and variability, developing spatially explicit foraging models to refine exposure estimates in aquatic and terrestrial food webs, providing guidance on conducting risk assessments for open water and upland disposal of dredged materials, and completing ecological risk assessments for large waterways. We have completed two risk assessments for placement of dredged materials containing measurable concentrations of DDT and metabolites. These projects demonstrate the technical flexibility offered by our scientists in the development of transport and fate analyses to support ecological exposure assessments, development of tools to evaluate the potential effects of bioaccumulation, and completion of large risk assessments involving bioaccumulative substances. Under this project, our scientists have completed reviews of monitoring data, conducted literature searches and reviews, provided evaluation of transport and fate, bioaccumulation, and risk studies, developed reports, and developed and managed databases.

One product of this effort is the development of a tool called TrophicTrace for calculating the potential human health and ecological risks associated with bioaccumulation of contaminants in sediments and dredged materials. The model can be used as a screening tool or can incorporate available site-specific data for more refined estimates of potential risk. It was designed to be used within the Corps' tiered approach to dredged material management. This tool can be used to provide health- and ecologically-protective estimates of potential risk using results from sediment chemistry tests or 28-day bioaccumulation tests. The model, available from the Corps website, currently incorporates several example data sets for various human and ecological receptors. The user can edit the demonstration model parameters as well as create new models based on different fish species and/or site-specific human and ecological exposure parameters. The model incorporates interval analysis to quantify uncertainty based on ranges of input parameters (e.g., minimum, average, upper bound on the average, and maximum).

Another tool we have developed is the Spatially Explicit Exposure Model (SEEM) for terrestrial systems. Tools for exposure analysis currently available to the risk assessment community range from simple statistical calculations applied broadly across an entire site (average, maximum, 95% UCL, percentiles) to complex GIS-based modeling. Models such as SEEM that evaluate population-level risks and include spatial considerations such as habitat quality, but also remain accessible to a range of users, are not readily available. SEEM is an exposure model that balances assessment power with usability/accessibility. This model is being developed for incorporation within the Army Risk Assessment Modeling System (ARAMS) as a spatially explicit, population exposure module. SEEM improves the analysis of population risk by allowing the user to evaluate the exposure to each individual within the defined local population and track each individual as it employs different foraging approaches (e.g., radial/nesting versus random walk). In addition, SEEM increases the realism of the exposure assessment process by incorporating habitat quality considerations at a resolution finer than the entire site. SEEM may be used as a standalone model, but ultimately it is designed to draw input parameters from the other modules within ARAMS.

FishRand-Migration is a similar modeling tool, but is designed for aquatic systems. Dr. von Stackelberg provided the technical lead on development of this probabilistic bioaccumulation model, which was originally developed in support of the RI/FS for a large Superfund site. This mechanistic, time-varying model is based on a modeling approach developed by Frank Gobas of Simon Frasier University. The model relies on solutions of differential equations to describe the uptake of bioaccumulative contaminants over time, and incorporates both sediment and water sources to predict uptake based on prey consumption and food web dynamics. The model was calibrated to data for the site using Bayesian updating statistical techniques. The model successfully underwent peer review in 2000.

Guidance for Assessing Risk of Mixtures of Organic Contaminants: We prepared a technical review for USEPA and the Corps on approaches used to characterize the toxicity of mixtures of organic contaminants to fish. We also developed a cumulative distribution of toxic tissue concentrations of chlorinated cyclodiene pesticides to fish. We are in the process of developing a novel approach for USEPA and the Corps to assess toxic effects of dietary and water-borne doses of PAHs to fish. For this effort we reviewed literature, summarized data, and are estimating protective dose levels.

Comparative Risk Assessment Framework for the Dredged Materials Management Program: We developed a comparative risk assessment framework for the Corps that identifies characteristics of various placement and treatment alternatives for dredged materials that contribute to potential environmental risk. The framework was developed for use by environmental managers in identifying important transport and fate mechanisms and routes of potential exposure, and to illustrate the need for a comprehensive site assessment. A peer-reviewed paper on this work was awarded the Integrated Risk Assessment Paper of the Year for 2002 by *Human and Ecological Risk Assessment:* "A Comparative Screening-Level Ecological and Human Risk Assessment for Dredged Material Management Alternatives in New York/New Jersey Harbor," Hum. Ecol. Risk Assess. 8:603–626.

Summary: We have developed numerous tools to support cost-effective environmental decision-making related to the disposal of dredged materials. These tools are applicable across a wide variety of sites and contexts, and are not exclusive to dredged materials.

- These tools have assisted in the evaluation of a variety of environmental decisions, ranging from placement of dredged materials to a comparison of remedial alternatives and/or management actions at waste sites.
- Modeling tools of this kind provide a mechanism and framework for evaluating site-specific data, and in particular, the potential effects of management actions in terms of future concentrations and risks.

Table 1. Case history information

Project Name	Team Members/Roles	Scope of Services
Multi-site Risk Assessment Framework Document and Work Plan Support for the Wisconsin Public Service Corporation Manufactured Gas Plant Sites	Charles Menzie, Principal Michael Kierski, Project Manager Ted Wickwire, Joe Famely, Ben Amos, Cheri Butler, Technical Support Susan Driscoll Kane, Technical Advisor	Assisted in the developed of a risk assessment framework to be used to conduct baseline risk assessment at six MGP sites in Wisconsin. Have applied the framework to aid in development of two site-specific work plans.
Support for Development of Risk-based Methods to Assess Potential Impacts of PAHs in Sediments at MGP Sites	Charles Menzie, Principal Susan Driscoll Kane, Project Manager Ted Wickwire, Meg McArdle, Joe Famely, Ben Amos, Cheri Butler, Technical support;	Developed models for evaluating uncertainty and variability, developing spatially explicit foraging models to refine exposure estimates in aquatic and terrestrial food webs, providing guidance on conducting risk assessments for open water and upland disposal of dredged materials, and completing ecological risk assessments for large waterways.
Salem Harbor Area Former MGP Sites	Ted Wickwire, Project Manager Charles Menzie, Principal, Technical Advisor Margaret McArdle, Technical Advisor Joseph Famely, Project Scientist	Multi-media ecological and human health risk characterization, including assessment of the health of benthic communities following bioremedial activities. Project included sediment sampling and habitat survey and screening assessment. Second site involved surface water sampling and a sediment triad analysis to evaluate potential ecological risk in the sediment.
Messer Street MGP	Charles Menzie, Principal Ted Wickwire, Meg McArdle, Technical Support	A human health and ecological risk assessment was designed and conducted to assess risk from PAHs and other contaminants associated with a former MGP on the Winnipesaukee River in Laconia, New Hampshire. Site-specific exposure data were collected including fish and shellfish PAH tissue concentrations. Sediment toxicity testing was also performed. Assisted with developing sediment remediation goals and performed post remediation monitoring.
Tools for Streamlining Ecological Risk Assessments at RCRA Corrective Action Facilities	Linda Ziccardi, Project Manager for implementation	Developed risk assessment tools to streamline ERA process by early identification and refinement of areas of concern and application of a consistent set of receptors, assessment and measurement endpoints, and toxicity values. Overall objective of the process was to develop standardized approaches to and tools for ERA that enhance the usefulness of data for risk-based decision-making, while remaining consistent with EPA guidance.
Risk Based Decision Tools to Support Environmental Decision-making under the Dredged Material Management Program	Charles Menzie, Principal in Charge Susan Kane Driscoll, Project Manager Ben Amos, Joe Famely, Ted Wickwire, Technical Support	Developed tools to evaluate the potential for human health and ecological impacts associated with bioaccumulation of sediment-based contaminants

Table 2. Former manufactured gas plant sites—representative experience of Exponent personnel

Location	Client	Type of Work
Arizona		
Phoenix	Arizona Public Service	Conducted human health risk assessment for residents of apartment building located on former MGP site.
California		
Los Angeles	Confidential	Provided technical support and senior technical review for RI/FS.
Oakland	Confidential	Provided technical support and senior technical review for RI/FS.
Colorado		
Fort Collins	Confidential	Human health risk assessment.
Connecticut		
Stamford	Northeast Utilities	Provided guidance on how to conduct this and other risk assessments; identified sampling needs.
Delaware		
Wilmington	Delmarva Power	Developed exposure scenarios, estimated exposure, and modeled chemical fate and transport; output of work was used by DFI for SITES model application.
Florida		
St. Augustine	Unified Gas Improvement	Cost allocation litigation support.
St. Augustine	GEI Consultants, Inc.	Developed risk-based soil cleanup levels for redevelopment of former MGP site.
Tallahassee	Confidential	Conducted ecological risk assessment at urban park on former MGP site.
Georgia		
Athens	Georgia Power Company, Atlanta Gas Light Company	Conducted ecological risk assessment; FETAX toxicity testing.
Illinois		
Alton	Union Electric	Responsible for human health risk assessment including quantitative uncertainty analysis.
Chicago Area	Confidential	Provided technical support during remediation of former MGP site in residential area including risk analysis of benzene vapors, statistical analysis of monitoring data, and engineering consulting.
Chicago Area	Confidential	Performed a biological survey of the river adjacent to a former MGP site to evaluate whether the former facility was having an effect on the biological integrity of the river. Also provided strategy support on next phases of the site evaluation.
Waukegan Harbor	Mercury Marine	Conducted risk assessment in concert with engineering plans for new marina at former MGP site.

Location	Client	Type of Work
Iowa		
Cedar Rapids	MWH Americas, Inc.	Performed a screening level ecological risk assessment and qualitative benthic macroinvertebrate survey for MWH at this MGP site, which helped gain closure of the site.
Des Moines	MWH Americas, Inc.	Performed a screening level ecological risk assessment for MWH at this MGP site, which helped gain closure of the site.
Kentucky		
Louisville	Louisville Gas & Electric	Responsible for human health and ecological risk assessments, worked with the State on applications of guidance, and developing remedial target levels
Maryland		
Baltimore	Confidential	Provided technical support and senior technical review for RI/FS, risk assessment, strategy development, remedial alternative analysis, remedial research, and closure plan development for inner harbor industrial park redevelopment.
Baltimore	Baltimore Gas and Electric	Provided technical support and senior technical review for remedial research, and closure plan development.
Massachusetts		
Attleboro	Eastern Gas	Provided expert witness testimony related to human health effects associated with exposure to complexed cyanides.
Beverly	Massachusetts Electric Company	Developed field program and conducted ecological risk assessment.
Boston Area	Insurers	Used environmental forensics methods to determine how contamination occurred at three former manufactured gas plants located in Lynn, Malden, and Salem, in the Boston area.
Boston Harbor	Honeywell	Evaluated timing of release and location of sediment contamination resulting from multiple sources including a former MGP plant.
Everett	Boston Gas	Responsible for Massachusetts Contingency Plan ecological risk assessment and aquatic studies within Mystic River.
Holyoke	Northeast Utilities	Responsible for Massachusetts Contingency Plan ecological risk assessments; developed and implemented aquatic sampling programs along the Connecticut River.
Nantucket	Nantucket Electric	Developed risk assessment scope of work; negotiated with Massachusetts DEP on conduct of Massachusetts Contingency Plan Phase II risk assessment.
Perkins Park	Massachusetts Electric Company	Conducted an ecological risk assessment under the Massachusetts Contingency Plan for a former MGP site.
Salem	National Grid/ Massachusetts Electric/ KeySpan Energy Delivery	Completed multi-media ecological and human health risk characterization at a coastal MGP site.
Salem	Boston Gas, New England Power	Responsible for Massachusetts Contingency Plan ecological risk assessments.

Location	Client	Type of Work
Michigan		
23 sites	London Market Insurers	Technical and litigation support related to the chemical stability of the materials of construction of storage vessels at MGP sites located in East Flint, Lansing, Kalamazoo, Jackson, Zilwaukee and elsewhere.
Missouri		
Columbia	Union Electric	Responsible for human health risk assessment and interacted with State to determine suitable modeling approach.
Nationwide		
	Electrical Power Research Institute	Provided research planning for site assessments and remedial actions at MGP sites.
	Electrical Power Research Institute	Evaluated the power of sediment quality guidelines to predict sediment toxicity. Analysis involved review of test data from MGP sites.
	Gas Research Institute	Developed a comprehensive multimedia exposure model handbook to assist utilities in remediating former MGPs.
	Gas Research Institute	Prepared Volume III of the four-volume GRI guidance document, Management of Manufactured Gas Plant Sites.
New Hampshire		
Danvers	Massachusetts Electric Company	Conducted human health risk assessment at former MGP site.
Laconia	Haley & Aldrich	Designed and conducted a human health and ecological risk assessment to assess risk from PAHs and other contaminants associated with a former MGP on the Winnipesaukee River.
Laconia	Northeast Utilities and Energy North	Conducted risk assessments and developed risk-based site-specific remediation goals.
Lynn	Massachusetts Electric Company	Designed and conducted ecological risk assessment under Massachusetts Contingency Plan guidance.
Marblehead	Massachusetts Electric Company	Conducted a human health and ecological risk assessment at a former MGP site.
North Adams	Massachusetts Electric Company	Designed and conducted risk assessments used in remedial design development and calculation of cleanup criteria.
New Mexico		
Albuquerque	Public Service of New Mexico for CDM Engineers	Developed risk-based soil cleanup levels accounting for direct soil exposure and vapor intrusion for redevelopment of a former MGP site. This site has been remediated.
New York		
Bronx	Insurers	Determined how contamination occurred at the Hunt's Point coal gas and water gas plant. .
Long Island	Insurers	Used environmental forensics methods to determine how contamination occurred at each of seven Long Island former MGPs: Bayshore, Glen Cove, Halesite, Hempstead, Patchogue, Rockaway Park, and Sag Harbor.
Manhattan	Insurers	Determined how contamination occurred at the West 18th Street, a coal gas plant dating to 1834.

Location	Client	Type of Work
Pelham	Insurers	Determined how contamination occurred at the Pelham Parkway MGP using Sanborn maps, utility commission reports, aerial photographs, and other resources.
Queens	Insurers	Determined how contamination occurred at the Astoria MGP, at one time the largest plant in the world.
Saratoga Springs	Niagara Mohawk Corporation	Reviewed and commented on all documents prepared by EPA and its consultants on risks at this Superfund site.
Western New York State	New York State Electric & Gas	Responsible for human health and ecological risk assessments for several MGP sites located on lakes and rivers.
Utica	Niagara Mohawk Corporation	Responsible for human health and ecological risk assessments, developed clean-up levels, risk communication, and testing in support of remedial strategies.
North Carolina		
Charlotte	Duke Power	Provided training and support to Duke Power personnel in conducting risk assessment and air sampling at the site.
Fayetteville	Carolina Power & Light, City of Fayetteville	Conducted human health and ecological risk assessment at former MGP site. Developed risk-based site-specific remediation goals.
Raleigh	North Carolina Power and Light	Provided possible litigation support related to risks associated with the site.
Oregon		
Eugene	Eugene Water and Electric Board	Conducted RI/FS and risk assessment; provided technical support for strategy development and cost allocation.
Virginia		
Shenandoah River	Confidential	Developed Hazard Ranking System score for former MGP site.
Tributary to James River	Confidential	Conducted health and ecological risk assessments at former MGP site.
Washington		
Renton	Quendall Terminals (Limited Partnership)	Developed investigation, interim removal, and disposal plans for asbestos contaminated with PAH. Provided technical support in regulatory negotiations. Instrumental in convincing EPA to not list this site.
Renton	City of Renton	Regulatory analysis, technical support, economic analysis, remedial failure analysis, and redevelopment support to client for site development plan.
Seattle	Puget Sound Energy	Evaluated sources of PAH at Union Station site (former MGP, railroad terminal and iron foundry). Provided expert reports and depositions.
Seattle	Seattle Parks Department	Gasworks Park RI/FS review and technical assistance to regulatory agency site manager.
Tacoma	Puget Power, Seattle City Light	Hazard assessment; health risk evaluation for a *de minimis* settlement.

Location	Client	Type of Work
Wisconsin		
Ripon	MWH Americas, Inc.	Responded to WDNR comments on past sediment investigations and developing a risk-based approach for moving forward with the project.
Sheboygan	Natural Resource Technology, Inc. (NRT)	Assisted NRT in preparing a quality assurance project plan and sampling analysis plan for the Campmarina MGP site.
Multiple	NRT	Assisted NRT in development of the Multi-site Risk Assessment Framework document for six former MGP sites under the Superfund Alternatives Site (A) Program on behalf of Wisconsin Public Service Corporation.

Other Resources

Exponent has highly qualified resources that we could bring to bear on projects to assist Integrys and their remedial investigation/feasibility study (RI/FS) consultants with needs on specific MGP projects. Our services would complement those of the RI/FS consultants, and include specialized human health risk communication support (Anderson), forensic interpretation at sites (Boehm and Saba), natural resource damage assessment claim support (Booth), assessment of bioavailability of specific chemicals (Lowney), groundwater to surface water transport of contaminants (Mohsen), and vapor intrusion modeling (Turnham). The people highlighted include leaders in their respective fields who would be available for advice on these topics as the need arises. A short biographical sketch of each of these individuals is provided.

Dr. Elizabeth L. Anderson is the Group Vice President of Exponent Health. Prior to joining Exponent, Dr. Anderson was President and CEO of Sciences International, a health and environmental consulting firm. She specializes in risk assessment as a basis for addressing the complex problems that arise in the context of regulatory and legal matters related to health and the environment for national and international companies and governments.

Dr. Anderson has more than 25 years of experience in working both within government institutions and for corporate entities. Previously, for the U.S. Environmental Protection Agency (EPA), she founded and directed the Agency's Carcinogen Assessment Group and the central risk assessment programs for 10 years. In this capacity, she was Executive Director of the EPA committee that initially adopted risk assessment as a basis for carrying out the Agency’s regulatory mandates. She has also worked extensively on international risk assessment issues to address human health and ecological consequences of exposure to environmental toxicants, including for private companies, governments, the World Health Organization, and the Pan American Health Organization.

Dr. Paul D. Boehm is Group Vice President and Principal Scientist, with overall responsibility for Exponent’s Environmental business. He has devoted his 30 years of consulting experience to advising industrial, legal, and government clients on scientific aspects of the investigation of contaminated sediments and terrestrial sites, oil spills, oil and gas geochemistry, environmental monitoring, exposure and bioavailability assessment, and the use of environmental forensic methods to apportion liabilities. His main scientific focus has been on the environmental chemical aspects of aquatic and terrestrial contamination, inclusive of persistent organic pollutants, petroleum, PAHs, and petrochemicals.

Dr. Boehm has specifically practiced in the areas of environmental forensics: allocation and dose reconstruction, petroleum chemistry, and natural resource damage assessment (NRDA) for oil spills, Superfund sites, medical exposures, and transactional matters. His extensive knowledge of the strategic application and practice of environmental forensics (chemical fingerprinting, transport and fate, source attribution, and allocation) relates to PAHs, petroleum hydrocarbons, PCBs, dioxins, and other compounds. His expertise also includes the transport and fate of chemicals in surface water and groundwater, contaminated sediments assessments, environmental impact assessments for new international capital projects, and environmental studies for LNG projects.

Mr. Pieter Booth is a Principal in Exponent's EcoSciences practice. He has 28 years of experience as an environmental scientist and program manager specializing in ecological risk assessment and natural resource damage assessment (NRDA). Mr. Booth is currently managing a program for General Motors Corporation, to provide site-specific ecological risk assessments and to develop corporate ecological risk assessment guidance for General Motors' program managers. For other industrial clients, Mr. Booth assists in developing overall strategies for environmental issues, designing site-specific assessments, and negotiating with state and federal agencies. In addition, he has supervised the collection and analysis of environmental data and the development of PC-based data management and negotiation tools. Mr. Booth has led numerous projects directed at the characterization and remediation of contaminated sediments and he has helped to create guidance and policy for sediment management programs in Puget Sound and San Francisco Bay.

Mr. Booth is nationally recognized for his NRDA work, particularly his management of the recently settled Saginaw River and Bay and Lake Hartwell/Twelvemile Creek NRDAs. He has been project manager or consulting expert on NRDAs for industrial clients in several other high-profile natural resource damage cases. In these roles, he has provided technical support to legal teams in the development of case strategy and in the supervision and preparation of materials for litigation support under CERCLA, RCRA, the Clean Water Act, and the regulatory programs of various states.

Ms. Yvette Wieder Lowney is a Managing Scientist with 20 years of professional and technical project management experience. She specializes in human health risk assessment, with special focus on evaluating health effects associated with exposure to metals, particularly under non-standard exposure scenarios (e.g., childhood, or intermittent adult exposures), and to organic contaminants from industrial sites. While focusing on performing site-specific, multipathway risk assessments, Ms. Lowney has gained experience in data aggregation, preparing technical position papers that describe appropriate risk assessment methods, critically reviewing risk assessment guidance and regulatory policies, and developing cleanup standards for use in voluntary or mandated cleanup of sites and in Brownfields redevelopment. In addition, she has supported clients in negotiations with regulatory agencies and public presentations.

In the context of conducting risk assessments for metal-containing soils, Ms. Lowney has been closely involved in developing data regarding the bioavailability of metals from soils. She is managing multi-year research projects focused on developing robust databases for relative bioavailability to human and ecological receptors, with the eventual goal of generating validated bench-top extraction models for assessing the relative bioavailability of metals from soil, for application in both human health and ecological risk assessments.

Dr. Farrukh Mohsen is a Managing Engineer in Exponent's Environmental Sciences practice and is based in Albany, New York. He has 28 years of experience in hydrogeology and groundwater flow and contaminant transport modeling. He has applied his technical strengths in assisting corporate clients nationwide in providing expert opinions in litigation, environmental compliance, and liability allocations. Dr. Mohsen focuses primarily on developing an understanding of transport and fate of constituents in the subsurface both in groundwater and in soil vapor. He has helped his clients in determining the source of groundwater contamination, designing and evaluating remedial options, conducting risk assessments, assisting in regulatory negotiations, achieving environmental compliance, delivering public presentations, providing expert opinions, and refuting claims by other experts.

Dr. Tarek Saba is a Senior Scientist in Exponent's Environmental Sciences practice. He has 7 years of consulting experience in groundwater hydrology, numerical simulation of contaminant transport and fate, design/optimization of various groundwater remediation scenarios, and advanced chemical forensics. Dr. Saba has used these skills to optimize pump and treat systems for chlorinated solvents in a New Hampshire Superfund site, develop a Department of Defense decision support system to evaluate cost-effectiveness of source zone treatment, and evaluate publicly available groundwater flow models for the EPA. Dr. Saba has developed several 2-D and 3-D models to simulate nonaqueous phase liquids (NAPL) dissolution in the subsurface and to design hydraulic controls and source area treatments. Dr. Saba has combined his numerical analysis skills with chemical fingerprinting methods to identify sources of chlorinated solvents, NAPL, tar, PCBs, and petroleum hydrocarbons at contaminated sites. At the Paoli rail yard Superfund site, he identified PCB sources and approximate spill timing, resulting in a $38 million remedial cost recovery settlement in favor of his client.

Mr. Paul Turnham is a Managing Scientist in Exponent's Health Sciences practice. He is a civil engineer and a licensed professional engineer. He has more than 15 years experience working in the fields of quantitative human health risk assessment, site characterization and remediation, and environmental transport and fate. He specializes in the development and application of site- and case-specific approaches to risk and exposure assessment. He has performed and provided day-to-day management of risk and exposure assessments for private clients and in support of litigation. Projects he has managed include residential sites, CERCLA (Superfund) sites both for risk assessment-related services and in support of PRP groups for share allocation issues, a RCRA clean closure site, sites subject to state oversight, and combustion sources such as a hazardous waste-burning cement kiln, a coal-fired power plant, and coke oven batteries.

Mr. Turnham has evaluated health risks arising from actual and hypothetical exposures to environmental media and indoor air impacted by chlorinated solvents, petroleum compounds, metals (in particular arsenic and chromium), polychlorinated biphenyls and dioxins, and asbestos and man-made vitreous fibers. He has assessed the potential risks from the vapor intrusion exposure pathway at residential, commercial and industrial properties. This work included development of a risk assessment and sampling and analysis work plan for potential residential exposures at Superfund site. Mr. Turnham has also led site investigations and remedial actions at sites subject to state regulations and voluntary cleanup programs.

Attachment 1

Project Team Resumes

Exponent

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Charles A. Menzie, Ph.D.
Principal Scientist

Years of Experience: 35 years

Credentials and Professional Honors

Ph.D., Biology, City University of New York, 1978
M.A., Biology, City College of New York, 1974
B.S., Biology, Manhattan College, 1971

Professional Profile

Dr. Charles A. Menzie is a Principal Scientist and Director of Exponent's EcoSciences practice. His primary area of expertise is the environmental fate and effects of physical, biological, and chemical stressors on terrestrial and aquatic systems. Over the past two decades most of this work has been focused on chemicals. Dr. Menzie has worked at more than 120 sites and has been involved in approximately a dozen NRDA-related cases. His experience includes leading human health and ecological risk evaluations at approximately thirty NPL, SAS, and RCRA sites. These include many sites with sediment contamination issues, several of which are recognized as the most challenging sites in the country. Some of these sites have incorporated re-use and restoration components and have won regional and national awards, and recognition and economic benefits for the owners.

Dr. Menzie is recognized as one of the leaders in the field of risk assessment and was awarded the Risk Practitioner Award by the Society for Risk Analysis. He has served on the Council of SRA and the Board of SETAC, the two major professional organizations in this field.
Dr. Menzie has been involved in the development of sediment guidance working directly with the regulatory agencies and through the industry-sponsored Sediment Management Workgroup (SMWG). He has taken the lead on the development of guidance documents for industry and government, focusing on methods that are workable and acceptable to a broad range of parties. He helped to draft the ASTM Standard for Risk-Based Corrective Action (RBCA) for chemical release sites and extended that standard to ecological considerations. In addition, Dr. Menzie has developed and applied methods for identifying third parties who have contributed to contamination in aquatic and terrestrial environments. His expertise in chemical transport and fate includes organochlorine compounds (e.g., PCBs, dioxins, many pesticides), polycyclic aromatic hydrocarbons (PAHs), benzene and other light aromatic hydrocarbons, chlorinated volatile compounds (e.g., TCE and PCE), phthalate esters, petroleum hydrocarbons, metals (e.g., arsenic, cadmium, lead, vanadium, nickel, and zinc), and cyanide compounds.

Relevant Experience: Manufactured Gas Plants (MGP)

Dr. Menzie began working on MGP-related risk issues in the mid-1980s, when he conducted assessments at the first MGP site to be placed on the NPL list. He was also one of the first to defend utilities against NRDA claims at MGP sites. Over the last twenty years, Dr. Menzie has evaluated both human health and ecological risks associated with more than 40 MGP sites. This includes assessments of a number of MGP site in USEPA Region 5 (Illinois, Indiana, and Wisconsin). He is the primary author of the Gas Research Institute (GRI) Guidance on human health and ecological risk assessment for MGP sites. He currently is a Principal Investigator for EPRI-funded research on the toxicity of soils and sediments at MGP sites and is currently working on an EPRI guidance document on how to apply Monitored Natural Recovery (MNR) methods for contaminated sediments at MGP sites. Dr. Menzie was also Principal Investigator for the Environmentally Acceptable Endpoints (EAE) Program that focused on the bioavailability of PAHs in surface soils. This program was subsequently extended to evaluations of PAHs in sediments. Dr. Menzie is a co-author of the USWAG-sponsored white paper on naphthalene toxicity and implications for risk assessment and risk management, with an emphasis on MGP sites. Dr. Menzie also has experience with vapor intrusion issues at MGP sites and was the first scientist and risk assessor to address these issues at such sites.

Dr. Menzie has published several papers related to the assessment of risks at MGP sites and is author of the critical review on sources of exposure to carcinogenic PAHs. This paper was prepared to help provide the utility industry and regulatory agencies with a perspective on PAHs in soils at MGP and other sites. Dr. Menzie has also published on exposures to cyanides including the complex cyanides that can be present at some MGP sites. He has given expert testimony on behalf of individual utilities on exposures and risks associated with MGP-related waste residuals.

Dr. Menzie has guided evaluations of background for PAHs and metals in a wide variety of cases. These evaluations have involved surface soils in urban and rural environments and sediments in various water bodies.

Experience in USEPA Region 5

Dr. Menzie is familiar with the environmental issues at many of the MGP sites that will be considered as part of this program as well as how they are viewed by regulatory agencies. He has worked with regulatory agencies in Illinois and Wisconsin (and other Region 5 states) and with USEPA Region 5 since the 1980s. He has been invited to give courses and participate in industry and government-sponsored workshops in the Region. He has served as a peer review expert for some of the larger risk assessments conducted in Region 5. As noted above, Dr. Menzie has worked on a number of MGP sites in Illinois, Wisconsin, and Indiana and is familiar with the expectations of both the state and federal regulators. Because of his work on risk issues, Dr. Menzie has been very successful at developing strategic approaches that have benefited clients from a monetary standpoint and have led to environmentally sound solutions. Feedback from some Region 5 clients indicates that Dr. Menzie's contributions to projects have saved tens of millions of dollars in remedial costs and resulted in outcomes that had high net benefits for the environment. The latter is especially important for utilities that are working closely with surrounding communities.

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Michael W. Kierski, Ph.D.
Managing Scientist

Years of Experience: 20 years

Credentials and Professional Honors

Ph.D., Environmental and Occupational Health, University of Minnesota, 1992
B.A., Environmental Biology, St. Mary's College of Minnesota, 1984

Professional Profile

Dr. Kierski provides senior-level expertise in human and ecological risk assessment. Over the past 20 years, Dr. Kierski has evaluated risks associated with chemicals in air, biota, surface water and sediment, soil, and groundwater. He has specialized expertise in the fate and effects of metals such as lead and cadmium, hydrocarbons such as benzene and polycyclic aromatic hydrocarbons (PAHs), synthetic organic chemicals such as PCBs, pesticides, and chlorinated solvents, and explosives. His research emphasis during his academic career was related to metals bioavailability.

Much of Dr. Kierski's work is directed toward the evaluation, remediation, and redevelopment of contaminated properties sites. This requires not only technical expertise but also an ability to work with regulatory agencies at the state level (e.g., in Indiana, Wisconsin, Iowa, Illinois, Michigan, New York, North Carolina, New Jersey) and at the federal level (USEPA, U.S. Fish and Wildlife Service, and the Department of Defense). Dr. Kierski's primary clients include electric and gas utilities, chemical companies, the Department of Defense, law firms, and other environmental and engineering companies. Dr. Kierski is often called upon to represent these clients in public and regulatory forums.

Dr. Kierski has worked on numerous USEPA-led NPL and RCRA sites, where he either performed or managed the baseline risk assessment component of the remedial investigation, and prepared the risk-related components of the feasibility studies. Most of his federal work has been located within USEPA Region 5, and concentrated most heavily within Wisconsin, Illinois, Michigan, and Ohio. He has a good working relationship with both human health and ecological risk assessors within Region 5, the States of Wisconsin, Illinois, Michigan, and Ohio, and has worked within the regulatory framework of each of these states.

As part of MGP projects, Dr. Kierski has managed and assisted in the development of site-specific sediment and surface water evaluations, conducting biological assessment of the river environments adjacent to the MGP sites, provided strategy support on MGP site investigations including the regulatory framework that would be considered most appropriate, and has performed numerous human health and ecological risk assessments.

Dr. Kierski has worked on a number of MGP sites over his career, primarily in Iowa, Wisconsin, and Illinois. He has worked with Natural Resources Technology (NRT) to develop the Multi-Site Risk Assessment Framework (RAF) Document for the MGP sites under the USEPA Superfund Alternatives Site (SAS) Program on behalf of Wisconsin Public Service Corporation. He has also provided technical support on the development of three of the seven site-specific RI/FS work plans under development thus far for MGP sites in Wisconsin.

Dr. Kierski developed a similar, more streamlined guidance document for MGP sites located in Iowa, to help adopt a consistent approach for performing surface water and sediment investigations and evaluations at MGP sites on behalf of MidAmerican Energy. This document was used by the Iowa Department of Natural Resources (IDNR) as a guidance document on MidAmerican's MGP site evaluations. The process within this guidance was used to cost-effectively evaluate and obtain closure at two specific sites that required further sediment evaluation and risk characterization. As part of these projects, Dr. Kierski interfaced with IDNR staff on behalf of MidAmerican Energy to develop the guidance document and negotiate the level of risk evaluation that would be required at each site.

In Wisconsin, Dr. Kierski has worked on numerous sites including NPL sites, and is currently working on a number of projects where he interfaces with Wisconsin Department of Natural Resources staff. His current projects include MGP sites, and a high profile ecological risk assessment that he is managing at the Badger Army Ammunition Plant, which includes site-specific bioaccumulation studies and bird evaluations. In addition, Dr. Kierski has worked closely with the Wisconsin State Health Department both at Badger and at a recent redevelopment site within the State.

Within the State of Illinois, Dr. Kierski has worked on many NPL sites and RCRA sites where he has been the lead or managing risk assessor. He has worked closely with Dr. Thomas Hornshaw, IEPA's lead environmental toxicologist and risk assessor, on many of these projects. His current projects in Illinois include strategy support on MGP sites and the performance of biological assessments associated with MGP sites.

While not within USEPA Region 5, Dr. Kierski worked on a group of 15 MGP sites within the State of Iowa on behalf of MidAmerican, and provided both human health and ecological risk assessment support. He also works on two USEPA-led MGP sites within the State of Iowa.

Dr. Kierski has managed a number of high profile risk assessments where a robust human health or ecological risk assessments were needed, which required a great deal of regulatory and public interface. At the Savanna Army Depot Activity located in northwestern Illinois, Dr. Kierski managed a $2 million baseline ecological risk assessment for the Old Burning Ground. This evaluation required a multiphase site investigation and ecological risk assessment, and involved a number of working meetings with USEPA, IEPA, USFWS, IDNR, and DOD staff.
Dr. Kierski chaired the working meetings and directed the performance and development of the BERA. This BERA won an award from the U.S. Army Corps of Engineers in 2004, and was estimated to have saved the DOD $20–40 million in remediation costs.

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Margaret E. McArdle
Senior Scientist

Years of Experience: 9 years

Credentials and Professional Honors:

M.S., Marine Environmental Science, Marine Science Research Center, Stony Brook University, New York, 1999
B.S., Zoology *(high distinction)*, University of Rhode Island, 1996
Phi Beta Kappa Academic Society

Professional Profile

Margaret E. McArdle is a Senior Scientist in Exponent's EcoSciences practice. She has 9 years of experience in evaluating the exposure and effects of contaminants in aquatic and terrestrial systems to ecological receptors. She conducts ecological risk assessments in compliance with state and/or federal program regulatory requirements (e.g., RCRA and USEPA). Ms. McArdle develops quality assurance project plans, field sampling plans, and work plans, as well as reviews and validates data for use in ecological risk assessments. She develops conceptual models, toxicity reference values for aquatic life and wildlife, and wildlife exposure models for ecological risk assessments. Ms. McArdle also applies statistical approaches to evaluate toxicity test data and field assessment data; she also applies weight-of-evidence approaches to ecological risk assessments. She manages staff for field sampling programs and ecological risk assessments. Ms. McArdle also provides technical support and manages tasks associated with litigation-related activities. Her other areas of expertise include endocrine disruption in aquatic life and the bioavailability of contaminants present in sediments and surface water.

Ms. McArdle has experience using the sediment triad approach to assess the bioavailability and toxicity of polycyclic aromatic hydrocarbon (PAH) mixtures in sediments at manufactured gas sites (MGP) sites. She also participated in research for the Electric Power Research Institute and its utility members, which examined the influence of various forms of "black carbon," including coal tars and coke, on reducing bioavailability and toxicity of PAHs in sediment to aquatic organisms.

Examples of Relevant Project Experience

Assessed the body burdens of PAHs in aquatic biota tissues collected from a large river next to a former MGP site in southern Vermont. Designed and conducted the field sampling and analysis plan. Compared measured concentrations of PAHs in aquatic biota tissue to human health and ecological risk based concentrations in a preliminary risk evaluation.

Contributed to research for the Electric Power Research Institute and its utility members that examined the influence of various forms of "black carbon," including coal tars and coke, on reducing bioavailability and toxicity of PAHs in sediment to aquatic organisms. Conducted sediment assessments, including the interpretation of sediment chemistry and toxicity tests data, for MGP sites.

Contributed to a book chapter for the Electric Power Research Institute on assessing ecological risks of PAH-contaminated sediments.

Contributed to developing a methodology for deriving a dietary dose of total PAHs that is protective of fish. This work was done for USEPA and the U.S. Army Corps of Engineers.

Conducted an ecological risk assessment for a RCRA site in Taunton, Massachusetts. Collected representative samples of surface water, sediment, and biota (e.g., blue crabs, yellow perch, and fiddler crabs) for chemical analysis. Evaluated chemical data, sediment toxicity data and benthic invertebrate community data to evaluate ecological risk from exposure to PCBs, mercury, and dichlorobenzenes in surficial sediments.

Managed a human health and ecological risk assessment for a property along the Mystic River in Boston, Massachusetts. The assessment evaluated exposures to arsenic, lead, PAHs, extractable petroleum hydrocarbons (EPH) and PCBs in groundwater, soil, sediment and biota. Considered future uses of property in human health risk assessment.

Managed a human health and ecological risk assessment for a former incinerator facility in northeast Massachusetts. Dioxins, furans, PAHs and certain metals were found in soils and sediments above background levels. Potential risks from these chemicals to a recreational fisher, trespasser, utility worker, construction worker, and parking lot landscaper were evaluated. The environmental characterization, which was conducted for a nearby pond, evaluated risk to aquatic organisms and semi-aquatic wildlife based on body burdens of contaminants in fish and benthic invertebrates, and on estimated exposure to contaminated sediment and prey.

Conducted an ecological risk assessment for a site containing wetlands in northeast Massachusetts. Evaluated potential risk from metals and PAHs in sediment and wetland soil to the environment based on a comparison to *location conditions* or background levels and evaluations for aquatic life and wildlife based on site-specific information (e.g., toxicity test bioassays, bioaccumulation tests, and food chain modeling). Developed cleanup numbers in sediment and soil that would be protective of ecological receptors at the site.

Conducted an ecological risk assessment and provided technical support to the feasibility study of a former U.S. Army base in California, which included four upland areas of concern and one containing marine sediments. Characterized risk to aquatic organisms, fish, and wildlife through a combination of empirical investigation and modeling. Contaminants of concern included PAHs, PCBs, DDT, dieldrin, and lead.

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W. Theodore Wickwire
Senior Scientist

Years of Experience: 12 years

Credentials and Professional Honors:

M.F.S., Forest Science, Yale University School of Forestry and Environmental Studies, 1996
A.B., Biology and Environmental Sciences *(summa cum laude)*, Bowdoin College, 1992
Phi Beta Kappa; James Bowdoin Scholar

Co-Author of the HERA Integrated Risk Assessment Paper of Year, 2002.
Kane Driscoll, S.B., W.T. Wickwire, J.J. Cura, D.J. Vorhees, C.L. Butler, D.W. Moore, and T.S. Bridges. 2002. A comparative screening-level ecological and human health risk assessment for dredged material management alternatives in New York/New Jersey Harbor. Hum. Ecol. Risk Asses. 8(3):603–626.

Professional Profile

Mr. W. Theodore Wickwire is a Senior Scientist in Exponent's EcoSciences practice. He has 12 years of experience in evaluating the exposure and effects of contaminants in aquatic and terrestrial ecosystems. He is an ecologist focusing on aquatic and terrestrial ecological risk assessment. He conducts and manages ecological risk assessments including development of quality assurance project plans, design and implementation of multi-media field sampling programs, development of conceptual models, application of wildlife exposure models, implementation of weight-of-evidence risk assessment approaches, preparation of final risk characterization reports, development of preliminary remediation goals, and risk communication. Mr. Wickwire incorporates ecological principles in wildlife exposure models and oversees the development of modeling packages to improve the realism of exposure modeling incorporating wildlife behaviors relative to habitat suitability.

In addition, he identifies opportunities to enhance ecological risk assessment by incorporating population assessment, spatial exposure assessment, and habitat quality analyses into the exposure and effects assessments. He also designs and implements long-term biomonitoring programs, such as a program to assess changes in site conditions after *in situ* treatment applications.

Examples of Relevant Project Experience

Managed a pair former MGP sites in Salem Harbor, MA (Collins Cove and Beverly MGP Sites). For National Grid (formerly Massachusetts Electric Company), developed a comprehensive assessment at a former manufactured gas plant in Salem, Massachusetts. The project began with the design and implementation of a multi-year sediment monitoring program to evaluate changes in the benthic community following *in situ* treatment application – nutrient injection. Additional assessment was completed under the Massachusetts Contingency Plan (MCP) and included development of a scope of work, design and completion of a multi-media field program (terrestrial, wetland, aquatic), research for toxicological benchmarks and toxicity reference values, employment of terrestrial and aquatic bioaccumulation models, completion of food chain models, interpretation of benthic community studies and completion of the ecological risk assessment report. Applied a weight-of-evidence approach to integrate multiple lines of evidence. Project included both terrestrial and aquatic components. After completion of the risk assessment, worked closely with the client to evaluate remedial alternatives with a specific focus on bioavailability of remnant historic coal tars and weathered PAHs.

At a second MGP Site for the same client and in the same area, managed and completed the ecological risk assessment at the former manufactured gas plant in Beverly, Massachusetts. Work included design of a field program to collect sediment, surface water, and biota for analysis. Developed the scope of work and led the field team. In addition, managed the analysis and integration of data and biological studies using a weight-of-evidence approach, and the completion of the ecological risk assessment report. Worked closely with the site engineer to apply findings to the remedial strategy.

Served as project manager on an aquatic risk assessment focusing on a site within the Mississippi River in the St. Louis, Missouri, area. This included developing a screening assessment to evaluate site conditions and designing a comprehensive field program to determine the extent of analysis and evaluate ecological conditions within the area of influence. Iidentified experienced river captains to provide a platform for sediment, surface water, and fish collection in the high flow waters of the Mississippi River. Working under extremely difficult conditions, the team adapted standard still water sampling methods to the high flow waters. Managed data evaluation and authored risk assessment report.

Assisted the Science Advisory Board for Contaminated Sites (SAB), in British Columbia, Canada with the development of a Screening Risk Assessment (SRA-Level 1) Guidance. The document focused on determining whether further assessment was required at a site at which contaminant concentrations exceeded screening standards. Specifically, the guidance focused on determining whether any complete exposure pathways and/or receptors were present on the site and required further review. The guidance used a decision-tree approach.

Provided input to the USEPA National Center for Environmental Assessment (NCEA) design team for Causal Analysis/Diagnosis Decision Information System (CADDIS) regarding development of a conceptual modeling tool. Participated in a number of reviews and discussions regarding key components of the program.

Authored portions of the Army Corps of Engineers' Upland Testing Manual (UTM). Developed a case study demonstrating the key concepts within each chapter of the manual. Developed figures, organized, and reviewed the document.

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Linda M. Ziccardi

Senior Scientist

Years of Experience: 19 years

Credentials and Professional Honors

B.S., Natural Resource Management and Applied Ecology, Cook College of Rutgers University, 1985

Graduate courses in environmental science, aquatic toxicology, water law, and natural resource management at Rutgers University

Professional Profile

Ms. Linda Ziccardi is an ecologist with 19 years of experience evaluating environmental impacts at industrial and development sites nationwide. Her particular expertise is conducting ecological risk assessments for chemically impacted sites in compliance with CERCLA. Her projects have included fish, wildlife, and vegetation baseline assessments, bioaccumulation studies, and quantitative risk analyses. Ms. Ziccardi performs bioenergetics-based food chain modeling and ecotoxicological analyses to evaluate risks to wildlife from contaminant exposure. She has participated in regulatory negotiations on risk assessment issues on behalf of industry, and has also provided technical support for ecological risk assessments conducted for USEPA and the U.S. Departments of Energy and Defense. Ms. Ziccardi has served on USEPA biological technical assistance groups, has co-authored several publications, and has presented papers on ecological risk assessment at professional society meetings. She recently served on USEPA work groups that are working toward development of ecological risk-based soil screening levels and a framework for metals risk assessment.

Examples of Relevant Project Experience

Managed several ecological risk assessments within USEPA Region 5. For example, she was the manager for the ecological risk assessment that was conducted as part of the RCRA facility investigation for a former automobile assembly plant in Lordstown, Ohio. This project utilized the tools for streamlining ecological risk assessments at RCRA corrective action facilities for sites within Region 5 developed by Exponent. She designed and directed field activities to collect fish, invertebrates, surface water, and sediment to characterize exposure to wildlife receptors foraging at stormwater detention ponds on the facility. Chemicals of concern at this sited included metals and PAHs. The ecological risk assessment process involved negotiations with the regulatory agencies, and USEPA accepted the final ERA with a no further action decision for the facility with regard to ecological risk.

Conducted ecological site characterizations and preliminary risk analyses for Middleground Landfill in Bay City, Michigan. Managed the RCRA ecological risk assessments for active industrial facilities at several other Region 5 sites in Ohio and Michigan, incorporating the tools for streamlining ecological risk assessments at RCRA corrective action facilities developed by Exponent. Work at these sites involved mapping vegetation cover types and wildlife habitats, sampling fish, invertebrates, surface water, and sediment, and identifying potential exposure pathways, key ecological receptor species, and contaminants of concern. Developed work plans and cost estimates to perform ecological site characterizations, threatened and endangered species consultations, and bioaccumulation modeling for petroleum hydrocarbons, metals, and PCBs in terrestrial and aquatic environments.

Managed the high-profile ecological risk assessment of PCBs in the Lower Fox River and Green Bay, Wisconsin, for a group of pulp and paper companies. Ecological receptors that were investigated included fish, passerine birds, piscivorous birds, and mink. Information from a detailed habitat characterization was used to quantify exposure areas for each of the wildlife receptors. An extensive field investigation was conducted including sampling of fish, invertebrates, sediment, and surface water from more than 39 miles of the Fox River and the lower half of Green Bay. Risk conclusions were drawn based on the synthesis and analyses of data regarding the ecological and physical conditions of the system, available population studies of key receptors, and site-specific and literature-derived toxicological information. This project was unique in that it used both a dioxin toxic equivalency (TEQ) approach and a spatially explicit exposure assessment using a GIS to assess risks to wildlife from PCBs.

Also in Wisconsin, designed and conducted field investigations at the Oconomowoc Electroplating Superfund site in Ashuppin. Performed geostatistical data analyses using existing sediment analytical data and developed a sampling plan for the assessment of a freshwater marsh that was impacted by cyanide and metals from the facility's outfall. This project included collection of surface water and sediment samples for chemical analyses and bioassays.

At a former manufactured gas plant in New York, served as the task leader for fish and wildlife impact analyses. Performed a habitat characterization including covertype mapping, and a threatened and endangered species consultation. The project involved evaluating exposure pathways and contaminant concentrations in surface water and sediment to determine the potential for adverse ecological effects.

Member of the field team for the extent and bioavailability of remaining oil study being conducted as part of the natural resource damage assessment for a large tanker spill in Prince William Sound, Alaska. Sampled fish, bivalves, mollusks, polychaetes, sea weed, crustaceans, and sediment to determine the extent and bioavailability of PAHs in the sediment and biota, and to assess the potential for injury to organisms at higher levels of the food chain. Data from these studies are being used in the ongoing natural resource damage assessment for this high-profile petroleum spill.

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Susan Kane Driscoll
Managing Scientist

Years of Experience: 19 years

Credentials and Professional Honors:

Ph.D., Environmental Sciences, University of Massachusetts, 1994
B.S., Natural Resources, University of Rhode Island, 1981

Co-author of the HERA Integrated Risk Assessment Paper of Year, 2002
Kane Driscoll, S.B., W.T. Wickwire, J.J. Cura, D.J. Vorhees, C.L. Butler, D.W. Moore, and T.S. Bridges. 2002. A comparative screening-level ecological and human health risk assessment for dredged material management alternatives in New York/New Jersey Harbor. Hum. Ecol. Risk Asses. 8(3):603–626.

Professional Profile

Dr. Susan Kane Driscoll is a Managing Scientist in Exponent's EcoSciences practice. She is an aquatic toxicologist, with 19 years of experience in toxicology, specializing in ecological risk assessment, environmental chemistry, sediment toxicity testing, and the toxicity and bioavailability of sediment-associated contaminants to aquatic organisms and wildlife.
Dr. Driscoll has directed or participated in numerous ecological risk assessments for RCRA, Superfund, and hazardous waste sites, serving a variety of industrial, utility, and governmental clients. She has extensive experience in designing and conducting laboratory and field aquatic toxicity and environmental fate studies in accordance with rigorous quality assurance practices. She has designed and contributed to numerous environmental programs that were used to develop technically defensible solutions to environmental problems and has negotiated their acceptance with state and federal authorities.

Dr. Driscoll is a specialist in the field of sediment toxicology and her original research and publications in the areas of bioavailability and toxicity of sediment-associated contaminants are widely cited. She has extensive knowledge of sediment toxicity testing, the technical basis and predictive ability of various sediment quality benchmarks, and has served as a reviewer for the development of emerging benchmarks.

Examples of Relevant Project Experience

Managed an ecological and human health risk assessment for a RCRA site in Taunton, Massachusetts. Designed extensive sampling and sediment toxicity testing program that demonstrated minimal impact to aquatic organisms and wildlife from exposure to PCBs, mercury, and dichlorobenzenes in surficial sediments.

Conducted research for the Electric Power Research Institute and its utility members on the application of the EPA equilibrium partitioning sediment benchmarks for PAH mixtures to contaminated sediments at manufactured gas plant sites. Research examined influence of various forms of "black carbon," including coal tars and coke, on reducing bioavailability and toxicity of PAHs in sediment to aquatic organisms.

Provided technical assistance to client in the development of a standardized risk assessment approach for sediments at MGP sites in Wisconsin. Prepared technical information used by client in discussions with various regulatory agencies, including Wisconsin Department of Natural Resources and USEPA Region 5.

Selected Publications and Technical Reports

Kane Driscoll, S.B, and R.M. Burgess. 2007. An overview of the development, status, and application of Equilibrium Partitioning Sediment Benchmarks for PAH mixtures. Hum. Ecol. Risk. Assess. 13: 286-301.

Kane Driscoll, S.B., C.B. Amos, M.E. McArdle, B. Southworth, C.A. Menzie, and A. Coleman. 2004. Sediment biotoxicity at former MGP and coking sites. Prepared for Electric Power Research Institute (EPRI), Palo Alto, CA, New York State Electric & Gas Corporation, Binghamton, NY, Central Hudson, Poughkeepsie, NY, and PSEG Services, LLC, Newark, NJ.

Kane Driscoll, S.B., M.E. McArdle, M.S., C.A. Menzie, T. Thompson, L. Mortensen, and A. Fitzpatrick. 2003. Using polycyclic aromatic hydrocarbons in sediments for judging toxicity to aquatic life: Volume I and II. Final Report. Electric Power Research Institute (EPRI), Palo Alto, CA.

Selected Presentations

Kane Driscoll, S.B. A methodology for deriving a dietary dose of PAHs that is protective of fish. Platform presentation, International Conference on Remediation of Contaminated Sediments in Savannah, GA, January 22–24, 2007. Session chair: "Bioavailability of Contaminants."

Kane Driscoll, S.B., C.A. Menzie, M.E. McArdle, and A. Coleman. 2004. Application of site-specific equilibrium partitioning sediment benchmarks for PAH mixtures to manufactured gas plants. 25th Annual Meeting of SETAC North America, Portland, OR, November 14–18, 2004.

Kane Driscoll, S.B., M.E. McArdle, C.A. Menzie, T. Thompson, and A. Coleman. 2003. Application of sediment quality guidelines for PAHs to manufactured gas plants. 2nd International Conference on Remediation of Contaminated Sediments, Venice, Italy, 2003.

Kane Driscoll, S.B., and C.A. Menzie. 2003. Using NIMO/GTI project results in decision making at MGP sites. Invited Speaker, Conference on Research to Develop Environmentally Acceptable Endpoints for Impacted Sediments and Groundwater at MGP Sites, Syracuse, NY, 2003.

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Lisa J. Yost, M.P.H., DABT
Managing Scientist

Years of Experience: 30 years

Credentials and Professional Honors

M.P.H., Environmental and Industrial Health, University of Michigan, 1980
B.S., Botany, Miami University, 1977

Diplomate, American Board of Toxicology (1990 to present)
Hazardous Waste Operations and Emergency Response 40-hour training program
Hazardous Waste Operations Management and Supervisor 8-hour training program

Professional Profile

Ms. Lisa Yost is a Managing Scientist in Exponent's Health Sciences practice and is based in St. Paul, Minnesota. She is a board-certified toxicologist with expertise in evaluating human health risks associated with substances in soil, water, and the food chain. She has conducted or supervised risk assessments under CERCLA, RCRA, or state-led regulatory contexts involving a wide range of chemicals and exposure situations. Ms. Yost assists clients in negotiating with regulatory agency representatives or other parties to resolve issues related to human exposure to toxic substances. She seeks to develop and apply sound technical approaches that realistically characterize potential risk and meet clients' environmental and business objectives. Her particular areas of specialization include exposure and risk assessment, risk communication, and the toxicology of chemicals such as PCDDs and PCDFs, PCBs, pentachlorophenol (PCP), trichloroethylene (TCE), mercury, and arsenic.

Examples of Relevant Project Experience

Currently coordinating the HHRA efforts of a project team addressing PCDD/F, PAHs, and other chemicals of potential concern under Michigan Department of Environmental Quality lead in Region 5. Helped to develop the site-specific risk assessment work plan for both a screening level deterministic assessment and a comprehensive probabilistic HHRA. In this work, she evaluated exposure and biomonitoring data collected by the University of Michigan and worked with the project team to incorporate relevant elements into the work plan approach.

Worked on two relevant projects in Wisconsin and another in Illinois. In the first Wisconsin project, served as senior technical reviewer and manager of an air modeling runs and consideration of exposure pathways related to estimated air releases of PCDD/Fs at the French Island Generating Plant in LaCrosse, Wisconsin. Helped identify project scope, reviewed all project deliverables and worked with Exponent's air modeler on describing model outcomes for the client. In the second Wisconsin project, retained to assist Wisconsin Energy Corporation staff and their consultants to develop an analysis of potential exposures and risks, if any, related to sulfates in a quarry used for swimming. Participated in calls with client representatives and discussed possible means to compare any potential exposures and risks to standards (e.g., consumption of drinking water at the secondary standard, or swimming in the ocean, which has elevated sulfates relative to surface water) and discussed sulfate toxicological studies. This work was directed toward developing materials to address potential questions from the public or the press. In Illinois, provided assistance in evaluating significance of offsite air concentrations related to a former MGP in Barrie Park. Issues included the degree of site-related versus background input for contaminants of potential concern.

Served as lead toxicologist at a former MGP with residual petroleum hydrocarbons in soil and groundwater in Oregon. The site was undergoing investigation and risk assessment under regulatory guidelines identified by the Oregon Department of Environmental Quality (DEQ). Conducted comprehensive exposure pathway analyses, including the evaluation of the potential for cross-media contamination, and identified limited exposure potential. Worked with the Exponent project team in negotiating with DEQ.

Managed a project to develop risk-based cleanup levels for a former bulk fuel terminal in Seattle, Washington. Worked with a team of contractors to develop a cost-effective approach that was protective of public health and the environment. Selected approach was based on toxic constituents of petroleum hydrocarbons (i.e., benzene, toluene, ethylbenzene, xylene, and PAHs) rather than total petroleum hydrocarbons and greatly reduced areas identified as requiring cleanup. Presented the approach to risk assessment for the site at meetings with the Washington State Department of Ecology.

Provided technical oversight, toxicological review, and risk communication support on a risk assessment conducted as part of an environmental impact statement in development of a refinery in Fjardaal, Iceland. In this context, helped to develop the risk assessment approach to apply air model estimates and evaluate all potential human health pathways related to release of PAHs, SO_2 and fluoride from the plant. Assisted the client in presenting the approach to the Icelandic regulatory board and in crafting risk communication materials to be used for the public.

Served as part of an Exponent team providing technical support on a comprehensive risk assessment of multiple chemicals including PCBs and PAHs in sediments within an industrialized area in Seattle, Washington, along the Duwamish River. Issues included the identification of likely exposure pathways for area residents and visitors, consumption rates for fish and shellfish, and the sustainability of resource consumption as assumed by USEPA.

Managed an upland investigation for a former pulp and paper mill in Ketchikan, Alaska, where Exponent scoped and completed a focused sampling effort for a fast-track site characterization and risk assessment conducted under USEPA and state oversight. Supported negotiations with agency project managers to apply a decision-framework approach to the investigation, including use of source material sampling to focus on limited chemicals and areas of concern; accurate characterization of offsite sources of PCDDs and PCDFs, PAHs, and arsenic; appropriate comparisons with background concentrations for metals and PCDDs and PCDFs; and use of realistic exposure estimates in risk estimates. Represented our client in numerous public meetings and meetings with USEPA and state regulators.

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Colleen A. Cushing
Senior Scientist

Years of Experience: 14 years

Credentials and Professional Honors:

B.S., Mathematics and Philosophy, Willamette University, Salem, Oregon (*magna cum laude*), 1988

Professional Profile

Ms. Colleen Cushing is a Senior Scientist in Exponent's Health Sciences practice based in the Chicago office, with 14 years of experience in human health risk assessment and data analysis. Ms. Cushing is experienced in conducting multi-pathway human health risk assessments of industrial, residential, and recreational scenarios, using site-specific data from soils, groundwater, and surface water for both organic and inorganic chemicals. To evaluate potential subsurface vapor intrusion of volatile and semivolatile chemicals, she has used USEPA's Johnson and Ettinger vapor intrusion model. She has presented results of risk assessments to state and federal regulators and stakeholders. She is also experienced in conducting assessments for consumer products and children's health, often involving novel exposure pathways. She has conducted an exposure assessment for a brominated flame retardant under USEPA's pilot Voluntary Children's Chemical Evaluation Program (VCCEP), which included an evaluation of breast milk ingestion, and the use of biomonitoring data and a pharmacokinetic model. She also evaluated children's potential risk from CCA-treated wood and one of its replacement projects ACQ-treated wood, which included estimating potential intake from residue on the wood surface. In her assessments, she has incorporated results from air dispersion models and the Integrated Exposure and Uptake Biokinetic model for children's lead exposures.

Examples of Relevant Project Experience

Managed project and prepared a screening-level health-based assessment of potential exposures to volatile and semivolatile organic compounds associated with a former manufactured gas plant. Exposure scenarios included a daycare center, a recreation center, future residential development, and future construction workers. Data for groundwater and soil were compiled into a relational database from 14 existing reports. Followed procedures outlined in USEPA's Risk Assessment Guidance for Superfund Sites and their most current guidance for evaluating the vapor intrusion pathway. Assessment included a scenario and pathway-specific six-step screening process to refine the list of chemicals of interest, to streamline any future assessment work. Presented results to a stakeholder group and USEPA regulator.

Managed project and prepared a human health risk assessment for a site impacted by historical commercial use of chlorinated solvents. Used USEPA's Johnson and Ettinger vapor intrusion model to assess subsurface vapor intrusion modeling of volatile and semivolatile compounds under both a hypothetical future commercial building scenario and the planned commercial building scenario. Negotiated with state regulators to gain approval for a rapid, focused soil removal, and to facilitate an expedited review of submitted documents. Oversaw preparation of a comprehensive data validation report and ecological assessment of the site. Prepared a site management plan that incorporated minor modifications to the planned building and groundwater monitoring.

Performed a human health risk assessment of as part of a remedial investigation and feasibility study (RI/FS) for an electronics site in Ohio. Media evaluated included soils, sediments, sludge, groundwater, and surface water. Chemicals of interest included metals and polycyclic aromatic hydrocarbons (PAHs). Aggregated data from multiple sampling events for use in both the human and ecological assessments, and assessed potential risks for current onsite workers and offsite recreational visitors, as well as hypothetical future residents.

Assessed potential human health risks associated with emissions of chemicals from a coal-fired power plant reported by a local utility company under the Toxic Release Inventory (TRI). Estimated air concentrations to which receptors might be exposed using the results of air dispersion modeling combined with TRI emissions data, then compared potential exposures to risk-based screening levels.

Currently coordinating an internal team tasked with evaluating potential human exposures. To meet tight client deadlines, assembled a team consisting of 34 staff members in 11 offices from five different practices. Used internal company IT resources and programming capabilities (at no cost to the client) to convert thousands of single-page image files into a usable electronic format. Efficiency, cost-effectiveness, and product quality was maintained by using technologies such as web-based teleconferencing and real-time sharing of electronic files, the development of comprehensive instructions, and establishing a system of internal review and quality control.

Conducted a human health risk assessment for a former mining site. Assessed potential risks to recreational visitors and construction workers from lead and arsenic. Incorporated results from the adult lead model, and evaluated both chronic and subchronic exposures to arsenic. Assessment included consideration of site-specific conditions such as snow cover, steep terrain, and limited access.

Conducted risk calculations for a multipathway risk assessment for a river in West Virginia that involved evaluation of risks associated with exposures to chemicals in recreational and occupational scenarios. Compiled analytical data for sediments and surface water, modeled fish-tissue concentrations using a bioconcentration factor, and derived exposure-point concentrations for both organic and inorganic substances present onsite. Developed a linked spreadsheet to manipulate toxicity information, exposure algorithms, and exposure-point concentrations and estimate risks for the multi-pathway risk assessment. Quantitatively estimated risks associated with the consumption of fish, inadvertent ingestion of onsite sediments, and dermal contact with onsite sediments and surface water.

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C. Bennett Amos
Scientist

Years of Experience: 4 years

Credentials and Professional Honors:

B.S., Environmental Science, University of Massachusetts, 2002
A.S., Environmental Science Technology (with honors), Holyoke Community College, 2000
OSHA Certified Eight-Hour HAZWOPER Annual Refresher Training in Hazardous Waste Operations and Emergency Response, updated annually
Phi Theta Kappa National Honors Society

Professional Profile

Mr. Bennett Amos is a Scientist in Exponent's EcoSciences practice. He has 4 years of experience in evaluating the exposure and effects of contaminants in aquatic and terrestrial ecosystems. He is an environmental scientist focusing on aquatic and terrestrial ecological risk assessment. He has experience in environmental consulting for state, federal, and private sector clients in support of Superfund, MCP, NRD, and litigation projects. His expertise is in ecological risk assessment and the design and implementation of field investigations involving the sampling of soil, sediment, surface water, and biota. Mr. Amos is capable in literature review, research, data management, GIS mapping, research and development, and technical writing.

Prior to joining Exponent, Mr. Amos worked at Menzie-Cura & Associates, Inc., where he gained his experience in ecological risk assessment. Prior to his work with MCA, he worked as a field biologist for a pesticide consulting firm, was responsible for the day-to-day operation of a drinking water analytical laboratory, and assisted in MA Title V inspections, percolation testing, soil profiling, gravel pit exploration, lot surveying, and artificial wetland construction.

Examples of Relevant Project Experience

Led and assisted the design and implementation of numerous sediment, soil, surface water, and biota sampling efforts, including organizing with laboratories, subcontractors, and personnel from multiple offices. Several of these projects were in support of USEPA-led RCRA programs.

Assisted in sampling of sediments at a former coking facility in New Jersey. The field program included sediment reconnaissance and real-time field PAH analysis to allow for the sampling of a range of target analytes. Assisted in the analysis of chemical, physical, and toxicological data generated from this event, and the preparation of the associated technical report to the client.

Designed and implemented the sampling of sediments at two former MGP facilities on the Hudson River. Organized internal and subcontractor personnel for the field sampling effort. Assisted in the sampling of sediments, analysis of chemical, physical, and toxicological data, and preparation of the technical report for delivery to the client.

Designed and implemented the sampling of sediments at a former MGP facility in northern Indiana. Organized the logistics of shipping equipment and moving personnel to the site, and organized local subcontractors to assist in the sampling. Performed the sediment sampling. Assisted in the analysis of chemical, physical, and toxicological data, and prepared the technical report for delivery to the client, which was added to a larger corrective action report, which will be submitted to USEPA Region 5 and Indiana Department of Environmental Management.

Supported the ecological risk assessment for the settling ponds and spoils disposal area site at Badger Army Ammunition Plant, Baraboo, Wisconsin. Assisted in the development of a master database for the site that incorporated analytical data for soil and biological media from multiple sampling events. Assisted in the development of ecological hazard quotients using food chain models. Continuing to support the ecological risk assessment for this site.

Presentations

Menzie, C.A., B. Amos, and U. Ghosh. A mechanism for delivery of activated carbon to sediment. Fourth International Conference on Remediation of Contaminated Sediments. Savannah, GA. January 22–25, 2007.

Kane Driscoll, S.B., M. McArdle, C.B. Amos, C.A. Menzie, and A. Coleman. 2005. Development of a database of toxic doses of PAHs to fish. Estuarine Research Federation 2005 Conference, Norfolk, VA, October 16–20, 2005.

Kane Driscoll, S., B. Amos, M. McArdle, C. Menzie, and A. Coleman. Application of equilibrium partitioning sediment benchmarks (ESBs) for PAH mixtures to manufactured gas plant sites. Poster presentation, Society for Risk Analysis Roundtable Discussion of Emerging and Still Urgent Issues in Risk Analysis, July 14, 2004.

von Stackelberg, K.E., C. Butler, J. Famely, B. Amos. 2004. Risk management for threatened and endangered species at US Army Installations. Society For Risk Analysis Annual Meeting, December 5–8, 2004.

Menzie, C.A., B. Amos, and M.L. Nelson. 2003. Relying on natural or enhanced benthic biological barriers for reducing exposure to sediment contamination. Poster presentation, EPRI In-situ Contaminated Sediment Capping Workshop, Cincinnati, OH, May 12–14, 2003.

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Joseph J. Famely
Scientist

Years of Experience: 6 years

Credentials and Professional Honors:

A.B., Psychology and Environmental Sciences *(magna cum laude)*, Bowdoin College, 2000

Professional Profile

Mr. Joseph J. Famely is a Scientist in Exponent's EcoSciences practice. He has 6 years of experience in environmental consulting for state, federal, and private sector clients in support of Superfund, MCP, NRD, and litigation projects. His expertise is in ecological risk assessment, the design and management of complex databases, GIS mapping, and the design and implementation of field investigations. He has extensive field experience collecting soil, sediment, surface water, and biota and using water quality meters.

Prior to joining Exponent, Mr. Famely performed ecological and human health risk assessments, led field investigations, and provided litigation support at Menzie-Cura & Associates. There, he conducted numerous literature searches in the areas of biological fate and effects, and regulatory analysis, and regularly provided statistical support for exposure and risk calculations.

Examples of Relevant Project Experience

Provided field, database, and risk assessment support for a former MGP site in Salem Harbor, Massachusetts (Collins Cove MGP Site). For National Grid (formerly Massachusetts Electric Company), implemented a multi-year sediment biomonitoring program to evaluate changes in the benthic community following *in situ* treatment application – nutrient injection. Under the Massachusetts Contingency Plan (MCP), implemented a multi-media field program (terrestrial, wetland, aquatic) and supported the ecological risk assessment. In addition to toxicological benchmark research, toxicity reference value research, bioaccumulation model implementation and food chain model implementation, managed and manipulated a large database to support both human health and ecological risk calculations.

Supported the development of a risk assessment framework document for Wisconsin Public Service Corporation's former MGP sites. The work included developing screening tables to be used in the ecological and human health screening evaluations.

Performed a sediment screening assessment for a former MGP site in Ripon, Wisconsin. The analysis included a sediment screening following Wisconsin DNR guidelines and USEPA guidance on Equilibrium Partitioning Sediment Benchmarks (ESBs) for the protection of benthic organisms.

Performed a sediment screening assessment for a Nicor Gas former MGP site in Illinois. The analysis included a sediment screening following USEPA guidance on ESBs for the protection of benthic organisms.

Provided database support services for the baseline ecological risk assessment of the Badger Army Ammunition Plant (BAAP) Site in Sauk County, Wisconsin. BAAP is a RCRA site with USEPA Region 5 oversight.

Provided research support in an environmental forensics case at a landfill at the Sauget Area II Superfund site in Cahokia, Illinois.

Provided field and risk assessment support for the W.R. Grace Acton Plant Superfund site in Acton, Massachusetts.

Provided modeling support for an assessment of bioaccumulation of PCBs in fish at the Hudson River Superfund site for USEPA Region 2.

Cheri L. Butler
Project Team Member

Years of Experience: 10 years

Credentials and Professional Honors:

B.A., Biology, College of the Holy Cross, 1997

Co-Author of the HERA Integrated Risk Assessment Paper of Year, 2002.
Kane Driscoll, S.B., W.T. Wickwire, J.J. Cura, D.J. Vorhees, C.L. Butler, D.W. Moore, and T.S. Bridges. 2002. A comparative screening-level ecological and human health risk assessment for dredged material management alternatives in New York/New Jersey Harbor. Hum. Ecol. Risk Asses. 8(3):603–626.

Professional Profile

Ms. Butler has 10 years of experience evaluating aquatic and terrestrial exposure and effects of contaminants in the environment. Her experience conducting human health and ecological risk assessments includes development of quality assurance project plans, design and implementation of multi-media field sampling programs, development of conceptual models and human exposure profiles, preparation of final risk characterization reports, and development of preliminary remediation goals. She is also skilled in database design, management, and quality control. Ms. Butler is familiar with approaches for evaluating petroleum hydrocarbons and with probabilistic risk assessment methods. She has contributed to the development of a probabilistic framework for evaluating the suitability of dredged material for disposal. She is currently conducting risk assessments under the Superfund program.

Examples of Relevant Project Experience

Ms. Butler has provided risk assessment support at MGP sites and sites in Wisconsin and Indiana. She contributed to the development of a risk assessment framework document for Wisconsin Public Service Corporation’s former MGP sites. She also provided risk assessment support for the engineering evaluation/cost analysis for the St. Augustine Former MGP Site in St. Augustine, Florida, and for the feasibility study for Site 11 (Open Burning Unit) at Jefferson Proving Ground (JPG) in Madison, Indiana. The purpose of the streamlined risk evaluation performed at the St. Augustine Site was to identify areas that required remediation as well as guide the selection of types of remediation appropriate for those areas. Similarly, at JPG, Ms. Butler conducted a human health risk assessment (HHRA) and ecological risk assessment (ERA) screening evaluation that was used to streamline the selection of the remediation area at Site 11. At Badger Army Ammunition Plant (BAAP) in Baraboo, Wisconsin, Ms. Butler used recent data to re-evaluate potential ecological risks for wildlife that may use the Final Creek, Settling Ponds, and Spoils Disposal Areas Site.

Ms. Butler has also completed numerous multimedia risk assessments in accordance with CERCLA and RCRA Corrective Action program. Two of these assessments were conducted for USEPA-led NPL sites. Ms. Butler was part of a team of scientists working along with USEPA to design a sampling plan to collect data suitable for risk assessment, conduct human health and ecological risk assessments, and develop preliminary remediation goals.

Margaret A. Zak
Senior Scientist

Years of Experience: 28 years

Credentials:

M.S., Coursework in Toxicology, University of Pittsburgh, 1987–1989
M.S., Ecology, Pennsylvania University, 1984
B.B., Biology/Chemistry, University of Pittsburgh, 1978

Professional Profile

Ms. Margaret Zak has more than 28 years of environmental experience in the industrial, consulting, government, and non-profit sectors. Her experience includes: project management of major industrial projects, preparation of sampling and analysis plans and investigation/remediation reports, management and implementation of human health and ecological risk assessments, and project cost tracking and scheduling.

Ms. Zak has been involved in the human health and ecological risk assessment process, both from a management and implementation perspective, since 1990. Her human health and ecological experience includes: development of upfront corporate strategies and presentation of these strategies in a risk methodology document for regulatory review and approval, development of risk-based sampling and analysis plans, development of site-specific conceptual site models, development of site-specific exposure parameters that consider current regulatory guidance, the peer reviewed literature and unique characteristics of a site, and preparation of final risk characterization reports. Ms. Zak is experienced in negotiating with federal and state regulatory agencies in development of sampling and analysis plans, remedial investigation reports, feasibility studies, and remediation plans. The outcome of these negotiations was to develop mutually acceptable methodologies/procedures for the investigation and remediation of sites using technically defensible, risk-based procedures resulting in cost effective remedial solutions.

Examples of Relevant Project Experience

Served as Project Manager/Risk Manager for a Fortune 500 steel company who formerly owned and operated a steel siding facility in Akron, Ohio being investigated under USEPA's RCRA program. Soil and groundwater were the focus of the investigation. Served as the main strategy/review person for the human health and ecological risk assessments that were conducted to determine areas that needed to be remediated. This required numerous strategic negotiations with USEPA Region 5. The risk-based approach resulted in a Record of Decision that required only a monitored natural attenuation program for groundwater, which was a significant cost savings to the PRPs.

Served as Risk Manager on a RCRA corrective action project for a fully integrated steelmaking facility in Gary, Indiana. Developed and managed the human health and ecological risk-based strategy as part of the RCRA corrective action program. USEPA Region 5 was the agency providing regulatory oversight of the RCRA process. The human health risk methodology developed for this facility involved a unique approach to developing worker-specific exposure parameters for various operating areas of the plant that resulted in minimal areas to be investigated in the Phase II soil investigation. A risk-based perimeter groundwater monitoring approach was proposed to USEPA for the facility.

Served as Project Manager/Risk Manager for a Fortune 500 corporation’s former steelmaking facility located south of Chicago, Illinois that was entered into IEPA’s voluntary cleanup program in 1993. The project consisted of three phases of site investigation, a human health and ecological risk evaluation, development of risk-based remediation goals, and remediation of the property for industrial/ commercial use. Using a risk-based approach following IEPA’s formal risk assessment program, a cost-effective, risk-based remedial solution was implemented. The corporation received a No Further Remediation letter from the IEPA and is currently involved in a joint-venture with another major development entity to develop the site for mixed-used.

Served as Project Manager/Risk Manager on a vessel slip sediment risk evaluation for a Fortune 500 corporation’s former steelmaking facility located south of Chicago, Illinois. Developed a risk-based human health and ecological strategy for evaluating sediment results from two vessel slips that were sampled by the IEPA approximately four years ago. A risk strategy document was submitted to the IEPA to evaluate future recreational receptors using the slips for fishing purposes. The strategy focused on the fact that only bioaccumulative chemicals are appropriate to evaluate by modeling their concentrations in sediments to fish that are potentially caught and eaten. The former steel site will be redeveloped in the near future for commercial/residential use with the potential for recreational use along the slips.

Served as Project Manager/Risk Manager for a Fortune 500 corporation’s former steelmaking facility, Joliet, Illinois. Managed the human health and ecological risk assessments performed for the former 57-acre former steelmaking facility, as well as served as overall Project Manager. The site was being investigated under IEPA’s voluntary Site Remediation Program (SRP). A comprehensive site investigation work plan for soil and groundwater sampling, which included the risk assessment methodology, was submitted to the state for review and approval.

Served as Risk Manager for a Fortune 500 steelmaking company’s former steelmaking facility in Duluth, Minnesota. Developed and managed the human health and ecological risk-based strategy as part of the CERCLA program. The site consisted of both an upland portion of property and offshore estuary sediments. Soils and sediments were investigated under a Consent Order issued by MPCA that required submittal of both remedial investigation and feasibility study reports to MPCA, MDH, and USEPA Region 5. Responsible for developing the risk-based strategy that formed the basis of the soil and sediment investigations and negotiating with the regulatory agencies providing oversight of the process. The risk assessment resulted in focused soil remediation in the upland areas of the site and identified areas in the estuary requiring sediment remediation. The project team developed a unique approach to minimizing sediment remediation by engaging the regulatory agencies as well as local trustees (MDNR, USFWS) in developing a habitat enhancement plan to restore native species/habitat without the invasive removal of sediments.

Attachment 2

Project Team Publications

Project Team Publications

Relevant Publications and Presentations

Manufactured Gas Plant Sites and Related Chemicals (PAHs, cyanides, select metals, and hydrocarbons)

Cura, J.J., S.B. Kane Driscoll, R. Lacey, M. McArdle, and C.A. Menzie. 2001. Assessing ecological risks of PAH-contaminated sediments. In: Sediments Guidance Compendium. Electric Power Research Institute (EPRI), Palo Alto, CA.

Harkey, G.A., S.B. Kane Driscoll, and P.F. Landrum. 1997. Effect of feeding in 30-day bioaccumulation assays using *Hyalella azteca* in fluoranthene-dosed sediment. Environ. Toxicol. Chem. 16(4):762–769.

Kane Driscoll, S.B, and R.M. Burgess. In press. An overview of the development, status, and application of Equilibrium Partitioning Sediment Benchmarks for PAH mixtures. Hum. Ecol. Risk. Assess.

Kane Driscoll, S.B. 1996. Sediment accumulation and toxicity of fluoranthene to freshwater amphipods. Benthic Ecology Meeting, Columbia, SC, March 7–10, 1996.

Kane Driscoll, S.B. 1998. Invited Participant and Session Leader, U.S. Army Corps of Engineers Workshop on Environmental Risk Assessment and Dredged Material Management: Issues and Application. San Diego, CA, 1998.

Kane Driscoll, S.B. 2007. A methodology for deriving a dietary dose of PAHs that is protective of fish. Platform presentation, International Conference on Remediation of Contaminated Sediments in Savannah, GA, January 22–24, 2007. Session chair: "Bioavailability of Contaminants."

Kane Driscoll, S.B., and A.E McElroy. 1993. A comparison of bioaccumulation and biotransformation of benzo[a]pyrene in three species of polychaete worms. Society of Environmental Toxicology and Chemistry, Houston, TX, 1993.

Kane Driscoll, S.B., and A.E. McElroy. 1992. Biotransformation of benzo[a]pyrene by three species of polychaete. Society of Environmental Toxicology and Chemistry, Cincinnati, OH, 1992.

Kane Driscoll, S.B., and A.E. McElroy. 1993. Metabolism of benzo[a]pyrene in three species of marine annelids. Gordon Research Conference on Drug Metabolism, Plymouth, NH, 1993.

Kane Driscoll, S.B., and A.E. McElroy. 1996. Bioaccumulation and metabolism of benzo[a]pyrene in three species of polychaete worms. Environ. Toxicol. Chem. 15:1401–1410.

Kane Driscoll, S.B., and A.E. McElroy. 1997. Elimination of sediment-associated benzo[a]pyrene and its metabolites by polychaete worms exposed to 3-methylcholanthrene. Aquat. Toxicol. 39(1):77–91.

Kane Driscoll, S.B., and C.A. Menzie. 2003. Using NIMO/GTI project results in decision making at MGP sites. Invited Speaker, Conference on Research to Develop Environmentally Acceptable Endpoints for Impacted Sediments and Groundwater at MGP Sites, Syracuse, NY, 2003.

Kane Driscoll, S.B., and P.F. Landrum. 1995. Toxicokinetics and critical body burdens of Fluoranthene in amphipod bioassays with *Hyalella azteca* and *Diporeia* sp. Invited talk, Society of Environmental Toxicology and Chemistry, Vancouver, BC, 1995.

Kane Driscoll, S.B., and P.F. Landrum. 1996. Bioaccumulation and critical body burden of Fluoranthene in estuarine amphipods. Society of Environmental Toxicology and Chemistry, Washington, DC, 1996.

Kane Driscoll, S.B., and P.F. Landrum. 1997. A comparison of equilibrium partitioning and critical body residue approaches for predicting toxicity of sediment associated fluoranthene to freshwater amphipods. Environ. Toxicol. Chem. 16(10):2179–2186.

Kane Driscoll, S.B., G.A. Harkey, and P.F. Landrum. 1997. Accumulation and toxicity of fluoranthene in sediment bioassays with freshwater amphipods. Environ. Toxicol. Chem. 16(4):742–753.

Kane Driscoll, S.B., P.F. Landrum, and E.A. Tigue. 1997. Accumulation and toxicity of fluoranthene in water only bioassays with freshwater amphipods. 1997. Environ. Toxicol. Chem. 16(4):754–761.

Kane Driscoll, S.B., S.C. Schaffner, and R.M. Dickhut. 1998. Toxicokinetics of fluoranthene to the amphipod, *Leptocheirus plumulosus*, in water-only and sediment exposures. Mar. Environ. Res. 45(3):269–284.

Kane Driscoll, S.B., T. Bridges, J.J. Cura, M. McArdle, and M. Nelson. 2002. A review of comparative risk assessment methods and their applicability to dredged material management decisions. 23rd Annual Meeting of SETAC North America, Salt Lake City, Utah, November 16–20, 2002.

Kane Driscoll, S.B., M.E. McArdle, C.A. Menzie, A. Coleman. 2002. Application of sediment quality guidelines of PAHs to manufactured gas plant sites. Presented at the 23rd Annual Meeting of SETAC North America, Salt Lake City, UT, November 16–20, 2002.

Kane Driscoll, S.B., M.E. McArdle, C.A. Menzie, and A. Coleman. 2002. Application of sediment quality guidelines of PAHs to manufactured gas plant sites. Presented at the 23rd Annual Meeting of SETAC North America, Salt Lake City, UT, November 16–20, 2002.

Kane Driscoll, S.B., M.E. McArdle, C.A. Menzie, T. Thompson and A. Coleman. 2003. Application of sediment quality guidelines for PAHs to manufactured gas plants. 2nd International Conference on Remediation of Contaminated Sediments, Venice, Italy, 2003.

Kane Driscoll, S.B., M.E. McArdle, C.A. Menzie, T.A. Thompson, and A. Coleman. 2003. An examination of the bioavailability and toxicity of sediment-associated PAHs at manufactured gas plants. Presented at the 24th Annual Meeting of SETAC North America, Austin, TX, November 9–13, 2002.

Kane Driscoll, S., B. Amos, M. McArdle, C. Menzie, and A. Coleman. 2004. Application of equilibrium partitioning sediment benchmarks (ESBs) for PAH mixtures to manufactured gas plant sites. Poster presentation, Society for Risk Analysis Roundtable Discussion of Emerging and Still Urgent Issues in Risk Analysis, July 14, 2004.

Kane Driscoll, S.B., C.A. Menzie, M.E. McArdle, and A. Coleman. 2004. Application of site-specific equilibrium partitioning sediment benchmarks for PAH mixtures to manufactured gas plants. 25th Annual Meeting of SETAC North America, Portland, OR, November 14–18, 2004.

Kane Driscoll, S.B., M. McArdle, C. Amos, C.A. Menzie, and A. Coleman. 2005. Development of a database of toxic doses of PAHs to fish. 18th Biennial Conference of the Estuarine Research Federation, Norfolk, VA, October 16–20, 2005.

Kane Driscoll, S.B., M. Reiss, and J. Steevens. 2005. Development of a novel dose-based toxicity benchmark for exposure of fish to PAHs. 26th Annual Meeting of SETAC North America, Baltimore, MD, November 16–20, 2005.

Kane Driscoll, S.B., M.E. McArdle, D. Burmistrov, M. Reiss, J.A. Steevens . 2006. A methodology for deriving a dietary dose of total polynuclear aromatic hydrocarbons that is protective of fish. Presented at the 27th Annual Meeting of SETAC North America, Montreal, Canada, November 5–9, 2006.

Lanno, R. and C.A. Menzie. 2005. Risk assessment of cyanide in water and soil. Chapter 17. In: Cyanide in Water and Soil: Chemistry, Risk, and Management. D.A. Dzombak, R.S. Ghosh, and G.M. Wong-Chong (eds.), CRC Press/Lewis Publishers, Boca Raton, FL, 2005.

Menzie, C.A. 1996. Chapters on Risk Assessment. In Management of Manufactured Gas Plant Sites. Edited by Hayes et al. Gas Research Institute. Amherst Scientific Publications.

Menzie, C.A. 1997. Implementing risk management at manufactured gas plant sites. Soil & Groundwater Cleanup. August/September. pp. 12–18.

Menzie, C.A. 1998. Risk communication and careful listening—resolving alternative world views. Hum. Ecol. Risk Asses. 4(3):619–622.

Menzie, C.A., 1999. Applying Risk-Based Solutions—the importance of communication. Environ. Eng. 35(4):20–22.

Menzie, C.A. and A. Coleman. 2007. Evaluating the risks of PAH-contaminated sediments. In: Human and Ecological Risk Assessment. March 2007.

Menzie, C.A., B. Potocki and J. Santodonato. 1992. Exposure to carcinogenic PAHs in the environment. Environ. Sci. Technol. 26(7):1278–1284.

Menzie, C.A., M. Hope Henning, J. Cura, K. Finkelstein, J. Gentile, J. Maughan, D. Mitchell, S. Petron, B. Potocki, S. Svirsky, P. Tyler. 1996. Special report of the Massachusetts weight-of-evidence workgroup: A weight-of-evidence approach for evaluating ecological risks. Hum. Ecol. Risk Asses. 2(2):277–304.

Menzie, C.A., W.J. Heiger-Bernays, C.R. Montgomery, D.G. Linz, and D.V. Nakles. 1996. Development of an ecological risk assessment framework based on contaminant availability. In: Ecotox—Environmental Contaminants through the Macroscope. Wuerz Publishing Ltd., Winnipeg, MB, Canada.

Menzie, C.A., Burke, A.M., Grasso, D., Harnois, M., Magee, B., McDonald, D., Montgomery, C., Nichols, A., Pignatello, J., Price, B., Price, R., Rose, J., Shatkin, J., Smets, B., Smith, J., Svirsky, S. 2000. An approach for incorporating information on chemical availability in soils into risk assessment and risk-based decision making. Hum. Ecol. Risk Asses. 6(3):479–510.

Menzie, C.A., J.J. Cura, S. Kane-Driscoll, R. Lacey, and M. McArdle. 2001. Assessing ecological risks of PAH-contaminated sediments. In: Proc. of the International Conference on Remediation of Contaminated Sediments, Venice, Italy, October 10–12, 2001. Battelle Press, Columbus, OH.

Menzie, C.A., J.J. Cura, S.B. Kane-Driscoll, R. Lacey, and M. McArdle. 2001. Assessing ecological risks of PAH-contaminated sediments. Proceedings, International Conference on Remediation of Contaminated Sediments, Venice, Italy, October 10–12, 2001.

Menzie, C.A., S.S. Hoeppner, J.J. Cura, J.S. Freshman, and E.N. LaFrey. 2002. Urban and suburban storm water runoff as a source of polycyclic aromatic hydrocarbons (PAHs) to Massachusetts estuarine and coastal environments. Estuaries 25(2):165–176.

Menzie, C.A., B. Amos, and U. Ghosh. 2007. A mechanism for delivery of activated carbon to sediment. Fourth International Conference on Remediation of Contaminated Sediments. Savannah, GA. January 22–25, 2007.

Shatkin, JA, M. Wagle, S. Kent, C.A. Menzie. 2002. Development of a biokinetic model to evaluate dermal absorption of polycyclic aromatic hydrocarbons from Soil. Hum. Ecol. Risk Asses. 8(4):713–734.

von Stackelberg, K., C.A. Menzie, and J.J. Cura. 1995. Risk assessment: helping to focus risk management objectives for MGP sites. Land Contamination & Reclamation. (Special issue) 3(4):24-29. Presented at the International Symposium and Trade Fair on the Clean-up of Manufactured Gas Plants, Prague, Czech Republic, September 19-21, 1995.

Ziccardi, L.M., and D. Bodishbaugh. 2006. Ecological risk screening levels for total petroleum hydrocarbons: A review. Presented at the Society of Environmental Toxicology and Chemistry (SETAC) Annual Meeting. Montreal, Canada.

Other Publications Relevant to Ecological and Human Health Risk Assessment

Burmaster, D.E., B. Murphy, J. Gushue and C.A. Menzie. 1987. A risk assessment for the Baird & McGuire Superfund Site. Presented at the Hazardous Materials International Conference, Washington, D.C., 1987.

Burmaster, D.E., K.M. Thompson, C.A. Menzie, E. Crouch and T. McKone. 1990. Monte Carlo techniques for quantitative uncertainty analysis in public health risk assessment. pp. 215–21. In: Proc. 1990 Hazardous Materials Control Research Institute Conference New Orleans, LA, 1990.

Burmaster, D.E., C.A. Menzie, J.S. Freshman, J.A. Burris, N.I. Maxwell and S.R. Drew. 1991. Assessment of methods for estimating aquatic hazards at Superfund-type sites: A cautionary tale. Environ. Toxicol. Chem. 10:827–842.

Callahan, C.A., C.A. Menzie, D.E. Burmaster, D.C. Wilborn and T. Ernst. 1991. On-site methods for assessing chemical impact on the soil environment using earthworms: A case study at the Baird & McGuire Superfund Site, Holbrook, MA. Environ. Toxicol. Chem. 10:817–826.

Cura, J.J. and C. Menzie. 1996. Methodologies for ecological risk assessment: the overall process and recent advances. Presented at the Water Environment Federation 69th Annual Conference & Exposition. Conference Workshop #12 - Ecological Risk Assessment: Why and How—An Important Tool in Environmental Decision Making, Dallas, TX, October 5–9, 1996.

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Gaudet, C.L., C.A. Menzie, and S. Ouellet. 2002. Risk-based assessment of soil contamination: generic versus site-specific approaches. Chapter 12, pp. 203–219. In: Environmental Analysis of Contaminated Sites. G.I. Sunahara, A.Y. Renoux, C. Thellen, C.L. Gaudet, and A. Pilon (eds.), John Wiley & Sons Ltd.

Iannuzzi, T.J., D.F. Ludwig, S.P. Truchon, L.M. Schmeising, and N.W. Gard. 2000. Natural resource injury assessment for polychlorinated biphenyls (PCBs) in the Lower Fox River System: Part I: Water, sediments and aquatic organisms. Presented at the SETAC 21st Annual Meeting. Nashville, TN.

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Landrum, P.F., E.A. Tigue, S.B. Kane Driscoll, D.C. Gossiaux, P.L. Van Hoof, M.L. Gedeon, and M. Adler. 2001. Bioaccumulation of PCB congeners by *Diporeia* spp.: Kinetics and factors affecting bioavailability. J. Great Lakes Res. 27(2):117–133.

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Menzie, C.A. 2002. The evolution of ecological risk assessment during the 1990s: challenges and opportunities. Chapter 16, pp. 281–299. In: Environmental Analysis of Contaminated Sites. G.I. Sunahara, A.Y. Renoux, C. Thellen, C.L. Gaudet, and A. Pilon (eds.), John Wiley & Sons Ltd.

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Menzie, C.A., and D.E. Burmaster. 1988. Overview of soil clean-up levels and risk based decision making. Presented at the HazMat '88 Conference, Atlantic City, NJ, June 14–16, 1988.

Menzie, C.A., and J. Cura. 1991. Loadings of pollutants in Massachusetts Bay. Presented at U.S. Environmental Protection Agency Conference on Estuaries, Sarasota, FL, February 24–26, 1991.

Menzie, C.A., and J.J. Cura. 1991. Environmental evaluations at hazardous waste sites. pp. 77–84. In: Proc. HMC-Northeast '91 Conference, Hazardous Materials Control Research Institute, Boston, MA, July 10–12, 1991.

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Menzie, C.A., B. Amos, and M.L. Nelson. 2003. Relying on natural or enhanced benthic biological barriers for reducing exposure to sediment contamination. Poster presentation, EPRI In-situ Contaminated Sediment Capping Workshop, Cincinnati, OH, May 12–14, 2003.

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Yost, L.J., W.J. Shields, D.C. Peek, R.A. Schoof, M.V. Ruby, and J.A. Maloy. 2000. Identification and hazard evaluation of crushed rock as an unexpected source of elevated arsenic in soil. Poster presented at the Society for Environmental Geochemistry and Health's Fourth International Conference on Arsenic Exposure and Health Effects, San Diego, CA, July 2000.

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APPENDIX C

RECORD LIST

WISCONSIN SITES

WISCONSIN PUBLIC SERVICES CORPORATION

CERLCA DOCKET NO. V-W-'06-C-847:

ILLINOIS SITES

THE PEOPLES GAS LIGHT AND COKE COMPANY

CERLCA DOCKET NO. V-W-'07-C-869:

NORTH SHORE GAS COMPANY

CERLA DOCKET NO. V-W-'07-C-877:

GREEN BAY MGP SITE

1984 STS Consultants, Ltd., *Subsurface Investigation, Old City Gas Plant, Green Bay, Wisconsin*, Job No. 13478.

1986 EDI Engineering & Science, Inc., *Site Investigation, Former Coal Gas Manufacturing Plant, North Adams Street, Green Bay, Wisconsin*, Report No. 20403.

1994 June 27, Natural Resource Technology, Inc., *Work Plan – Phase II Environmental, Investigation of Manufactured Gas Plant Sites – Green Bay – Sheboygan I – Two Rivers, Wisconsin*, Project No. 1043.

1994 July 27, Wisconsin Department of Natural Resources, Approval Letter to Wisconsin Public Service Corporation *Site Investigation at the Former Manufactured Gas Plants located in Green Bay and Two Rivers, Wisconsin*.

1994 August 18, Natural Resource Technology, Inc., Letter to James Reyburn, Wisconsin Department of Natural Resources, *Site Investigation at the Former Manufactured Gas Plants located in Green Bay and Two Rivers, Wisconsin*, Project No. 1059.

1994 October 21, Natural Resource Technology, Inc., *Sediment Sampling Work Plan Addenda – Green Bay and Two Rivers Manufactured Gas Plant Sites*, and transmittal letter to James Reyburn, Wisconsin Department of Natural Resources, *Sediment and Surface Water Sampling at the Former Manufactured Gas Plants located in Green Bay and Two Rivers, Wisconsin*, Project No. 1057 and 1059.

1994 October 31, Natural Resource Technology, Inc., Letter to Mr. Richard Stoll, Wisconsin Department of Natural Resources, *Monitoring Well Construction Variance Applications of Former Manufactured Gas Plant (MGP) Investigations in Green Bay and Two Rivers, Wisconsin*, Project No. 1057.

1995 March 31, Natural Resource Technology, Inc., Letter to Jim Reyburn, Wisconsin Department of Natural Resources, *Sediment Sampling at the Former Manufactured Gas Plants located in Green Bay and Two Rivers, Wisconsin*, Project No. 1059.

1995 June 9, Natural Resource Technology, Inc., *Phase II Environmental Investigation Report of Former Manufactured Gas Plant Site, Green Bay, Wisconsin*, Project No. 1057.

1995 July 6, Wisconsin Department of Natural Resources, Letter to Wisconsin Public Service Corporation, *Sediment Investigation at Former Manufactured Gas Plants located in Green Bay, Two Rivers, and Marinette*.

1995 August 9, Wisconsin Department of Natural Resources, Approval letter to Wisconsin Public Service Corporation, *Thermal Treatment of Soils from 5 Wisconsin Public Service Corporation (WPSC) Sites*.

1996 March 5, Natural Resource Technology, Inc., *Work Plan, Phase II Addendum Environmental Investigations of Manufactured Gas Plant Sites, Green Bay, Marinette, Oshkosk, Two Rivers, Wisconsin*, Project No. 1150.

1996 March 29, Wisconsin Department of Natural Resources, Comment Letter to Wisconsin Public Service Corporation, *Phase II Addendum Work Plan for Former Manufactured Gas Plant*.

1996 May 31, Natural Resource Technology, Inc., Letter to James Reyburn, Wisconsin Department of Natural Resources, *Phase II Addendum Investigation Work Plan Comments, Former Manufactured Gas Plant Sites, Green Bay, Marinette, Oshkosk, Tow Rivers, Wisconsin,* Project No. 1050.

1996 September 24, Natural Resource Technology, Inc., *Phase II Addendum Investigation Results, Former Green Bay Manufactured Gas Plant (MGP) Site, Green Bay, Wisconsin*, Project No. 1150.

1996 December 23, Natural Resource Technology, Inc., *Sediment Investigation Report, former Manufactured Gas Plant Site, Green Bay, Wisconsin*, Project No. 1150.

1997 May 21, Natural Resource Technology, Inc., *Remedial Action Options Report, Former Manufactured Gas Plant Site, Green Bay, Wisconsin,* Project No. 1150.

1998 February 17, Natural Resource Technology, Inc., Letter to Jim Reyburn, Wisconsin Department of Natural Resources, *Updated Groundwater Results for the Former Manufactured Gas Plant Site*, Project No. 1584.

2002 December 20, Natural Resource Technology, Inc., Letter to Kristen DuFresne, Wisconsin Department of Natural Resources, *Site Conditions Update and Remedial Action Options Report Addendum, Former Manufactured Gas Plant Site, Green Bay, Wisconsin,* Project No. 1150.

2003 February 5, Natural Resource Technology, Inc., *Remedial Work Plan, Former Manufactured Gas Plant Site, Green Bay, Wisconsin,* Project No. 1584.

2003 February 7, Wisconsin Department of Natural Resources, Comment Letter to Wisconsin Public Service Corporation, 700 North Adams Street, Green Bay, Wisconsin, *Site Conditions Update and Remedial Action Options Report Addendum*.

2003 February 20, Natural Resource Technology, Inc., *Response to WDNR Comments on Site Conditions Update and RAOR Addendum and Remedial Work Plan, Former Manufactured Gas Plant Site, Green Bay, Wisconsin*, Project No. 1584.

2003 March 10, Wisconsin Department of Natural Resources, Notice to Proceed with Remedial Work Plan letter to Wisconsin Public Service Corporation *Manufactured Gas Plant, 700 North Adams Street, Green Bay, Wisconsin, WDNR BRRT #02-05-000254*.

2003 December 30, Natural Resource Technology, Inc., *Remedial Action Documentation Report, Former Manufactured Gas Plant Site, Green Bay, Wisconsin,* Project No. 1584.

2004 March 12, Natural Resource Technology, Inc., *Groundwater Monitoring Update and Request for Sampling Reduction, Former Manufactured Gas Plant Site, Green Bay, Wisconsin,* Project No. 1584.

2004 December 10, Natural Resource Technology, Inc., *Groundwater Monitoring Update/Request for Reduction to Sem-Annual Sampling, Former Manufactured Gas Plant Site, Green Bay, Wisconsin,* Project No. 1584.

2006 February 1, Natural Resource Technology, Inc., *Groundwater Monitoring Update Period of November 1, 2004 through October 31, 2005, Green Bay Former Manufactured Gas Plant Site, 417 Elm Street, Green Bay, USEPA ID# WIN000509948, WI BRRTS# 02-05-000254*.

MANITOWOC MGP SITE

1988 November, EDI Engineering & Science, *Site Investigation, Former Coal Gas Manufacturing Plant, Manitowoc, Wisconsin*.

1988 November, EDI Engineering & Science, *Site Investigation, Former Coal Gas Manufacturing Plant, Manitowoc, Wisconsin, Addendum Report for the Winter Property*.

1991 December, WW Engineering & Science, *Environmental Site Investigation for Former Coal Gas Manufacturing Plant, Manitowoc, Wisconsin, Addendum for the Winter Property*.

1992 January, WW Engineering & Science, *Ground Water Monitoring Plan, Former Coal Gas Manufacturing Plant, Manitowoc, Wisconsin*.

1992 January, WW Engineering & Science, *Environmental Site Investigation, Former Coal Gas Manufacturing Plant, Manitowoc, Wisconsin*.

1992 October, WW Engineering & Science, *Treatability Test Report, Stabilization/Solidification, Coal Tar Impacted Soil/Sediments, Wisconsin Fuel & Light Company, Manitowoc, Wisconsin*.

1993 February, WW Engineering & Science, *Feasibility Study and Interim Remediation Plan, Coal Tar Impacted Soils, Wisconsin Fuel & Light Company*.

1993 February, WW Engineering & Science, *Treatability Test Report, Pilot Test Report, In-Situ Stabilization/Solidification, Coal Tar Impacted Soil/Sediments, Wisconsin Fuel & Light Company, Manitowoc, Wisconsin*.

1993 May 7, Wisconsin Department of Natural Resources, *Former Manufactured Gas Plant – 402 N. 10th St., Remedial Design Approval*.

1993 July 23, Wisconsin Department of Natural Resources, *Former Manufactured Gas Plant – 402 N. 10th St., Work Plan Approval*.

1995 March, Earth Tech., *Interim Environmental Site Closure for Former Coal Gas Manufacturing Plant, Manitowoc, Wisconsin*.

1995 September, Horizon Environmental Corporation, *Subsurface Investigation of Properties Adjacent to Former Wisconsin Fuel & Light Co. Coal Gas Manufacturing Plant, Manitowoc, Wisconsin*.

1996 April 10, Horizon Environmental Corporation, *Geoprobe Investigation at the Wisconsin Fuel &Light Co. Coal Gas Manufacturing Plant, Manitowoc, Wisconsin.*

1997 February, Horizon Environmental Corporation, *Subsurface Investigation Former, Wisconsin Fuel& Light Co. Coal Gas Manufacturing Plant, Manitowoc, Wisconsin.*

1997 June, Horizon Environmental Corporation, *Ground Water Control Investigation, Wisconsin Fuel & Light Company, Former Coal Gas Manufacturing Plant, Manitowoc, Wisconsin.*

1998 January, Horizon Environmental Corporation, *Groundwater Control System Installation and Start-up, Wisconsin Fuel & Light Company, Former Coal Gas Manufacturing Plant, Manitowoc, Wisconsin.*

1998 May, Horizon Environmental Corporation, *Annual Ground Water Monitoring, Wisconsin Fuel & Light Company, Former Coal Gas Manufacturing Plant, Manitowoc, Wisconsin.*

1999 May, Horizon Environmental Corporation, *Annual Ground Water Monitoring, Wisconsin Fuel & Light Company, Former Coal Gas Manufacturing Plant, Manitowoc, Wisconsin.*

2000 June, Horizon Environmental Corporation, *Annual Ground Water Monitoring, Wisconsin Fuel & Light Company, Former Coal Gas Manufacturing Plant, Manitowoc, Wisconsin.*

2001 May, Horizon Environmental Corporation, *Annual Ground Water Monitoring, Wisconsin Fuel &Light Company, Former Coal Gas Manufacturing Plant, Manitowoc, Wisconsin.*

2003 October 2, Wisconsin Department of Natural Resources, *Release of Coal Tar to the Manitowoc River, Surface Water Sampling Results, WPS Site (Former Wisconsin Fuel & Light), 402 North Tenth Street, Manitowoc, Wisconsin, BRRTS #02-36-000219.*

2003 October 14, Natural Resource Technology, Inc., *Operation, Maintenance and Monitoring Status Report, Reporting Period – July 2001 to August 31, 2003, Former Wisconsin Fuel & Light Manufacturing Gas Plant, 402 North Tenth Street, Manitowoc, Wisconsin, BRRTS #02-36-000219.*

2003 October 14, Natural Resource Technology, Inc., *Phase I Sediment Sampling Results for the Former Wisconsin Fuel & Light Manufacturing Gas Plant, 402 North Tenth Street, Manitowoc, Wisconsin, BRRTS #02-36-000219.*

2004 January 13, Wisconsin Public Service Corporation, *Observations for the Presence of Oil Sheens on the Manitowoc River, Former Wisconsin Fuel & Light Manufactured Gas Plant, Manitowoc, Wisconsin, BRRTS #02-36-000219.*

2004 August 3, Wisconsin Public Service Corporation, *Observations for the Presence of Oil Sheens on the Manitowoc River, Former Wisconsin Fuel & Light Manufactured Gas Plant, Manitowoc, Wisconsin, BRRTS #02-36-000219.*

2004 November 2, Natural Resource Technology, Inc., *Operation, Maintenance and Monitoring Status Report, Reporting Period – September 1, 2003 to August 31, 2004, Former Wisconsin Fuel &Light Manufacturing Gas Plant, 402 North Tenth Street, Manitowoc, Wisconsin, BRRTS #02-36-000219.*

2004 November 17, Wisconsin Department of Natural Resources letter to Wisconsin Public Service Corporation, *Public Health Consultation, Former Manufactured Gas Plant, 402 North 10th Street, Manitowoc WI, BRRTS: 02-36-000219.*

2005 October 7, Natural Resource Technology, Inc., *Operation, Maintenance and Monitoring Status Report, Reporting Period – September 1, 2004 to August 31, 2005, Former Wisconsin Fuel &Light Manufacturing Gas Plant, 402 North Tenth Street, Manitowoc, Wisconsin, USEPA ID# WIN000509949, BRRTS #02-36-000219.*

2005 October 20, Wisconsin Department of Natural Resources letter to Wisconsin Public Service Corporation, *Acknowledgement of Receipt, Former Wisconsin Fuel and Light Operation, Maintenance and Monitoring Status Report, BRRTS# 02-36-000219.*

MARINETTE MGP SITE

1991 STS Consultants, Ltd., Contamination Assessment, Former Coal Gasification Plant, Ely Street, City of Marinette, Wisconsin, Project No. 17538XF.

1992 September 9, Lee, Robert E., Results of June, 1992 Groundwater Monitoring, Ely Street Coal Gasification Plant, Marinette, Wisconsin.

1993 March 30, Simon Hydro-Search, Inc., Phase I Work Plan, Environmental Investigation of Manufactured Gas Plant Site, Marinette, Wisconsin, Project No. 304533047.

1993 April 20, Wisconsin Department of Natural Resources, Conditional approval letter to Wisconsin Public Service Corporation, *Phase I Work Plan, Environmental Investigation of Manufactured Gas Plant Site, Marinette, Wisconsin.*

1993 April 20, Natural Resource Technology, Inc., Letter to James Reyburn, Wisconsin Department of Natural Resources, *Phase I Work Plan Revisions, Former Marinette MGP Site.*

1994 September 13, Natural Resource Technology, Inc., Phase I Remedial Investigation Report - Former Manufactured Gas Plant Site, Marinette, Wisconsin, Project No. 1033.

1995 April 28, Natural Resource Technology, Inc., Sediment Sampling Work Plan Former Manufactured Gas Plant Site Marinette, Wisconsin, Project No. 1033.

1995 July 6, Wisconsin Department of Natural Resources, Comment letter to Wisconsin Public Service Corporation *Sediment Investigation at Former Manufactured Gas Plants located in Green Bay, Two Rivers, and Marinette*.

1995 August 9, Wisconsin Department of Natural Resources, Approval letter to Wisconsin Public Service Corporation, *Thermal Treatment of Soils from 5 Wisconsin Public Service Corporation (WPSC) Sites.*

1996 March 5, Natural Resource Technology, Inc., Work Plan, Phase II Addendum Environmental Investigations of Manufactured Gas Plant Sites, Green Bay, Marinette, Oshkosh, Two Rivers Wisconsin, Project No. 1150.

1996 May 31, Natural Resource Technology, Inc., Letter to James Reyburn, Wisconsin Department of Natural Resources, Phase II Addendum Investigation Work Plan Comments, Former Manufactured Gas Plant Sites, Green Bay, Marinette, Oshkosh, Two Rivers, Wisconsin, Project No. 1050.

1996 September 27, Natural Resource Technology, Inc, Letter to Mr. James Reyburn Former Marinette Manufactured Gas Plant Site, Marinette, Wisconsin (Phase II Addendum Investigation Results), Project No. 1150.

1996 November, Natural Resource Technology, Inc., Sediment Investigation Report Former Manufactured Gas Plant Located In Marinette, Wisconsin, Project No. 1033.

2002 April 5, Natural Resource Technology, Inc, Letter to Mr. Bruce Urben (Wisconsin Department of Natural Resources), Former Manufactured Gas Plant Site, Marinette, Wisconsin (City of Marinette proposed sediment dredging project at Boom Landing Park), Project No. 1549.

2003 March 31, Natural Resource Technology, Inc., Letter to Cathy Rodda, Wisconsin Department of Natural Resources, *Phase 2 Sediment Sampling Results from Boom Landing, Marinette, Wisconsin,* Project No. 1549.

2003 June 6, Natural Resource Technology, Inc., letter to Cathy Rodda, Wisconsin Department of Natural Resources, *Conceptual Design for Boom Landing, Marinette, Wisconsin*, Project No. 1549.

2003 July 30, Wisconsin Department of Natural Resources, General Agreement and Notice to Proceed letter to Wisconsin Public Service Corporation, *Response to Conceptual Design for Remediation of Menominee River Sediments for the Design Former Manufacturing Gas Plant Site in, Marinette, Wisconsin, WDNR BRRTS #02-38-000047.*

2003 August 6, Natural Resource Technology, Inc., Supplemental Site Investigation Report, Former Manufacturing Gas Plant Site, 1603 Ely Street, Marinette, Wisconsin, Project No. 1549.

2004 January 23, Wisconsin Public Service Corporation, *Application for Stream Dredging and Miscellaneous Structures Waterway Permits, Boom Landing Sediment Remediation, 480 Mann Street, Marinette, Wisconsin, WDNR BRRTS #02-38-000047.*

2004 February 24, Natural Resource Technology, Inc., Letter to Cathy Rodda, Wisconsin Department of Natural Resources, *Soil Boring Sampling Results from Boom Landing, Marinette, Wisconsin*.

2004 June 11, Natural Resource Technology, Inc., Remedial Design for the Sediment Remediation, Boom Landing, 480 Mann Street, Marinette, Wisconsin, Project No. 1549.

2004 June 21, Natural Resource Technology, Inc., Groundwater Monitoring Update, Former Manufactured Gas Plant Site, 1603 Ely Street, Marinette, Wisconsin, BRRTS ID #02-38-000047.

2004 August 4, Wisconsin Public Service Corporation, Dredging and Structure Permit Approval Request in Menominee River, Marinette, Wisconsin.

2004 August 12, Wisconsin Department of Natural Resources, Notice to Proceed letter to Wisconsin Public Service Corporation, Former Manufactured Gas Plant, 1603 Ely Street, Marinette, Wisconsin, WNDR BRRTS #02-38-000047, June 16, 2004 *Sediment Remedial Design*.

2005 January 14, Natural Resource Technology Inc., letter to John Robinson, Wisconsin Department of Natural Resources, *Supplemental Information for Proposed Sediment Remediation at Boom Landing, Former Manufactured Gas Plant Site, Marinette, Wisconsin*, Project No. 1549.

2005 September 20, Natural Resource Technology Inc., *Groundwater Monitoring Update: 2004 Well Construction, Repair and Abandonment; and November 22, 2004 and April 13 & 14, 2005 Groundwater Sampling Events, Former Manufactured Gas Plant Site, 1603 Ely Street, Marinette, Wisconsin, EPA ID# WIN0005099952, WI BRRTS ID# 02-38-000047*.

2006 June 5, Natural Resource Technology Inc., *September 2005 Groundwater Monitoring Update, Former Manufactured Gas Plant Site, 1603 Ely Street, Marinette, Wisconsin, EPA ID# WIN0005099952, WI BRRTS ID# 02-38-000047.*

OSHKOSK MGP SITE

1986 January, EDI Engineering & Science, Inc., *Site Investigation, Former Coal Gas Manufacturing Plant, Ceape Avenue, Oshkosh, Wisconsin*, Report No. 20402.

1993 May 26, Simon Hydro-Search, Inc., *Phase II Work Plan Environmental Investigation of Manufactured Gas Plant Site, Oshkosh, Wisconsin*, Project No. 304533000.

1993 October 22, Wisconsin Department of Natural Resources, Comment letter to Wisconsin Public Service Corporation, *Phase II Work Plan Environmental Investigation of Manufactured Gas Plant Site, Oshkosh, Wisconsin.*

1993 October 25, Wisconsin Department of Natural Resources, Letter to Foley and Lardner *WPS Consent Order* for WPS's property on Ceape Avenue, Oshkosh.

1993 November 24, Simon Hydro-Search, Inc., *Summary of Field Investigation Results during Test Pit Program at Former Manufactured Gas Plant Site, Oshkosh, Wisconsin.*

1994 June 23, Simon Hydro-Search, Inc., *Phase II Investigation Report - Environmental Investigation of Former Manufactured Gas Plant Facility, Oshkosh, Wisconsin,* Project No. 304533000.

1994 August 9, Simon Hydro-Search, Inc., *WPSC Oshkosh Former Manufactured Gas Plant Site Fox River Sediment Sampling Results*, Project No. 304533000.

1994 October 24, Wisconsin Department of Natural Resources, Letter to Wisconsin Public Service Corporation *Comments on Phase II Investigation Report and Fox River Sediment Sampling Results*.

1995 September 1, Natural Resource Technology, Inc., *Sediment Sampling Work Plan-Former Manufactured Gas Plant Site - Oshkosh, Wisconsin*, and transmittal letter to James Reyburn (Wisconsin Department of Natural Resources), Project No. 1073.

1996 March 5, Natural Resource Technology, Inc., *Work Plan, Phase II Addendum Environmental Investigations of Manufactured Gas Plant Sites, Green Bay, Marinette, Oshkosh, Two Rivers Wisconsin,* Project No. 1150.

1996 May 31, Natural Resource Technology, Inc., Letter to James Reyburn, Wisconsin Department of Natural Resources, *Phase II Addendum Investigation Work Plan Comments, Former Manufactured Gas Plant Sites, Green Bay, Marinette, Oshkosh, Two Rivers, Wisconsin*, Project No. 1050.

1996 October 2, Natural Resource Technology, Inc., Letter to James Reyburn, Wisconsin Department of Natural Resources, *Phase II Addendum Investigation Results, Former Oshkosh Manufactured Gas Plant (MGP) Site, Oshkosh, Wisconsin*, Project No. 1050.

1996 October 15, Natural Resource Technology, Inc., *Sediment Investigation Report - Former Manufactured Gas Plant Site - Oshkosh, Wisconsin*, Project No. 1150.

1997 October 22, Wisconsin Department of Natural Resources, Letter to Wisconsin Public Service Corporation, *Former Manufactured Gas Plant – Oshkosh, WI* regarding review of sediment investigation report.

1998 May 21, Natural Resource Technology, Inc., *Remedial Action Options Report, Former Manufactured Gas Plant Site Oshkosh, WI*, Project No. 1312 and 1177.

1998 November 25, Natural Resource Technology, Inc., *Pre-Remedial Design Work Plan, Former Manufactured Gas Plant Site, Wisconsin Public Service Corporation, Oshkosh, Wisconsin,* Project No. 1312.

2000 April 27, Natural Resource Technology, Inc. Remedial Design Report, Former Manufactured Gas Plant Site, Oshkosh, Wisconsin, Project No. 1312.

2000 December 15, Wisconsin Department of Natural Resources, Letter to Wisconsin Public Service Corporation, *Review of Remedial Design Report for Wisconsin Public Service Corp, Court St. & Ceape Avenue, Oshkosh*, WDNR BRRTS Unique ID #02-71-000256.

2001 May 29, Natural Resource Technology, Inc., Letter to Kathleen Sylvester (Wisconsin Department of Natural Resources), *Groundwater Monitoring Information and Sampling Plan Revisions, Former Manufactured Gas Plant Site, Court St., & Ceape Ave., Oshkosh, Wisconsin,* Project No. 1312.

2001 June 8, Wisconsin Department of Natural Resources, General agreement letter to Wisconsin Public Service Corporation, *Monitoring and Sampling Plan Revision, Wisconsin Public Service Corp., Court St. & Ceape Ave., Oshkosh,* WDNR BRRTS Unique ID # 02-71-000256.

2001 June 20, Natural Resource Technology, Inc., *Sediment Sampling and Analysis Plan (SAP) for the Former Oshkosh Manufactured Gas Plant (MGP) Site, Oshkosh, Wisconsin,* Project No. 1312.

2001 November 28, Natural Resource Technology, Inc., *Remedial Work Plan Submittal, Former Wisconsin Public Service Corporation Manufactured Gas Plant Site, Court St., & Ceape Ave., Oshkosh, Wisconsin,* Project No. 1312.

2002 January 4, Natural Resource Technology, Inc., Letter to Kathleen Sylvester, Wisconsin Department of Natural Resources, *Boring Logs and Additional Historical Drawings of MGP Structures, Former Wisconsin Public Service Corporation (WPSC) Manufactured Gas Plant (MGP) Site, Court St., & Ceape Ave., Oshkosh, Wisconsin,* Project No. 1312.

2002 March 1, Natural Resource Technology, Inc., Transmittal, to Kathleen Sylvester, Wisconsin Department of Natural Resources, *Oshkosh MGP Site Groundwater Monitoring Data*, Project No. 1312.

2002 March 4, Natural Resource Technology, Inc., Letter to Kathleen Sylvester, Wisconsin Department of Natural Resources, *Response to Remedial Work Plan Review Comments dated February 22, 2002 Former Wisconsin Public Service Corporation (WPSC) Manufactured Gas Plant (MGP) Site, Court St. & Ceape Ave., Oshkosh, Wisconsin*, Project No. 1312.

2002 March 7, Wisconsin Department of Natural Resources, Remedial Action Work Plan general approval letter to Wisconsin Public Service Corporation, *Remedial Action Workplan for WPS Manufactured Gas Plant site, Ceape & Court Streets, Oshkosh, WDNR BRRTS ID #02-71-000256..*

2002 December 3, Natural Resource Technology, Inc., *Sediment Investigation Report, Oshkosh Former MGP Site Remediation, Oshkosh, Wisconsin,* Project No. 1312.

2003 February 26, Natural Resource Technology, Inc., *Remedial Action Documentation Report, Former Manufactured Gas Plant Site, Oshkosh, Wisconsin,* Project No. 1312.

2003 February 28, Wisconsin Department of Natural Resources, Comment letter to Wisconsin Public Service Corporation, *Sediment Investigation Report dated December 3, 2002 for WPS Manufactured Gas Plant Site, Court St. and Ceape Ave., Oshkosh Wisconsin, BRRTS 02-71-000256.*

2003 March 31, Natural Resource Technology, Inc., *Supplemental Groundwater Monitoring and Bedrock Assessment Report and Response to February 28, 2003 Correspondence, Former Manufactured Gas Plant, Court Street and Ceape Avenue, Oshkosh, Wisconsin, BRRTS 02-71-000256.*

2003 June 3, Natural Resource Technology, Inc., *Remedial Action Documentation Report Addendum, Former Wisconsin Public Service Corporation Manufactured Gas Plant Site, Court Street and Ceape Avenue, Oshkosh, Wisconsin, BRRTS ID #02-71-000256*.

2003 June 25, Natural Resource Technology, Inc., *Quarterly Treatment System Update, Former Wisconsin Public Service Corporation Manufactured Gas Plant Site, Court St. and Ceape Ave. Oshkosh, Wisconsin,* BRRTS #02-71-000256.

2003 September 19, Natural Resource Technology, Inc., *Semi-Annual Operations, Maintenance and Maintenance and Optimization Report, Former Manufactured Gas Plant, Court Street and Ceape Avenue, Oshkosh, Wisconsin,* Project No. 1312.

2003 October 29, Wisconsin Department of Natural Resources, General Agreement Letter to

Wisconsin Public Service Corporation, *"Review of Supplemental Groundwater Monitoring and Bedrock Assessment Report," WPS – Manufactured Gas Plant Site, Ceape & Court Streets, Oshkosh, WDNR BRRTS ID #02-71-000256*.

2004 January 20, Natural Resource Technology, Inc., *Air Stripper Operation Report, Former Manufactured Gas Plant, Court Street and Ceape Avenue, Oshkosh, Wisconsin,* Project No. 1312.

2004 February 9, Natural Resource Technology, Inc., *2003 Annual Monitoring and Semi-Annual Operations, Maintenance and Maintenance, Former Manufactured Gas Plant, Court Street and Ceape Avenue, Oshkosh, Wisconsin,* Project No. 1312.

2004 February 16, Natural Resource Technology, Inc., *Work Plan for 2004 Bedrock Assessment, Former Manufactured Gas Plant, Court Street and Ceape Avenue, Oshkosh, Wisconsin,* Project No. 1312.

2004 March 16, Wisconsin Department of Natural Resources, Letter to Wisconsin Public Service Corporation, *Review of Bedrock Assessment Work Plan dated February 16, 2004 Wisconsin Public Service Corporation, Former Manufactured Gas Plant, Court Street and Ceape Avenue, Oshkosh, Wisconsin, Wisconsin BRRTS 02-71-000256.*

2004 August 30, Natural Resource Technology, Inc., *Semi-Annual Operations, Maintenance and Maintenance, Former Manufactured Gas Plant, Court Street and Ceape Avenue, Oshkosh, Wisconsin,* Project No. 1312.

2005 August 31, Natural Resource Technology, Inc., *Operation, Maintenance and Monitoring Semi-Annual Report and Supplemental Bedrock Assessment, Former Oshkosh MGP, Oshkosh, Wisconsin,* Project No. 1312.

2005 October 31, Natural Resource Technology, Inc., *Transmittal of Mid-Year Progress Data Tables, Former Wisconsin Public Service Corporation (WPSC) Manufactured Gas Plant (MGP) Site, Court Street & Ceape Avenue, Oshkosh, Wisconsin, BRRTS ID# 02-71-000256.*

STEVENS POINT MGP SITE

1986 EDI Engineering & Science, Inc., *Site Investigation, Former Coal Gas Manufacturing Plant, Crosby Avenue, Stevens Point, Wisconsin.*

1986 October 229, Donahue and Associates, *Soils Investigation, Wisconsin Public Service Corporation, Properties in Stevens Point, Wisconsin.*

1989 Twin City Testing Corporation, *Report of Monitoring Well Installation Program, Crosby Avenue Site, Stevens Point, Wisconsin.*

1990 March 7, Wisconsin Department of Natural Resources, Letter to Wisconsin Public Service Corporation, *Request for additional investigation of the Wisconsin Public Service manufactured coal gas site located on Crosby Road in Stevens Point, Wisconsin.*

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2004 August 31, Natural Resource Technology, Inc., *Bench Scale Treatability Study Results Summary, Wisconsin Public Service Corporation, Former Manufactured Gas Plant Site on School Street, Two Rivers Former, Wisconsin, BRRTS# 02-36-000255* Project No. 1569.

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22ND STREET STATION SITE

1992 January, Hanson Engineers Incorporated, *Preliminary Site Investigation Report*, 22nd Street Station Site, ComEd Parcel, Chicago, Illinois.

2000 March, Pioneer Environmental, *Phase I Environmental Site Assessment*, 22nd Street Station Site, Throop's Canal Parcel, Chicago, Illinois.

2000 June, Pioneer Environmental, *Draft Comprehensive Site Investigation Report*, 22nd Street Station Site, Throop's Canal Parcel, Chicago, Illinois.

2000 July, Barr Engineering Company, *Site Investigation Report*, 22nd Street Station Site, ComEd Parcel, Chicago, Illinois.

2000 December, Barr Engineering Company, *Draft Site Investigation Report*, 22nd Street Station Site, Throop's Canal Parcel, Chicago, Illinois.

2001 July, Burns & McDonnell, *Supplemental Site Investigation Work Plan*, 22nd Street Station Site, ComEd Parcel, Chicago, Illinois.

2002 February, Burns & McDonnell, *Supplemental Site Investigation Sampling Data*, 22nd Street Station Site, ComEd Parcel, Chicago, Illinois.

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2005 November, Burns & McDonnell, *Supplemental Site Investigation Event 3 Report*, 22nd Street Station Site, ComEd Parcel, Chicago, Illinois.

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2006 July, Burns & McDonnell, *Draft Geotechnical Investigation Summary Report*, 22nd Street Station Site, Throop's Canal Parcel, Chicago, Illinois.

2007 April, Burns & McDonnell, *Draft River Sediment Investigation Summary for The 22nd Street Station Former MGP Site*, Chicago, Illinois.

CRAWFORD STATION SITE

1992 February, Hanson Engineers Inc., *Preliminary Site Investigation Crawford Station Gas Production and Storage Facility*, Crawford Station Site, Chicago, Illinois.

2000 October, Burns & McDonnell, *Site Investigation Work Plan*, Crawford Station Site Parcels A & B, Chicago, Illinois.

2001 February, Burns & McDonnell, *Draft Scope of Work*, Crawford Station Site, Property C, Chicago, Illinois.

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2001 April, Burns & McDonnell, *Site Investigation Work Plan*, Crawford Station Site Parcel O, Chicago, Illinois.

2001 July, Burns & McDonnell, *Sampling Data Book*, Crawford Station Site Parcels A & B, Chicago, Illinois.

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2001 August, Burns & McDonnell, *Interim Remedial Action Plan*, Crawford Station Site Parcel O, Chicago, Illinois.

2001 November, Burns & McDonnell, *Propane Tank Area Work Plan*, Crawford Station Site Parcel O, Chicago, Illinois.

2001 November, Burns & McDonnell, *Letter Report for Propane Tank Area of Property O*, Crawford Station Site Parcel O, Chicago, Illinois.

2001 December, Burns & McDonnell, *Site Investigation Sampling Data Book*, Crawford Station Site Parcel O, Chicago, Illinois.

2002 February, Burns & McDonnell, *Draft Work Plan for Cleanup Pentanonic Treatability Study*, Crawford Station Site Parcels A & B, Chicago, Illinois.

2002 February, Burns & McDonnell, *Draft Work Plan for Cleanup Pentanonic Treatability Study*, Crawford Station Site Parcel O, Chicago, Illinois.

2002 May, Versar, Inc., *Phase II Subsurface Investigation – Central Can Company*, Crawford Station Site Parcel F, Chicago, Illinois.

2002 June, Burns & McDonnell, *Site Investigation Work Plan*, Crawford Station Site Parcel L, Chicago, Illinois.

2002 June, Burns & McDonnell, *Draft Site Investigation Report*, Crawford Station Site Parcel O, Chicago, Illinois.

2003 January, Biogenie, *Treatability Study on Hydrocarbon-Impacted Soil*, Crawford Station Site Parcels A & B, Chicago, Illinois.

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2003 November, Burns & McDonnell, *XTRA Intermodal Site Environmental Assessment*, Crawford Station Site Parcels A & B, Chicago, Illinois.

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2005 May, Hygieneering, *Bulk Sample Analysis Letter*, Crawford Station Site Parcels A & B, Chicago, Illinois.

2005 July, Geo Services, Inc., *Geotechnical Investigation Data along Sewer*, Crawford Station Site, Parcels A & B, Chicago, Illinois.

2005 July, Geo Services, Inc., *Geotechnical Investigation for the Crawford Facility*, Crawford Station Site, Parcel O, Chicago, Illinois.

2005 September, Hygieneering, *Asbestos Abatement Report*, Crawford Station Site Parcels A & B, Chicago, Illinois.

2005 October, Burns & McDonnell, *Data Summary of Portion of Parcel between 35th and 36th Streets*, Crawford Station Site Parcel O, Chicago, Illinois.

2006 September, Burns & McDonnell, *Comprehensive Site Investigation Work Plan*, Crawford Station Site Parcel S, Chicago, Illinois.

DIVISION STREET STATION SITE

1992 July, Hanson Engineers Inc., *Preliminary Site Investigation*, Division Street Station Site, Chicago, Illinois.

2001 May, Burns & McDonnell, *Site Investigation Work Plan*, Division Street Station Site, Boat Yard Parcel, Chicago, Illinois.

2000 June, Burns & McDonnell, *Site Investigation Data Book*, Division Street Station Site, Boat Yard Parcel, Chicago, Illinois.

2001 April, Barr Engineering Company, *Site Investigation Report*, Division Street Station Site, PGL Parcel, Chicago, Illinois.

2001 May, Burns & McDonnell, *Draft Site Investigation Report*, Division Street Station Site, Boat Yard Parcel, Chicago, Illinois.

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2003 July, Burns & McDonnell, *Remediation Objectives Report /Remedial Action Plan*, Division Street Station Site, PGL Parcel, Chicago, Illinois.

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2004 August, Burns & McDonnell, *Impractical Remediation Letter*, Division Street Station Site, PGL Parcel, Chicago, Illinois.

2006 March, Burns & McDonnell, *Remedial Action Completion Report*, Division Street Station Site, PGL Parcel, Chicago, Illinois.

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1991 November, Hanson Engineering Incorporated, *Preliminary Site Investigation – Willow Street Gas Production and Storage Facility*, Willow Street Station Site, Chicago, Illinois.

1992 January, Hanson Engineers Inc., *Preliminary Site Investigation*, Hawthorne Avenue Station Site, Chicago, Illinois.

2001 February, Barr Engineering Company, *Site Investigation Summary Report – A Portion of Willow Street Station MGP*, Chicago, Illinois .

2002 May, Burns & McDonnell, *Site Investigation Scope of Work*, Hawthorne Avenue Street Station Site, Chicago, Illinois.

2002 September, Burns & McDonnell, *Site Investigation Summary Report*, Hawthorne Avenue Station Site, Chicago, Illinois.

2002 September, Burns & McDonnell, *Supplemental Site Investigation Summary Report*, *A Portion of Willow Street Station Former Manufactured Gas Plant Site, Chicago, Illinois.*

2003 May, Burns & McDonnell, *Remediation Objectives Report/Remedial Action Plan, A Portion of Willow Street Station Former Manufactured Gas Plant Site, Chicago, Illinois.*

2003 June, Burns & McDonnell, *Site Investigation Report*, Hawthorne Avenue Station Site, Chicago, Illinois (Revised September 2003).

2003 July, Burns & McDonnell, *Remediation Objectives Report/Remedial Action Plan*, Hawthorne Avenue Station Site, Chicago, Illinois.

2003 August, Burns & McDonnell, *Remedial Action Completion Report, A Portion of Willow Street Station Former Manufactured Gas Plant Site, Chicago, Illinois.*

2003 August, Burns & McDonnell, *Remedial Action Sampling Data, A Portion of Willow Street Station Former Manufactured Gas Plant Site, Chicago, Illinois.*

2003 August, Burns & McDonnell, *Remedial Action Disposal Quantities*, Hawthorne Avenue Station Site, Chicago, Illinois.

2004 May, Burns & McDonnell, Revised *Tier 3 Assessment Evaluation*, Hawthorne Avenue Station Site, Chicago, Illinois.

2004 October, Gas Technology Institute, Chemical Fingerprint Analysis Report, Hawthorne Avenue Station Site, Chicago, Illinois.

2005 December, Burns & McDonnell, *Remedial Action Completion Report,* Hawthorne Avenue Station Site, Chicago, Illinois.

HOUGH PLACE STATION SITE

2001 February, ThermoRetec Consulting Corporation, *Site Investigation Report*, Hough Place Station Site, Chicago, Illinois

2001 May, Burns & McDonnell, *Site Investigation Work Plan*, Hough Place Station Site, Chicago, Illinois

2001 August, Burns & McDonnell, *Supplement Site Investigation Sampling Data*, Hough Place Station Site, Chicago, Illinois

2006 October, CTI GeoTechnical, *Geotechnical Report*, Hough Place Station Site, Chicago, Illinois

2006 December, Burns & McDonnell, *Draft River Sediment Investigation Summary*, Hough Place Station Site, Chicago, Illinois

NORTH STATION SITE

1999 October, Clayton Environmental Consultants, *Phase I Environmental Site Assessment, 1111-1127 North Halsted Street*, North Station Site, Coffee North Property, Chicago, Illinois.

1999 November, Clayton Environmental Consultants, *Limited Phase II Environmental Site Assessment, 1111-1127 North Halsted Street*, North Station Site, Coffee North Property, Chicago, Illinois.

2001 February, Barr Engineering Company, *Letter Report – Site Investigation and Interim Remedial Action Plan Summary*, North Station Site, LaSalle Chestnut Property, Chicago, Illinois.

2001 April, Barr Engineering Company, *Letter Report – Site Investigation and Interim Remedial Action Plan Summary*, North Station Site, ComEd Property, Chicago, Illinois.

2001 May, Hygieneering, Inc., *Offsite Environmental Soil Investigation Report*, North Station, Offsite R.O.W. Study Area, Chicago, Illinois.

2001 June, Burns & McDonnell, *Site Investigation Event 2 Work Pla*n, North Station Site, ComEd Property, Chicago, Illinois.

2001 June, Burns & McDonnell, *Site Investigation Event 2 Work Pla*n, North Station Site, LaSalle Chestnut Property, Chicago, Illinois.

2001 October, Burns & McDonnell, *Site Investigation Event 2 Sampling Data,* North Station Site, ComEd Property, Chicago, Illinois.

2001 November, Burns & McDonnell, *Site Investigation Sampling Data*, North Station Site, LaSalle Chestnut Property, Chicago, Illinois.

2002 June, Burns & McDonnell, *Site Investigation Event 2 Report*, North Station, ComEd Property, Chicago, Illinois.

2002 July, Levine-Fricke, *Soil Investigation Report – ComEd Crosby River Crossing, Kingsbury, and Hobbie Street*, North Station Site, Offsite R.O.W. Study Area, Chicago, Illinois.

2003 January, Gas Technology Institute, *Chemical Fingerprinting Analysis of Twenty-four Samples*, North Station Site, Offsite R.O.W. Study Area, Chicago, Illinois.

2003 May, Burns & McDonnell, *Offsite Environmental Supplemental Site Investigation Sampling Data*, North Station Site, Offsite R.O.W. Study Area, Chicago, Illinois.

2003 May, Burns & McDonnell, *Draft Offsite Environmental Supplemental Site Investigation Report*, North Station Site, Offsite R.O.W. Study Area, Chicago, Illinois.

2005 October, Burns & McDonnell., *Site Investigation Sampling Data*, North Station Site, Coffee North Property, Chicago, Illinois.

2006 June, Burns & McDonnell, *Site Investigation Report*, North Station, LaSalle Chestnut Property, Chicago, Illinois.

2006 August, Burns & McDonnell, *Remediation Objectives Report/Remedial Action Plan*, North Station, LaSalle Chestnut Property, Chicago, Illinois.

2006 October, Burns & McDonnell, *Draft River Sediment Investigation Work Plan*, North Station Former Manufactured Gas Plant Site, Chicago, Illinois.

2007 February, Burns & McDonnell, *Draft Site Investigation Report*, Division Halsted LLC Property (Coffee North), Chicago, Illinois.

2007 February, Burns & McDonnell, *Revised Site Investigation Sampling Data*, Division Halsted LLC Property (Coffee North), Chicago, Illinois.

2007 April, Burns & McDonnell, *River Sediment Investigation Summary*, North Station Former Manufactured Gas Plant Site, Chicago, Illinois.

NORTH SHORE AVENUE STATION SITE

1998 November, Dames and Moore, Revised Focused *Site Investigation/Remediation Objectives Report/Remedial Action Plan/Remedial Action Completion Report for Peoples Gas Roger Park Substation*, Chicago, Illinois.

2001 September, Burns & McDonnell., *Site Investigation Data Book,* North Shore Avenue Station Site, Pond Parcel, Chicago, Illinois.

2001 September, Burns & McDonnell., *Site Investigation Report*, North Shore Avenue Station Site, Pond Parcel, Chicago, Illinois.

2001 October, Burns & McDonnell., *Site Investigation Data Book,* North Shore Avenue Station Site, Main Parcel, Chicago, Illinois.

2001 October, Burns & McDonnell., *Site Investigation Report*, North Shore Avenue Station Site, Main Parcel, Chicago, Illinois.

2001 November, Burns & McDonnell., *Remediation Objectives Report/Remedial Action Plan/Remedial Action Completion Report*, North Shore Avenue Station Site, Pond Parcel, Chicago, Illinois.

2002 January, Burns & McDonnell., *Site Investigation Data Book*, North Shore Avenue Station Site, East Parcel, Chicago, Illinois.

2002 January, Burns & McDonnell., *Site Investigation Report*, North Shore Avenue Station Site, East Parcel, Chicago, Illinois.

2002 February, URS Corporation, Revised Focused *Site Investigation/Remediation Objectives Report/Remedial Action Plan/Remedial Action Completion Report for Peoples Gas Roger Park Substation*, Chicago, Illinois.

2002 April, Burns & McDonnell., *Remediation Objectives Report/Remedial Action Plan/Remedial Action Completion Report*, North Shore Avenue Station Site, Main Parcel, Chicago, Illinois.

2002 July, Burns & McDonnell., *R26 Letter*, North Shore Avenue Station Site, Main Parcel, Chicago, Illinois.

2002 May, Burns & McDonnell., *Remediation Objectives Report/Remedial Action Plan/Remedial Action Completion Report*, North Shore Avenue Station Site, East Parcel, Chicago, Illinois.

PITNEY COURT STATION SITE

1992 July, Hanson Engineers Incorporated, *Preliminary Site Investigation*, Pitney Court Station Site, Chicago, Illinois.

1995 June, Boelter Environmental Consultants, *Preliminary Assessment/Site Investigation Report*, Pitney Court Station Site, Chicago, Illinois.

1998 April, Environmental Resources Management, *Results of Field Investigation South Pitney Court Property*, Pitney Court Station Site, Chicago, Illinois.

1998 July, Boelter Environmental Consultants, *Split Sample and Site Investigation Oversight Report*, Pitney Court Station Site, Chicago, Illinois.

2001 February, Burns & McDonnell, *Site Investigation Scope of Work*, Pitney Court Station Site, Chicago, Illinois.

2002 January, Burns & McDonnell, *Letter – Scope for Additional Sampling*, Pitney Court Station Site, Chicago, Illinois.

2002 February, Burns & McDonnell, *Site Investigation Work Plan*, Pitney Court Station Site, Chicago, Illinois.

2002 July, Burns & McDonnell, *Draft Supplemental Site Investigation Report*, Pitney Court Station Site, Chicago, Illinois.

2003 April, Burns & McDonnell, *Supplemental Site Investigation – Event #2 Scope of Work*, Pitney Court Station Site, Chicago, Illinois.

2006 February, Burns & McDonnell, *Site Investigation Sampling Data Book*, Pitney Court Station Site, Chicago, Illinois.

2006 March, Burns & McDonnell, *Site Investigation Report*, Pitney Court Station Site, Chicago, Illinois.

2006 March, Burns & McDonnell, *Draft River Investigation Work Plan*, Pitney Court Station Site, Chicago, Illinois.

2006 June, Burns & McDonnell, *Supplemental Site Investigation Letter Report*, Pitney Court Station Site, Chicago, Illinois.

2006 October, Burns & McDonnell, *Draft Remediation Objectives Report*, Pitney Court Station Site, Chicago, Illinois.

2006 October, Burns & McDonnell, *Draft Remedial Action Plan*, Pitney Court Station Site, Chicago, Illinois.

SOUTH STATION SITE

1992 April, Hanson Engineers Incorporated, *Preliminary Site Investigation Report*, South Station Site, Chicago, Illinois.

1999 October, GEI Consultants, *Final Draft Comprehensive Site Investigation Report – Former Monarch Box and Paper Company Facility*, South Station Site, Parcels A & B, Chicago, Illinois.

2001 June, Hygieneering, *Offsite Environmental Site Investigation Report*, South Station Site, Chicago, Illinois.

2001 August, GEI Consultants, *Draft and Revised Parcel C Site Investigation Report*, South Station Site, Parcels C & D, Chicago, Illinois.

2001 August, GEI Consultants, *Draft and Revised Parcel D Site Investigation Report*, South Station Site, Parcels C & D, Chicago, Illinois.

2001 December, Burns & McDonnell, *Interim Remedial Action Plan*, South Station Site, Parcels A & B, Chicago, Illinois.

2003 September, Burns & McDonnell, *Site Investigation and Remedial Action Analytical Sampling Data Book*s, South Station Site, Parcels A & B, Chicago, Illinois.

2003 September, Burns & McDonnell, *Air Data Books*, South Station Site, Parcels A & B, Chicago, Illinois.

2004 June, Burns & McDonnell, *Draft Parkway Site Investigation Data*, South Station Site, Parcels C & D, Chicago, Illinois.

2004 August, Burns & McDonnell, *Remediation Objectives Report/Remedial Action Plan/Remedial Action Completion Report*, South Station Site, Parcels A & B, Chicago, Illinois.

2004 December, Burns & McDonnell, *Draft Scope of Work for Supplement Site Investigation*; South Station Site, Parcels C & D, Chicago, Illinois.

THROOP STATION SITE

1992 January, Hanson Engineers Incorporated (Hanson), *Preliminary Site Investigation Throop Street Station Gas Storage Facility, Chicago, Illinois.*

1992 April, Hanson, *Preliminary Site Investigation South Station Gas Production and Storage Facility, Chicago, Illinois.*

2001 June, Hygieneering Inc., *Draft Offsite Environmental Site Investigation Report On the Former Manufactured Gas Plant Site Commonly Known as South Station*, Chicago, Illinois.

2005 January, Burns & McDonnell, *Remedial Objective Report/Remedial Action Plan, Remedial Action Completion Report for the Former South Station MGP – Parcels A & B*, Chicago, Illinois.

2006 October, Burns & McDonnell, *Draft River Sediment Investigation Work Plan*, Throop Street Station Site, Chicago, Illinois.

2007 April, Burns & McDonnell, *Draft River Sediment Investigation Summary for the Former Throop Street Station and The former South Station – Parcel E*, Chicago, Illinois.

WILLOW STREET STATION SITE

1988 February, Illinois Environmental Protection Agency, *CERCLA Preliminary Assessment Report*, Willow Street Station Site, Chicago, Illinois.

1991 November, Hanson Engineering Incorporated, *Preliminary Site Investigation – Willow Street Gas Production and Storage Facility*, Willow Street Station Site, Chicago, Illinois.

2002 January, Burns & McDonnell, *Site Investigation Scope of Work*, Willow Street Station Site, Chicago, Illinois.

2002 February, Burns & McDonnell, *Draft Site Investigation Work Plan*, Willow Street Station Site, Chicago, Illinois.

2004 December, Burns & McDonnell, *PCB Remediation Documentation Report*, Willow Street Station Site, Chicago, Illinois.

2005 February, Burns & McDonnell, *Site Investigation Sampling Data Book*, Willow Street Station Site, Chicago, Illinois.

2005 February, Burns & McDonnell, *Site Investigation Report*, Willow Street Station Site, Chicago, Illinois.

2005 November, Burns & McDonnell, *Supplemental Site Investigation Report/Remediation Objectives Report/Remedial Action Plan*, Willow Street Station Site, Chicago, Illinois.

2005 December, META Environmental Inc., *Environmental Forensic Report, SDG: BR051202*, Willow Street Station Site, Chicago, Illinois.

2006 January, META Environmental Inc., *Environmental Forensic Report, SDG: BR060111*, Willow Street Station Site, Chicago, Illinois.

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2006 December, Burns & McDonnell, *Draft Data Summary Package*, Willow Street Station Site, Chicago, Illinois.

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2002 August, Burns & McDonnell, *Supplemental Site Investigation Sampling Data Book*, South Plant Site, NSG Parcel, Waukegan, Illinois.

2003 February, Burns & McDonnell, *Supplemental Site Investigation Report*, South Plant Site, NSG Parcel, Waukegan, Illinois.

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2003 August, Burns & McDonnell, *Draft Scope of Work for Akzo Nobel Investigation*, South Plant Site, Akzo Nobel Parcel, Waukegan, Illinois.

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2005 July, Burns & McDonnell, *Supplemental Off-Site Investigation – Waukegan Port Authority Property*, South Plant Site, Waukegan Port District Parcel, Waukegan, Illinois.

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2005 November, Burns & McDonnell, *Scope of Work for Port Authority Soil-Gas Sampling*, South Plant Site, Waukegan Port District Parcel, Waukegan, Illinois.

APPENDIX D

CONSULTANT STANDARD OPERATING PROCEDURES

STANDARD OPERATING PROCEDURE
TABLE OF CONTENTS

SOP SERIES SAS-01
FILE AND DATA MANAGEMENT

STANDARD OPERATING PROCEDURE NO. SAS-01-01

FIELD ACTIVITY DOCUMENTATION Revision 0

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes procedures for documenting field activities and guidance on types and specificity of data to be recorded. Procedures are included for documentation on field logbooks, field forms, and/or field electronic data recorders. This standard is also applicable to photographic documentation collected to support field observations of site conditions and field data entries.

2.0 EQUIPMENT AND MATERIALS

- Field logbooks;
- Field forms;
- Camera and/or camcorder; and
- Waterproof pens with non-erasable ink.

3.0 HEALTH AND SAFETY

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 FORMAT

4.1 FIELD LOGBOOK

Field logbooks shall be bound books that are permanently assigned to a specific project. The cover of each logbook will provide the following identifying information:

- Name of project/site;
- Project number; and
- Book number.

The consultant's contact person(s), address and phone number should be recorded on the inside cover of the field logbook. Only field logbooks with pre-numbered pages shall be used and no pages shall be removed from will be logbook.

4.2 Field Forms

Field recording forms are also used for data collection in a variety of activities. The forms include logs for boreholes, well construction, well sampling, etc. It is not necessary to duplicate information recorded on field forms into the field logbooks.

5.0 ENTRIES

5.1 Daily Entries

At the beginning of each daily entry, the following information is recorded:

- Date;
- Time of arrival at the site;
- Weather conditions;
- Physical/environmental conditions at the field site;
- Field personnel present and their responsibilities;
- Level of personal protection if other than Level D; and
- Signature of the person making the entry.

For investigation activities, the entry for each day will contain a complete record of the day's activities including, but not limited to, the following information, unless the data is recorded on field forms.

- Names and titles of site visitors;
- Information concerning sampling changes, scheduling modifications and change orders.
- Location, description and log of photographs of sampling points;
- Description of reference points for maps and photographs of sampling site;
- Field observations;
- Field measurements;
- Equipment calibration and maintenance;
- Sample identification numbers;
- Name of laboratory and overnight delivery service provider or name of laboratory courier and time of sample pick-up;
- Sample documentation, such as chain-of-custody form numbers and shipment air bill numbers;
- Decontamination procedures used;
- Documentation for investigation-derived wastes, such as contents and approximate waste volume in each drum, and number of drums generated;
- Time of departure from the site; and
- Signature of person responsible for observations and date.

Field logbooks are also used as a daily record for remediation activities. General entries similar to the ones listed above are used in remediation activity logbooks. In addition, daily entries regarding excavation activities, waste disposal quantities and methods of transport, system performance data from any remediation systems (e.g. soil vapor extraction systems, recovery well systems, etc.), system or equipment calibration or maintenance performed, and any other pertinent information regarding daily activities.

All logbook entries shall be printed legibly using a pen with waterproof, non-erasable ink. Any lines or pages inadvertently left blank will have a single line drawn through them with the logging person's initials and date written on the line.

When a field log form is used to record field data, all form fields will be completed in full on a daily basis. If a specific data entry area is not applicable, it will be clearly marked as such with the use of "NA" or a dashed line drawn through it. A single line will be drawn through any unused data entry areas on the form with the field person's signature on the line.

5.2 Entry Changes

Entry changes should be avoided by carefully entering data in the logbook. If a change is required, it should be made by drawing a single line through the original entry such that the original entry is not obscured and entering the correct information next to the original entry. The change in entry will be initialed and dated by the logger. Only the person making the entry may change it.

If there is a change in the person recording field notes during a particular day, that person shall be identified in the logbook prior to making entries. The new logger shall sign and date the logbook at the beginning and end of his entry.

6.0 FORM AND LOGBOOK MANAGEMENT

Site-specific field logbooks and forms will be kept in the in-office project file when not in use. If forms or logbooks are used in the field for an extended period of time, copies of used pages will be made, delivered to the office, and filed in the project file on a periodic basis.

7.0 PHOTOGRAPHIC AND VIDEO RECORDS

7.1 Photographic Record

Photographs shall be taken in the field on a daily basis to document field activities. Field log entries for each photograph may include:

- Photographer’s name;
- Project name and project number;
- Roll and frame number, or digital photograph number;
- Date and time;
- Description of photograph including sampling point, sample name, depth and other relevant identifying information, such as direction faced (e.g. “looking south”) and relationship of photograph to site features.

Photograph prints and negatives will be stored in the project file. Digital photographs will be stored in the electronic project file. If digital photographs are downloaded from the camera in the field, they will be transferred to the in-office electronic file on a regular basis. Photographic prints or paper copies of digital images will be identified with recorded field book entry information.

7.2 Video

Video site recordings will be logged in the field logbook with the following information:

- Recorder's name;
- Project name and project number;
- Date and time;
- Description of subject of video including identification of any persons appearing in video.

If video does not have accompanying audio, record a placard of the site name, date and time and subject of video at the beginning of the video. If the video recorder has an audio recording feature, a narration of the video identifying information may be used. The video tape or digital video disk (DVD) will be labeled with the project name, project number, date, location, and subject). The original, unaltered tape shall be placed in the official files.

8.0 REFERENCES AND ADDITIONAL RESOURCES

ASTM International, D0420-98R03 Guide to Site Characterization for Engineering Design and Construction Purposes.

ASTM International, D4840-99R04 Guide for Sample Chain-of-Custody Procedures.

ASTM International, D5434-03 Guide for Field Logging of Subsurface Explorations of Soil and Rock.

ASTM International, D6089-97R03E01 Guide for Documenting a Ground-Water Sampling Event.

USEPA, 2001, Environmental Investigations Standard Operating Procedures and Quality Assurance Manual (EISOPQAM), Region 4, Enforcement and Investigations Branch, SESD, Athens, Georgia, www.epa.gov/region4/sesd/eisopqam/eisopqam.html.

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001.

Author:	T. Gilles	Q2R & Approval By:	C. Barry	Q3R & Approval By:	M. Kelley

STANDARD OPERATING PROCEDURE
NO. SAS-01-02

PROJECT FILE MANAGEMENT
Revision 0

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines to assure the integrity and preservation of electronic files within the Network. It also describes the manner in which electronic files are to be identified and handled in the routine entry of data, reports, proposals, etc. onto computer hard drives and tapes.

2.0 EQUIPMENT AND MATERIALS

- Project files including, but not limited to, documents, data, photographs, correspondence and maps.
- Appropriate paper document storage supplies, furniture and facilities.
- Permanent electronic file storage equipment (computer hard drives and random access memory computer disks [CD-ROMs]).

3.0 FILE SECURITY

Adequate security will be maintained for both paper and electronic files relating to each project in accordance with its corporate document security policies.

4.0 PAPER FILES

4.1 ACTIVE PROJECTS

Paper files containing documents relating to an active project will be maintained at the consultant's office. All paper files will be sorted according to type and filed in accordance with the consultant's internal project-specific paper filing system. Paper documents from field activities will be brought from the field to the consultant's office for filing on a regular basis. All paper documents will be maintained in the active project files until final closure of the project.

4.2 CLOSED PROJECTS

Upon final closure of the project, all paper files containing documents relating to the project will be permanently archived in accordance with the consultant's internal file retention policies and client-specified file retention or archiving requirements. Discuss these procedures with the Project Manager.

5.0 ELECTRONIC FILES

5.1 ACTIVE PROJECTS

Electronic files containing documents relating to active project will be maintained at the consultant's office. All electronic files will be sorted according to type and filed in accordance with the consultant's internal electronic project filing system. Data saved electronically to field computers will be transferred to the consultant's in-office computer network on a regular basis via CD-ROMs or as attachments to electronic mail (email) transmissions. All electronic documents will be maintained in the active project files until final closure of the project.

5.2 CLOSED PROJECTS

Upon final closure of the project, all electronic files containing documents relating to the project will be permanently archived in accordance with the consultant's internal file retention policies and client-specified file retention or archiving requirements.

5.0 REFERENCES AND ADDITIONAL RESOURCES

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001.

SOP SERIES SAS-02
FIELD MEASUREMENTS – GENERAL

Author:	**T. Gilles**	**Q2R & Approval By:**	**J. Gonzalez**	**Q3R & Approval By:**	**M. Kelley**

STANDARD OPERATING PROCEDURE
NO. SAS-02-01

EQUIPMENT CALIBRATION, OPERATION, AND MAINTENANCE
Revision 0

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for controls, calibration, and maintenance of measurement and testing equipment to be used for obtaining samples for chemical analyses, for measuring field parameters, and for testing various parameter/characteristics. The purpose of this SOP is to ensure the validity of field measurement data generated during field activities as required in the Work Plan or as otherwise specified.

2.0 EQUIPMENT AND MATERIALS

- Measurement and testing equipment ;
- Equipment/instrumentation-specific operation manuals;
- Equipment/instrumentation-specific cases, battery chargers, and attachments; and
- Calibration standards (e.g. standard gas(es), calibration fluids, pH standards, etc.).

3.0 HEALTH AND SAFETY

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 EXECUTION

4.1 General

Field measurements are used to verify sampling procedures, assist in sample selection, and evaluate field conditions. A variety of equipment/instrumentation may be utilized to obtain the field measurements required to satisfy and document project goals outlined in Work Plans or otherwise specified. Therefore, instrument operators must be thoroughly familiar with the operation of measuring instruments. Users will complete the appropriate training and be certified, if required, before using the instrument in the field.

All equipment/instrumentation will be uniquely and permanently identified (model/serial number, equipment inventory number, etc.). Manufacturer's guides/operation manuals will be kept with the instrument or a designated area on the Site, as appropriate. The Site Manager or designee will obtain, identify, and control all equipment/instrumentation to be used during the project.

4.2 Calibration

Measuring equipment/instrumentation must be calibrated before initial use as recommended in the manufacturer's guide/operation manual. Equipment/instrumentation shall be re-calibrated following 1) the manufacturer's recommended calibration frequency, 2) long periods between uses, 3) readings observed above or below the range of the instrument, and/or 4) signs or evidence of equipment malfunction. Daily calibration and re-calibration activities will be recorded in the field logbook and/or on the appropriate field form and will include the following information:

- Date and time of calibration or re-calibration;
- Equipment/instrumentation manufacturer, make, and model;
- Equipment/instrumentation serial or unique inventory number;
- Method of calibration (may reference procedures outlined in the guide/instrument manual);
- Calibration standard(s) used; and
- Deviations, if any, from the manufacturer's recommended procedure(s) or calibration frequency.

4.3 Operation

Manufacturer's instructions will be followed for correct method(s) of operation. Equipment malfunctions and deviations, if any, from the manufacturer's recommended method(s) of operation will be documented in the field logbook and/or on the appropriate field form. Readings obtained from each instrument shall be recorded in the field logbook or on the appropriate field form.

4.4 Maintenance

Equipment/instrumentation will be maintained in accordance with the manufacturer's recommendations. Equipment/instrumentation that malfunctions or is scheduled for routine maintenance will be clearly labeled to prevent its continued use until repairs/maintenance is completed. The Site Manager or her/his designee will be responsible for ensuring that malfunctioning equipment is identified, marked for repair, repaired either in-house or by an outside company in accordance with manufacturer guidelines, checked following repair, and returned to service. The Site Manager or her/his designee will maintain an equipment log, which contains the following:

- Equipment/instrumentation manufacturer, make, and model;
- Equipment/instrumentation serial or unique inventory number;
- Recommended calibration frequency;
- Recommended maintenance frequency, as appropriate;
- Status (in service, not in use, or out of service for repair/maintenance);
- Dates of status changes (e.g. date returned to service); and
- Inspection and maintenance/repair dates.

5.0 REFERENCE

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001

STANDARD OPERATING PROCEDURE
NO. SAS-02-02

SURVEYING
Revision 0

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for surveying activities that will be performed by the consultant. Timeframes or budgets may not always allow for surveying by licensed surveying professionals. The consultant may need to obtain information in a timely and cost effective manner that will aid in project decisions (e.g. groundwater flow direction, hydraulic gradient, etc.). In these cases, the consultant will perform basic surveying to obtain this information. The purpose of this SOP is to outline general procedures to obtain reliable surveying data in support of project goals and decisions as required in the Work Plan or as otherwise specified.

2.0 EQUIPMENT AND MATERIALS

- Topcon Auto Level or equivalent;
- Tripod;
- Plumb line;
- Graduated surveying stick; and
- Field logbook and/or appropriate field form.

3.0 HEALTH AND SAFETY

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 EXECUTION

4.1 General

Survey equipment shall be inspected prior to commence of surveying activities to ensure that all components are present and functional. Graduations on the surveying stick should be well marked. Equipment not in satisfactory condition should be removed from service and repaired or replaced, as appropriate.

Operators must be thoroughly familiar with the operation of surveying equipment. Operators should complete the appropriate training and be certified, if required, before using the equipment in the field.

4.2 Benchmark Selection

A fixed, permanent reference point is critical for tying in surveying results to known site features and reproducing surveying results in the field. The benchmark should be a unique location, preferable one that would appear on a plat of survey, that is not likely have its elevation affected by field or outside activities (e.g. flange bolt on a fire hydrant, base of a property boundary stake, corner of a loading dock, etc.). The benchmark shall be documented and clearly described in the field logbook and/or on the appropriate field form. The location of the benchmark should also be measured relative to a minimum of two other permanent site features. These measurements should also be recorded in the field logbook and/or on the appropriate field form. Typically, a licensed surveyor will establish the benchmark which will be used on the site. If the benchmark cannot be established by a licensed surveyor, make sure the Project Manager is informed.

4.3 General Procedures

Surveying will be conducted following the procedures outlined below:

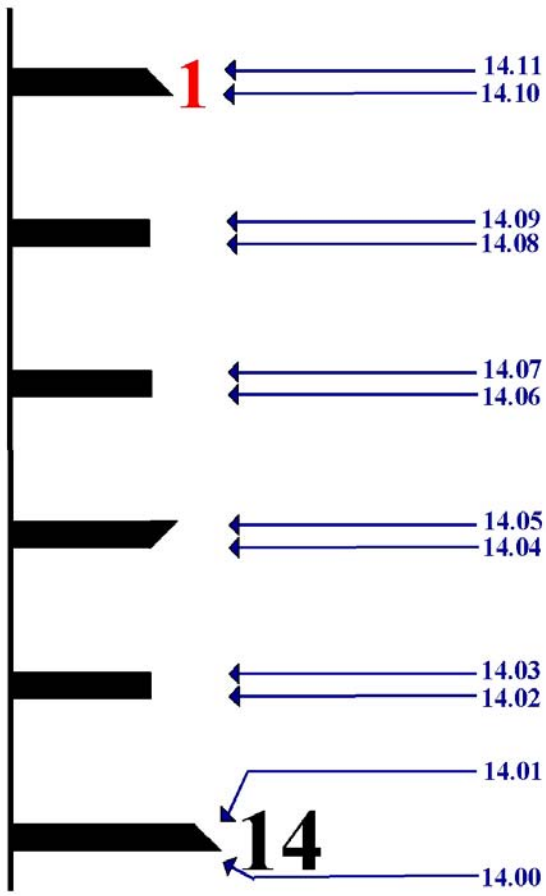
1. Make a table in the field logbook or utilized the appropriate field form to record the following information:
    a. Benchmark;
    b. Assigned benchmark elevation;
    c. Instrument Height(s);
    d. Temporary Benchmark(s);
    e. Survey points (e.g. monitoring well top of casing, ground surface, etc.); and
    f. Surveying stick graduation.

2. Locate a benchmark (BM).
3. Describe the BM in the field logbook and/or on the appropriate field form. The description must be detailed enough to allow a person unfamiliar with the Site to locate the BM.
4. Measure the location of the BM from at least two other permanent site features and record the measurements in the field logbook and/or on the appropriate field form.
5. Choose a location for the tripod that is in view of the benchmark and as many surveying points as possible.
6. Set up the tripod and attach the plumb line.
7. Adjust the tripod legs until the plumb line hangs at a 90-degree angle from the top plate of the tripod.
8. Place the Topcon Auto Level (or equivalent) on the tripod.
9. Adjust the auto level legs until the Topcon Auto Level is level as indicated by the leveling bubble (Note: The bubble should be centered in the circle).
10. Verify the auto level is level by rotating the auto level 90, 180, and 270-degrees. The bubble should be centered in the circle at all three positions. If the bubble is not centered in the circle, repeat Steps 7 through 10.
11. The surveying assistant will stand the surveying stick on the benchmark.
12. The operator should view the surveying stick through the Topcon Auto Level (or equivalent), read and record the surveying stick graduation that intercepts the center crosshairs of the auto level electronically or in the field logbook and/or on the appropriate field form as the back sight measurement.
13. The operator shall record Instrument Height #1 (IH_1), which is obtained by adding the surveying stick graduation to the arbitrary benchmark elevation (usually 100.00 feet), in the field logbook and/or on the appropriate field form.
14. The surveying assistant will stand the surveying stick on a surveying point.
15. The operator should view the surveying stick through the Topcon Auto Level (or equivalent), read and record the surveying stick graduation that intercepts the center crosshairs of the auto level in the field logbook and/or on the appropriate field form as the front sight measurement.
16. The operator shall record Survey Point #1 (SP_1) elevation, which is obtained by subtracting the surveying stick graduation from IH_1, electronically or in the field logbook and/or on the appropriate field form.

17. Repeat Steps 14 through 16 until all survey points or all survey points visible from the first instrument location have been measured.
18. Locate a Temporary Benchmark (TBM_1).
19. The surveying assistant will stand the surveying stick on TBM_1.
20. The operator should view the surveying stick through the Topcon Auto Level (or equivalent), read and record the surveying stick graduation that intercepts the center crosshairs of the auto level in the field logbook and/or on the surveying data form as the front sight measurement.
21. The operator shall record TBM_1 elevation, which is obtained by subtracting the surveying stick graduation from IH_1, electronically or in the field logbook and/or on the appropriate field form.
22. The operator shall relocate the instrument and repeats Steps 6 through 10. Note: During this time the surveying assistant should not remove the surveying stick from the top of TBM_1.
23. Once the instrument has been relocated and leveled, the operator should view the surveying stick through the Topcon Auto Level (or equivalent), read and record the surveying stick graduation that intercepts the center crosshairs of the auto level in the field logbook and/or on the surveying data form as the back sight measurement.
24. The operator shall record Instrument Height #2 (IH_2), which is obtained by adding the surveying stick graduation to the TBM_1 elevation determined in Step 21, electronically or in the field logbook and/or on the appropriate field form.
25. If all surveying points have been measured, skip to Step 36. If all surveying points have not been measured, proceed to step 26.
26. Repeat Steps 14 through 16 until all survey points or all survey points visible from the instrument location have been measured.
27. Locate another Temporary Benchmark ($TBM_\#$).
28. The surveying assistant will stand the surveying stick on $TBM_\#$.
29. The operator should view the surveying stick through the Topcon Auto Level (or equivalent), read and record the surveying stick graduation that intercepts the center crosshairs of the auto level in the field logbook and/or on the surveying data form as the front sight measurement.
30. The operator shall record $TBM_\#$ elevation, which is obtained by subtracting the surveying stick graduation from $IH_\#$, electronically or in the field logbook and/or on the appropriate field form.

31. The operator shall relocate the instrument and repeats Steps 6 through 10. Note: During this time the surveying assistant should not remove the surveying stick from the top of $TBM_{\#}$.
32. Once the instrument has been relocated and leveled, the operator should view the surveying stick through the Topcon Auto Level (or equivalent), read and record the surveying stick graduation that intercepts the center crosshairs of the auto level electronically or in the field logbook and/or on the appropriate field form as the back sight measurement.
33. The operator shall record Instrument Height # ($IH_{\#}$), which is obtained by adding the surveying stick graduation to the $TBM_{\#}$ elevation determined in Step 30, electronically or in the field logbook and/or on the appropriate field form.
34. Repeat Steps 14 through 16 until all survey points or all survey points visible from the instrument location have been measured.
35. If all surveying points have been measured, skip to Step 36. If all surveying points have not been measured, proceed to step 27.
36. The surveying assistant will stand the surveying stick on the benchmark.
37. The operator should view the surveying stick through the Topcon Auto Level (or equivalent), read and record the surveying stick graduation that intercepts the center crosshairs of the auto level in the field logbook and/or on the surveying data form as the front sight measurement.
38. The operator record BM elevation, which is obtained by subtracting the surveying stick graduation from $IH_{\#}$, electronically or in the field logbook and/or on the appropriate field form.
39. If the BM elevation is within 02/100 of an inch ($\pm$0.02) of the initial or assigned BM elevation, the surveying has been completed successfully. If the BM elevation is not within 02/100 of an inch ($\pm$ 0.02) of the initial or assigned BM elevation, an error was made or the tripod and/or auto level were bumped during surveying. In this case, the surveying activities were not completed successfully and must be repeated.

4.4 Reading the Surveying Stick



5.0 REFERENCE

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001

SOP SERIES SAS-03
SAMPLE COLLECTION – GENERAL

Author:	M. Skyer	Q2R & Approval By:	C. Barry	Q3R & Approval By:	M. Kelley

STANDARD OPERATING PROCEDURE
NO. SAS-03-01

SAMPLE IDENTIFICATION, LABELING, DOCUMENTATION AND PACKING FOR TRANSPORT
Revision 0

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes procedures for identifying, logging, packing, preserving and transporting environmental samples for chemical or physical analysis.

2.0 EQUIPMENT AND MATERIALS

- Sample containers;
- Sample labels;
- Field logbook;
- Pens with waterproof, non-erasable ink;
- Chain-of-custody (COC) forms;
- Custody seals
- Clear plastic sealing tape;
- Coolers for transporting samples to the laboratory;
- Ice (if required)
- Gallon-size sealable plastic bags; and
- Air bills or similar transportation provider forms.

3.0 HEALTH AND SAFETY

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 SAMPLE IDENTIFICATION

Sample identification will be used to identify each soil and quality control (QC) sample collected for chemical and physical analysis. The sample identification provides accurate sample tracking and facilitates retrieval of sample data. Sample identification will be used on sample labels, COC forms and other applicable sampling activity documentation. A list of sample identifications will be maintained in the field logbook. Each sample collected will be assigned a sample identification consisting of a unique sample identifier and a unique sample name separated by a dash. A discuss of sample identifiers and sample names is provided below (Sections 4.1 and 4.2 below).

Example: Sample identification = sample identifier-sample name

4.1 Sample Identifier

The sample identifier is a 9-digit code consistent with the USEPA's Electronic Data Deliverable Specification Manual. The sample identifier shall be formatted as a number series with 2 digits for the sample month, 2 digits for the day, 2 digits for the year, and a consecutive three digit for the sample. For example the first sample collected on June 5, 2007 would be assigned the unique identifier "060507001". Sample identifiers will not change when media (soil, water, etc.), location, or type of analysis changes.

4.2 Sample Name

Sample name will change when the media (soil, water, etc.) or location changes. Sample names will not change because different analyses are requested. Sample name will consist of three components: a three-character alpha site identification code for the site; a four- to five-character alpha numeric sample type code for the sample location; and a three digit sample characteristic code. An example of a completely numbered sample, with each component identified follows.

Example: AES-SP01-001

Where: AES – Any Environmental Site
SP01 – Soil probe location number 1
001 – Soil sample number 1

The site identification code (e.g. AES in the sample above) will remain the same for all samples collected at the Site.

The sample type code (SP01) will vary depending on sample type and location. The following are typical alpha codes to be used in the alphanumeric sample type code for samples:

- AS – air sparging sample;
- CF – confirmation soil sample;
- GP – gas probe sample;
- MW – groundwater monitoring well (if deep and shallow wells are sampled for the same location, this type code is modified to DMW (deep well) and SMW (shallow well);
- PZ – piezometer sample;
- RW – recovery well sample;
- SB – soil boring sample;
- SD – sediment sample;
- SP – soil probe sample;
- SS – surface soil sample;
- SR – source material (used if source material is known to exist);
- SV – soil vapor probe sample;
- SW – surface water sample;
- TP – test pit sample; and
- VE – vapor extraction sample.
- WC – waste characterization (may be preceeded by S for solid waste or L for liquid waste).

If additional sampling type codes are required, they will be specified in the site-specific work plan.

When completing soil borings and probes, if a water sample is collected from an open boring or probe location a “w” will be attached to the end of the alpha-numeric sample type code (e.g., SB01W). The numerical portion of the sample type code will indicate the sample location (i.e., boring location 01, 02, 03, etc.).

The three-digit sample characteristic code (001) indicates the type of analysis (chemical, QC or physical) and the number of samples collected from each media at a specific sampling location. The first digit will be zero through two for all chemical analysis: zero (0) for primary samples, one (1) for duplicate samples and two (2) for QC samples. The first digit will be three (3) for physical testing. The last two digits of the sample characteristic code will indicate the number of each sample collected from each medium at a specific location.

5.0 SAMPLE LABELING

The following information will be included on each sample label: site name/client, sample identification (sample identifier and sample name), name of sampler, sample collection date and time, depth of sample (if applicable), analyses or tests requested and preservations added. Information known before field activities (site name, analyses requested, etc.) can be preprinted on sample labels. Duplicate sample labels can be prepared when various sample aliquots must be submitted separately for individual analyses.

6.0 SAMPLE DOCUMENTATION

The following itemized list will be used as a general reference for completion of sample documentation:

- Record all pertinent sample activity in the field logbook in accordance with SOP SAS-01-01, Field Documentation and Reporting.
- Make or obtain a list of samples to be packaged and shipped that day.
- Determine number of coolers required to accommodate the day's shipment based on number of samples to be shipped, number of containers per sample and number of sample containers that will fit in each cooler.
- If samples are shipped by Federal Express or other express shipping service, complete an air bill.

- Assign chain-of-custody form to each cooler and determine which sample containers will be shipped in each cooler. (Note: More than one chain-of-custody form may be needed to accommodate number of samples to be shipped in one cooler).
- Determine which samples will be shipped under each chain-of-custody form. Each day that samples are shipped, record chain-of-custody form numbers, and air bill numbers (if used) in field logbook. Cross-reference air bill and chain-of-custody numbers.
- Complete COC forms in accordance with SOP SAS-03-02, Chain of Custody.
- Assign custody seals to each cooler and temporarily clip seals to each chain-of-custody form.
- Group paperwork associated with each cooler with a separate clip.
- Obtain necessary field team members' full signatures or initials on appropriate paperwork.

7.0 SAMPLE PACKING FOR TRANSPORT

The steps outlined below will be followed to pack the sample containers into coolers for shipment.

1. Each glass sample container will be wrapped with protective packing material.
2. Packing material will be placed in the bottom of each cooler for cushioning.
3. Sample containers will be placed inside each cooler, taking care not to overfill the cooler.
4. Ice will be double bagged sealable plastic bags and added to the cooler on top of the samples. Sample containers will be packed so that they are not in direct contact with ice. The remaining empty space in each cooler will be filled with packing material.
5. Packing material will be placed over the top of the bagged ice.
6. The chain-of-custody records will be signed, and the date and time at which the coolers are sealed for transport by a shipping company, or relinquished to a delivery service or the laboratory sample receiving department will be indicated.
7. Copies of chain-of-custody records will be separated. The original signature copies will be sealed in a large, sealable, plastic bag and taped to the inside lid of a cooler. A copy of each COC will be retained by the Site Manager.
8. If any cooler has a drain, the drain will be taped shut.
9. The lid to each cooler will be closed and latched. Custody seals will be affixed to each cooler between the lid and the body of the cooler. One custody seal will be placed on the front of the cooler, and one will be placed on the back. Custody seals will be covered with clear plastic tape. An example of a custody

seal is located in SOP SAS-03-02, Chain-of-Custody.

10. The cooler will be taped shut on both ends with several revolutions of tape. Also, tape will be wrapped several times around the cooler between the body of the cooler and the cooler lid.
11. Samples will be packed and transported to the analytical laboratory within one day of collection.

8.0 REFERENCES AND ADDITIONAL RESOURCES

ASTM International, D3694-96(2004) Standard Practices for Preparation of Sample Containers and for Preservation of Organic Constituents

ASTM International, D4220-95R00 Practices for Preserving and Transporting Soil Samples

ASTM International, D4840-99(2004) Standard Guide for Sampling Chain-of-Custody Procedures.

ASTM International, D6911-03 Guide for Packaging and Shipping Environmental Samples for Laboratory Analysis

International Air Transport Association (IATA), 2005, Dangerous Goods Regulations.
USEPA, 1981, *Final Regulation Package for Compliance with DOT Regulations in the Shipment of Environmental Laboratory Samples*, Memo from David Weitzman, Work Group Chairman, Office of Occupational Health and Safety (PM-273), April 13, 1981.

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/60/B-07/001.

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STANDARD OPERATING PROCEDURE NO. SAS-03-02

CHAIN OF CUSTODY Revision 0

1.0 PURPOSE

This Standard Operating Procedure describes procedures for preparation and use of the chain of custody (COC) form that accompanies field-collected soil, sediment, water, air or geotechnical samples. Procedures are also provided for preparation and use of custody seals for securing openings of sample containers during transport of samples to the analytical laboratory. COC forms and custody seals are used to provide documentation of sample integrity from the time of collection to time of sample receipt and acceptance by the analyzing laboratory or testing laboratory.

2.0 EQUIPMENT AND MATERIALS

- COC forms;
- Custody seals;
- Gallon-size plastic sealable bags; and
- Clear plastic packing tape.

3.0 HEALTH AND SAFETY

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 METHODS/PROCEDURES

4.1 Chain of Custody Form Items to Complete

Attachment A presents an example COC form. The following general information must be completed on the COC form:

- Laboratory name, address, telephone number;
- Document control number;
- Site manager name on Attention line;
- Project number;
- Site name;
- Complete field sample identification;
- Sample collection date for soil, sediment and water samples or sample start and collection dates for ambient air monitoring samples;
- Time of sample collection for soil, sediment and water samples or sample start and collection times for air monitoring samples;
- Sample matrix (i.e. liquid, solid, or gas);
- Number of containers;
- Analysis or testing method requested;
- End pressure, Summa can identification number, and flow controller serial number for air monitoring BTEX samples and filter identification number for air monitoring PM10 samples.
- Sample preservatives used (other than ice) in Remarks column;
- Turn-around time requested (specify if turn-around time is business or calendar days) in Special Instructions box;
- Signature of person(s) conducting sampling;
- Strike line with samplers initials and the date samples are relinquished in order to complete unused portion of COC form;
- Signature of person relinquishing the sample custody (person relinquishing custody must be a sampler to ensure chain of custody is maintained);
- Signature of person transporting samples to the lab if other than sampler/relinquisher or third-party carrier;

- **DO NOT** write "FedEx" or other third-party carrier's name in the Relinquished To box. The air bill and carrier's established custody documentation procedure is used to verify custody during transportation.
- Date and time samples are relinquished;
- Custody seal identification numbers; and
- Freight bill identification number in Special Instructions box or at bottom of Remarks column (if third party shipper is used to transport).

4.2 Chain of Custody Form and Procedures

- If a sampling event requires the use of more than one shipping container (cooler for soil/sediment/water samples or box for certain air monitoring samples or soil samples for geotechnical testing) a separate COC form must be completed for each shipping container. For each container, the associated COC form must list only the samples contained in that container.
- When it is known that numerous chains of custody will be required for a project or for a single sampling event, it is acceptable to pre-type the laboratory name, address, telephone number, project number, site name, 3-letter project name abbreviation in Document Control Number area, and site manager name. These are the only information fields that may be pre-typed.
- Each COC should contain a unique document control number in the format: 3-letter project name abbreviation – identification number – 4 digit year, e.g. AES-001-2006, AES-002-2006 and so on. For each project COC identification numbers should be assigned sequentially beginning with 001 for each calendar year. (Exception: for remediation ambient air monitoring projects that span two or more calendar years, continue sequential numbering throughout the project.)
- The COC form must be completed in ink.
- Corrections must be made by drawing a single line through the data that is in error and initialing and dating at the end of the line. The use of correction fluid or tape is not allowed. Do not write over text or numbers to correct. If multiple corrections are needed, copy correct information to a new COC and destroy copy with errors.
- If the number of samples included in the shipping container is less than the number of data entry lines on the COC, draw a single diagonal line running from left down to the lower right hand corner of the field sample data area. The sampler's initials and date must appear along the line.

- Seal the completed COC form in a plastic storage bag. For cooler shipping containers, tape the bag to the inside of the cooler lid prior to sealing the cooler. For box shipping containers, insert the bagged COC form into the box prior to sealing the box.
- If samples are to be shipped by a third party carrier (e.g. Federal Express) the third party carrier does not need to sign the chain of custody. The COC form may be sealed inside the container prior to shipping. If samples are to be hand-delivered to a laboratory by someone other than the sampler/relinquisher (e.g., site construction manager or laboratory courier), the sampler/relinquisher must transfer custody by having the carrier sign in the "Received By" section of the COC form and enter the date and time of transfer. Then seal the COC form inside the container.

4.3 Custody Seal Procedures

A sample custody seal is a strip of adhesive paper used to detect unauthorized tampering with samples prior to receipt by the laboratory. Attachment A presents an example of a completed custody seal. Custody seals are pre-numbered and should be used instead of laboratory custody seals whenever possible.

- A minimum of two custody seals are used per shipping container, one on each long side of the cooler or across each opening of a box. For coolers, one of the custody seals must be placed from the lid to the side of the cooler such that it would be necessary to break the seal in order to open the shipping container. Cover each custody seal with a single piece of clear packing tape wrap it around the perimeter of the cooler. For boxes, place a custody seal across each opening of the box (top and bottom) and cover with a piece of packing tape, making sure tape is secured in such a way that it cannot easily be removed.
- The relinquisher must sign and date each custody seal in ink and include the site identification abbreviation in the custody seal number area.
- Each custody seal has a pre-printed unique six-digit identification number. This number along with the site identification abbreviation must be transferred exactly to the Custody Seal Number box on the COC. The identification number of all custody seals used in conjunction with the COC must be listed on the COC. If a custody seal other than the pre-numbered one, a unique identification number must be printed on the seal and transferred exactly to the Custody Seal Number box on the COC.

5.0 DATA MANAGEMENT AND RECORDS MANAGEMENT

A copy of the COC forms and freight bills used in the above procedure will be transferred to the Project Manager and maintained in the project-specific file as part of the official chain of custody record.

6.0 QUALITY CONTROL AND QUALITY ASSURANCE

- Each COC will be checked for accuracy and completeness (i.e. sample list complete, sample data entered correctly etc.) by another member of the field sampling team before samples are relinquished for transport. In the event the sampler is the sole person on-site, the COC will be checked for accuracy and completeness within 24 hours of the sampling event by a member of the project team.
- Review of the COC forms and freight bills used in the above procedure will be conducted during evaluations of sampling procedures by personnel. The COC forms will also be reviewed as part of the data validation process when the laboratory returns the completed COCs following receipt and analysis of samples.

7.0 REFERENCES AND ADDITIONAL RESOURCES

ASTM, International, 1999, D 4840-99 (2004) Standard Guide for Sample Chain-of-Custody Procedures.

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001.

ATTACHMENT A
EXAMPLE CHAIN-OF-CUSTODY FORM AND CUSTODY SEAL

Request for Chemical Analysis and Chain of Custody Record

Send Results to:	Laboratory:	Document Control No.:
	Address:	Lab. Reference No. or Episode N
	City/State/ZIP:	
Attention:	Telephone:	

Project Number:									Sample Type			Number of Containers	Parameter/Method Code							
Site Name:									Matrix											
Sample Number			Sample Event		Sample Depth (in feet)		Sample Collected		Liquid	Solid	Gas									Remarks
Group or SWMU Name	Sample Point	Sample Designator	Round	Year	From	To	Date	Time												

Sampler *(Print Name)*:		Sampler *(signature)*:		Custody Seal Number	Special Instructions
Relinquished By *(signature)*: 1.	Date/Time	Received By *(signature)*: 1.	Date/Time	Ice Present in Container: Yes ☐ No ☐	Temperature Upon Receipt:
Relinquished By (signature): 2.	Date/Time	Received By (signature): 2.	Date/Time	Laboratory Comments:	

Signature ______________________________

Date ______________ # ______ -112504

STANDARD OPERATING PROCEDURE
NO. SAS-03-03

SAMPLE LOCATION IDENTIFICATION AND CONTROL
Revision 0

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for the identification of sample locations and field measurements of topographic features, water levels, geophysical parameters, and physical dimensions frequently required during groundwater, hazardous waste, and related field investigation activities. The scope of such measurements depends on the purpose of the field investigation. Samples collected from each sampling location will have a unique sample identification in accordance with SAS-03-01.

All sampling locations shall be uniquely identified and depicted on an accurate drawing or a topographic or other site map, or be referenced in such a manner that their location(s) are established and reproducible. A sample location must be identified by a coordinate system or other appropriate procedures which would enable an independent investigator, to collect samples from reproducible locations. Repetitive sampling might be performed, for example, to monitor the progress of a remedial program, to check for suspected erroneous results from an initial sampling, or to check the reproducibility of results.

2.0 EQUIPMENT AND MATERIALS

- Site map;
- Surveying equipment;
- Measuring tape;
- Field notebooks/logs; and
- GPS unit.

3.0 SAMPLE LOCATION IDENTIFICATION

Locations for collection of samples are assigned alphanumeric codes which are used to coordinate laboratory data tracking and graphic depiction of sample locations on drawings and figures. Samples collected from each sampling location will have a unique sample identification in accordance with SAS-03-01. Each sample location is issued a unique numeric code that corresponds to a specific map location on a plan view of a site and vicinity. An alpha-code (letter) is used to describe the type of sampling activity performed at the specific numeric location. The following alpha codes will be used:

Air	AS	Air Sparging Point
	GP	Gas Probe
	GM	Gas Monitoring Well
	SV	Soil Vapor Probe
	VE	Soil Vapor Extraction Well
Material	AC	Asbestos Containing Material
	LS	Lead Wipe Sample
Sediment	SD	Sediment
Soil	SB	Soil Boring
	SS	Surface Soil
	TP	Test Pit
	EB	Excavation Base
	EW	Excavation Well
Water	MW	Groundwater Monitoring Well
	PZ	Piezometer
	PW	Potable Water Well
	RW	Recovery Well
	TW	Temporary Monitoring Well
	SW	Surface Water
	SG	Surface Water Staff Gauge

A typical series of alpha numeric codes for a site might include test pit locations TP01 through TP12; borings SB01, SB02, SB03; monitoring wells MW01, MW02, MW03, etc.

Each sample location will have only one alphanumeric code. A borehole drilled for the purpose of installing a monitoring well will be identified as MW01. There should not be a location SB01 for soil sample location identification and MW01 for groundwater sample location identification.

Note that soil borings performed for the purpose of collecting a groundwater grab sample (e.g. through screened auger, open borehole, Geoprobe®, Hydro-Punch®, etc.) are identified as soil borings, not monitoring wells. These types of sampling locations may be further identified on site figures with a clarifying suffix (GW), such as SB01 (GW). The site map legend will explain the meaning of all symbols used to identify sampling points.

If previous work has been performed at a site, the alphanumeric code should continue with previous successive numbers. If there is any potential for conflict with existing sample number identifiers, the proposed sample number should begin with series 101, 1001, or other appropriate system. Dashes should be eliminated from sample number identifiers, such as SB101 should be used instead of SB-101.

4.0 SURVEYED LOCATIONS

Survey control should be performed following monitoring well and borehole installations by a surveyor licensed in the state of the project site. Vertical elevations to the top of each new well casing will be established within ± 0.01 foot. Ground surface elevations at each well and borehole location should be established within ± 0.1 foot. Vertical and horizontal datum shall be specified in the Site-Specific Work Plan and may include established and/or historical site datum. Appropriate datum references shall be documented in the master project file and final reports.

Lateral locations based on an established grid system will be determined for each sampling location. Lateral locations should be calculated to within ± 1-foot. The site map should include at minimum sampling locations, structure boundaries, property boundaries, nearby surface water, site grid system origin according to either a state plane coordinate system or latitude and longitude, bar scale, and a north arrow. Specific state reporting and mapping requirements should be checked prior to final plan development.

In conducting vertical surveys, the following procedures should be used or should be referenced in subcontractor service agreements with licensed surveyor:

- When practical, level circuits will close on a bench mark other than starting bench mark;
- Readings should be recorded to the closest 0.01 foot using a calibrated rod;
- Foresight and backsight distances should be reasonably balanced;
- Rod levels should be used;
- No side shot should be used; and
- Benchmarks should be traceable to USGS benchmarks.

5.0 TRIANGULATION

Triangulation shall be used if a registered surveyor is not contracted. This method encompasses distance measurement from sampling points relative to two and sometimes three known points. Distance measurements should be accurate to within ±1 foot allowing for sag in the measuring tape and other inaccuracies. Measuring to two known points is typically adequate for rough measurements made with a pocket transit and 100-foot tape; however, measuring to three known points reduces potential error. Distance measurements should be made relative to distinctive features having a probable life span in excess of 10 years. Examples include the following:

- Power pole located on north side of plant entrance #1 driveway;
- SE corner of plant building 2 located at 111 Survey Circle; or
- NW corner of retaining wall running north-south along Bass Creek.

Unacceptable triangulation points include fence posts, trees, temporary stakes or markers etc., unless these features are to be located within 15 days by survey.

When locating sampling points, decide which site features will be important to illustrate on a site map in the report. If appropriate, also locate areas of known or suspected spills and manholes which may represent migration pathways. Establish relative locations of these and other pertinent site features by triangulation.

The client should be consulted regarding the existence of plant drawings or other surveyed maps which accurately show the relative location of major site features. The field notebook should record information describing the drawing (e.g., who it was prepared by, date, drawing number, etc.) and describe the points on the drawing being used for triangulation purposes.

If only one site feature is convenient for triangulation, the remaining two reference points can be established by running a line toward a more distant site feature, which can be easily located later, and the recorded distance from a defined point along that line.

6.0 GLOBAL POSITIONING SYSTEM (GPS)

Global Positioning System (GPS) is an appropriate method to determine the location of site investigation features in limited circumstances, and is solely at the discretion of the project manager.

There are significant accuracy limitations with GPS which limits the effectiveness of this technology in the role of sample location. For sites where accuracy less than ± 10 feet is acceptable, or surveying is impractical, GPS is a suitable sample location method. GPS is not suitable for sites requiring a higher degree of accuracy. However, the recording of GPS coordinates is encouraged for all sites where monitoring wells or other permanent features may be obscured by snow, vegetation, or other obstructions. In such cases, GPS may assist in locating the monitoring well, etc. despite the accuracy limitations.

7.0 REFERENCES

ASTM International, 2002, D5906-02 Guide for Measuring Horizontal Positioning During Measurements of Surface Water Depths.

USEPA, 2001, Environmental Investigations Standard Operating Procedures and Quality Assurance Manual (EISOPQAM), Region 4, Enforcement and Investigations Branch, SESD, Athens, Georgia, www.epa.gov/region4/sesd/eisopqam/eisopqam.html.

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/60/B-07/001.

Zilkoski, David B., J.H. Richards, and G.M. Young , 1992, Results of the General Adjustment of the North American Vertical Datum of 1988, American Congress on Surveying and Mapping, Surveying and Land Information Systems, Vol. 52, No. 3, 1992, pp.133-149.

SOP SERIES SAS-04
SAMPLING QUALITY CONTROL

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STANDARD OPERATING PROCEDURE
NO. SAS-04-01

DATA QUALITY GENERAL CONSIDERATIONS
Revision 0

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes general guidelines that are to be used in conjunction with the USEPA mandatory data quality objectives (DQO) process. Guidelines are intended to assist with planning and conducting quality sampling operations in the field.

2.0 EQUIPMENT AND MATERIALS

Equipment and materials will vary based on the type of data and method of data collection. In general, the following equipment and materials shall be utilized to assist with the collection and recording of quality data:

- Site map(s);
- Field logbook and/or appropriate field forms;
- Method-specific, laboratory-provide containers for the collection of samples for chemical analysis;
- Chain of custody (COC) forms;
- Measuring tape(s), Global Position System (GPS), or other equipment necessary to document sample location; and
- Camera.

3.0 HEALTH AND SAFETY WARNING

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 SAMPLING CONSIDERATIONS

There are two categories of sampling collection activities. The categories include 1) collection of screening data with definitive confirmation and 2) collection of definitive data. The decision making process in each category incorporates a wide range of analytical methods and provides quality analytical data.

Screening data provides a quick, preliminary assessment of site contamination that involves rapid, non-rigorous methods of sample preparation and less precise analytical methodologies. Preliminary assessments of types and levels of contaminants can be made quickly which allows for the greatest amount of data with the least expenditure of time and money. Screening data generally produces data that can be identified and quantified, but may not be relatively precise. A minimum of 10 percent of the screening data must be confirmed using definitive data. Without sufficient confirmation data, screening data will not be recognized as quality data.

Data that is generated by stringent analytical methods (e.g. approved USEPA methods) is defined as definitive data. Whether generated on or off-site, the quality assurance/quality control (QA/QC) protocol of the analytical methods must be achieved. Analytical and total measurement of error must be calculated for the data to be considered definitive. Definitive data is generally analyte-specific and can be confirmed by subsequent analysis (e.g. duplicate, matrix spike/matrix spike duplicate, etc.). Printed or electronic data, spectra, and chromatographs are typically provided as backup information.

Several factors must be considered prior to data collection to ensure the data obtained meets the DQOs and is appropriately addressed and incorporated into procedures outlined the Site-Specific Work and/or Field Sampling Plan (FSP) or otherwise specified in activity- or task-specific SOPs:

- Representative Sampling Sites – Selection of representative sampling sites is dependent on the type of investigation undertaken.
- Analytical Methods/Parameters – The analytical methods/parameters shall be dictated by the constituents of potential concern (COPCs), sample media, potential range of chemical concentrations, site conditions, and field investigator’s knowledge.

- Sample Collection Method – The sample collection method to be used shall be dictated by the investigation, analytical methods/parameters, and category of data desired (screening data with definitive confirmation or definitive data).
- Sampling Equipment – The sampling equipment shall be dictated by the investigation, category of data desired (screening data with definitive confirmation or definitive data), analytical method, sampling method, and the potential for the equipment materials to affect analytical results (e.g. cross-contamination potential, sorption potential, etc.).

5.0 REFERENCES AND ADDITIONAL RESOURCES

ASTM International, 2000, D6568 Standard Guide for Planning, Carrying Out, and Reporting Traceable chemical Analyses of Water Samples.

ASTM International, 2004, D7069-04 Guide for Field Quality Assurance in a Ground-water Sampling Event.

USEPA. 1994a. Evaluation of Sampling and Field-Filtration Methods for the Analysis of Trace Metals in Ground Water s. September 1994, EPA/600/SR-94/119.

USEPA, 1995. Method 1669: Sampling Ambient Water for Trace Metals at EPA Water Quality Criteria levels. April 1995, EPA/621/R-95/114.

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001.

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STANDARD OPERATING PROCEDURE
NO. SAS-04-02

DATA QUALITY OBJECTIVES
Revision 0

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for determining Data Quality Objectives (DQOs). The USEPA has established a mandatory DQO process for sites to ensure that all data is scientifically valid. The DQO process also establishes protocols to support decision making which includes defining the type, number, and quality of the environmental data to be collected.

2.0 DATA QUALITY OBJECTIVES PROCESS

The DQO process is a series of seven steps that facilitate the planning of environmental data collection activities. DQOs are qualitative and quantitative statements developed from the DQO process. The DQO process helps investigators ensure that data collected are of the right type, quantity, and quality needed to support environmental decisions.

The following are the seven steps of the DQO process (USEPA 2006):

1. State the problem.
2. Identify the goal of the study.
3. Identify information inputs.
4. Define the boundaries of the study.
5. Develop the analytic approach.
6. Specify performance or acceptance criteria.
7. Develop the plan for obtaining data.

This DQO process shall define qualitative and quantitative criteria for determining when, where, and how many samples (measurements) to collect for a desired level of confidence. The DQO process shall be employed during the planning stages of any field investigation activities that include analytical data collection. This information along with sampling procedures, analytical procedures, and appropriate quality assurance/quality control (QA/QC) procedures shall be documented in the Quality Assurance Project Plan (QAPP), Field Sampling Plan and SOPs, and/or Site-Specific Work Plan(s).

3.0 DATA QUALITY OBJECTIVE (DQO) LEVELS

Data collected and analyzed from a field investigation is categorized by five DQO levels. Each of these levels is determined by the types of technology and documentation used, and the analytical degree of sophistication. These DQO levels are numbered I through V, with Level I being the lowest quality data and Level V the highest. These DQO levels will be used when determining the appropriate data collection methods for achieving the goals of the field investigation.

3.1 DQO Level I

DQO Level I data typically are field screening data collected in real-time using portable instruments, e.g. photoionization detector (PID). This DQO level is normally used to aid in sample point selection and to differentiate highly impacted samples from low-level impacts. Level I analyses are used for qualitative data collection only, and results cannot be considered quantitative. Instrument calibration provides the quality control component for Level I data.

3.2 DQO Level II

DQO Level II data is typically characterized by field analysis of samples using portable instruments that can be used on-site, e.g. portable gas chromatograph (GC) instrument. This level is considered semi-quantitative due to lack of supporting QA/QC documentation. Instrument calibration provides the quality control component for Level II data.

3.3 DQO Level III

DQO Level III data is data generated in an analytical laboratory using USEPA and other recognized standard methods with rigorous QA/QC protocols. The analytical laboratory can be either an on-site mobile laboratory or a remote laboratory. Level III data is considered quantitative; it provides identification and quantification of chemicals in environmental samples. This data may be used for evaluating compliance of sample results relative to environmental standards, in risk assessment studies, and may be compared to results of other samples collected at a similar DQO level.

3.4 DQO Level IV

DQO Level IV data is the same as DQO Level III with the addition of rigorous documentation including raw data from the analytical laboratory instruments. Level IV analytical data is quantitative and defensible. Superfund investigations normally require DQO Level IV for data used in conducting formal human health risk assessment studies. Standard USEPA-designated field procedures are required on all investigations requiring DQO Level IV quality data. Any deviations from these methods shall be documented in the field logbook and/or on the appropriate field form, or in the approved Site-Specific Work and/or Sampling Plan. Field personnel involved in data collection shall be aware that such deviations in the fieldwork may reduce the DQO level of the data, with a subsequent reduction in data usability.

3.5 DQO Level V

DQO Level V data include deviations from the standard suites of parameters normally analyzed under the USEPA protocols. DQO Level V procedures are by definition non-standard and, therefore, they are not discussed in detail. DQO Level V procedures generally require pre-approval before use and shall be addressed in Site-Specific Work and/or FSP(s), as appropriate.

4.0 REFERENCES AND ADDITIONAL RESOURCES

ASTM International, D7069-04 Guide for Field Quality Assurance in a Ground-water Sampling Event.

USEPA, 1990, Quality Assurance/Quality Control Guidance for Removal Activities, Sampling QA/QC Plan and Data Validation Procedures, Interim Final, EPA/540/G-90/004.

USEPA, 2001, Environmental Investigations Standard Operating Procedures and Quality Assurance Manual (EISOPQAM), Region 4, Enforcement and Investigations Branch, SESD, Athens, Georgia.

USEPA, 2002a, Quality Management Plan for the Superfund Division, Region 5, Chicago, Illinois.

USEPA, 2002b, Guidance for Quality Assurance Project Plans, EPA QA/G-5, EPA/240/R-02/009.

USEPA, 2006, Guidance on Systematic Planning Using the Data Quality Objectives Process, EPA QA/G-4, EPA/240/B-06/001.

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001.

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STANDARD OPERATING PROCEDURE
NO. SAS-04-03

QUALITY CONTROL SAMPLES
Revision 0

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for the collection of quality control (QC) samples. QC samples are utilized to evaluate field and laboratory quality control procedures and the precision, accuracy, representativeness and comparability of data obtained during investigative activities.

2.0 EQUIPMENT AND MATERIALS

Equipment and materials for the collection and analysis for quality control samples shall be identical to those used for the collection and analysis of the sample of similar media and collection method.

3.0 HEALTH AND SAFETY WARNING

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 QUALITY CONTROL SAMPLES

QC samples include field duplicate samples, matrix spike (MS) and matrix spike duplicate (MSD) samples, trip blanks, and field/equipment blanks.

4.1 Field Duplicate Samples

Duplicate samples are collected from various media to evaluate the representativeness and comparability of data obtained during investigative activities. These samples shall be collected at the same time, using the same procedures, the same equipment, and in the same types of containers as the original sample. They shall also be preserved in the same manner and submitted for the same analyses as the requested analytes. Collection of duplicate composite samples requires the installation of duplicate automatic samplers if automatic samplers are used for sample collection. The minimum/required frequency of duplicate sample collection for each sample media shall be specified in the Quality Assurance Project Plan (QAPP), Field Sampling Plan (FSP), and/or Site-Specific Work and/or Sampling Plan(s). If the frequency of collection is in conflict between the above mentioned documents, the Site-Specific Work shall take precedence. The evaluation of these samples is described in the QAPP.

4.2 Matrix Spike and Matrix Spike Duplicate Samples

MS/MSD samples are collected from various media to evaluate the precision and accuracy of laboratory procedures. As with field duplicate samples, MS/MSD samples shall be collected at the same time, using the same procedures, the same equipment, and in the same types of containers as the original sample. They shall also be preserved in the same manner and submitted for the same analyses as the requested analytes. The minimum/required frequency of MS/MSD sample collection for each sample media shall be specified in the QAPP, FSP, and/or Site-Specific Work and/or Sampling Plan(s). If the frequency of collection is in conflict between the above mentioned documents, the Site-Specific Work shall take precedence. The evaluation of these samples is described in the (QAPP).

4.3 Trip Blanks

Trip blanks are used as control or external quality assurance/quality control (QA/QC) samples to detect contamination that may be introduced in the field (either atmospheric or from sampling equipment), in transit to or from the sampling site, or in bottle preparation, sample log-in, or sample storage sites within the laboratory. Trip blanks will also reflect contamination that may occur during the analytical process. Trip blanks are samples of reagent free water which are prepared in a controlled environment prior to field mobilization. These samples are prepared by the analytical laboratory. The trip blanks are kept with the laboratory provided containers through the sampling process and returned to the laboratory with the other samples. Trip blanks must be used for samples intended for VOC analysis and are analyzed for VOCs only. The minimum/required frequency of trip blanks for each sample media shall be specified in the QAPP, FSP, and/or Site-Specific Work and/or Sampling Plan(s). If the frequency of collection is in conflict between the above mentioned documents, the Site-Specific Work shall take precedence. The evaluation of these samples is described in the QAPP.

4.4 Field/Equipment Blanks

Field/equipment blanks are used to determine 1) if decontamination procedures are being carried out properly and there is no "carryover" from one sample to another and 2) ensure that disposable equipment is free of measurable concentrations of constituents of potential concern. Field/equipment blank shall be collected by pouring distilled or DI water onto or into the sampling equipment and direct filling the appropriate sample containers with the DI water from the sampling equipment. Field blank will be handled and treated in the same manner as all samples collected unless noted otherwise below. The minimum/required frequency of trip blanks for each sample media shall be specified in the QAPP, FSP, and/or Site-Specific Work and/or Sampling Plan(s). If the frequency of collection is in conflict between the above mentioned documents, the Site-Specific Work shall take precedence. The evaluation of these samples is described in the QAPP.

5.0 REFERENCES AND ADDITIONAL RESOURCES

USEPA, 1990, Quality Assurance/Quality Control Guidance for Removal Activities, Sampling QA/QC Plan and Data Validation Procedures, Interim Final, EPA/540/G-90/004.

USEPA, 2001, Environmental Investigations Standard Operating Procedures and Quality Assurance Manual (EISOPQAM), Region 4, Enforcement and Investigations Branch, SESD, Athens, Georgia.

USEPA, 2002a, Quality Management Plan for the Superfund Division, Region 5, Chicago, Illinois.

USEPA, 2002b, Guidance for Quality Assurance Project Plans, EPA QA/G-5/ EPA/240/R-02/009.

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001.

STANDARD OPERATING PROCEDURE NO. SAS-04-04

EQUIPMENT DECONTAMINATION Revision 0

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for decontamination of equipment prior to its 1) initial use onsite 2) reuse at another sampling interval or location, and 3) demobilization from Site as specified in the Site-Specific Work Plan or as otherwise specified. Personnel decontamination is described in the site-specific Health and Safety Plan (HASP).

2.0 EQUIPMENT AND MATERIALS

Decontamination equipment and materials may vary based on the size or type of equipment, but generally include the following:

- Decontamination detergents (e.g. Alconox);
- Tap water;
- Deionized, distilled and organic-free water;
- Acid solution (optional);
- Approved cleaning solvent (e.g. isopropanol, hexane, Stoddard) (optional and/or site-specific);
- Metal scrapers;
- Brushes;
- Buckets;
- Steam cleaner or high-pressure, hot water washer;
- Racks, normally metal (not wood) to hold miscellaneous equipment;
- Buckets, 55-gallon drums, or other approved storage containers;
- Plastic sheeting;
- Utility pump (optional);
- Paper towels;
- Personal protective equipment; and

- Logbook and/or appropriate field form.

3.0 HEALTH AND SAFETY WARNINGS

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific HASP based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 EXECUTION

4.1 General Requirements

All expected types and levels of contamination shall be discussed during field activity planning and a decontamination plan sufficiently scoped within the Site-Specific Work Plan. Until proven otherwise, all personnel and equipment exiting the area of potential contamination/work zone will be assumed to be contaminated. Personnel involved in decontamination efforts shall be equipped with the same personal protective equipment as those conducting the field activity until a lower level of risk can be confirmed.

Decontamination procedures may be subject to federal, state, local, and/or the client’s regulations. All regulatory requirements shall be satisfied, but the procedures adopted shall be no less rigorous than those presented in this SOP.

Climatic conditions anticipated during decontamination activities may impact the implementation of the procedures describe in this SOP. Special facilities or equipment may be needed to compensate for weather conditions (e.g. temporary, heated structures for winter work). In addition, it may be necessary to establish special work conditions during periods of high heat or cold stress.

4.2 Preparation

4.2.1 Site Selection

The equipment decontamination facility or area shall be located in an area where contaminants can be controlled and at the boundary of a “clean zone” or “cold zone”. The location shall also be selected to prevent equipment from being exposed to additional or other contamination. When Site layout and size allow, a formal “contamination reduction zone” or “warm zone” shall be established in which decontamination efforts will be conducted. This area shall be conspicuously marked as “off-limits” to all personnel not involved with the decontamination process.

The equipment decontamination facility or area shall also be located where decontamination fluids and materials can be contained and easily discarded or discharged into controlled areas of waste. This facility or area shall have adequate space for the storage of unused and used storage containers, until such time as they can be relocated or disposed of.

4.2.2 Decontamination Pad

Some Site may have an existing decontamination pad. If a decontamination pad has been previously constructed, it shall be evaluated for logistics capabilities, such as water supply, electrical power, by-product handling capabilities, and cleanliness. An existing decontamination pad shall be used or modified to the extent practical. If a decontamination pad is not present or the existing pad cannot be used or modified for use, a pad consisting of a sturdy base, lined with plastic sheeting of high-density polyethylene with four raised sides and a sump for collection of fluids will be constructed unless otherwise specified by the Site-Specific Work Plan. Some field activities, which consist of hand sampling or other small equipment, may not require a decontamination pad. In these cases, buckets, small wash tubs, or small pools may be sufficient for equipment decontamination.

4.2.3 Water Supply

Large volumes of water, often exceeding 1,000 gallons per day, may be required for decontamination activities, especially for drill rigs and other large equipment. The water used for decontamination must be clean, potable water. In most cases, municipal water supplies are adequate. Private potable water supplies shall be evaluated on a case-by-case basis prior to use.

4.2.4 Cleaning Equipment and Supplies

A portable steam cleaner or high-pressure hot water washer is normally required to clean contaminated heavy machinery (e.g. drill rig, backhoe, etc.) as well as materials and associated tools. Most steam cleaners and washers are commercially available for both portable generators or supplied AC power. Site logistical considerations may dictate the type of equipment required. Typical steam cleaners/washers operated on relatively low water consumption rates (2 to 6 gallons per minute) and can be used in conjunction with other cleaning fluids mixed with the water. High-pressure steam is preferred to high-pressure water because of steam's ability to volatilize organics and to remove oil and grease from equipment. Since units tend to malfunction easily and are susceptible to frequent maintenance and repair (especially under frequent use and freezing conditions), a second or back-up unit should be available onsite or arranged for with a nearby vendor to the extent practical, for longer duration field activities.

Garden sprayers may be used for final rinsing or cleaning. However, these sprayers shall be limited to use with small hand tools and sampling equipment. Since these sprayers tend to malfunction or break down easily, a second or backup sprayer shall be maintained onsite.

Metal scrapers and brushes shall be used to physically remove heavy mud, dust, etc. from equipment prior to and during the equipment rinses. Scrapers and brushes are relatively inexpensive and shall be replaced as necessary to support cleaning activities.

Decontamination solutions may consist of the following:

- Laboratory detergent shall be a standard brand of laboratory detergent such as Alconox® or Liquinox®;
- Nitric acid solution (10 percent) will be made from reagent-grade nitric acid and deionized water;
- Cleaning solvent;
- Potable water;
- Deionized water;
- Distilled water; and
- Organic-free water.

The use of cleaning solvents shall be carefully considered prior to use with respect to safety, handling and disposal, and potential impact to analytical results and the environment.

Potable, deionized, distilled, and organic-free water should contain no heavy metals or other inorganic compounds (i.e., at or above analytical detection limits) as defined by a standard Inductively Coupled Argon Plasma Spectrophotometer (ICP) scan and no pesticides, herbicides, extractable organic compounds, and less than 5 µg/l of purgeable organic compounds as measured by a low-level GC/MS scan. The level of QA/QC required during the project to verify and document the purity of the water and the number of rinsate blanks required to verify and document the effectiveness of decontamination procedures shall be based on data quality and project objectives as specified by the Site-Specific Work and/or Quality Assurance Project Plan (QAPP). The use of non-potable or untreated potable water supply for decontamination is not acceptable.

4.3 Equipment and Vehicle Decontamination Procedures

4.3.1 General Procedures

The following procedures are presented as general guidelines and shall be followed unless otherwise required by the Site-Specific Work Plan or otherwise specified:

1. Physical removal of particles;
2. Steam or water wash with potable water to remove particles;
3. Rinse critical pieces of equipment with an approved cleaning solvent or nitric acid solution (optional and/or site-specific);
4. Steam or water wash with a mixture of detergent and potable water;

5. Steam or water rinse with potable water; and
6. Air dry.

4.3.2 Special Case – Drilling Equipment

During decontamination of drilling equipment and accessories, clean auger flights, drill rods, and drill bits as well as all couplings and threads. Generally, decontamination can be limited to the back portion of the drill rig, drill rig tires, and parts that come in direct contact with samples or casings or drilling equipment placed into or over the borehole.

Some items of drilling equipment cannot typically be decontaminated. These items include wood materials (e.g. planks), porous hoses, engine filters, etc. These items shall not be removed from site until ready to dispose of in an appropriate manner.

Other drilling equipment that requires extensive decontamination is water or grout pumps. Circulating and flushing with a potable water and detergent solution followed by potable may be sufficient to clean them. However, if high or unknown contaminant concentrations or visible product is known to exist, then disassembly and thorough cleaning of internal parts shall be required before removal of the equipment from the Site.

4.4 Sampling Equipment Decontamination Procedures

4.4.1 General Procedures

Sampling equipment shall be decontaminated prior to its 1) initial use onsite 2) reuse at another sampling interval or location, and 3) demobilization from Site using the following procedure as general guidelines unless otherwise required by the Site-Specific Work Plan or otherwise specified:

1. Physical removal of particles;
2. Rinse with an approved cleaning solvent or nitric acid solution (optional and/or site-specific);
3. Wash and scrub with a detergent and potable water solution;
4. Rinse with potable water;
5. Rinse with high-grade water (deionized, distilled, or organic-free);
6. Air dry; and

7. Wrap in aluminum foil, shiny side out, for transport.

4.4.2 Special Cases

Steel tapes, water and interface probes, transducers, and thermometers, shall be cleaned with a detergent solution and rinsed with high-grade water. Water quality meters shall be rinsed with high-grade water.

Pumps typically require extensive decontamination. Circulating and flushing with a potable water and detergent solution followed by potable water is generally not acceptable for pumps using for sample collection. Pumps shall be disassembled and internal parts thoroughly cleaned with a detergent solution followed by potable water rinse and a high-grade water rinse.

4.5 Well Material Decontamination Procedures

Decontamination of well construction materials, including end cap, screen, and riser pipe, whether polyvinyl chloride (PVC), stainless steel, or other material will be addressed in the Site-Specific Work Plan. Well construction materials shall be handled while wearing latex, nitrile, or equivalent gloves.

4.6 Equipment Segregating and Labeling

Decontaminated equipment shall be stored separating from contaminated equipment in a manner that prevents the recontamination of “clean” equipment. Equipment that is cleaned utilizing these procedures shall receive a final decontamination process at the completion of field activities and will be tagged, labeled, or marked with the date that the equipment was cleaned.

4.7 Disposal Practices

4.7.1 General Disposal Requirements

Disposal practices shall be in accordance with the procedures specified in the Site-Specific Work Plan. Decontamination derived waste shall be contained, consolidated, and disposed shall be conducted to prevent the spread of contaminants offsite or to "clean" locations onsite and in a manner consistent with the acceptable disposal practices for the type and concentration of wastes that may be contained in the decontamination derived waste. Contaminated equipment or solutions shall not be discarded in any manner that may lead to the contamination of the environment by the migration of hazardous constituents from the Site by air, surface, or subsurface transport mechanisms.

4.7.2 Onsite Storage, Treatment, and Disposal

On controlled, secured facilities, most decontamination derived waste shall remain onsite pending waste characterization and disposal. The decontamination derived waste shall be labeled and stored in a manner that does not pose a threat to contamination of personnel or areas to be sampled or a threat of release to the environment. Liquids and solids shall be containerized separately in approved storage containers. Each storage container shall be labeled with the following:

- Contents (e.g. decontamination fluids);
- Incompatibilities (if applicable);
- Accumulation date; and
- Contact person and phone number.

In some cases, an onsite treatment system is available for certain types of decontamination derived waste. Treatment of decontaminated derived wastes shall be performed in accordance with any applicable permit requirements and federal, state, and local laws and regulations.

In some cases, certain materials that are not contaminated or contain very low levels of contamination may be disposed of onsite. Such materials may include may include drill cuttings, wash water, drilling fluids, and water removed during the purging or sampling of wells. The low level of contamination (concentrations below applicable cleanup objectives) shall be confirmed prior to onsite disposal. Onsite disposal shall comply with federal, state, and local laws and regulations.

4.7.3 Offsite Disposal

In most cases, decontamination derived waste cannot be disposed of or treated onsite. Decontaminated derived waste shall be properly characterized prior to shipment to a licensed and approved treatment, storage, and disposal facility. Decontamination fluids discharged to sanitary and/or storm sewers shall be properly permitted prior to discharge. Offsite disposal shall comply with federal, state, and local laws and regulations.

5.0 DOCUMENTATION

Decontamination activities, including deviations for general procedures, shall be recorded in the field logbook and/or on the appropriate field form as specified in SOP SAS-01-01 or as required by the Site-Specific Work.

6.0 REFERENCES

ASTM International, D5088-02 Practices for Decontamination of Field Equipment Used at Waste Sites.

USEPA, Region IV, 2001, Environmental Investigations Standard Operating Procedures and Quality Assurance Manual (EISOPQAM), Enforcement and Investigations Branch, SESD, Athens, Georgia.

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/60/B-07/001.

SOP SERIES SAS-05
SUBSURFACE INVESTIGATION METHODS

STANDARD OPERATING PROCEDURE NO. SAS-05-01

SUBSURFACE EXPLORATION CLEARANCE Revision 0

1.0 PURPOSE

The purpose of this standard operating procedure (SOP) is to ensure intrusive site activities are conducted with the knowledge and approval of property owners, utility providers, and governmental agencies, as appropriate, in a manner that minimizes potential exposure to subsurface hazards and damage to subsurface utilities. Clearance of intrusive activity areas must be obtained from appropriate authorities and site operators. This clearance comes in the form of 1) permission to enter a property, 2) ensuring subsurface conditions will not be encountered that endanger the safety of site personnel, subcontractors, and authorized visitors, and 3) demarcation of subsurface utilities/structures.

2.0 HEALTH AND SAFETY WARNING

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

3.0 SITE ACCESS AND ENTRY

Access to properties subject to activities conducted under the contracted scope of services/work order is the responsibility of the client as set forth in the environmental engineering and consulting services agreement. The client will give reasonable access to client-owned properties for performance of services. If the client does not own or operate the property, it will secure an access agreement or other authorization for consultant access to the site that will address the terms of access as well as any access restrictions.

Site entrance procedures are as follows:

- The client will be advised of the date and time of site entrance and the purpose of the entrance.
- In addition, if the site is not owned by the client, the owner of the property will be advised of the date and time of site entrance and the purpose of the entrance.
- Entrance to the site shall be through the main gate or other entrance specified by the client or owner.
- If a site contact is present at the site, the consultant will introduce herself/himself and provide the site contact with a business card. The consultant shall also identify other personnel who are or will be on-site and explain their functions.
- The consultant will complete any general sign-in procedures required for site entrance, unless otherwise instructed by the client or property owner.
- If a liability waiver is presented that is not pre-agreed to by the consulting company and the client or owner, the consultant will call her/his Project Manager for instructions.
- If entry is refused, the consultant will leave the site entrance and call her/his Project Manager for instructions.
- The time of site entrance, or refusal of entrance will be included in the field logbook entry for the day.

4.0 SITE CLEARANCE

Site clearance is required prior to commencement of any investigation or remediation activities. Three categories of site clearance are required:

1. Property boundary identification,
2. Utility clearance, and
3. Clearance of any on-site subsurface obstructions, hazards or protected structures identified by the client or property owner.

4.1 Property Boundary Identification

The first step in site clearance is to demarcate the property boundaries. A client- or property owner-provided plat of survey will be used if available. If no current plat of survey is available, the client or property owner may be asked to have a licensed surveyor conduct a survey and mark the property boundaries or the consultant may hire a surveyor to conduct the survey on behalf of the client. All property boundaries should be fully known and marked prior to commencement of any site investigation activities. If an investigation location appears to be outside of the property boundaries that encompass the area to which access has been granted, the Project Manager shall be consulted prior to commencement of any activity at that location.

4.2 Utility Clearance

Written clearance of all underground utilities (private, commercial, and public) must be obtained prior to commencing intrusive site activities (e.g. soil borings, GeoProbe advancement, test pit or trench excavation). Utility clearance is vital for safe operations and provides notification to utility companies of intrusive work being conducted in the vicinity of underground lines and structures. The utility clearance process is initiated by calling a state- or city-specific one-call utility clearance hotline. One-call center information may be obtained by calling “811” or visiting http://www.call811.com/state-specific.aspx. Generally, utility clearance must be requested at least 48 hours in advance of the commencement of intrusive activities. In some states, including Illinois, utility clearance is the responsibility of the contractor performing the intrusive work (e.g. drilling subcontractor or excavation company) rather than the contracting environmental consultant.

Assemble the following information to make the call or provide this information to the subcontractor:

- Name, address and phone number of person making request;
- Type and extent (size of excavation) of work being performed;
- Start date and time of excavation;
- Address, including street, number, city, and county (township range, section and quarter section information may also be required);
- Nearest crossroad; and
- General legal description, if available.

The following table lists the one-call-center contact information for the Midwest.

	One Call System Name	Non-Emergency	Emergency	Website
Illinois (except City of Chicago)	J.U.L.I.E. Joint Utility Locating Information for Excavators	(800) 892-0123	- - -	http://www.illinois1call.com
City of Chicago	DIGGER	(312) 744-7000	- - -	http://www.cityofchicago.org
Indiana	I.U.P.P.S. Indiana Underground Plant Protection Service	(800) 382-5544	- - -	http://www.iupps.org
Iowa	Iowa One Call	(800) 292-8989	(800) 292-8989	http://www.iowaonecall.com
Kansas	Kansas One Call	(800) 344-7233	- - -	http://kansasonecall.com
Michigan	MISS DIG System Inc.	(800) 482-7171	- - -	http://www.missdig.org/MissDig/
Missouri	Missouri One Call System	(800) 344-7483	- - -	http://www.mo1call.com
Wisconsin	DIGGER	(800) 242-8511	(800) 500-9592	http://www.diggershotline.com

Utility location agencies may only mark-out utilities on public right-of-ways adjacent to the property under investigation and sewer and water departments may not be included in the locating services provided by the one-call centers. Request additional information from any utility companies or public utilities departments not included in the one-call locating services. It may be advisable at some properties to hire a private utility locating contractor to do additional on-site clearance prior to commencement of intrusive activities. Consult with the Project Manager about conducting additional locating activities if the information provided by the one-call center is not complete with respect to what is known about possible underground utilities at the site.

Do not proceed with any intrusive activities until all utility clearances and mark-outs have been performed by the locating services or participating utility companies. Do not proceed without verification from the subcontractor that the utility clearance has been performed if it was the subcontractor’s responsibility to request the utility locating service. Prior to start of intrusive activities, walk the site and surrounding public right-of-way with the subcontractor locating any utility markers and discuss procedures for avoiding marked utilities during the site investigation. If at any time, a potential hazard exists at a proposed investigation location that cannot be resolved with available information and utility location markings, contact the Project Manager for instructions.

4.3 On-Site Subsurface Obstructions, Hazards and Protected Structures Clearance

The property owner (client or third party) or a designated representative shall also be contacted prior to commencement of any intrusive activities to obtain additional information regarding on-site subsurface obstructions, hazards or protected structures and clearance to conduct the activities in pre-determined locations on the site. If possible, as part of the investigation planning activities, obtain architectural or engineering drawings of the site that include building layouts and locations of subsurface utilities and structures. Schedule an on-site meeting prior to commencement of activities to review locations of proposed locations for intrusive activities. Request that the owner or his authorized representative mark or flag the locations of any known subsurface obstruction, hazard or structure that must not be damaged. In some cases, it may be appropriate to make a site visit prior to the on-site review meeting to mark out proposed subsurface investigation locations for approval by the owner or his representative. During the review meeting, if verbal approval is given to proceed, make an entry in the field logbook including the date, time and person granting approval along with details of the approval given. Record any refusals of permission to perform intrusive activities in the same manner. Include detailed information regarding the reason for the refusal in the field logbook.

If permission for any proposed intrusive activities is refused by the property owner or his representative, inform the Project Manager. If the investigation location approval meeting is performed on a day scheduled for investigation activity, and any locations are not authorized by the owner or his representative, contact the site manager immediately for instructions. Do not proceed with any intrusive activity in the non-authorized locations unless subsequent approval is forthcoming, and do so only upon receiving approval to proceed from the owner/representative and the site Project Manager. Make a detailed record of the refusal and subsequent resolution in the field logbook.

On vacant or undeveloped sites, or sites located in remote areas, on-site client/owner approval of investigation areas may not be practical. In such situations, prior approval of investigation areas may be obtained from the client or owner by means of a site investigation map that includes investigation locations (boreholes, test pit or trench locations, monitoring wells, etc.). Site features, boundary lines, and any known subsurface utilities or structures shall also be included on the site investigation map to provide the reviewer with adequate information to determine if any subsurface hazards exist in the vicinity of any of the proposed intrusive activities.

5.0 REFERENCES

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001

USEPA, Region IV, 2001, Environmental Investigations Standard Operating Procedures and Quality Assurance Manual (EISOPQAM), Enforcement and Investigations Branch, SESD, Athens, Georgia

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STANDARD OPERATING PROCEDURE
NO. SAS-05-02

FIELD LOGGING AND CLASSIFICATION OF SOIL AND ROCKS
Revision 0

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for logging and classifying soil samples and rock cores during subsurface explorations as described in the Site-Specific Work Plan, or as otherwise specified, for the purposes of characterizing subsurface geologic conditions at a Site.

2.0 EQUIPMENT AND MATERIALS

General:

- Ruler or tape measure in 0.01-foot increments;
- Field logbook and field boring log forms;
- Pen(s) with waterproof, non-erasable ink;
- Camera;
- 5-gallon bucket and wire or nylon brushes, decontamination water, laboratory grade detergent (Alconox or similar), and paper towels;
- Aluminum foil or roll-plastic; and
- Personnel protective equipment, as appropriate, including nitrile gloves for handling impacted soil samples.

Soil Logging:

- Large sharp stainless-steel knife;
- Slim stainless-steel spatula or carpenter's 5-in-1 tool;
- Color chart;
- Comparative charts; and
- Pocket penetrometer.

Rock Coring and Logging:

- Core box(es);
- Hand lens; and
- Comparative charts.

3.0 HEALTH AND SAFETY

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 DRILLING METHODS SELECTION

It is advisable to select several alternative methods and be prepared to use them if field conditions dictate a drilling technique change. Drilling methods should be selected based on the following factors:

- The expected nature of the subsurface materials to be encountered in the boring;
- Site accessibility, considering the size, clearance, and mobility of the drilling equipment;
- Availability of drilling water and the acceptability of drilling fluids in the well;
- Diameter and depth of the well desired, including consideration of the need to set casing to prevent commingling of different transmissive zones; and
- The nature and effects of contaminants expected during the drilling.

5.0 GENERAL PROCEDURES

Geologic logging and material classification shall be conducted only by a trained logging technician (e.g. geologist, hydrogeologist, engineer, or environmental scientist). Field data and observations associated with field logging and material classification shall be documented during logging and for all drilling and sampling activities in accordance with SOP SAS-01-01, Field Documentation and Reporting, if not otherwise specified in this SOP. All field drilling activities should be recorded in a field logbook and/or on a field boring log form. In addition, tools and equipment used while logging boreholes shall be decontaminated between boring/probe locations and prior to each sampling event in accordance with the Quality Assurance Project Plan (QAPP).

6.0 LOGGING AND DOCUMENTATION PROCEDURES

The logging technician shall record all pertinent drilling information in the field logbook and/or on the field boring log form (Attachment A). At a minimum, the following technical information with respect to pre-sampling, drilling operations and observations, and sample recovery loss shall be recorded, if applicable:

- Project name and number;
- Location (well or boring/probe number) or other sample station identification, including a rough sketch;
- Name of the logging technician overseeing the drilling operations;
- Drill rig manufacturer and model;
- Drilling company name and city and state of origin;
- Driller and assistant(s) names;
- Drilling method(s) and fluids used to drill the borehole;
- Drilling fluid manufacturer;
- Drilling fluid gain or loss;
- Depth of drilling fluid loss;
- Water source (e.g. fire hydrant, faucet, municipality, etc.);
- Borehole diameter;
- Borehole start time and date;
- Borehole completion time and date;
- Sample type (e.g. split spoon, macrocore, etc.);
- Hammer weight/drop and blow counts;
- Sample recovery/loss and explanation of loss, if known;
- Description of soil and/or rock classification and lithology;
- Lithologic changes and boundaries;

- Depth to water (first encountered [during drilling] and stabilized [upon completion of drilling]);
- Total borehole depth;
- Evidence of impact (e.g. staining, odors, free-phase product, etc.);
- Well materials, construction, and placement information (e.g. casing type and diameter, screen type and diameter, etc.);
- Sample identifications and depths for chemical and geotechnical samples;
- A description of any tests conducted in the borehole; and
- Problems with the drill rig or drilling process.

When rock coring is performed, the following information shall also be recorded:

- Top and bottom of cored interval;
- Core length;
- Coring rate in minutes per foot;
- Core breakage due to discontinuities (e.g. natural fractures versus coring-induced breaks);
- Total core breakage; and
- Number of breaks per foot.

7.0 SOIL SAMPLE CLASSIFICATION AND DESCRIPTIONS

7.1 Description of Hierarchy

The required order of terms is as follows:

1. Depth measured in tenths of a foot;
2. Soil color;
3. Major soil type (e.g. CLAY). This descriptor can include the secondary soil constituent as a modifier (e.g. silty CLAY);
4. Unified Soils Classification System (USCS) Group Symbol in parentheses (e.g. ML);
5. Evidence of environmental impacts, if encountered (e.g. free-phase product, staining, sheen, etc.);
6. Other soil components of the sample listed with the appropriate percent descriptor (i.e. “with”, “some” or “trace.”);
7. Consistency, relative density or degree of cementation;

8. Moisture and plasticity, if relevant; and
9. Miscellaneous (e.g. condition of sample, deposition, fractures, seams, bedding dip, bedding features, fossils, oxidation, etc.).

7.2 Color

The color descriptions will be consistent with the Munsell Soil Color Chart, Geological Society of America (GSA) Rock Color Chart, or as required by the Work Plan or otherwise specified. Write the Munsell color name with the Munsell color identification number in parenthesis following the color name. The major color is listed first with any accessory color(s) thereafter (e.g. clay, yellowish gray (5Y 7/2) with pale green (5G 7/2) mottles). If descriptors are used for other soil components, the color designation follows each descriptor.

7.3 Soil Types

Soil descriptions and classification shall be conducted in accordance with the USCS (ASTM D2488-06). The order and presentation of the primary textural classification terms is as follows:

1. Major soil type (e.g. CLAY). This descriptor can include the secondary soil constituent as a modifier (gravelly, sandy, silty, or clayey). Nouns are unabbreviated (e.g. CLAY); “TOPSOIL” is an adequate single term for the naturally occurring organic soil found at the ground surface. In urban areas, “FILL” is used to denote previously disturbed soil, followed by a description of the major and minor soil components (e.g. “FILL, silty clay with some fine sand”). USCS Group Symbol follows the major soil component in parentheses.
2. Other soil components of the sample are listed in descending order of percentage using adjectives “with”, “some” and “trace.”
3. Using the Wentworth Scale in Attachment E, add size, sorting or angularity modifiers to granular material descriptions as appropriate.

7.4 Consistency and Relative Density

The relative density of cohesionless soils and the consistency of cohesive soils should be included in visual classifications. Attachments B and C can be used in describing the consistency of cohesive soils and the relative density of cohesionless soils, respectively.

A pocket penetrometer will be used to measure consistency of cohesive soils with the result recorded on the field boring log form. Attachment B includes information for determining soil consistency from penetrometer measurements.

7.5 Moisture Content

Moisture Content – Criteria for describing moisture content of soils are described in Attachment D.

7.6 Miscellaneous Descriptions

1. Structure – Some soils possess structural features (e.g. fissures, slickensides, or lenses) that if present, should be described.
2. Accessories or Inclusions – Elements such as rock fragments, fine roots, or nodules are included in the soil description following all other modifiers for the major components of the soil matrix. Any mineralogical or other significant components should be described, as well as man-made or apparently foreign constituents that indicate the presence and possible source of fill material.
3. Environmental Impacts – If monitoring instruments or visual observations indicate the potential presence of environmental impacts, it will be noted in detail. Additional information for describing specific types of impacts may be found in the Work Plan.

To provide consistency in logging soils, tables with additional guidelines for soil description are included in Attachment E.

8.0 ROCK CLASSIFICATION

8.1 Lithology and Texture

The logging technician should describe the lithology of the rock and its mineral composition. The geological name, such as granite, basalt, or sandstone, usually describes the rock's origin. The stratigraphic unit should be identified and assigned the local geological name, if appropriate. Stratigraphic age or period should be identified, if possible. Modifiers will be included to describe the rock texture, including grain size, sorting, packing, cementation, etc. (e.g. interlocking, cemented, or laminated-foliated).

8.2 Color

The color descriptions will be consistent with the Munsell Soil Color Chart, Geological Society of America (GSA) Rock Color Chart, or as required by the Work Plan or otherwise specified. Write the Munsell color name with the Munsell color identification number in parenthesis following the color name. The major color is listed first with any accessory colors thereafter. If secondary or tertiary descriptors are used, the color designation follows each descriptor.

8.3 Hardness

Terms used to describe hardness are described below. One common method to determine hardness is the Mohs Scale of Hardness, which is defined as follows:

Descriptive Term	Defining Characteristics
Very Hard	• Cannot be scratched with a knife. • Does not leave a groove on the rock surface when scratched.
Hard	• Difficult to scratch with a knife. • Leaves a faint groove with sharp edges.
Medium	• Can be scratched with a knife. • Leaves a well-defined groove with sharp edges.
Soft	• Easily scratched with a knife. • Leaves a deep groove with broken edges.
Very Soft	• Can be scratched with a fingernail.

8.4 Weathering

Terms used to describe weathering are described below (ASTM D 5434-03):

Descriptive Term	Defining Characteristics
Fresh	• Rock is unstained. • May be fractured, but discontinuities are not stained.
Slightly	• Rock is unstained. • Discontinuities show some staining on the surface, but discoloration does not penetrate rock mass.
Moderate	• Discontinuous surfaces are stained. • Discoloration may extend into rock mass along discontinuous surfaces.
High	• Individual rock fragments are thoroughly stained and can be crushed with pressure of a hammer. • Discontinuous surfaces are thoroughly stained and may crumble.
Severe	• Rock appears to consist of gravel-sized fragments in "soil" matrix. • Individual fragments are thoroughly discolored and can be broken with fingers.

8.5 Rock Matrix Descriptions

Grain size is a term that describes the fabric of the rock matrix. It is usually described as fine-grained, medium-grained or coarse-grained. The modified Wentworth scale should be used or as required by the Work Plan or otherwise specified.

A description of bedding (after Ingram, 1954) or fracture joint spacing should be provided according to the following:

Spacing	Bedding	Joints/Fractures
< 1 inch	Very thin	Very close
1 – 4 inches	Thin	Close
4 inches to 1 foot	Medium	Moderately close
1 foot to 4.5 feet	Thick	Wide
> 4.5 feet	Very Thick	Very Wide

Discontinuity descriptors are terms that describe number, depth, and type of natural discontinuities. They also describe density, orientation, staining, planarity, alteration, joint or fractural fillings and structural features.

9.0 ROCK CORE HANDLING

The following guidelines shall be followed for rock core handling:

1. Core samples must be placed into core boxes in the sequence of recovery, with the top of the core in the upper left corner of the box.
2. At the bottom of each core run, spacer blocks must be placed to separate the runs. The spacer should be indelibly labeled with the drilling depth to the bottom of the core run regardless of how much core was actually recovered from the run.
3. Spacer blocks should be placed in the core box and labeled appropriately to indicate zones of core loss, if known. Where core samples are removed for laboratory testing, blocks equal to the core length removed should be placed in the box. Note: If wooden core boxes are used, spacer blocks should be nailed securely in place.
4. The core boxes for each boring should be consecutively numbered from the top of the boring to the bottom.
5. The core boxes containing recovered rock cores should be photographed. One core box should be photographed at a time with the box lid framed in the picture to include information printed on the inside of the lid. Be sure to include a legible scale in the picture. Photographs are taken in the field most easily and efficiently with natural light and while the core is fresh.
6. When transporting a boxed core, the box should be moved only if the lid is closed and secured with tape or nails.

10.0 REFERENCES AND ADDITIONAL RESOURCES

ASTM International, 2007, D653-07b Terminology Relating to Soil, Rock, and Contained Fluids.

ASTM International, 1999, D1586-99 Standard Method for Penetration Test and Split-Barrel Sampling of Soils.

ASTM International, 2006, D2488-06 Practice for Description and Identification of Soils (Visual-Manual Procedure).

ASTM International, 2001, D4083-89R01E01 Practice for Description of Frozen Soils (Visual-Manual Procedure).

ASTM International, 2007, D4543-07 Practice for Preparing Rock Core Specimens and Determining Dimensional and Shape Tolerances.

ASTM International, 2002, D5079-02 (2006) Practice for Preserving and Transporting Rock Core Samples.

ASTM International, 2003, D5434-03 Guide for Field Logging of Subsurface Explorations of Soil and Rock.

ASTM International, 2000, D5715-00 (2006) Test Methods for Estimating the Degree of Humification of Peat and Other Organic Soils (Visual/Manual Method).

ASTM International, 2004, D6236-98 (2004) Guide for Coring and Logging Cement- or Lime-Stabilized Soil.

ASTM International, 2004, D7099-04 Terminology Relating to Frozen Soil and Rock.

Johnson, R.B., and J.V. DeGraff, 1988, Principles of Engineering Geology, John Wiley and Sons, New York.

U.S. Army Corps of Engineers, 2001, Engineering Manual EM1110-1-1804 - Engineering and Design - Geotechnical Investigations, January 1.

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001.

Wentworth, C.R., 1922, A scale of grade and class terms for clastic sediments, Journal of Geology, 30: 377-392.

ATTACHMENT A
DRILLING LOG

Drilling Log

	Project Name		Project No.	Boring/Monitoring Well Number
	Site-Specific Coordinates		Ground Elevation	Page 1 of 1
	Total Depth (feet)	Hole Size (inches)	Driller (s)	
Drilling Rig			Drilling Company	
Date	To	Logged By:	Reviewed by:	Approved by:

Elevation (feet)	Depth (feet)	Description	Graphic Log	SAMPLING Sample Type	Sample Interval	Blow Counts per 0.5'	N Value	Sample Recovery/Length (feet)	Penetro-meter (TSF)	PID Reading (PPM)	Remarks (▽ Depth to water while drilling; ▼ Depth to water after drilling)
	1										
	2										
	3										
	4										
	5										
	6										
	7										
	8										
	9										
	10										
	11										
	12										
	13										

ENVIRONMENTAL LOG COPY OF OSI 2003.GPJ BURNS_MO.GDT 8/30/07

ATTACHMENT B
CONSISTENCY OF COHESIVE SOILS

CONSISTENCY OF COHESIVE SOILS

Consistency	Rule-of-Thumb	Blows Per Foot[1] (N value)[2]	Penetrometer (tons/ft^2)
Very Soft	Core (height = twice diameter) sags under own weight	0 – 1	0.0-0.25
Soft	Can be easily pinched in two between thumb and forefinger	2 – 4	0.26-0.49
Firm (Medium Stiff)	Can be imprinted easily with fingers	5 – 8	0.5-0.99
Stiff	Can be imprinted with considerable pressure from fingers	9 – 15	1.0-1.99
Very Stiff	Barely can be imprinted by pressure from fingers	16 – 30	2.0-3.99
Hard	Cannot be imprinted by fingers	> 30	4.0+

Notes:
1) Blows as measure with a 2-inch outer diameter (OD), 1 3/8-inch inner diameter (ID) sampler driven 1 foot by a 140-pound hammer falling 30 inches. See Standard Methods for Penetration Test and Split-Barrel Sampling of Soils, ASTM D1586-99.
2) N value is the sum of the blows from 6 inches to 12 inches and from 12 inches to 18 inches in the 2-foot sample.

ATTACHMENT C
RELATIVE DENSITY OF COHESIONLESS SOILS

RELATIVE DENSITY OF COHESIONLESS SOILS

Consistency	Rule-of-Thumb	Blows Per Foot (N value)[2]
Very Loose	Easily penetrated with a ½-inch diameter steel rod pushed by hand	0 - 4
Loose	Easily penetrated with a ½-inch diameter steel rod pushed by hand	4 - 10
Medium Dense	Easily penetrated with a ½-inch diameter steel rod driven with a 5-pound hammer	11 - 30
Dense	Penetrated a foot with a ½-inch diameter steel rod driven with a 5-pound hammer	31 - 50
Very Dense	Penetrated only a few inches with a ½-inch diameter steel rod driven with a 5-pound hammer	> 50

Notes:
1) Blows as measure with a 2-inch outer diameter (OD), 1 3/8-inch inner diameter (ID) sampler driven 1 foot by a 140-pound hammer falling 30 inches. See Standard Methods for Penetration Test and Split-Barrel Sampling of Soils, ASTM D1586-99.
2) N value is the sum of the blows from 6 inches to 12 inches and from 12 inches to 18 inches in the 2-foot sample.

ATTACHMENT D
CRITERIA FOR ESTIMATING MOISTURE CONTENT OF SOILS

CRITERIA FOR ESTIMATING MOSITURE CONTENT OF SOILS

Adapted from USACE EM 1110-1-1804 and ASTM D 2488-06

Term	Description of Relative Moisture
Dry	Absence of moisture, dusty, dry to the touch
Moist	Damp, no visible water
Wet	Fine grained: well above optimum water content Coarse grained: visible free water
Saturated	Water is dripping from sample, usually encountered below water table

ATTACHMENT E
STANDARD SOIL DESCRIPTORS

STANDARD SOIL DESCRIPTORS

Grain Size Terminology		
Soil Type		**Diameter**
Boulders		12-inches or greater
Cobbles		3- to 12 inches
Gravel	Coarse	0.75-inch to 3 inches
	Fine	0.19-inch to 0.75-inch
Sand	Very Coarse	1 mm to 2 mm
	Coarse	0.5 mm to 1 mm
	Medium	0.25 mm to 0.5 mm
	Fine	0.06 mm to 0.25 mm
Silt		0.004 mm to 0.06 mm
Clay		Less than 0.004 mm

Notes:
1) mm = millimeter
2) Based on Wentworth Grain Size Scale for Sediment (Wentworth 1922).
3) This terminology can also be used to describe clast size in rock cores.

Estimated Plasticity for Silt and Clay Content		
Thread Diameter (inches)	**Plasticity Index (PI)**	**Identification**
1/4	0	Silt
1/8	5 – 10	Clayey Silt
1/16	10 – 20	Clay and Silt
1/32	20 – 40	Silty Clay
1/64	40	Clay

Relative Proportions of Components	
Descriptive Term	**Percent**
Trace	1 – 10
Little	11 – 20
Some	21 – 30
And	30 – 50

Adapted from ASTM D2488-06

STANDARD OPERATING PROCEDURE
NO. SAS-05-03

WELL INSTALLATION
Revision 0

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for the installation of monitoring wells, observation wells, and recovery/injection wells as described in the Site-Specific Work Plan, or as otherwise specified. Monitoring and observations wells are installed to 1) determine depth to groundwater and monitor fluctuations in groundwater elevation, 2) determine and monitor the depth and thickness of free-phase products (if present), 3) obtain groundwater and/or free-phase product samples for laboratory analysis, and 4) facilitate aquifer characterization. Recovery wells are installed to conduct testing and operation of systems for groundwater pumping, free-phase product recovery, and aquifer injection.

2.0 EQUIPMENT AND MATERIALS

Field personnel shall use the well construction equipment and materials required by the Site- Specific Work Plan, or as otherwise specified.

3.0 HEALTH AND SAFTEY

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 CONSIDERATIONS

4.1 General requirements

Well installation procedures should meet regulatory agency requirements. In addition, licensing and/or certification of the driller may be required. A trained supervising technician (e.g. geologist, hydrogeologist, engineer, or environmental scientist) should be present during well installation to document the subsurface stratigraphy and construction details for each well.

The well designs should meet two basic criteria: 1) groundwater and/or other fluids (e.g. free-phase product) must move freely into the well, and 2) vertical migration of surface water or undesired groundwater to the well intake zone must, to the extent possible, be eliminated. In addition to these criteria, factors that influence the location of wells should be considered and include the following:

- Project objectives of the Site-Specific Work Plan;
- Data Quality Objectives outlined in the Quality Assurance Project Plan (QAPP);
- Location of facilities and/or source areas to be monitored;
- Groundwater gradient;
- Location of aboveground and underground utilities and manmade features; and
- Accessibility to desired well location sites.

4.2 Well Installation Materials Selection

Materials used in the construction of wells must remain essentially chemically inert with respect to free-phase products and dissolved contaminants in the groundwater for the duration of the investigation period remedial action.

The most commonly used well construction materials are PVC and stainless steel. PVC is the least expensive and easiest material to use. It is generally believed that PVC does not decompose in contact with groundwater containing low concentrations of organics. Stainless steel is chemically inert, provides greater structural strength, and its use may be advantageous for large-diameter wells or groundwater containing high concentrations of organics or free-phase products. Teflon casing is chemically inert but is very expensive.

Well casing and screen are available in threaded or unthreaded sections and typically in lengths of 5, 10, and 20 feet. Threaded pipe joints may be wrapped with Teflon tape to facilitate joining and to improve the seal. Sections of casing and screen should be assembled onsite to allow inspection immediately before installation. No solvents or adhesive compounds should be used on the threaded PVC or Teflon pipe.

Well materials should be cleaned before well installation. Two methods are acceptable: high-pressure hot water or steam, and detergent wash and distilled rinse. The former is preferred because it is easier and faster.

4.3 Well Types and Construction Specifications

4.3.1 Monitoring and Observation Wells

Monitoring and observation wells construction should be performed as outlined in the Site-Specific Work Plan or as otherwise specified. In general, the design of the wells consists of a section of slotted well casing or well screen connected to a riser pipe that extends above the ground surface. Typically, a gravel or sand filter pack is placed in the annular space between the screen and the borehole wall. A 2-foot seal composed of hydrated bentonite pellets/chips is placed on top of the filter pack. The remaining height of annulus is sealed and/or grouted to the surface with a cement, bentonite/cement, or high solid bentonite grout. A lockable protective casing is constructed over the stick-up portion of the wells. The diameter of the borehole and the inside diameter of any drill casing or hollow stem auger should generally be at least 3 inches greater than the outside diameter of the well casing and screen. This annular clearance facilitates the placement of the filter pack and grout around the outside of the well screen and casing. The monitoring well screens are generally installed at the level of the water table, typically 10 to 15 feet long, to adequately monitor seasonal fluctuation of the water table. This SOP discusses stick-up well construction; however, flush-mount well construction may also be used as outlined in the Site-Specific Work Plan or otherwise specified.

4.3.2 Recovery/Injection Wells

Construction specifications for recovery/injection wells can vary based several factors including, but not limited, to 1) the type(s) of recovery/injection to be performed, 2) engineering evaluation objectives, 3) data quality objectives, and 3) site geology. Recovery/injection wells should be constructed as outlined in the Site-Specific Work Plan, or otherwise specified.

4.4 Borehole Advancement

4.4.1 General

Boreholes used to install wells should be drilled with the following objectives:

- To provide geological data on subsurface conditions, namely stratigraphy, occurrence of groundwater, and depth to bedrock;
- To obtain representative disturbed or undisturbed samples for identification and laboratory testing; and
- To install wells.

Prior to drilling, the following steps must be taken:

- Obtain permits from appropriate local, state, and/or federal agencies. If there is a fee for permits, drilling subcontractors usually include this as part of their fee.
- Notify (verbally or in writing) the appropriate local, state, and/or federal authorities, as appropriate, in advance of the date that drilling and installation is scheduled to begin;
- Perform a subsurface utility clearance, as outlined in SOP SAS-05-01, at all planned drilling locations;
- Prepare and implement field health and safety procedures as outlined in the HASP(s); and
- Make provisions for containment, storage, and disposal of all cuttings, drilling fluids, discharge water, and other refuse generated during well installation. Note: Permitting and waste characterization may be necessary prior to disposal activities.

4.4.2 Selection of Drilling Method

Drilling methods should be selected based on the following factors:

- The expected nature of the subsurface materials to be encountered in the boring;
- Site accessibility, considering the size, clearance, and mobility of the drilling equipment;
- Availability of drilling water and the acceptability of drilling fluids in the well;
- Diameter and depth of the well desired, including consideration of the need to set casing to prevent commingling of different transmissive zones; and
- The nature and effects of contaminants expected during the drilling.

5.0 MONITORING AND OBSERVATION WELL INSTALLATION

5.1 Well Components

Typical well components in general order of placement are as followings:

1. Surface casing (if used);
2. Well casing;
3. Screen(s);
4. Filter pack (gravel or sand pack);
5. Bentonite seal;
6. Annular seal (grout);
7. Well head protector casing; and
8. Well head apron and guard posts.

Surface casing, if needed, should be installed during borehole advancement for sealing the ground surface and subsurface transmissive zones not desired to be intercepted by the well from the borehole. Surface casing may also be needed to provide lateral support for loose unconsolidated formations that may slough into or collapse around the borehole during drilling or well installation. Casing may be extended in a telescopic fashion to permit casing through intermittent transmissive zones at greater depths to limit casing size and cost requirements.

The well casing is the primary conduit to the desired borehole interval to be monitored. It serves to seal off other stratigraphic zones from the groundwater inside the well and provides unobstructed access to the well screens. The well casing extends from the top of the well screen to either above or flush with the ground surface. It is typically a single-walled pipe, flush-threaded, of the smallest diameter to facilitate sampling equipment and to support its own weight during installation.

Screens are perforated or slotted sections of casing typically of the same size and material as the well casing. The purpose of the well screen is to allow water and/or other fluids (i.e., product) to enter the well easily while preventing entry of large amounts of sediment. The slot size of the well screen is usually determined based on selection of the filter pack material. Both are commonly related to the grain size analysis of the formation material. Methods of determining appropriate screen slot size are listed in the EPA Manual of

Water Well Construction Practices (USEPA 1976). Typically, 10-slot (0.010 inch slot width) or 20-slot (0.020 inch slot width) screens are used. The length of the screen depends on the sampling objective, water level fluctuations, product thickness, and thickness of the transmissive zone of the formation.

A filter pack consisting of clean silica sand or pea gravel is placed in the annular space extending to at least 2 feet above the top of the screen. The filter pack will stabilize the aquifer formation, minimize the entry of fine-grained material into the screen, permit use of screens with different sizes of slot, and will increase the effective well diameter and water collection zone.

A bentonite seal consisting of pellets or chips should be installed above the filter pack to seal more effectively the well's water collection zone and to prevent the intrusion of overlying grout material into the filter pack. The bentonite pellets or chips should be slowly poured from the top of the borehole to prevent bridging. At least 3 feet of bentonite seal should be placed on top of the filter pack. If the bentonite seal is above the saturated zone, the bentonite pellets or chips should be hydrated with distilled water before grouting the remaining annular space. The hydrated pellets or chips should be allowed to set for a minimum of 15 minutes. Bentonite chips are preferred over pellets or balls when the seal is below the water table because the chips hydrate less rapidly and bridging is less common.

The annular space above the bentonite seal should be grouted with a cement, high-solids bentonite, or bentonite/cement grout up to 2 feet below the ground surface. The primary purpose of grouting is to minimize the vertical migration of water to the groundwater intake zone and to increase the integrity of the well casing.

A 2-foot concrete plug should be installed above the annular grout. The concrete plug is used to set the protective well cover and to prevent frost heave of the concrete pad or apron. The concrete apron should be at least 3.5 inches thick, and it should be sloped to allow water drainage away from the well.

A protective cover with a locking cap should be installed after the well has been set. This cover will protect the exposed well casing from damage and will provide security against tampering with the well. The protective cover typically consists of a steel pipe or box around the well casing. The protective cover is set at least 2 feet into the concrete plug and wellhead apron. Weep holes (approximately ¼-inch diameter) are drilled into the base of the protective cover above the concrete apron to allow drainage.

Well-head aprons and guard posts, when used, provide additional surface protection to the well and are generally used for wells in high traffic areas or where a more permanent structure is desired.

5.2 Installation Procedures

The decision to install a well at a particular location is often decided in the field upon completion of the boring and subsurface sampling. If the borehole diameter is not sufficient to install a well, either the borehole should be reamed using a larger diameter auger or a new borehole should be drilled. The new borehole should be at least 5 feet away from the initial boring. The initial soil boring should be abandoned according to the procedures outlined in SOP SAS-05-05. If a well is not installed, the boring should be abandoned in accordance with SOP SAS-05-05.

Over-drilling generally should not be conducted to provide room for a well sump or additional filter pack material at the bottom of the borehole beneath the well casing. However, for wash rotary boreholes drilled in soft or highly plastic sediments, loose cuttings may fall to the borehole bottom after backwashing. In this case, it may be necessary to install a 2-foot layer of sand or gravel at the bottom of the boring to provide a firm base on which to set the well assembly to limit settling of the well casing and screen under its own weight.

For mud rotary boreholes, excess drilling fluids should be flushed from the borehole before installing the filter pack and grout seal. This can be accomplished by one or both of the following means:

- Flush the well using the drilling equipment by pumping clean water down the drill pipe without circulating the returned fluid. This should be accomplished at low pump pressure and with care to avoid scouring or fracturing of the formations.
- Insert casing and screens with a backwash valve on the bottom end, and then flush the borehole via the well casing at low pressures. The backwash valve not only provides an outlet for flushing, but also provides pressure relief so the screens are not damaged by the backwash fluid pressures.

The latter method should be conducted only if it is determined that the former is not possible, or if the drilling fluid must remain in place in order to install the filter pack.

Connect the screen and well casing while wearing latex gloves. Insert and lower the screen and well casing into the borehole in 10-foot increments. Hand-tighten connections to prevent them from leaking or becoming loose. The final section of pipe should be measured and field cut, if necessary, before connecting to allow for a stick-up of 2½ feet. The cut end should be rasped and/or sanded smooth, taking care not to let fillings of casing material cling to the inside.

Backwash the boring, if necessary, and pour in sand or gravel to seat and support the casing and screen. Based on boring and casing diameters, determine volume of filter pack material required to place the filter approximately 2 feet above the top of the screens. Install filter pack using the following methods, as appropriate.

- Slowly pour filter material down annulus, being careful to evenly distribute the material around the casing and to avoid the material becoming packed between the sidewall and casing. Use a small-diameter pipe to dislodge packed material and to ensure adequate height and settlement of the filter pack.

- Pour filter material down tremie pipe placed between boring sidewall and casing. In this method, clean potable or distilled water should be poured in along with the sand or gravel to prevent packing within the tremie. The bottom of the tremie should be kept above the filter material top by at least 5 feet to permit the filter material to evenly fall around the screens. Pack the material with the tremie pipe to ensure adequate height and settlement of the filter pack.

Pour bentonite pellets or chips down the annulus on top of the filter pack. The bentonite should be placed rapidly to prevent swelling and bridging around the casing when it hydrates. The bentonite should be allowed to hydrate for at least 15 minutes before grouting.

The remaining annulus should be sealed by pumping grout via a tremie pipe from the bottom of the annular space of the borehole until the grout returns to the surface displacing all remaining drilling fluid and formation water. The bottom of the tremie pipe should not be placed within 4 feet of the bentonite seal. Grouting mixture and technique should be in accordance with Site-Specific Work Plan requirements, or as otherwise specified. Grout will typically settle 1 to 2 feet. Remove excess grout to allow 2 feet of annular space for the concrete plug.

After the grout has stiffened sufficiently, install the concrete plug up to the ground surface. Set the protective cover, if possible, such that at least 2 feet of its length is embedded in the concrete below the ground surface. It should also be set such that it is not more than approximately 30 to 36 inches above the level where the sampling personnel must stand. A concrete pad approximately 3 feet in diameter and 3.5 feet thick should be formed around the base of the protective cover. The concrete pad should be sloped away from the protective cover to allow flow away from the well. Weep holes should be drilled through the protective cover nominally 1 inch above the top of the concrete apron.

The protective casing should be marked with identifying decals. A locking device should be installed to prevent unauthorized entry or vandalism of the well. The top of the well casing should be notched with a file to provide a reference point in which to measure water and/or product levels. The elevation of the top of the well casing (reference point) and ground surface at the well should be surveyed relative to a benchmark. The location of the well should also be surveyed in reference to the site coordinate system as required by the Site-Specific Work Plan, or as otherwise specified.

Develop well within 24 to 72 hours following well installation according to the well development procedures outlined in SAS-05-04.

6.0 DOCUMENTATION

Documentation of well installation should be the responsibility of the supervising field technician. A generic well completion report should be prepared after the well is installed (Attachment A).

The drilling and well installation activities should be recorded in the field logbook and/or on the appropriate field forms. The following information should be recorded during and upon completions of every well installation:

- Project name and number;
- Well location identification;
- Date of installation and time completed;
- Drilling method, crew names, and rig identification;
- Drilling depths;
- Generalized subsurface stratigraphy;
- Total length of casing and screens;
- Depth to and length of screened intervals;
- Depth to top of filter pack;
- Depth to top of bentonite seal;
- Depth to top of grout;
- Depth of surface casing (if applicable);
- Elevation of top of well casing and ground surface; and
- Name of supervising field technician.

The driller must also prepare any state-required well completion forms in accordance with state regulatory requirements.

7.0 REFERENCES AND ADDITIONAL RESOURCES

ASTM International, 2004, D5092-04 Standard Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers.

ASTM International, 2005, D6001-05 Guide for Direct-Push Ground Water Sampling for Environmental Site Characterization.

ASTM International, 2004, D6724-04 Guide for Installation of Direct-Push Ground Water Monitoring Wells.

ASTM International, 2004, D67-25-04 Practice for Direct-Push Installation of Prepacked Screen Monitoring Wells in Unconsolidated Aquifers.

USEPA, 1976, Manual of Water Well Construction Practices, EPA/570/9-75/001.

USEPA, 2002, Ecological Assessment Standard Operating Procedures and Quality Assurance Manual, SESD, Region 4, Ecological Assessment Branch, Athens, Georgia.

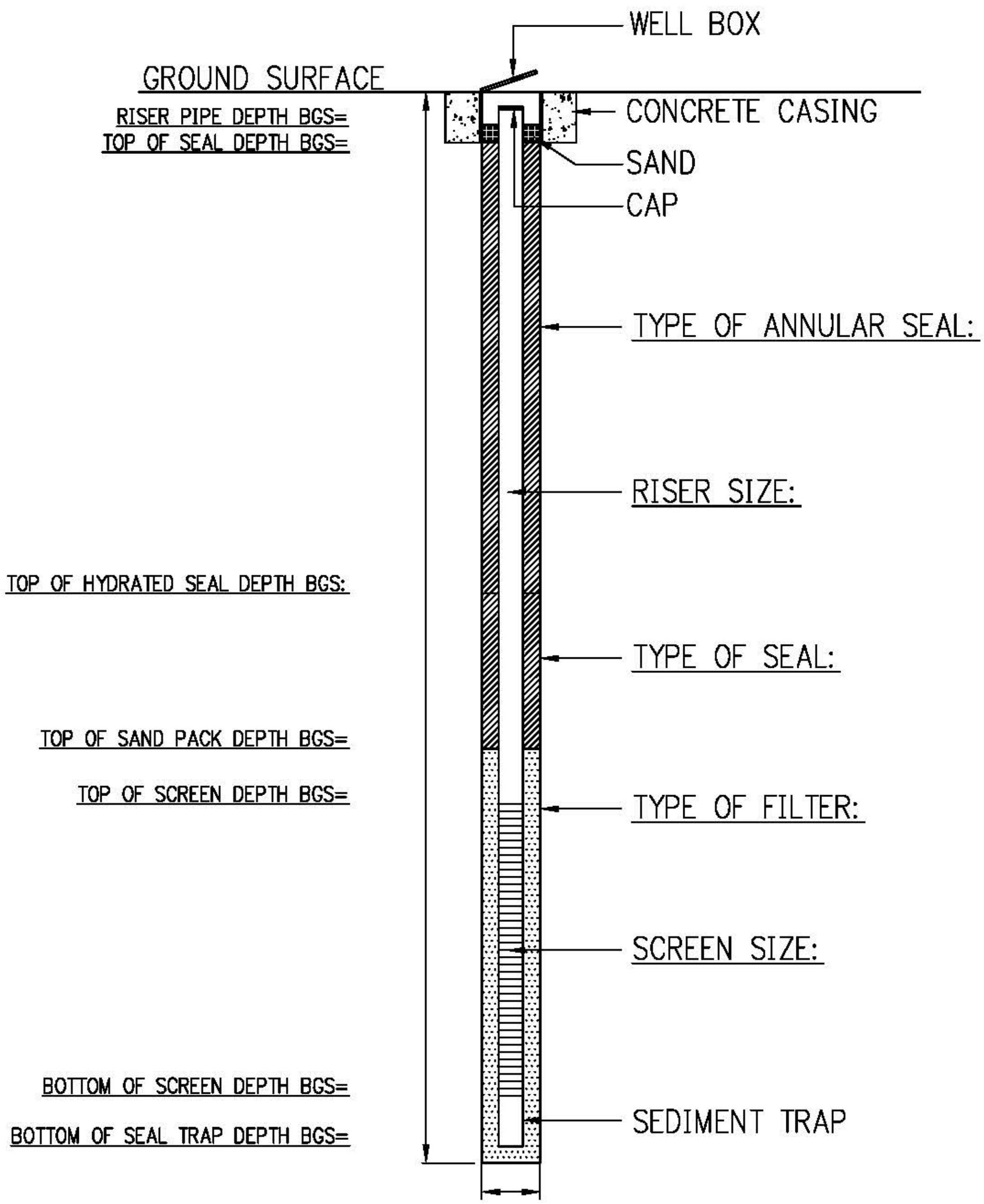
USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001.

ATTACHMENT A
WELL INSTALLATION LOGS

WELL INSTALLATION LOG

No. ________

CLIENT	COORDINATES N	PROJECT	PROJECT NO.
PROJECT LOCATION	E	TOP OF RISER ELEVATION (DATUM)	DATE
STRATUM MONITORED		LOGGED BY	
DRILLING COMPANY		APPROVED BY	



NOT TO SCALE

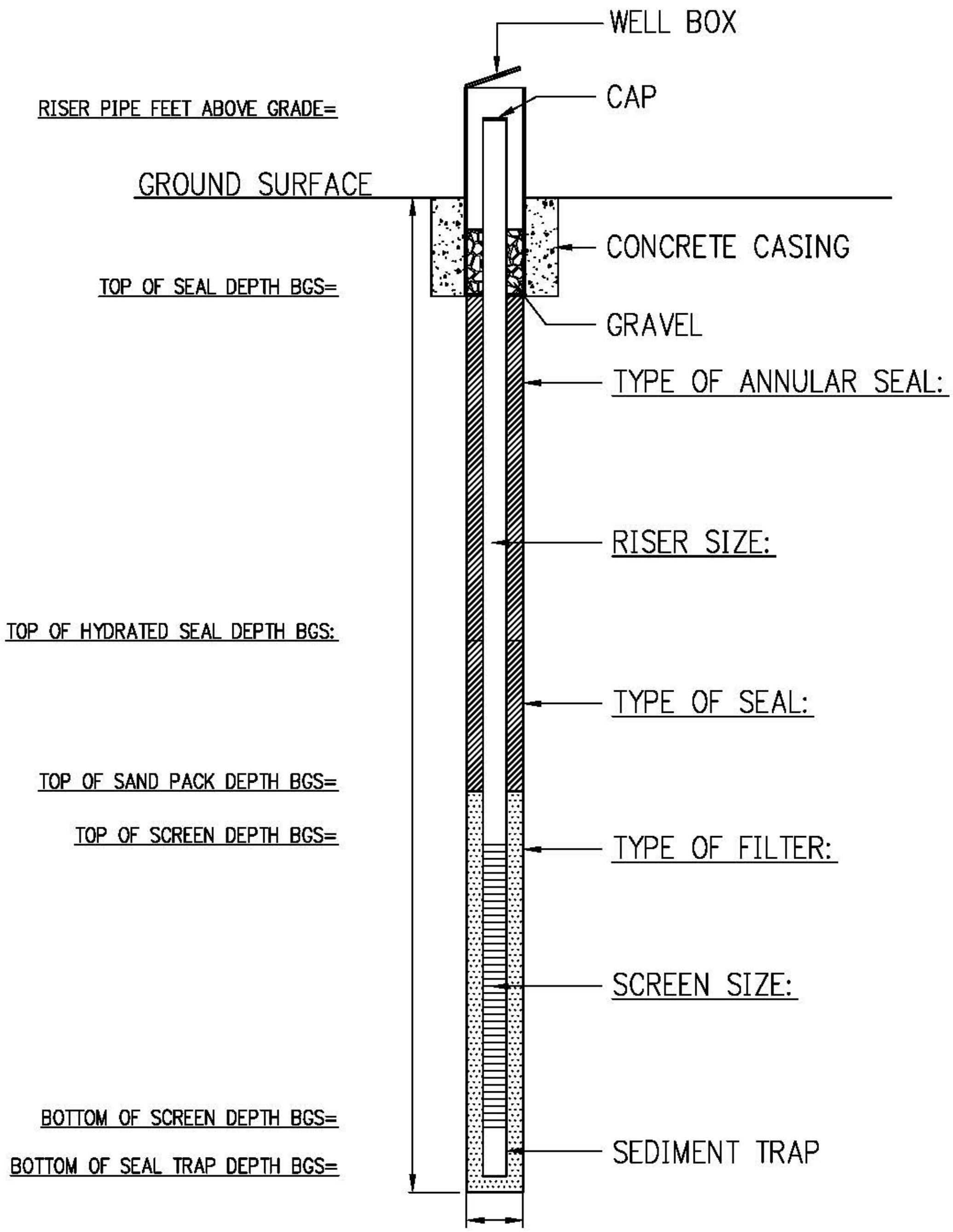
METHOD OF INSTALLATION:

REMARKS:

WELL INSTALLATION LOG

No. ________

CLIENT	COORDINATES N	PROJECT	PROJECT NO.
PROJECT LOCATION	E	TOP OF RISER ELEVATION (DATUM)	DATE
STRATUM MONITORED		LOGGED BY	
DRILLING COMPANY		APPROVED BY	



NOT TO SCALE

METHOD OF INSTALLATION:

REMARKS:

Author:	T. Gilles	Q2R & Approval By:	C. Barry	Q3R & Approval By:	M. Kelley

STANDARD OPERATING PROCEDURE
NO. SAS-05-04

WELL DEVELOPMENT
Revision 0

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for developing wells. Well development is conducted to 1) remove drilling fluids or mudcake from the filter pack, borehole wall, and formation materials, 2) remove any loose, fine-grain, formation materials (e.g. fine sand, silt, and clay) from the filter pack and well screen to eliminate, to the extent possible, impact the integrity of groundwater and/or product samples and aquifer characterization test results, and 3) restore the natural permeability of the formation adjacent to the borehole.

2.0 EQUIPMENT AND MATERIALS

Equipment and materials will vary by development method. Field personnel should use the equipment and materials required by the Work Plan or otherwise specified for the development method(s) selected for the project. All non-disposable equipment, including pumps, hoses, containers, and bailers, shall be decontaminated before and after introduction into wells. Equipment decontamination should be performed in accordance with SOP SAS-04-04 and/or requirements of the Site-Specific Work Plan.

3.0 HEALTH AND SAFETY WARNING

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 DEVELOPMENT METHODS

4.1 Air Lifting

The airlift method involves pumping compressed air down an eductor pipe placed inside the well casing. Due to its inert characteristic, nitrogen is the preferred gas for air lifting. Pressure is applied intermittently and for short periods causing the water to surge up and down inside the casing. Once the desired surging is accomplished, continuously applied air pressure should be used to blow water and suspended sediments upward and out of the well.

The use of standard air for well development may impact permeability of the formation surrounding the well screen and groundwater quality. Considerable care must be exercised to avoid injecting air directly through the well screen. Air can become trapped in the formation materials outside the well screen and affect subsequent chemical analyses of water samples and hydraulic conductivity measurements. The bottom of the air pipe should not be placed below the top of the screened section of casing.

Another restriction of the use of air is the submergence factor. The submergence factor is defined as the height of the water column above the bottom of the air pipe (in feet) divided by the total length of the air pipe. To result in efficient airlift operation, the submergence factor should be at least 20 percent. This may be difficult to achieve in shallow monitoring wells or wells that contain small volumes of water.

4.2 Surging or Plunging

A surge block is a round plunger with pliable edges (constructed of a material such as rubber belting) that will not catch on the well screen. Moving the surge block forcefully up and down inside the well screen causes the water to surge in and out through the screen accomplishing the desired cleaning action. The amount of pressure generated by the surging must be closely monitored to prevent cracking of the well casing or screen.

A well slug may also be used to create a surging effect through the filter pack and formation. A slug consists of a PVC rod or pipe (with capped ends) sufficiently weighted to rapidly sink in water. The slug is alternately lowered into and retrieved from the water in the casing to create a water level differential that induces flow into or out of the well to accomplish the desired cleaning action. This method is less aggressive than using a surge block. For shallow wells or wells in which the water column in the casing is small, care must be exercised when lowering the slug so as not to drive the slug into the bottom of the casing or against the screens.

4.3 Bailing or Pumping

A bailer that is heavy enough to sink rapidly through the water can be raised and lowered through the water column to produce the surging action that is similar to that caused by a surge block or well slug. The bailer, however, has the added capability of removing turbid water and fines each time it is brought to the surface. Bailers are very useful for developing shallow and slow yielding wells. As with surge blocks, it is possible to produce pressure great enough to crack PVC casing. Bailers are the simplest and least costly method of developing a well, but are time-consuming.

Pumping can be used effectively in wells where recharge is rapid. The type and size of the pump used is contingent upon the well design. Pumps also allow removal of turbid water and fines. However, pumps are more difficult to decontaminate than a bailer is.

5.0 EXECUTION

The following procedures shall be adhered to unless well development requirements are otherwise specified in the Site-Specific Work Plan:

1. Measure the depth to groundwater in accordance with the guidelines described in SOP SAS-08-01. The standing water volume (V) in the well to be developed shall be calculated using one of the following formula in accordance with the Site-Specific Work Plan:

   Borehole Volume Calculation

   $V = nA (B - C) + CD$

   Where, n = porosity of the filter pack;
   A = height (in feet) of the saturated filter pack;
   B = volume (in gallons per foot) of water in the borehole (see Table below);
   C = volume (in gallons per foot) of water in the well casing (see Table below); and
   D = height of standing water column (in feet) in the well.

   Well Volume Calculation

   $V = CD$

   Where, C = gallons per foot of water in the well casing (see Table below); and

D = height of standing water column (in feet) in the well.

Diameter-Specific Volume Per One Foot of Casing/Borehole					
Diameter (Inches)	**Volume Per Foot of Casing/Borehole (Gallons)**		**Diameter (Inches)**	**Volume Per Foot of Casing/Boring (Gallons)**
0.25	0.0026		4.0	0.6528
0.50	0.0102		6.0	1.469
0.75	0.0230		8.0	2.611
1.0	0.0408		10.0	4.081
2.0	0.1632		12.0	5.876

2. Measure water quality parameters immediately prior to and during well development at a minimum frequency of once per well volume removed in accordance with SOPs SAS-08-02 and SAS-08-03. The water quality parameters should generally include pH, specific conductance and/or actual conductivity, temperature, dissolved oxygen, and turbidity, unless otherwise specified in the Site-Specific Work Plan. Record water quality parameters, as well as visual turbidity and evidence of impact (e.g. free phase product, sheen, odors, etc.) observations in the field logbook and/or on the appropriate field form.
3. Remove a minimum of 10 standing water volumes or the volume required to allow water quality parameters to stabilize, whichever is greater. A well that will not yield sufficient volume must be bailed or pumped dry, allowed to recover to within 90% of the pre-development standing water volume, and then bailed or pumped dry a second time. The criteria for parameter stability are summarized below.

Water Quality Parameter	Stability Criteria[1]
pH	+/- 0.1 Std. Units
Temperature	+/- 0.5°C
Specific Conductance or Actual Conductivity	+/- 3% microsiemens/cm @ 25°C or +/- 3% microsiemens/cm
Dissolved Oxygen	+/- 0.3 milligrams/Liter
Turbidity	+/- 10% NTU or three consecutive readings ≤ 10 NTUs

4. Containerize development water in approved, labeled containers (e.g. 55-gallon drums, polyethylene storage tanks, baker tanks, etc.) as required by the Site-Specific Work Plan or otherwise specified.

6.0 DOCUMENTATION

Well development activities will be documented in the field logbook and/or appropriate field form, describing the procedures used and any significant occurrences that are observed during development such as apparent recharge rates in the well, condition of the groundwater, and organic vapor readings. Well development data including the depth to static water, standing water volume in the well, standing water volume calculations, total volume of water removed, number of well volumes removed, and water quality parameters also will be recorded in the field logbook and/or on the field activity form.

7.0 REFERENCES AND ADDITIONAL RESOURCES

USEPA, 2002, Ecological Assessment Standard Operating Procedures and Quality Assurance Manual, SESD, Region 4, Ecological Assessment Branch, Athens, Georgia.

USEPA, May 2002, Ground-Water Sampling Guidelines for Superfund and RCRA Project Managers, Regions 5 and 10, EPA/542/S-02/001.

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001.

[1] USEPA, May 2002, Ground-Water Sampling Guidelines for Superfund and RCRA Project Managers, Revision 2, EPA/542/S-02/001.

STANDARD OPERATING PROCEDURE
NO. SAS-05-05

BOREHOLE AND WELL ABANDONMENT
Revision 0

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for borehole and well abandonment. When boreholes and wells are no longer need to complete project goals and objectives, they must be properly abandoned to prevent them from acting as a conduit for migration of contaminants from the ground surface to the water table or between transmissive zones.

2.0 EQUIPMENT AND MATERIALS

Equipment and materials may vary based on borehole and well accessibility and depth and well construction. Field personnel should use the equipment and materials required by the Site-Specific Work Plan or otherwise specified for the project. All non-disposable equipment shall be decontaminated before and after introduction into borehole or well. Equipment Decontamination should be performed in accordance with SOP SAS-04-04 and/or requirements of the Site-Specific Work Plan.

3.0 HEALTH AND SAFETY

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 CONSIDERATIONS

Borehole and well abandonment procedures should meet applicable regulatory agency requirements. In addition, licensing and/or certification of the driller may be required. A trained supervising technician (e.g. geologist, hydrogeologist, engineer, or environmental scientist) should be present during well abandonment to document the activities. The supervising technician should complete and submit a well abandonment form, if required, to the appropriate regulatory agency. Attachment A contains a generic borehole / well abandonment form. If wells are abandoned the relevant procedures must be implemented and relevant forms, specified by the regulatory agency must be completed.

5.0 EXECUTION

Unless otherwise specified in the Site-Specific Work Plan, the following guidelines shall be followed. The preferred well abandonment method is to completely remove the well casing and screen from the borehole. This may be accomplished by auguring with a hollow-stem auger over the well casing down to the bottom of the borehole, thereby removing the grout, bentonite seal, and filter pack from the hole. The well casing shall be then removed from the borehole with the drill rig. The remaining borehole is subsequently backfilled with the appropriate backfill material. The backfill material (e.g. bentonite, Portland cement, etc) shall be placed into the borehole from the bottom to the top by pressure grouting with the positive displacement method (tremie method) to within two feet of the ground surface. The top two feet of the borehole shall be filled with concrete or material similar to surrounding features (e.g. asphalt, topsoil, etc.) to ensure a secure surface seal (plug). If the area has heavy traffic and/or construction use, the location will be barricaded until the plug has cured or concrete plug recessed below ground surface will be used to maintain the surface seal. This abandonment method can typically be accomplished on small-diameter wells (4-inches or less in diameter) without much difficulty.

The use of hollow-stem augers for casing removal on large-diameter wells (diameter greater than 4-inches) typically ranges from very difficult to almost impossible. On large-diameter wells with little to no grout, a drill stem with a tapered wedge assembly or solid-stem auger should be used to ream out the borehole and extract the well materials. Wells that are badly corroded and/or have thickly grouted annular space have a tendency to twist and/or break off in the borehole. Should this occur, the well will have to be grouted with the remaining casing left in the borehole. In this case, the well and borehole shall be pressure grouted by placing a tremie pipe in bottom of the well casing, which will be the well screen or bottom sump area below the well screen. The pressurized grout will be forced out through the well screen into the filter pack and up the inside of the well casing sealing holes and breaks that are present. The tremie pipe shall be retracted slowly as the grout fills the casing. The well casing shall be cut off even with the ground surface and filled with grout to ground surface. If the casing has been broken off below the surface, the grout shall be tremied to within two feet of the ground surface and then finished similar to the surrounding features.

Brittle polyvinyl chloride (PVC) well casings may be more difficult to remove from the borehole than stainless-steel casings. If the PVC well casing breaks during removal, the borehole shall be cleaned out by using a drag bit or roller cone bit with the wet rotary method to grind the casing into small cuttings that will be flushed out of the borehole by the drilling fluid. Another method is to use a solid-stem auger with a carbide auger head to grind the PVC casing into small cuttings that will be brought to the surface by the rotating flights. After the casing materials have been removed from the borehole, the borehole shall be cleaned out and pressure grouted with the approved grouting materials. As previously stated, the borehole shall be finished with a concrete surface plug or site-specific surface restoration material with adequate surface protection, unless otherwise directed or required by the Site-Specific Work Plan.

6.0 REFERENCES AND ADDITIONAL RESOURCES

ASTM International, 2005, D5299-99 (2005) Standard Guide for Decommissioning of Ground Water Wells, Vadose Zone Monitoring Devices, Boreholes, and Other Devices for Environmental Activities.

USEPA, 2001, Environmental Investigations Standard Operating Procedures and Quality Assurance Manual, Region 4, Enforcement and Investigations Branch, SESD, Athens, Georgia.

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001.

ATTACHMENT A
BOREHOLE / WELL ABANDONMENT FORM

BOREHOLE / WELL ABANDONMENT FIELD FORM

PROJECT INFORMATION

Site: ____________________ Client: ____________________

Project Number: ____________ Task #: ________ Start Date: ____________ Time: ________

Field Personnel: ____________________ Finish Date: ____________ Time: ________

GENERAL INFORMATION

Ownership (Controlling Party): ____________________

Street Address: ____________________

City: ____________________

County: ____________________

State: ____________ Zip: ________

Township: ________ Range: ________ Section: ________

________ 1/4 of the ________ 1/4 of the ________ 1/4

If Known, Latitude: ________ Longitude: ________

If Known*, Northing: ________ Easting: ________

*Coordinate System: ____________________

Reason for Abandonment:

Permit Number (If applicable): ____________________

BOREHOLE / WELL INFORMATION

Borehole / Well ID: ____________ Unique Well ID:

Installation Date: ____________

☐ Borehole

☐ Monitoring Well

☐ Water Well

Attach Well Completion Report, if available

☐ Other (specify): ____________________

Construction Type:

☐ Drilled ☐ Driven (Sandpoint)

☐ Other (specify): ____________________

Formation Type:

☐ Unconsolidated Materials ☐ Bedrock

Borehole/Well Details:

Borehole Diameter: ________ Inches

Total Borehole Depth: ________ FT BGS

Casing Diameter: ________ Inches ☐ Not Applicable

Total Casing Depth: ________ FT BGS ☐ Not Applicable

Depth to Water: FT BGS ☐ Not Encountered

SEALING INFORMATION

Pump & Piping Removed? ☐ Yes ☐ No ☐ Not Applicable

Liner(s) Removed? ☐ Yes ☐ No ☐ Not Applicable

Screen Removed? ☐ Yes ☐ No ☐ Not Applicable

Entire Casing Removed? ☐ Yes ☐ No* ☐ Not Applicable

If No, Upper 2 feet Removed? ☐ Yes ☐ No

Method of Sealing Material Placement:

☐ Conductor Pipe - Gravity ☐ Tremie Pipe - Pumped

☐ Screened & Poured ☐ Other (specify): ________

Sealing Material Rose to Surface? ☐ Yes ☐ No

Material Settled After 24 Hours? ☐ Yes* ☐ No

*If Yes Was Hole Re-Topped? ☐ Yes ☐ No

Sealing Material Used	From	To	Volume/Quantity
	Surface		

SEALING WORK PERFORMED BY

Individual's Name: ____________ License Number:

Company Name: ____________

Street Address: ____________

City: ____________ State: ________ Zip: ________

STANDARD OPERATING PROCEDURE
NO. SAS-05-06

TEST PIT EXCAVATION, LOGGING, AND SAMPLE COLLECTION
Revision 0

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for conducting test pit excavation, logging and sample collection as described in the Site-Specific Work Plan, or as otherwise specified, for the purposes of characterizing subsurface conditions at the site.

2.0 EQUIPMENT AND MATERIALS

- General:
  - Excavator or backhoe;
  - Metal shovel;
  - Spray paint or survey lathe and tape;
  - Visquene sheeting;
  - Tape measure in 0.01-foot increments;
  - Field logbook and field boring log forms;
  - Pen(s) with waterproof, non-erasable ink;
  - 5-gallon bucket and wire or nylon brushes, decontamination water, laboratory grade detergent (Alconox or similar), and paper towels;
  - Aluminum foil or roll-plastic wrap;
  - Stakes and fluorescent flagging tape;
  - Camera; and
  - Personnel protective equipment, as appropriate.
- Soil Logging:
  - Knife, spatula, carpenter’s 5-in-1 tool or similar cutting tool;
  - Soil color chart;
  - Comparative charts; and
  - Pocket penetrometer.

- Soil Sampling:
  - Sample containers and labels;
  - Sample cutting/extracting equipment (scoops, trowels, shovels, hand augers);
  - Metal mixing bowls;
  - Coolers and ice;
  - Chain of custody forms;
  - Custody seals;
  - Gallon size sealable plastic bags; and
  - Clear plastic packaging tape.

3.0 HEALTH AND SAFETY WARNING

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 GENERAL PROCEDURES

Test pit procedures shall be conducted only by a trained logging technician. Subsurface utilities shall be cleared prior to mobilization to the site in accordance with SOP SAS-05-01. Field data and observations associated with test pit activities shall be documented in accordance with SOP SAS-01-01, if not otherwise specified in this SOP. All test pit excavation activities should be recorded in a field logbook and/or on a test pit excavation field form. In addition, equipment used while logging shall be decontaminated between test pit locations in accordance with the SOP SAS-04-04 or as otherwise specified in the Quality Assurance Project Plan (QAPP) and/or Site-Specific Work Plan.

5.0 DOCUMENTATION PROCEDURES

The field technician shall record all pertinent excavation information in the field logbook and/or on the appropriate field form. At a minimum, the following technical information with respect to excavation operations and observations shall be recorded, if applicable:

- Project name and number;
- Location (e.g. test pit number) or other sample station identification, including a rough sketch;
- Name of the logging technician overseeing the excavation operations;
- Excavating equipment manufacturer and model;
- Excavating company name and city and state of origin;
- Equipment operator and assistant(s) names;
- Excavation start time and date;
- Excavation completion time and date;
- Excavation dimensions (length and width, and depth)
- Description of soil and/or rock classification and lithology;
- Lithologic changes and boundaries;
- Depth to water first encountered during excavation
- Depth to stabilized water level following excavation
- Sample identifications; depths and time collected for chemical and geotechnical samples;
- Evidence of impact (e.g. staining, odors, free-phase product, etc.); and
- Problems with the excavating equipment or process.

6.0 TEST PIT EXCAVATION PROCEDURES

- Identify the test pit locations and mark limits of excavation using spray paint or survey lathe and tape.
- Confirm absence of subsurface utilities in the test pit excavation areas. If subsurface utilities are present in test pit location, contact the project manager to discuss alternative locations for test pit.
- Lay visquene sheeting to be used for soil stockpiling on ground next to test pit location and secure in place. If topsoil is present, it may be stockpiled separately for restoration of ground surface when test pit is completed.

- Begin excavation making shallow cuts of 6 inches to 1 foot to allow descriptive logging of soil and soil transitions. Stockpile soil on visquene sheeting.
- Sketch the development of the test pit in the field notebook. Complete vertical profiles at multiple locations along the length of the test pit if variation of subsurface materials occurs along the length. Sketch a cross section of the longitudinal length of the test pit.
- Record physical characteristics of the material excavated including Unifies Soil Classification System (USCS) soil type, litho logy, color, odor, moisture, structures, foreign objects and observations of environmental impacts in the field logbook or field form. Follow soil description and classification procedures provided in SOP SAS-05-02.
- Take photographs to document excavation and log photographs in the field logbook or on the field form.
- If soil samples are required for chemical or geotechnical analysis, collect samples from soil in the bucket of the excavator or soil stockpile. Have communication signals set up with excavator operator and/or other subcontractor personnel to indicate that a soil sample will be taken so that the equipment can be stopped for safe sample retrieval. Do not at any time go into the test pit.
- Soil samples shall be collected in accordance with SOP SAS-06-01. Decontaminate sampling equipment between each sample collected in accordance with SOP SAS-04-04. Samples shall be prepared for analysis in accordance with SOP SAS-03-01.
- Once the excavation is complete, record the depth, length and width of the excavation in the field logbook and/or on the appropriate field form.
- Backfill the test pit with the material excavated from the test pit unless other backfilling instructions are specified in the Site-Specific Work Plan. If topsoil was set aside for ground surface restoration, place it on top of the excavation area.
- Decontaminate excavator or backhoe bucket between each test pit in accordance with SOP SAS-04-04.
- Test pits must be backfilled before the end of the work day; no test pits shall be left open overnight.
- Replace markings for limits of test pit excavations if they are to be located by survey at a later date.

7.0 REFERENCES AND ADDITIONAL RESOURCES

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001.

Author: T. Gilles Q2R & Approval By: C. Barry Q3R & Approval By: M. Kelley

STANDARD OPERATING PROCEDURE
NO. SAS-05-07

TEST PIT BACKFILLING AND COMPACTION
Revision 0

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for backfilling and compacting test pits. When test pits are no longer need to complete project goals and objectives, they must be properly backfilled and compacted to minimize health and safety liabilities, prevent them from acting as a conduit for migration of contaminants, and return the location to pre-excavation conditions.

2.0 EQUIPMENT AND MATERIALS

Equipment and materials may vary based on test pit accessibility and depth. Field personnel should use the equipment and materials required by the Site-Specific Work Plan or otherwise specified for the project. All non-disposable equipment shall be decontaminated after introduction into the test pit. Equipment decontamination should be performed in accordance with SOP SAS-04-04 and/or requirements of the Site-Specific Work Plan.

3.0 HEALTH AND SAFETY

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 CONSIDERATIONS

The preference for test pit backfilling is generally to return excavated materials to the test pit in the order in which they were excavated. However, the presence or suspected contaminants may require another source of backfill material. The selection of backfill material will be based on several factors, including but not limited to, concentrations of contaminants in excavated materials, test pit location (e.g. street, landscaped area, etc.), subsurface site features, ability to mechanically compact backfill materials, engineering evaluations, health and safety concerns, and access agreements. If the test pit extends below the water table, 3-inch stone shall be used to backfill the excavation to the top of the water table. Backfill material(s) will be specified in the Site-Specific Work Plan. The excavation area shall be returned to pre-excavation conditions or as otherwise specified in the Site-Specific Work Plan, applicable permit(s), and/or access agreement(s). As necessary, a qualified engineer will be consulted prior to selection of backfill and compaction material(s), equipment and method(s).

5.0 BACKFILLING AND COMPACTION

5.1 Trench Box Methods

The test pit excavated using a trench box will be backfilled, as the trench box is systematically raised, to ground surface. Care will be taken to minimize bridging as the backfill is placed. When test pit excavations exceed 4 feet in depth and self-compacting backfill material is not used, the backfill material will be placed in lifts and compacted using the excavator bucket, excavator track/wheel, or vibratory plate compactor or as specified in the Site-Specific Work Plan, applicable permit(s), and/or access agreement(s).

5.2 End Dump Methods

Test pits excavated without a trench box could be backfilled using end dump methods. When test pit excavations exceed 4 feet in depth and self-compacting backfill material is not used, the backfill material will be placed in lifts and compacted using the excavator bucket, excavator track/wheel, or vibratory plate compactor or as specified in the Site-Specific Work Plan, applicable permit(s) and/or access agreement(s).

6.0 REFERENCES AND ADDITIONAL RESOURCES

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001.

SOP SERIES SAS-06
SOIL SAMPLING AND MEASUREMENT PROCEDURES

STANDARD OPERATING PROCEDURE
NO. SAS-06-01

SOIL SAMPLING FOR CHEMICAL ANALYSES AND GEOTECHNICAL TESTING
Revision 0

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for obtaining surface and subsurface soil samples as stated in the Site-Specific Work Plan or as otherwise specified. Soil sampling is conducted for the purpose of chemical analyses and geotechnical testing to evaluate surface and subsurface conditions.

2.0 EQUIPMENT AND MATERIALS

In addition to materials provided by a subcontractor, the field personnel should have the following:

- Sample bottles/containers and labels;
- Sample cutting/extracting equipment (scoops, trowels, shovels, hand augers);
- Field logbook and/or the appropriate field form(s);
- Depth and length measurement devices with 0.01-foot measurement units;
- Camera;
- Stakes and fluorescent flagging tape;
- Decontamination materials;
- Coolers and ice;
- Chain of custody forms;
- Custody seals;
- Gallon size sealable plastic bags;
- Clear plastic packaging tape; and
- Personal protective equipment.

3.0 HEALTH AND SAFETY

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 SAMPLE TYPE, METHOD, AND EQUIPMENT SELECTION

4.1 Preparation

Site-Specific Work and/or Field Sampling Plans (FSP) which involve soil sampling shall be carefully conceived with respect to data quality objectives (DQOs) and cost effectiveness. Soil samples shall be strategically located to collect a representative fraction of soils with the minimum number of samples. To facilitate complete and successful sampling efforts by minimizing uncertainties with respect to site characterization the following factors shall, at a minimum, by considered during preparation activities:

- Project goals and DQOs;
- Location and duration of historical property uses (if available);
- Location and duration of current property uses;
- Chemical properties of contaminants of potential concern (COPCs);
- Anticipated location(s) of COPCs (e.g. surface, subsurface, etc.);
- Anticipated geologic conditions including presence and elevation of groundwater;
- Site accessibility; and
- Results of previous site reconnaissance and investigations (if available).

4.2 Field Considerations

Field personnel shall review and be familiar with Site-Specific Work and/or FSPs prior to commencement of sampling activities. Field personnel will also facilitate complete and successful sampling efforts by calibrating and operating field instruments/meters used for sample media screening in accordance with SOP SAS-02-01. In addition, field personnel shall be cognizant of the following during investigative activities:

- Indications of COPCs not previously anticipated;
- Evidence (e.g. visual, olfactory, etc.) of COPCs in locations not previously anticipated;
- Geologic conditions not anticipated;
- Changes in site accessibility; and
- Meteorological conditions (e.g. high humidity, rain, etc.) that have the potential to negatively impact operation and performance of field screening instruments, and sample quality.

Field personnel shall notify the Project Manager when field conditions and observations deviate from those anticipated during sampling event preparations. The Project Manager shall approve any deviation from the Work and/or Sampling Plans prior its occurrence. Deviations and approval to deviate from Site-Specific Work and/or FSPs shall be documented in the field logbook and/or on the appropriate field form by the field personnel.

5.0 SAMPLE TYPES

5.1 Grab Samples

Grab samples are collected to identify and quantify compounds at a specific location or interval. Grab samples are limited in areal and vertical extent. A grab sample shall be comprised of no more than the minimum amount of soil necessary to obtain the volume of sample dictated by the required sample container.

5.2 Composite Samples

Composite samples are a mixture of a given number of sub-samples/aliquots and are collected to characterize the average composition of a given surface area, vertical interval, etc. The number of sub-samples/aliquots forming a composite sample shall remain consistent with the context of the investigation. The number and pattern for collection of sub-samples/aliquots within a grid, interval, etc. shall be selected based on project goals and DQOs and shall not change. Composite sampling is associated with two potential interferences:

1. Low concentrations, if present in individual sub-samples/aliquots, may be diluted to the extent that the total composite concentration is below the analytical reporting limits.
2. Sub-samples/aliquots that are predominantly moist clay can be difficult to composite to produce a homogenous mixture. The resulting sample, as represented by the portion selected by the analytical chemist, may not be representative of an average of all the sub-samples/aliquots.

6.0 SAMPLING METHOD

6.1 Random

Random sampling involves the subjective collection of samples based on personal judgment. Soil samples are typically selected from an area(s) within a suspected area of contamination. Generally, this method is utilized with site screening investigations when there is no strong indication of contamination or distinct depositional areas are present that provide excellent screening samples.

6.2 Biased

Biased sampling involves the collection of samples based on evidence of contamination (e.g. staining, stressed vegetation, elevated field screening results, etc.). Background and control samples are also considered biased, since they are collected from locations anticipated to be impacted or expected to be clean.

6.3 Grid-Based

Grid-based sampling involves the systematic collection of samples based on the size and configuration of an area. This approach is used to characterize the presence and distribution of contaminants and is commonly utilized for large areas. Grid size will be selected during the preparation phase and shall be specified in the Work or Sampling Plan. Common grid sizes shall be developed based on the size and configuration of the area, project goals, and DQOs. It may be appropriate and acceptable to integrate several different grid sizes in a single investigation.

When a Site is extremely large (typically over several acres), it may not be practical and cost-effective to consider sampling every grid. In this case, it will be necessary to statistically select a sub-set of the total number of grids in order to reduce the number of samples collected. On the other hand, it may be more appropriate to use relatively inexpensive screening level analytical techniques to define the areas that will need to be sampled and analyzed for a higher level of data quality. In all cases, grid points shall be located using a site survey and shall be semi-permanently marked to facilitate relocating the sample locations for subsequent sampling.

7.0 SAMPLING EQUIPMENT AND PROCEDURES

7.1 Manual Sampling

In general, hand sampling using manually operated equipment is a quick and inexpensive sampling technique for shallow depths when precise data or high quality control is generally not required. The most common hand-operated samplers are hand augers, plugs, tubes, split-barrel or fixed piston samplers that are pushed or driven by hand.

Hand augers are easily used at depths less than 10 feet. The most commonly used, manually-operated hand augers include the ship, closed-spiral, and open-spiral augers. In operation, a hand auger shall be attached to the bottom of a length of pipe that has a cross-arm at the top. The hole shall be drilled by turning this cross-arm at the same time the operator presses the auger into the ground. As the auger is advanced and becomes filled with soil, it shall be taken from the hole, and the soil shall be removed. Additional lengths of pipe will be added as required to reach the sampling depth as required by the Site-Specific Work Plan or otherwise specified. Care shall be taken to prevent (to the extent possible) mixing of the soil from upper portions of the hole with lower samples. This is most likely to be a problem when augers are used to advance a hole and obtain samples from soil cuttings.

Pushed samplers can be used to obtain samples within about 3 feet of the surface or, with appropriate extensions, ahead of an augured hole. The sampler will be pushed to the desire depth by the operator. The pusher sampler shall be used with extension(s) and/or in combination with a hand auger to reach sample depths greater than 3 feet below ground surface. When the sampler becomes filled with soil, it shall be taken from the hole and the soil removed. Care shall be taken to prevent mixing of soil from upper portions of the hole with lower samples.

Because of the unpredictable operations that may have been used at many uncontrolled waste sites, sampling devices will never be forced into an abruptly hard material. The stiffness may be a natural lithology change, a rock ledge or cobble, or a buried drum. If resistance is encountered while auguring or pushing a sampler, the procedure will be stopped. The depth at which resistance was met should be recorded into the field logbook and/or on the appropriate field form.

7.2 Direct Push Technology (DPT) Sampler

A macrocore is a thick-walled steel tube with an inner disposable acetate or Teflon liner. The standard macrocore is either 1 $^{3}/_{8}$-inch or 2-inch in inside diameter, and is typically two to four feet long. The macrocore is advanced into the ground and retrieved in one continuous movement using hydraulics and extension rods, as necessary.

Upon retrieval, excess soil is wiped from the macrocore's exterior, the ends of the macrocore are removed, and the liner is removed from the macrocore. Once the liner has been removed from the macrocore, it is cut to facilitate soil classification and sampling. Sample logging and classification are described in SOP SAS-05-02. The liner is then disposed of in accordance with the Site-Specific Work Plan. Macrocore decontamination procedures are described in SOP SAS-04-04.

7.3 Split-Spoon Sampler

The split-spoon sampler is a thick-walled steel tube that is split lengthwise. A cutting shoe is attached to the lower end of the barrel; the upper end contains a check valve and is connected to the drilling rods. When a boring is advanced to the point that a sample is to be taken, drill tools are removed, and the sampler is lowered into the hole attached to the bottom of the drill rods.

The split-spoon sampler is driven by a 140-lb hammer falling 30 inches. The split-spoon sampler shall be driven 18 inches into the ground or until 50 blows have been applied in a 6-inch increment, a total of 100 blows have been applied, or there is no observable advance of the sampler after 10 successive blows. The effort taken to drive the sampler shall be recorded at 6-inch intervals and the sampler shall be removed from the boring. The density of the sampled material shall be determined by summing the blow counts for the second and third 6 inches of penetration ("standard penetration resistance" or "N-value") per ASTM D 1586-99. Only disturbed samples are obtained using this procedure.

The standard size split-spoon sampler is 2-inch outside diameter (OD), $1^3/_8$-inch inside diameter (ID), and 24 inches long. When soil samples are taken for chemical analysis, a 2- or 2½-inch ID sampler shall be used to provide a larger volume of material, but cannot be used to calculate strength or density properties as stated in the ASTM D 1586-99 test method.

Upon retrieval, excess soil or drilling fluid shall be rinsed or wiped from the sampler's exterior, the cutting shoe removed, and sampler broke open into the two halves. The sample shall be logged and classified in accordance with SOP SAS-05-02. Samples for chemical analyses and/or geotechnical testing shall be collected using the laboratory-approved and analytical-method required sample containers. The sampler tube shall then be decontaminated. The split-spoon sampler shall be decontaminated between sample intervals in accordance with SOP SAS-04-04.

Liner tubes or sleeves may be incorporated in certain samplers to contain samples temporarily. The liner tubes may be constructed from brass, plastic, or other inert materials used to store and transport the samples. If a sample is to be stored in the liner tube, the tube ends shall first be covered with Teflon film, followed by a plastic slip cap. On each sample end, the Teflon film shall be trimmed, and the cap sealed with vinyl tape to the liner tube. If the sampler is not to be stored in the liner, it will be transferred from the sampler to the appropriate sample container using either the liner tube or a stainless steel or plastic spoon or spatula.

When taking samples for geotechnical testing, the disturbed soil samples shall be removed from the sampler shall be placed in a sealable glass jar or other containers approved by the geotechnical laboratory and labeled to indicate the project name and number, boring number, sample number, and depths at top and bottom of the sample interval. This information shall be marked on the jar lid using a permanent marker. Other information required by the Site-Specific Work and/or FSP shall be recorded in the field logbook and/or on the appropriate field form.

7.4 Continuous Core Barrel Sampler (CME-Type)

A continuous core barrel sampler (CME-Type) is 5 feet long and fits inside the lead auger of the hollow-stem auger column. The sampler retrieves a 5-foot section of partially disturbed soil samples. The sampler assembly consists of either a split barrel or solid barrel that can be used with or without liners. The split-barrel sampler is most commonly used because it is easier to access and remove the core samples. The core barrel sampler takes the place of the pilot bit, thereby reducing sampling time. The sampler is most efficient in clays, silts, and fine sand.

The sampler shall be attached to the drill rod and locked in-place inside the auger column. The open end of the sampler shall extend a short distance ahead of the cutting head of the lead auger. The hollow-stem auger column shall be advanced 5 feet while the soil enters the non-rotating core sampling barrel. The barrel shall then be retrieved with the drill rod, and the core extruded from the sampler. The sample shall be logged and classified in accordance with SOP SAS-05-02. Samples for chemical analyses and/or geotechnical testing shall be collected using the laboratory-approved and analytical-method required sample containers. The sampler tube shall then be decontaminated in accordance with SOP SAS-04-04.

7.5 Thin-Walled (Shelby) Tube Samplers

Thin-walled samplers, such as a Shelby tube, should be used to collect relatively undisturbed samples of soil from borings. The samplers are constructed of steel tubing about 1 to 3 mm thick, depending upon its diameter. The lower end has a tapered cutting edge. The upper end is fastened to a sample head adapter with a check valve to help hold the sample in the tube when the tube is being withdrawn from the ground. Thin-walled tube samples are obtained by any one of several methods including pushed-tube, Pitcher sampler, Denison sampler, and piston sampler methods.

In obtaining pushed-tube samples, the tube shall be advanced by hydraulically pushing it in one continuous movement with the drill rig. At the end of the designated push interval and before lifting the sample, the tube shall be twisted to break the bottom of the sample. The tube shall be retrieved from the boring using the drill rig. One of two methods shall be employed for handling the sample once it is retrieved from the boring:

1. Extruding the sample from the sample tube in the field using an extruding device on the drilling rig, and subsequently handling and containerizing the specimen at the drilling site.
2. Leaving the sample in the sampling tube, preparing it for transportation, with subsequent extrusion and handling elsewhere.

A hydraulic extruder shall be used in all cases to minimize disturbance. To extrude the sample from the tube, the tube shall be connected to the extruding device in the appropriate fashion for that type extruder. Some extruding devices push the sample in the same direction that the sample entered the tube, pushing out the top, while others push it out the bottom. It does not matter for environmental sampling, but the orientation of the sample shall be known and kept clear by the sampling personnel. The sample shall be caught on a split section of PVC pipe lined with polyethylene sheeting or aluminum foil. Waxed paper will not be used. Drilling fluids shall be carefully poured off and cuttings or slough material at the top end of the sample raked away, leaving only the true sample interval. The sample shall be transferred to a cutting board by lifting with the poly/sheeting or aluminum foil and length of the sample shall be measured. The sample shall be logged and classified in accordance with SOP SAS-05-02. Samples for chemical analyses and/or geotechnical testing shall be collected using the laboratory-approved and analytical-method required sample containers. The sampler tube shall then be decontaminated in accordance with SOP SAS-04-04.

Shelby tubes will not be reused for subsequent sampling intervals. A sufficient number of decontaminated sampling tubes shall be brought to the sampling location to complete the required scope of work and protected from being contaminated before use.

7.6 Cuttings or Wash Samples

Drill cuttings or wash samples may be taken as the boring is advanced. A stainless steel or plastic scoop shall be used to obtain a sample from the cuttings pile. The shovel used by drilling personnel to move cuttings shall be stainless steel. The sample shall be logged and classified in accordance with SOP SAS-05-02. Samples for chemical analyses and/or geotechnical testing shall be collected using the laboratory-approved and analytical-method required sample containers. The sampling equipment shall then be decontaminated in accordance with SOP SAS-04-04.

7.7 Roto-Sonic Samples

Roto-sonic uses vibration to advance a core sampler in one continuous movement and collect relatively undisturbed soil and/or rock materials as it is advanced. Upon retrieval of core sampler from the ground, the collected soil and/or rock material is transferred to a plastic liner using vibration.

Once the soil and/or rock material has been transferred to the liner, the liner is cut to facilitate soil classification and sampling. The sample logging and classification are described in SOP SAS-05-02. Samples for chemical analyses and/or geotechnical testing are to be collected using the laboratory-approved and analytical-method required sample containers. The liner is then disposed of in accordance with the Site-Specific Work Plan. The core shall be decontaminated between sample intervals in accordance with SOP SAS-04-04.

7.8 Test Pit Excavation and Sampling

Test pits, including trenches, consist of open shallow excavations used to determine the subsurface conditions for engineering and geological purposes. Test pits are typically conducted for subsurface characterization and to investigate underground structures that may contain impacts. Test pits shall be excavated manually or by machine (e.g. backhoe, bulldozer, or trackhoe), as required by the Site-Specific Work Plan or otherwise specified, and will be in accordance with OSHA regulations, 29 CFR 1926, 29 CFR 1910.120, and 29 CFR 1910.134. Test pit shall be logged and classified in accordance with SOP SAS-05-06.

Soil samples shall be collected from the backhoe/trackhoe bucket or directly from the wall or base of the test pit, depending on the depth of the pit. Disturbed samples shall be collected using a stainless steel scoop, shovel, or trowel. Undisturbed samples shall typically be collected using a hand auger and/or other coring tool. Samples for chemical analyses and/or geotechnical testing shall be collected using the laboratory-approved and analytical-method required sample containers. The sampling equipment shall then be decontaminated in accordance with SOP SAS-04-04.

7.9 Surface Soil Sampling

Surface soil samples are collected to determine the surface soil conditions. Surface soil samples are generally collected at depths of less than 1 to 3 feet below the ground surface.

Before sample collection, all surface materials (i.e., excess gravel, vegetation, etc.) shall be removed from the sample location. Soil samples shall be collected using a stainless steel scoop, trowel, hand auger, or other equipment as required by the Site-Specific Work Plan or otherwise specified. Samples for chemical analyses and/or geotechnical testing shall be collected using the laboratory-approved and analytical-method required sample containers. The sampling equipment shall then be decontaminated in accordance with SOP SAS-04-04. The sample appearance, depth, and location should be recorded in the field logbook and/or on appropriate field form.

7.10 Other Soil Sampling Methods

Sites may present unique features or conditions that require soil sampling equipment and techniques other than those discussed above. In these cases, the sampling equipment and procedures shall be described in the Site-Specific Work Plan.

8.0 ANALYTICAL SAMPLE PREPARATION

Sections of the sample representative of the entire sampling interval shall be selected for chemical analyses and/or geotechnical testing. Based on analytical requirement and contracted laboratory specifications, chemical analysis samples shall be placed in appropriate sample containers. Specific analytical sample preparation procedures are as follows.

- Using a decontaminated sampling instrument, remove the desired thickness and volume of from the sample retrieval device.
- Conduct a direct screening of the sample with a photoionization detector (PID).
- Describe and classify the sample in accordance with SOP ENV-05-02, Field Logging of Soil and Rocks.
- **Volatile Organic Compounds (VOCs) –** Discrete soil samples for VOC analyses will be collected as soon after sample retrieval as possible. Unless otherwise specified, soil samples for volatile organic compound (VOC) analyses shall be collected by either Powerstop Handle™ or EnCore™ sampler methods in conformance to USEPA Method 5035 requirements. Attachment A presents procedures for Powerstop Handle™ and EnCore™ sample collection. Secure container lid, apply label containing sample identification information and place in cooler with ice.
- **Semivolatile Organic Compounds (SVOCs), Metals, Cyanide, PCBs, Pesticides, Herbicides, and Organic Carbon –** Soil samples for these analytes will be collected after collecting VOCs. Place soil in a container for homogenization. Samples will be homogenized using clean stainless steel mixing bowls, spoons, knifes, etc. Sample aliquots will be placed directly from the sample retrieval device into the stainless steel bowl. The soil will be thoroughly mixed in the bowl to homogenize the sample and then placed directly

into appropriate sample containers. Secure container lid, apply label containing sample identification information and place in cooler with ice.

- **Physical Characteristics –** For geotechnical testing of cohesive samples, cut minimally disturbed sections of the specimen and place it in the appropriate sample container. Samples for geotechnical testing, including Shelby tubes shall be handled and packaged in accordance with standard practices for geotechnical investigations or as required by the Site-Specific Work Plan or otherwise specified. If contamination potentially exists, samples shall be identified as potentially containing hazardous or toxic chemicals.
- Samples shall be identified, labeled, documented and prepared for transport in accordance with SOP SAS-03-01, Sample Identification, Labeling, Documentation and Packaging for Transport.
- SOP SAS-03-2 Chain-of-Custody procedures shall be followed in preparing the samples for transport to the analytical laboratory.
- Sampling equipment and tools shall be decontaminated between each sample in accordance with SOP SAS-04-04.

Containerize any investigation-derived solid and liquid waste, including decontamination water, label and store for disposal at an appropriate disposal facility. Consult with Project Manager regarding disposal of waste.

Samples should be preserved and holding times should be observed according to analytical requirements and laboratory specifications, as required by the Site-Specific Work and/or FSPs, or as otherwise specified. If replicate or split samples are required, adjust the sections so that the additional samples are essentially identical.

9.0 DOCUMENTATION

Sample identification, labeling, and custody control shall be performed in accordance with requirements specified in SOP SAS-03-01 and SAS-03-02. Specific procedures for describing the samples and logging subsurface soil samples are presented in SOP SAS-05-02. Soil sampling activities shall be recorded in the field logbook and/or on the appropriate field form as specified in SOP SAS-01-01 or as required by the Site-Specific Work Plan.

10.0 REFERENCES AND ADDITIONAL RESOURCES

ASTM International, 1999, D1586-99 Standard Method for Penetration Test and Split-Barrel Sampling of Soils.

ASTM International, 2000, D4220-95 (2000) Practices for Preserving and Transporting Soil Samples.

ASTM International, 2004, D5730-04 Guide for Site Characterization for Environmental Purposes with Emphasis on Soil, Rock, the Vadose Zone, and Ground Water.

USEPA, 2001, Environmental Investigations Standard Operating Procedures and Quality Assurance Manual, Region 4, Enforcement and Investigations Branch, SESD, Athens, Georgia.

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001.

ATTACHMENT A
ENCORE^{TM} AND POWERSTOP HANDLE^{TM} SAMPLING PROCEDURES

ENCORE™ SOIL SAMPLING PROCEDURE

- Remove EnCore™ sampler and cap from its re-sealable pouch and attach T-handle to sampler body. (**Note**: when dealing with soft or sandy solid, it may be necessary to retract the plunger in the sampler before sample collection.)

- Using the T-handle for leverage, push the sampler into a freshly exposed surface of soil until the sampler is full.

- Brush any soil off the sampler head and securely attach the sampler cap by pushing with a twisting motion.

- Complete the sample label and attach to the sampler body; place labeled sampler in its re-sealable pouch and seal the pouch.

- Repeat the procedure for two additional samples collected from the same soil stratum or the same area. (**Note:** this step may be eliminated or the number of samples reduced if the suspected level of VOCs is known [i.e., low or high concentration sample]. Consult method 5035 or discuss procedure with an analytical laboratory for further details.)

- Use a stainless steel spoon or similar tool to collect an additional sample from the same soil stratum or the same area. Place collected material in a 2-ounce, wide-mouth jar with no preservatives. (**Note:** this additional soil volume is for dry weight and percent moisture determination. This step is not necessary if additional soil from the sample location is collected for other parameter analyses upon which dry weight and percent moisture will be determined.)

- Immediately place samples in a cooler with ice.

Ship EnCore™ samples (next day priority delivery) to the contract laboratory the day they are collected. Alternatively, arrange to have samples picked-up by the laboratory or delivered to the laboratory by field personnel within 24 hours of collection.

POWERSTOP HANDLE™ SAMPLING PROCEDURE

1. Load Sampling Device

Insert EasyDraw Syringe™ into the appropriate slot (5 or 10-gram heavy, 5 or 10-gram medium, 5 or 10-gram light or 13 gram position) on the Powerstop Handle™ device and remove end cap from syringe.

EPA Method 5035 Recommended 5-gram slot positions:

- Use the heavy position for dense clay;
- Use the light position for dry sandy soil; and
- Use the medium position for all others.

2. Collect Sample

Push EasyDraw Syringe™ into a freshly exposed surface of soil until the syringe is full. Continue pushing until the soil column inside the syringe has forced the plunger to the stopping pint. (**Note**: unlike other sample collection devices, there is no headspace air in the syringe to displace.) EasyDraw Syringe™ delivers approximately 5, 10, or 13 grams. Actual weight will be determined at the laboratory. No scale or balance required in the field.

3. Eject Sample Into Vial

Remove the syringe from the Powerstop Handle™ device and insert the syringe into the open end of 40-ml vial, and eject sample into pre-tared vial by pushing on the syringe plunger. Avoid getting dirt on the threads of the 40-ml vial. Cap vial immediately and put on ice. Sample must be received by within 48 hours of sampling if samples are not chemically preserved in the field.

STANDARD OPERATING PROCEDURE
NO. SAS-06-02

SOIL SAMPLING FOR MICROORGANISMS
Revision 0

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for the collection of soil samples for analysis of their microbial constituents. While samples are generally collected from uncontaminated soils, samples collected from contaminated soils may be used to evaluate the feasibility and/or progress of natural or enhanced biotreatment activities. This SOP shall be used in conjunction with SOP SAS-06-01 (Soil Sampling for Chemical Analyses and Geotechnical Testing), which describe general soil sample collection techniques.

2.0 EQUIPMENT AND MATERIALS

Any of the equipment used to collect surface or subsurface soil samples may be used to obtain a volume of soil from which a sub-sample can be extracted using sterile techniques for microbial analysis. A stainless steel spoon or trowel, as described in the following sections, shall be used to collect the sub-sample. Sample containers must be sterile. Wide-mouthed 500-mL Pyrex or polypropylene bottles with autoclavable screw caps, which have been autoclaved for 15 minutes at 250^{o}F and 15 psi or 530-mL sterile Whirl-pak® bags (Fisher Scientific Company) shall be used unless otherwise specified by the Work and/or Sampling Plan(s).

3.0 SPECIAL CONSIDERATIONS

The stainless steel spoon or towel used to collect the sample or sub-sample shall be decontaminated prior to sampling and following the collection of each sample or sub-sample in accordance with SOP SAS-04-04. Following the decontamination, either of the two sterilization procedures may be followed.

- Sterilization Procedure 1 - Spoons or trowels shall be individually packaged in aluminum foil and autoclaved for 30 minutes and 250^{o}F at 15 psi. Each sterile sampler shall be used only once, decontaminated, and then re-sterilized.

- Sterilization Procedure 2 – The spoon or scoop portion of the trowel shall be dipped in denatured alcohol, shaken gently, and then ignited. Please note that this procedure may only be used if no flammable, ignitable, or explosives are present on Site.

4.0 EXECUTION

4.1 Surface Sample Collection

If samples are desired directly at the surface, sterile spoons or trowels shall be used to collect the samples. Samples shall be collected in accordance with the procedures outlined in SOP SAS-06-01 with the following exceptions:

1. In order to facilitate the collection of a representative sample, the top one-inch of soil shall be scraped from approximately one-square foot and the sample collected from the underlying material.
2. Samples will be placed into sterile containers, which shall be closed immediately and placed on ice. Please note that microbial samples are not to be frozen.

4.2 Subsurface Sample Collection

Shovels, core samplers, backhoes, split-spoon samplers, and thin wall tube samplers may be used to collect subsurface samples for microbial analysis. Augers or any method that disturbs the soil column shall not be used. Sample shall be collected in accordance with the procedures outlined in SOP SAS-06-01 with the following exceptions:

1. Once the volume of soil is collected by one of the above procedures, a sub-sample shall be collected from the center of the soil sample, avoiding all surfaces which have been in contact with the non-sterile sampling device.
2. Samples will be placed into sterile containers, which shall be closed immediately and placed on ice. Please note that microbial samples are not to be frozen.

5.0 REFERENCES AND ADDITIONAL RESOURCES

ASTM International, 2004, D3694-94(2004) Standard Practices for Preparation of Sample Containers and for Preservation of Organic Constituents.

USEPA, 1978, Microbiological Methods for Monitoring the Environment, EPA-600/8-78-017.

USEPA, 2001, Environmental Investigations Standard Operating Procedures and Quality Assurance Manual, Region 4, Enforcement and Investigations Branch, SESD, Athens, Georgia.

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001.

SOP SERIES SAS-07

SEDIMENT SAMPLING AND MEASUREMENT PROCEDURES

STANDARD OPERATING PROCEDURE
NO. SAS-07-01

SEDIMENT THICKNESS DETERMINATION
Revision 0

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for the poling method of determining the thickness of soft sediments. Measurements shall be determined to assist in determining suitability of soft sediment for sample collection and information on the depositional environment in the sample collection location.

2.0 EQUIPMENT AND MATERIALS

- Pole or pole sections that can be placed together marked in one-foot increments that are subdivided into one-inch increments;
- Field logbook and/or the appropriate field form(s);
- Decontamination materials;
- Personal protective equipment; and
- Camera.

3.0 HEALTH AND SAFETY

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 EXECUTION

The following procedure shall be followed unless otherwise specified by the Site-Specific Work Plan:

1. Maneuver the boat or wade to the sampling location. When wading, take care to minimize disturbance of soft sediment as much as possible by moving slowly.
2. Slowly lower the pole to the sediment surface to avoid disturbance of any flocculent sediment.
3. Stop when slight resistance is encountered, read the pole at the water surface to the nearest inch and record the measurement as the depth to top of sediment from water surface.
4. Push the pole into the sediment until refusal occurs.
5. Read pole at the water surface to the nearest inch and record the measurement as the depth to refusal measurement.
6. Slowly withdraw the pole from the sediment and water to keep sediment disturbance to a minimum.
7. Record any observations, such as type of sediment adhering to the pole and visible signs of contamination.
8. Decontaminate the pole or pole sections in accordance with SOP SAS-04-04.
9. Calculate the soft sediment thickness by subtracting the depth of top of sediment measurement from the depth of refusal measurement and record the calculation and result.

5.0 DOCUMENTATION

Sampling activities shall be documented in the field logbook or on an appropriate field form as outline in SOP SAS-01-01 and/or specified the Site-Specific Work Plan. Visual observations, as discussed above, shall also be recorded in the field logbook or on the field form.

6.0 REFERENCES AND ADDITIONAL RESOURCES

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001.

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STANDARD OPERATING PROCEDURE
NO. SAS-07-02

DESCRIPTION AND CLASSIFICATION OF SEDIMENTS
Revision 0

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the procedure for field description and classification of sediments by means of visual inspection and manual testing.

2.0 EQUIPMENT AND MATERIALS

- Field logbook and/or appropriate field forms;
- Pens with waterproof, non-erasable ink;
- Munsell Soil Color Chart, GSA Rock Color Chart, or equivalent;
- Slim stainless-steel spatula or carpenter's 5-in-1 tool;
- Hand lens (optional);
- Camera;
- Decontamination supplies and equipment; and
- Personal protective equipment.

3.0 HEALTH AND SAFETY

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Work on water requires that marine health and safety procedures are used in addition to standard health and safety procedures. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 SEDIMENT DEFINITIONS

Sediments can be granular or chemical in composition. NOAA (1998) defines granular sediment as material for which percentages of individual components that make up the sediment can be determined by gross or microscopic inspection. Granular sediment can be composed of particulates from three classes of material: biogenic, mineral/lithic, and glass. The glass referred to is volcanic glass and is likely to be present in significant quantities only in areas of active or recent volcanic activity. Since areas with volcanic activity are rare on the North American continent, methods for describing volcanic glass sediments will be determined on a site-specific basis and will not be further discussed in this SOP. Biogenic material is the remains or traces of once-living organisms. Mineral/lithic material is all mineral grains not included in other granular sediment classes. Precipitates and carbonaceous materials occurring in quantities greater than 50 % are classified as chemical sediments and will not be discussed in this SOP.

5.0 GENERAL PROCEDURES

Sediment logging and material classification shall be conducted only by a trained logging technician (e.g. geologist, hydrogeologist, engineer, or environmental scientist). Field data and observations associated with field logging and material classification shall be documented during logging and for all investigation and sampling activities in accordance with SOP SAS-01-01, if not otherwise specified in this SOP. All field drilling activities shall be recorded in a field logbook and/or on the appropriate field form. In addition, tools and equipment used while logging sediment shall be decontaminated between sampling locations/stations and prior to each sampling event in accordance with the Quality Assurance Project Plan (QAPP).

6.0 SEDIMENT CLASSIFICATION PROCEDURES

6.1 General Classification

Determine if the sediment is primarily biogenic or mineral/lithic. If the sediment contains 30% or more of a single fossil group or 50% or more total biogenic content, classify the sediment as biogenic. This classification cannot always be determined in the field and may require additional microscopic inspection of the sediment by a paleontologist or biologist. (Note: Classification of types of biogenic sediment beyond general terms of percentage composition and general physical characteristics by visual inspection is outside the scope of this SOP and will not be discussed further.) If the sediment contains mineral/lithic particles in excess of 50% by visual inspection, use a field classification of mineral/lithic.

6.2 Sediment Physical Classification

Classify the sediment sample similarly to soil using the ASTM visual-manual procedure (ASTM D2488-06). (See SOP SAS-05-02, Field Logging and Classification of Soil and Rocks for additional guidance.) If sample is biogenic, some of the following parameters may not apply. Record the following physical parameters, if applicable, in the field logbook or field form:

- Sample color, using Munsell color descriptors and identification numbers, immediately after sample collection;
- Sample color, using Munsell descriptors and numbers, after exposure to the air, if a color change occurs;
- Odor (identify organic odors by particular type if possible [e.g. petroleum-based]);
- Major sediment class (biogenic or mineral/lithic);
- Major mineral/lithic type (e.g. SAND, silty CLAY) or biogenic type (if possible);
- Other granular components and qualitative description of percentage using “with”, “some” or “trace”;
- Particle shape and angularity;
- Any depositional structures (stratification, lamination, etc.)
- Sample consistency;
- Sample grading (sorting) for coarse-grained samples;
- Dry strength, dilatancy, toughness and plasticity for fine-grained samples;
- Evidence of environmental impacts, if encountered (e.g. staining, sheen, or free-phase product) or any foreign materials (brick fragments, manufactured glass, coal fragments, etc.).

7.0 REFERENCES AND ADDITIONAL RESOURCES

ASTM International, 2006, D2488-06 Standard Practice for Description and Identification of Soils (Visual-Manual Procedure).

U.S. Department of Commerce, National Oceanographic and Atmospheric Agency (NOAA) 1998, Proposed NGDC/Curators' Classification for Granular Sediments (Modified from the ODP Sediment Classification Scheme), web address: http://www.ngdc.noaa.gov/mgg/curator/paula1.htm.

USEPA, 2001, Environmental Investigations Standard Operating Procedures and Quality Assurance Manual (EISOPQAM), Region 4, Enforcement and Investigations Branch, SESD, Athens, Georgia.

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/60/B-07/001.

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STANDARD OPERATING PROCEDURE
NO. SAS-07-03

SEDIMENT SAMPLING
Revision 0

1.0 PURPOSE

This Standard Operating Procedure (SOP) presents guidelines for selecting sediment sampling locations and general procedures for the collection of sediment samples. This SOP addresses continental sediments only. Estuarine and oceanic sediment sampling is beyond the scope of this document and will not be discussed. This SOP addresses sample collection for characterization of chemical or physical parameters. Requirements for collection of samples for biological characterization are addressed in a separate SOP.

2.0 EQUIPMENT AND MATERIALS

Sampling equipment and materials vary be collection method. However, some standard equipment and materials are required regardless of collection method:

- Ruler or tape measure in 0.01 –foot increments;
- Sample containers and labels;
- Sample cutting/extracting equipment (scoops, spatulas, trowels, shovels, etc.);
- Field logbook and/or the appropriate field form(s);
- Depth measurement devices;
- Decontamination materials;
- Chain of custody forms;
- Custody seals;
- Coolers and ice packs;
- Personal protective equipment;
- Camera; and
- Global positioning system (GPS) (optional).

3.0 HEALTH AND SAFETY

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Work on water requires that marine health and safety procedures are used in addition to standard health and safety procedures. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 PERMITTING

Sampling performed within navigable waters and critical habitats may fall under the jurisdiction of one or more federal, state, or local agencies, including by not limited to the United States Army Corp of Engineers (USACOE), US Department of Fish and Wildlife, and state Department of Natural Resources. Prior to the commencement of sampling activities, appropriate permit(s), if applicable, shall be obtained.

5.0 SAMPLE SITE SELECTION

The sediment sampling site will be selected based on a number of factors including among others the presence of environmental impacts on adjacent land, presence of water discharge or outfall area, type of water body (e.g. lake, river, pond, etc.), sediment type, and depth to sediment. In water that is generally navigable, the only requirement for site selection may be ability to access the investigational site by boat. Sediment investigations in rivers, creeks or canals, will usually require additional information for sample site selection including such factors as stream flow velocity; depth, cross section and plan view of stream, and man-made and natural structures that affect stream flow, among others. In many cases, the USACOE and state geological surveys have extensive records for US waters and should be consulted prior to sediment sampling site selection. An experienced geologist or hydrologist should also be consulted prior to site selection.

A pre-sampling site visit is necessary to determine access points and best locations for sampling. Current aerial or satellite photographs of the site may be viewed prior to the initial site visit to obtain a general overview of possible access and sampling locations. Sampling sites may be selected during the site reconnaissance. Sampling locations can be indicated by reference to onshore features, such as buildings, fence lines, trees, etc. If natural features, such as trees are used, they will be marked by paint or colored flags for easy identification. A sketch map will be drawn in the field logbook or on a field form showing reference points and any measurements to be used to locate sampling points. If offshore sites are selected, a GPS can be used to find latitude and longitude coordinates for sampling points. These coordinates will be recorded on a site sampling map or field form, and in the field logbook.

6.0 SEDIMENT SAMPLING EQUIPMENT

Sediment sampling devices will be selected based on depth to sediment, type of sediment, type and size of sample required. Shallow sediment samples can be collected by trowel, scoop or shovel, which is decontaminated before use and between use at each specific sampling location. Manual augering equipment (tube or bucket auger); manual coring devices with Teflon or acetate liners; or barge-mounted drilling/boring equipment (e.g., hollow-stem auger rig, roto-sonic rig, direct push technoglogy, etc.) can be used to collect samples. Dredging equipment for larger samples include Peterson, Eckman, and Ponar. A sediment sampling equipment selection table (Attachment A), which was adapted from Ohio EPA, Sediment Sampling Guide (Ohio EPA 2001) and USEPA SOP #2016 – Sediment Sampling provides (USEPA 1994), provides additional information for selection and use of sediment sampling equipment. The Site-Specific Work Plan will specify the sampling equipment and method(s) to be used. Sampling equipment should be selected to minimize disturbance of potentially impacted sediments.

7.0 SAMPLE COLLECTION PROCEDURES

- Prior to mobilization to the field, consult with the contracted analytical laboratory to ascertain if they require any sediment-specific sample collection procedures to be followed to ensure that samples are acceptable for the analyses to be conducted and provided in adequate volume for analyses.
- Using a decontaminated sampling instrument, remove the desired thickness and volume of sediment from the sampling location.
- If sediment is not saturated, conduct a direct screening of the sample with a photoionization detector (PID).

- Describe and classify the sample in accordance with SOP SAS-07-02, Description and Classification of Sediments.
- **Volatile Organic Compounds (VOCs) –** Discrete sediment samples for VOC analyses will be collected as soon after sample retrieval as possible. Any surface water should be decanted from the sediment before collecting the samples. Pre-preserved vials or jars with Teflon-lined lids will be used if moisture content of soil is too high to allow collection of 5-gram samples for vials. Attachment B provides a detailed sampling procedure for pre-preserved vials. If jars are used, they will be filled to provide zero-headspace samples. Secure container lid, apply label containing sample identification information and place in cooler with ice.
- **Semivolatile Organic Compounds (SVOCs), Metals, Cyanide, PCBs, Pesticides, Herbicides, and Organic Carbon –** Sediment samples for these analytes will be collected after collecting VOCs. Any surface water should be decanted from the sediment before placing it in a container for homogenization. Samples will be homogenized using clean stainless steel mixing bowls, spoons, knifes, etc. Sample aliquots will be placed directly from the sample retrieval device into the stainless steel bowl. The soil will be thoroughly mixed in the bowl to homogenize the sample and then placed directly into appropriate sample containers. Secure container lid, apply label containing sample identification information and place in cooler with ice.
- **Physical Characteristics –** Sediment samples collected for physical characterization should be carefully placed into a large glass jar directly from the sampler to mitigate sample disturbance. Secure container lid, apply label containing sample identification information and place in transportation container.
- Samples shall be identified, labeled, logged, stored and prepared for shipment in accordance with SOP SAS-03-01, Sample Labeling, Logging, Storage and Shipment.
- SOP SAS-03-02 Chain-of-Custody procedures shall be followed in preparing the samples for transport to the analytical laboratory.
- Sampling equipment and tools shall be decontaminated between each sample in accordance with SOP SAS-04-04.
- Containerize any investigation-derived solid and liquid waste, including decontamination water, label and store for disposal at an appropriate disposal facility. Consult with Project Manager regarding disposal of waste.

8.0 DOCUMENTATION

Sampling activities shall be documented as outline in SOP SAS-01-01 and as specified the Site-Specific Work Plan. Visual observations are particularly important and may prove invaluable in interpreting sediment quality study results. These visual observations, including weather and water body conditions during the sampling event, shall also be recorded in the field logbook and/or on the appropriate field form.

9.0 REFERENCES AND ADDITIONAL RESOURCES

ASTM International, 2003, D3975-93(2003) Standard Practice for Development and Use (Preparation) of Samples for Collaborative Testing of Methods for Analysis of Sediments.

ASTM International, 2005, D3976-92(2005) Standard Practice for Preparation of Sediment Samples for Chemical Analysis.

ASTM International, 2003, D4823-95(2003)e01 Guide for Core Sampling Submerged, Unconsolidated Sediments.

Ohio Environmental Protection Agency, Division of Surface Water, 2001, Sediment and Sampling Guide and Methodologies, 2nd Ed., November.

USEPA Region V, 1984, Methods Manual for Bottom Sediment Sample Collection, EPA-905-4-004, May.

USEPA, 1994, SOP #2016 – Sediment Sampling, November 17.

USEPA, 2001, Environmental Investigations Standard Operating Procedures and Quality Assurance Manual, Region 4, Enforcement and Investigations Branch, SESD, Athens, Georgia.

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001.

ATTACHMENT A
SEDIMENT SAMPLING EQUIPMENT SELECTION TABLE

SEDIMENT SAMPLING EQUIPMENT SELECTION TABLE[1,2]

Sample Type	Model	Current	Substrate	Remarks
GRAB	Spoon Scoop	Zero To Slight	All	• Use only in relatively calm and shallow water • Relatively little sample disturbance • Simple and inexpensive • Fines may washout when retrieved through water column
CORE	Tube Auger	Zero To Slight	Clay and Silt	• Use only in relatively calm and shallow water • Extension handles can be used for deeper waters. • Relatively little sample disturbance • Simple and inexpensive • Fines may washout when retrieved through water column
CORE	Bucket Auger	Zero To Slight	Clay to Fine Gravel	• Use only in relatively calm and shallow water • Extension handles can be used for deeper waters. • Relatively little sample disturbance • Simple and inexpensive • Fines may washout when retrieved through water column
GRAB	Eckman	Zero To Very Slight	Clay and Silt	• Use in relatively calm water • Pebbles and branches may interfere with jaw closure • Excellent jaw shape and cut • Relatively little sample disturbance • Poor stability – Light weight allows for tendency to “swim” in a current, which sometimes causes miss triggers • 0.02 square meter sample area • Weight with sample is 10 kilograms

[1] Ohio Environmental Protection Agency, Division of Surface Water, 2001, Sediment and Sampling Guide and Methodologies, 2nd Ed., November.
[2] USEPA, 1994, SOP #2016 – Sediment Sampling, November 17.

SEDIMENT SAMPLING EQUIPMENT SELECTION TABLE[1,2]
(Continued)

Sample Type	Model	Current	Substrate	Remarks
GRAB	Petite Ponar Peterson	Zero To Very Slight	Clay to Fine Gravel	• Needs relatively calm/sheltered waters • Good stability • Poor jaw shape and cut • Sample disturbance • Less washout if extra weights are used • More cumbersome than an Eckman – Requires a winch • 0.1 – 0.2 square meter sample area • Weight with sample is 30 – 50 kilograms
CORE	Manual	Zero To Strong	Clay to Sand (Inserts needed for sandy samples)	• Recommended for use in shallow water • Deployed by hand or driver (hammer) • Extension handles can be used for deeper waters.
CORE	Coring Tubes	Zero To Moderate	Clay to Sand (Inserts needed for sandy samples)	• Quick and easy • Relatively undisturbed sample • Small sample volume • Samples sometimes compressed
CORE	Gravity	Zero To Moderate	Clay and Silt	• Recommended for rivers • Depths up to 10 meters
CORE	Split Spoon, Roto-Sonic, Direct Push Technology, etc.	Zero To Moderate	Clay to Sand (Inserts needed for sandy samples)	• Recommended for use in shallow water • Deployed by hand or driver (hammer) • Vertical profile remains intact and is visible • Point design can reduce sample compaction • Stones can interfere with collection • Equipment is heavy

[1] Ohio Environmental Protection Agency, Division of Surface Water, 2001, Sediment and Sampling Guide and Methodologies, 2nd Ed., November.
[2] USEPA, 1994, SOP #2016 – Sediment Sampling, November 17.

ATTACHMENT B
ENCORE AND POWERSTOP SAMPLING PROCEDURES

ENCORE™ SOIL SAMPLING PROCEDURE

- Remove EnCore™ sampler and cap from its re-sealable pouch and attach T-handle to sampler body. (**Note**: when dealing with soft or sandy solid, it may be necessary to retract the plunger in the sampler before sample collection.)

- Using the T-handle for leverage, push the sampler into a freshly exposed surface of soil until the sampler is full.

- Brush any soil off the sampler head and securely attach the sampler cap by pushing with a twisting motion.

- Complete the sample label and attach to the sampler body; place labeled sampler in its re-sealable pouch and seal the pouch.

- Repeat the procedure for two additional samples collected from the same soil stratum or the same area. (**Note:** this step may be eliminated or the number of samples reduced if the suspected level of VOCs is known [i.e., low or high concentration sample]. Consult method 5035 or discuss procedure with an analytical laboratory for further details.)

- Use a stainless steel spoon or similar tool to collect an additional sample from the same soil stratum or the same area. Place collected material in a 2-ounce, wide-mouth jar with no preservatives. (**Note:** this additional soil volume is for dry weight and percent moisture determination. This step is not necessary if additional soil from the sample location is collected for other parameter analyses upon which dry weight and percent moisture will be determined.)

- Immediately place samples in a cooler with ice.

Ship EnCore™ samples (next day priority delivery) to the contract laboratory the day they are collected. Alternatively, arrange to have samples picked-up by the laboratory or delivered to the laboratory by field personnel within 24 hours of collection.

POWERSTOP HANDLE SAMPLING PROCEDURE

1. Load Sampling Device

Insert EasyDraw Syringe™ into the appropriate slot (5 or 10-gram heavy, 5 or 10-gram medium, 5 or 10-gram light or 13 gram position) on the Powerstop Handle™ device and remove end cap from syringe.

EPA Method 5035 Recommended 5-gram slot positions:

- Use the heavy position for dense clay;
- Use the light position for dry sandy soil; and
- Use the medium position for all others.

2. Collect Sample

Push EasyDraw Syringe™ into a freshly exposed surface of soil until the syringe is full. Continue pushing until the soil column inside the syringe has forced the plunger to the stopping pint. (**Note**: unlike other sample collection devices, there is no headspace air in the syringe to displace.) EasyDraw Syringe™ delivers approximately 5, 10, or 13 grams. Actual weight will be determined at the laboratory. No scale or balance required in the field.

3. Eject Sample Into Vial

Remove the syringe from the Powerstop Handle™ device and insert the syringe into the open end of 40-ml vial, and eject sample into pre-tared vial by pushing on the syringe plunger. Avoid getting dirt on the threads of the 40-ml vial. Cap vial immediately and put on ice. Sample must be received by within 48 hours of sampling if samples are not chemically preserved in the field.

SOP SERIES SAS-08
GROUNDWATER SAMPLING AND MEASUREMENT PROCEDURES

STANDARD OPERATING PROCEDURE
NO. SAS-08-01

GROUNDWATER AND NON-AQUEOUS PHASE LIQUID MEASUREMENT
Revision 0

1.0 PURPOSE

The purpose of this standard operating procedure (SOP) is to describe method(s) to measure groundwater, Light Non-Aqueous Phase Liquids (LNAPL) and Dense Non-Aqueous Phase Liquids (DNAPL) elevations and thicknesses in groundwater monitoring wells, observation wells, and recovery wells as required in the Site-Specific Work Plan or as otherwise specified.

2.0 EQUIPMENT AND MATERIALS

- Notebook, field logbook, and/or the field activity form;
- Steel add-on tape or electronic water level indicator;
- Electronic water level indicator;
- Electronic oil/water interface probe;
- Pressure transducer (as appropriate for the conditions);
- Gasket adapted to the diameter of the transducer cable;
- Data logger;
- Decontamination equipment and supplies (in accordance with the guidelines in SOP SAS-04-04).
- Personal protective equipment; and
- Chalk

3.0 HEALTH AND SAFETY WARNINGS

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 GENERAL REQUIREMENTS

Water level, LNAPL, and DNAPL (if present) measurements should be obtained at wells designated in the Site-Specific Work Plan. Water level, LNAPL, and DNAPL levels should be measured in referenced to a common elevation or datum, preferably to a USGS benchmark located at the site. Water level, LNAPL, and DNAPL depths should be measured from a reference point marked on the top of the casing, which, in turn, is referenced to a permanent benchmark.

Water and product level measurement devices shall be decontaminated as per SOP SAS-04-04 or as specified in the Site-Specific Work Plan before and after measuring at each location.

Care shall be exercised to avoid direct skin contact while measuring water level and product depth. All equipment should be decontaminated before and after each measurement as per SOP SAS-04-04. Water and product level measurements should be recorded in the field logbook and/or the field activity form.

5.0 MEASUREMENT METHODS AND PROCEDURES

5.1 Discrete Groundwater Level Measurement

Discrete water level measurements should be made by determining the depth to the water surface from the top of the well casing at the fixed reference point. The fixed reference point is established by permanently marking a point on the outer edge (lip) of the well casing. Caution should be exercised so that filings do not fall into the well.

The depth to water can be determined using a steel add-on tape or electronic water level indicator. The steel add-on tape consists of a measuring tape that has 1-foot increments and a 1-foot section at the end of the tape with 0.01-foot increments. The end of the tape is coated with chalk and lowered into the well. The water depth is read from the saturated mark on the chalked tape and added to the depth interval measured at the top of the well casing

Electronic water level indicators are conducting probes that activate an alarm and a light when they intersect the water. The sounder wire is marked in 0.01-foot intervals to indicate depth. All sounders are equipped with weights to maintain line tension for accurate readings. The typical operating procedures for an electronic water level indicator are as follows:

- Lower the sounder wire until it just makes contact with the water in the well and the indicator light goes on or the pulsating alarm is sounded. Record the position of the wire relative to the reference point at the top of the well casing. Record the actual water level reading to the nearest 0.01-foot. Repeat to confirm depth.
- Withdraw the sounder from the well.
- Record the water depth in the field logbook and/or the field activity form.
- Decontaminate the sounder wire and electrode in accordance with SOP SAS-04-04.

Discrete water levels are typically required from a series of wells when data for preparing groundwater contour maps are needed. However, discrete water levels may also be required when monitoring the changes in water level during aquifer testing if aquifer response is sufficiently slow. Continuous water level measurements are discussed in Section 5.4 of this SOP.

5.2 Discrete LNAPL Level Measurement

Discrete LNAPL or product level measurements should be made by determining the depth to the product and water surface from the top of the well casing at the fixed reference point. The fixed reference point is established by permanently marking a point on the outer edge (lip) of the well casing. Caution should be exercised so that filings do not fall into the well.

The depth of the product and water level should be obtained using an electronic oil/water interface probe. An oil/water interface probe has a multi-conducting probe that activates different signals, typically pulsating beeps and continuous alarms, when they intersect the product and water, respectively. The sounder wire is marked in 0.01-foot increments to indicate depth. The interface probe is equipped with a weight to maintain line tension and obtain accurate readings. The typical operating procedures for an electronic oil/water interface probe are as follows:

- Check the interface probe battery by pressing the test button to ensure the device is operating properly before and after taking the level measurement. Daily battery checks should also be made and documented in the logbook.
- Lower the interface probe until it makes contact with the product in the well and the product indicator light goes on or the continuous alarm is sounded. Record the position of the wire relative to the reference point to the nearest 0.01-foot. Repeat to confirm the depth of the product.
- Continue to lower the interface probe, through the product layer, until it makes contact with the water level in the well and the water indicator light goes on or the pulsating alarm is sounded. Record the position of the wire to the reference point to the nearest 0.01-foot. Repeat to confirm the depth of the water.
- Withdraw the probe from the well.
- Record the product and water depth in the field logbook and/or the field activity form.
- Decontaminate the sounder wire and probe in accordance with the guidelines in SOP SAS-04-04.

5.3 Discrete DNAPL Level Measurement

Discrete DNAPL or product level measurements should be made by determining the depth to the product and water surface from the top of the well casing at the fixed reference point. The fixed reference point is established by permanently marking a point on the outer edge (lip) of the well casing. Caution should be exercised so that filings do not fall into the well.

The depth of the water and product level should be obtained using an electronic oil/water interface probe. An oil/water interface probe has a multi-conducting probe that activates different signals, typically continuous alarms and pulsating beeps, when they intersect the water and product, respectively. The sounder wire is marked in 0.01-foot increments to indicate depth. The interface probe is equipped with a weight to maintain line tension and obtain accurate readings. The typical operating procedures for an electronic oil/water interface probe are as follows:

- Check the interface probe battery by pressing the test button to ensure the device is operating properly before and after taking the level measurement. Daily battery checks should also be made and documented in the logbook.

- Lower the interface probe until it makes contact with the water in the well and the water indicator light goes on or the beeping alarm is sounded. Record the position of the wire relative to the reference point to the nearest 0.01-foot. Repeat to confirm the depth of the water.
- Continue to lower the interface probe, through the water, until it makes contact with the product level in the well and the product indicator light goes on or the continuous alarm is sounded. Record the position of the wire to the reference point to the nearest 0.01-foot. Repeat to confirm the depth to the product.
- Withdraw the probe from the well.
- Record the water and product depth in the field logbook and/or the field activity form.
- Decontaminate the sounder wire and probe in accordance with the guidelines in SOP SAS-04-04.

5.4 Continuous Water Level Measurement

Continuous water level measurements are made by determining the height of the water column above a pressure transducer and electronically recording fluctuations in this height with a data logger. The continuous recording of height of water above the transducer is used for aquifer testing where rapid changes in water level are anticipated. The typical operating procedures for a continuous water level system are as follows:

- Enter the program into a data logger that has fully charged batteries. Alkaline batteries are preferred. During use, the battery voltage should not drop below the minimum voltage specified by the manufacturer; damage to the data logger and loss of recorded data could result.
- Select a pressure transducer for use in a given well that is compatible with both water quality and anticipated pressure sensitivity range (i.e., 5 psi, 30 psi, etc.). The pressure range selected is dictated by the anticipated range in the water column above the transducer and by the desired precision in measurement.
- Connect the transducers to the data logger in the field following manufacturer’s instructions. Typically, four to eight input channels are available on the system. Other factors affecting the sampling configuration include cable length; distance between monitored wells; terrain; local human activities (traffic, plant operations); and the ability to secure the system from weather and vandals.
- Attach the transducer cable to the data logger and calibrate in air according to manufacturer’s instructions. If multiple data loggers are used, internal clock synchronization should also be performed.

- Measure water level and depth to the bottom of the well before lowering the transducer into the well. Water levels are measured with an electrical water level indicator; total depth of the well is measured with a device compatible with well depth.
- Secure a sanitary fitting (commonly a gasket adapted to the cable diameter) at the surface of the well. Lower transducer into the well through the sanitary fitting to a depth between the water level and the bottom of the well. The transducer must be kept submerged during the period of measurement. Take care to keep the piezometric crystal at the tip of the transducer out of any fine sediment that has accumulated in the bottom of the well. On some transducers, the crystal is protected from sediment intrusion. Measure water level again; record the time indicated on the data logger digital display and water level. From these readings (and other periodic manual water level measurements), the water levels can be converted to elevations.
- Transfer data stored in the data logger periodically to a portable computer. The frequency of data transfer depends on available memory and conditions encountered in the field. Data may be transferred as frequently as daily. If the data logger has a wrap-around memory, the information should be transferred so that records are not recorded over.

6.0 REFERENCES AND ADDITIONAL RESOURCES

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001.

STANDARD OPERATING PROCEDURE NO. SAS-08-02

LOW-FLOW GROUNDWATER SAMPLING Revision 0

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the procedures and guidelines for conducting low-flow groundwater sampling. This SOP provides a method that minimizes the impact of the purging process on groundwater chemistry and volume of water for disposal.

2.0 EQUIPMENT AND MATERIALS

- Map of well locations;
- Well construction information;
- Tools and well keys, as required to facilitate access to wells;
- Water level measuring device (electronic water level indicator, interface probe, or weighted steel tape);
- Adjustable rate peristaltic pump or an adjustable rate low-flow submersible or positive displacement bladder pump (Note: The Site-Specific Work and/or Field Sampling Plan (FSP) shall specify the type of pump required);
- 1/4 to 3/8-inch Teflon®, polyvinyl chloride (PVC), or polypropylene tubing;
- Flow measurement supplies (e.g. graduated cylinder and stop watch);
- Power source, if applicable;
- Compressed inert gas source (for use with bladder pump), if applicable;
- Flow-through cell;
- Groundwater quality/indicator parameter monitoring instruments (flow-through cell capable);
- Instrument operation manual(s);
- Instrument calibration standard(s);
- Container(s) for purge water storage (e.g. 5-gallon buckets, polyethylene storage tank, etc.);
- Sample containers and labels, as appropriate for the analytical method(s) selected;
- Field filtration equipment, if applicable;
- Chain of custody forms and seals;

- Cooler(s) with double-bagged ice;
- Polyethylene sheeting, as appropriate;
- Decontamination materials;
- Personal protection equipment; and
- Field logbook and/or appropriate field form.

3.0 HEALTH AND SAFETY

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 APPLICATION OF SAMPLING METHOD

Low-flow is one of several acceptable sampling procedures. Low-flow sampling shall not be used when one or more of the following conditions are present:

- Well will not accept or allow placement of the sampling device;
- Non-aqueous phase liquids (NAPLs);
- Formation screened will not allow drawdown to stabilize; and
- Water column is less than 2 feet in height.

5.0 EXECUTION

To the extent practical, sampling shall begin at the monitoring well with the least contamination and proceed systematically to the monitoring wells with the most contamination using the procedure outlined in the following subsections unless otherwise required by the Site-Specific Work and/or FSPs.

5.1 Preparation

The sampler shall create a work area around the monitoring well to minimize the potential for cross-contamination. Work area preparations may include the placement of polyethylene sheeting prevent sampling equipment from coming in contact with the ground surface. The sampler shall barricade and/or flag the work area, if required by the Site-Specific HASP. The sampler shall also arrange the sampling equipment and supplies to facilitate efficient execution of groundwater sampling procedures.

5.2 Well Gauging

Groundwater and NAPL, if present, elevation measurements shall be obtained in accordance with SOP SAS-08-01 or as otherwise specified in the Site-Specific Work and/or FSPs. The sampler shall also obtain the total well depth from top of casing (in feet to the nearest 0.01-foot) using a water level indicator, interface probe, or steel tape, as required by the Site-Specific Work and/or FSP or otherwise specified. Total well depths may be obtained prior to the sampling and provided to the sampler. If total well depth is required to be measured immediately prior to sampling, the sampler will take precautions to minimize the displacement of sediments, if present, within the well during gauging activities. In general, the use of an interface probe shall be limited to wells containing NAPL or elevated concentrations of constituents of concern. Groundwater and NAPL elevation measurements and total well depth measurements shall be recorded in the field logbook and/or on the appropriate field form.

5.3 Standing Water Column and Casing Volume Calculations

The sampler shall calculate the standing water column and casing volume using the following formulas:

Standing Water Column $_{\text{(Feet)}}$ = TD $_{\text{(FT BTOC)}}$ – DTW $_{\text{(FT BTOC)}}$

Where: TD = Total Well Depth
FT BTOC = Feet below top of well casing
DTW = Depth to Water

Casing Volume $_{\text{(Gallons)}}$ = Standing Water Column $_{\text{(Feet)}}$ X Volume per One Foot of Casing $^{\text{WDS}}$ $_{\text{(Gallons/Foot)}}$

Where: $^{\text{WDS}}$ = Well diameter-specific (see table below)

Well Diameter-Specific Volume Per One Foot of Casing				
Well Diameter (Inches)	**Volume Per Foot of Casing (Gallons)**		**Well Diameter (Inches)**	**Volume Per Foot of Casing (Gallons)**
0.25	0.0026		4.0	0.6528
0.50	0.0102		6.0	1.469
0.75	0.0230		8.0	2.611
1.0	0.0408		10.0	4.081
2.0	0.1632		12.0	5.876

The sampler shall recorded calculations in the field logbook and/or on the appropriate field form.

5.4 Pump/Tubing Intake Positioning

The sampler should determine and place or position the pump/tubing intake as appropriate relative to the position of the water level, screened interval, and constituents of concern. Refer to the flow chart provided in Attachment A. The sampler shall slowly raise or lower the pump or tubing when placing or positioning intake in order to minimize the displacement of sediments, if present, within the well. The pump model/type, tubing type, inner diameter, and length, and pump/tubing intake depth/elevation shall be recorded in the field logbook and/or on the appropriate field form. If the water quality instruments can be programmed to calculate the one tubing volume, the data collected during pump/tubing intake placement/positioning shall be entered into the instrument. If the instrument cannot be programmed to calculate the tubing volume, this volume shall be calculated by the sampler using the following formula.

Tubing Volume $_{\text{(Gallons)}}$ = Tubing Length $_{\text{(Feet)}}$ x Volume per One Foot of Tubing $^{\text{TDS}}$ $_{\text{(Gallons/Foot)}}$

Where: $^{\text{TDS}}$ = Tubing inner diameter-specific; tubing manufacturer provided information.

The calculated tubing volume shall also be recorded in the field logbook and/or on the appropriate field form.

5.5 Equipment Assembly and Calibration

The sampler shall connect the tubing from the well to the inflow fitting at the bottom of the flow-through cell. A length of tubing shall be connected to the outflow fitting at the top of the flow-through cell with the other end extending into a 5-gallon bucket. The 5-gallon bucket shall be used to collect the purge water. Groundwater quality/indicator parameter monitoring instruments will be calibrated in accordance with the instrument operation manual(s) and SOP SAS-02-01 using the manufacturer prescribed calibration standards. During instrument calibration, the instrument shall be set up to measure and record data in the units (e.g. microsiemens per centimeter (uS/cm), milligrams per liter (mg/L), etc.) specified in the Site-Specific Work and/or Sampling Plan(s). Calibration shall be documented in the field logbook and/or on the appropriated field form. Following calibration, the instruments shall be connected to the flow-through cell.

5.6 Flow Rate and Drawdown Determination

The sampler shall re-gauge the depth to groundwater from the top of well casing. The sampler shall turn on the pump at its lowest setting and determine the flow rate by measuring the volume of water removed over a one-minute period using a graduated cylinder and stop watch or other approved flow rate measuring device. The sampler shall monitor the water column drawdown and shall adjust the pump to avoid a drawdown of more than 0.3 feet (4 inches). The flow rate of the pump shall generally be adjusted to between 0.2 and 0.5 Liters per minute (L/min). During pump start-up, drawdown may exceed 0.3 feet provided the drawdown stabilizes and the groundwater level does not fall below the intake level. Pump adjustments shall be made within the first 15 minutes of purging. The final flow rate and stabilized drawdown shall be recorded in the field logbook and/or on the appropriated field form.

5.7 Purging and Groundwater Quality/Indicator Parameter Monitoring

The Site-Specific Work and/or FSPs shall specify the groundwater quality/indicator parameters to be monitored, which typically include temperature, pH, specific conductance or actual conductivity, oxidation-reduction potential, dissolved oxygen, and turbidity. Parameter monitoring will begin after a minimum of tubing volume has been purged from the well. The sampler shall monitor and record in the field logbook and/or on the appropriate field form parameters every three to five minutes (during continuous purging) until parameters have stabilized. Parameter stabilization is considered to be achieved when three consecutive readings, taken within 3 to 5 minute intervals are within the parameter-specific limit listed in the table below or as specified in the Site-Specific Work and/or Sampling Plan(s).

Parameter	**Stabilization Criteria**[1]
Conductance, Specific Electrical	+/- 3% S/cm @ 25^{o}C
Conductivity, Actual[2]	+/- 3% S/cm
Dissolved Oxygen	+/- 0.3 mg/L
Oxidation-Reduction Potential	+/- 10 mV
pH	+/- 0.1 standard units
Temperature	+/- 0.5 ^{o}C
Turbidity	+/- 10% NTUs or three consecutive readings less than or equal to 10 NTUs

Once the parameters have stabilized, purging is considered complete and sample collection shall commence.

5.8 Sample Collection

While water is being purged from the well, groundwater samples shall be collected directly into the laboratory provided sample containers from the tubing, before the water has passed through the flow-through cell. This shall be accomplished by using a by-pass assemble or disconnecting the flow-through cell to obtain the sample. Samples shall be collected in order of analyte stability, as summarized below, unless otherwise specified by the Site-Specific Work and/or FSPs:

- Volatile organic compounds (VOCs);
- Semi-volatile organic compounds (SVOCs);
- Non-filtered, non-preserved samples (e.g. PCBs, sulfate, etc.);
- Non-filtered, preserved samples (e.g. phenols, nitrogen, cyanide, total metals, etc.);
- Filtered, non-preserved samples;
- Filtered, preserved immediately samples (e.g. dissolved metals); and
- Miscellaneous parameters.

[1] USEPA, 2002, Ground-Water Sampling Guidelines for Superfund and RCRA Project Managers, EPA 542-S-02-001
[2] Based on the stabilization criteria for specific electrical conductance as published in the documented cited above

Quality Control (QC) samples, if required, will be collected consecutively to ensure appropriate duplicate sample collection in accordance with SOP SAS-04-03. Immediately following collection, samples shall be placed in an iced cooler.

5.9 Post-Sample Collection

Non-Dedicated and dedicated sampling equipment, which does not remain within the well casing, shall be removed from the monitoring well. The reusable and/or dedicated equipment and instruments shall be decontaminated in accordance with SOP SAS-04-04 or as otherwise specified by the Site-Specific Work and/or Sampling Plan(s). Disposable equipment and supplies shall be disposed of in accordance with procedures outlined in the Site-Specific Work and/or FSPs. The sampler shall secure the well casing using a slip or expandable well cap. The flush-mount lid shall be bolted down or the protective cover lid closed and locked, as appropriate.

6.0 DOCUMENTATION

Sample information, labeling, and custody control shall be performed in accordance with requirements specified in SOP SAS-03-01 and SAS-03-02. Sampling activities shall be recorded in the field logbook and/or on the appropriate field form as specified in SOP SAS-01-01 or as required by the Site-Specific Work and/or FSPs.

7.0 REFERENCES AND ADDITIONAL RESOURCES

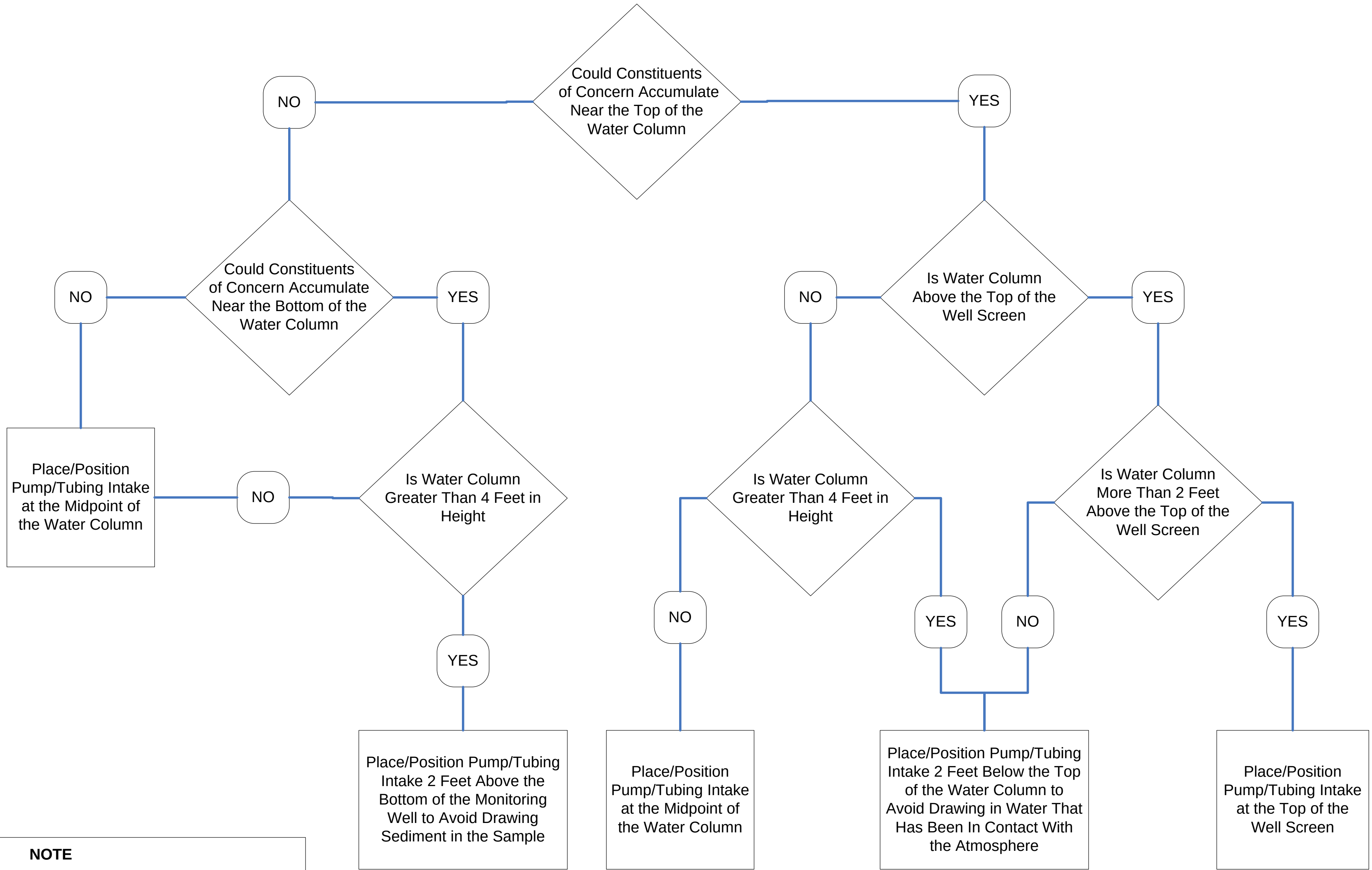
USEPA, 2002, Ground-Water Sampling Guidelines for Superfund and RCRA Project Manager, Region 5 and Region 10, EPA 542-S-02-001.

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/60/B-07/001.

ATTACHMENT A
PUMP/TUBING INTAKE PLACEMENT/POSITIONING FOR LOW-FLOW GROUNDWATER SAMPLING

TITLE

SOP SAS-08-02
ATTACHMENT A
PUMP/TUBING INTAKE PLACEMENT/POSITIONING FOR LOW FLOW GROUNDWATER SAMPLING



NOTE

If water column height is less than 2 feet, do not use the low flow sampling method.

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STANDARD OPERATING PROCEDURE
NO. SAS-08-03

WELL-VOLUME APPROACH GROUNDWATER SAMPLING
Revision 0

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for obtaining groundwater samples using the well-volume approach from groundwater monitoring wells, recovery wells, or observation wells as described in the Site-Specific Work Plan or as otherwise specified for the purpose of determining groundwater quality. The well-volume approach involves the purging of the stagnant water within the well and stabilization of water quality indicator parameters prior to sampling.

2.0 EQUIPMENT AND MATERIALS

- Map of well locations;
- Tools and well keys, as required to facilitate access to wells;
- Water level measuring device (e.g. electronic water level indicator, interface probe, or weight steel tape);
- Well construction information, as appropriate;
- Calculator / Conversion Chart
- Pump, if required by the Site-Specific Work and/or Field Sampling Plan (FSP);
- Teflon®, polyvinyl chloride (PVC), or polypropylene pump-specific tubing, if applicable;
- Power Source, if applicable;
- Bailer – Disposable (for disposable for purging and sampling), PVC (for purging only), and/or stainless steel (for purging and/or sample collection), if required by the Site-Specific Work and/or FSP;
- Rope, if applicable;
- Disposable plastic cups or stainless steel cup;
- Groundwater quality/indictor parameter monitoring instruments;
- Instrument operation manual(s);
- Instrument calibration standard(s);
- Container(s) for purge water storage (e.g. 5-gallon bucket, polyethylene storage tank, etc.);

- Sample containers and labels, as appropriate for the analytical method(s) selected;
- Field filtration equipment, if applicable;
- Chain of custody forms and seals;
- Cooler(s) with double-bagged ice;
- Polyethylene sheeting, as appropriate;
- Personal protective equipment;
- Decontamination materials and supplies;
- Field logbook and/or appropriate field form; and

3.0 HEALTH AND SAFETY WARNINGS

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 APPLICATION

The well-volume approach is one of several acceptable sampling procedures. The well-volume approach involves the purging of the stagnant water within the well and stabilization of water quality indicator parameters prior to sampling. While this method can be used in wells screened in any formation, it is generally used to sample low-permeability formations.

Newly constructed and developed wells shall be allowed a minimum of 48-72 hours to stabilize before sampling is performed. Once a well is purged, it should be sampled within 2 hours. If a purged well is allowed to sit longer than the prescribed 2 hours the water contained in the well casing may no longer be representative of aquifer conditions and the well shall be re-purged with one exception. If a well is purged dry, it should be sampled when a sufficient volume of water is present. In general, the sample collection shall take place within 24 hours of bailing or pumping the well dry.

5.0 EXECUTION

To the extent practical, sampling shall begin at the monitoring well with the least contamination and proceed systematically to the monitoring wells with the most contamination using the procedure outlined in the following subsections unless otherwise required by the Site-Specific Work and/or FSPs.

5.1 Preparation

The sampler shall create a work area around the monitoring well to minimize the potential for cross-contamination. Work area preparations may include the placement of polyethylene sheeting prevent sampling equipment from coming in contact with the ground surface. The sampler shall barricade and/or flag the work area, if required by the Site-Specific HASP. The sampler shall also arrange the sampling equipment and supplies to facilitate efficient execution of groundwater sampling procedures.

5.2 Well Gauging

Groundwater and non-aqueous phase liquid (NAPL), if present, elevation measurements shall be obtained in accordance with SOP SAS-08-01 or as otherwise specified in the Site-Specific Work and/or FSP. The sampler shall also obtain the total well depth from top of casing (in feet to the nearest 0.01-foot) using a water level indicator, interface probe, or steel tape, as required by the Site-Specific Work and/or FSP or otherwise specified. Total well depths may be obtained prior to the sampling and provided to the sampler. If total well depth is required to be measured immediately prior to sampling, the sampler will take precautions to minimize the displacement of sediments, if present, within the well during gauging activities. In general, the use of an interface probe shall be limited to wells containing NAPL or elevated concentrations of constituents of concern. Groundwater and NAPL elevation measurements and total well depth measurements shall be recorded in the field logbook and/or on the appropriate field form.

5.3 Standing Water Column Calculation

The sampler shall calculate the standing water column using the following formula:

Standing Water Column $_{(Feet)}$ = TD $_{(FT\ BTOC)}$ – DTW $_{(FT\ BTOC)}$

Where: TD = Total Well Depth
FT BTOC = Feet below top of well casing
DTW = Depth to Water

The sampler shall record the calculation in the field logbook and/or on the appropriate field form.

5.4 Volume Calculations

The sampler shall calculate the volume of water required to be purged prior to sampling. Depending on data quality objectives, state- or regulatory program-specific requirements, and the Site-Specific Work and/or FSP, one of two methods may be used: casing volume or borehole volume. In general, a minimum of three volumes of water, casing or borehole, shall be purged prior to sample collection (see section 5.6 below) in addition to stabilization of groundwater quality indicator parameters.

5.4.1 Casing Volume Calculation:

The sampler shall calculate the casing volume, which is the volume of water inside the well casing only, using the following formula.

One Casing Volume $_{(Gallons)}$ = Standing Water Column $_{(Feet)}$ X Volume per One Foot of Casing ^{WDS} $_{(Gallons/Foot)}$

Where: ^{WDS} = Well diameter-specific (see table below)

Well Diameter-Specific Volume Per One Foot of Casing				
Well Diameter (Inches)	**Volume Per Foot of Casing (Gallons)**		**Well Diameter (Inches)**	**Volume Per Foot of Casing (Gallons)**
0.25	0.0026		4.0	0.6528
0.50	0.0102		6.0	1.469
0.75	0.0230		8.0	2.611
1.0	0.0408		10.0	4.081
2.0	0.1632		12.0	5.876

The sampler shall record the calculation in the field logbook and/or on the appropriate field form.

5.4.2 Borehole Volume Calculation

The sampler shall calculate the borehole volume, which is the volume of water inside the well casing and volume of water inside the filter pack, using the following formula. Please note that this calculation requires the sampler to know the borehole diameter, filter pack height/elevation, and filter pack porosity.

One Borehole Volume $_{(Gallons)}$ = n ((A X B) – (A X C)) + (C X D)

Where: n = porosity of the filter pack (generally assumed to be 25% or 0.25)

A = height (in feet) of saturated filter pack

B = borehole diameter-specific volume (see table below)

C = well diameter-specific volume (see table below)

D = standing water column (see Section 5.4.1 above)

Diameter-Specific Volume Per One Foot of Borehole or Casing					
Diameter (Inches)	**Volume Per Foot of Borehole or Casing (Gallons)**		**Diameter (Inches)**	**Volume Per Foot of Borehole or Casing (Gallons)**
0.25	0.0026		4.0	0.6528
0.50	0.0102		6.0	1.469
0.75	0.0230		8.0	2.611
1.0	0.0408		10.0	4.081
2.0	0.1632		12.0	5.876

The sampler shall record the calculation in the field logbook and/or on the appropriate field form.

5.5 Equipment Assembly and Preparation

5.5.1 Pumps

Extreme caution should be exercised to ensure that the equipment does not cause cross-contamination from one well to the next. Therefore, dedicated tubing and pumps are preferred. If it is not practical to dedicate a pump to a specific well, the pump shall be decontaminated in accordance with SOP SAS-04-04. Tubing should always be dedicated and never used for more than one well.

The sampler shall place or position the pump/tubing intake not greater than 6 feet below the dynamic water level in the well and a minimum of one foot above the well sump to the extent practical. The sampler shall slowly raise or lower the pump or tubing when placing or positioning intake in order to minimize the displacement of sediments, if present, within the well. The pump model/type, tubing type, inner diameter, and length, and pump/tubing intake depth/elevation shall be recorded in the field logbook and/or on the appropriate field form.

5.5.2 Bailers

If a non-dedicated PVC and/or stainless steel bailer(s) is/are used, the bailer(s) must be decontaminated in accordance with SOP SAS-04-04 prior to well purging. The bailer shall be secured using rope to a purge water storage container, protective cover, flush-mount lid, or other object such that the bailer can be retrieved from the well. The rope that will enter the well casing shall not come in with the ground.

5.6 Purging and Groundwater Quality/Indicator Parameter Monitoring

The Site-Specific Work and/or FSP shall specify the groundwater quality/indicator parameters to be monitored, which typically include temperature, pH, and specific conductance or actual conductivity. In some instance, oxidation-reduction potential may also be monitored. Due to the potential disturbance of the water column, dissolved oxygen and turbidity are generally not utilized as stabilization parameters. However, visual clarity is generally documented during purging process. Parameter monitoring will begin after a minimum of one volume, casing or borehole (as specified by the Site-Specific Work and/or FSP) has been purged from the well. The sampler shall monitor and record in the field logbook and/or on the appropriate field form parameters a minimum of every well volume until parameters have stabilized. Parameter stabilization is considered to be achieved when three consecutive readings, taken every well volume are within the parameter-specific limit listed in the table below or as specified in the Site-Specific Work and/or FSP and a minimum of three volumes, casing or borehole (as specified by the Site-Specific Work and/or FSP), have been evacuated from the well or the well is purged dry, whichever occurs first. Purging methods are discussed in Sections 5.6.1 and 5.62 below.

Parameter	**Stabilization Criteria**[1]
Conductance, Specific Electrical	+/- 3% S/cm @ 25^{o}C
Conductivity, Actual[2]	+/- 3% S/cm
pH	+/- 0.1 standard units
Temperature	+/- 0.5 ^{o}C

Once the parameters have stabilized and a minimum of three volumes, casing or borehole (as specified by the Site-Specific Work and/or FSP), have been evacuated from the well or the well is purged dry, sample collection shall commence (see Section 5.7 below).

5.6.1 Pumps

Following pump/tubing intake placement, the sampler shall commence with purging by turning on the pump. During pumping, intermittently collect pump discharge in a container of known volume for a period of not less than 1 minute to determine the pump flow rate. The approximate pump flow rate shall be documented in the field logbook and/or on the appropriate field form. The sampler shall monitoring groundwater quality/indicator parameters, as described in above, by collecting pump discharge in a disposable plastic cup, stainless steel cup, or other manner befitting the monitoring instruments. Groundwater quality/indicator parameters shall be recorded in the field logbook and/or on the appropriate field form along with the time and volume of water purged. The evacuated/purged water shall be containerized in an approved storage container as required by the Site-Specific Work and/or FSP.

[1] USEPA, 2002, Ground-Water Sampling Guidelines for Superfund and RCRA Project Managers, EPA 542-S-02-001
[2] Based on the stabilization criteria for specific electrical conductance as published in the documented cited above

5.6.2 Bailers

The sampler shall slowly lower and raise the bailer in the well in order to minimize the displacement of sediments, if present, within the well. The sampler shall monitoring groundwater quality/indicator parameters, as described in above, by collecting bailer discharge in a disposable plastic cup, stainless steel cup, or other manner befitting the monitoring instruments. Groundwater quality/indicator parameters shall be recorded in the field logbook and/or on the appropriate field form along with the time and volume of water purged. The evacuated/purged water shall be containerized in an approved storage container as required by the Site-Specific Work and/or FSP.

5.7 Sample Collection

5.7.1 Pumps

In general, groundwater samples shall only be collected from adjusted rate peristaltic pumps or adjustable rate low-flow submersible or positive displacement pumps. Groundwater samples shall be collected directly into the laboratory provided sample containers from the tubing, before the water has passed through the flow-through cell. This shall be accomplished by using a by-pass assemble or disconnecting the flow-through cell to obtain the sample. Samples shall be collected in order of analyte stability, as summarized below, unless otherwise specified by the Site-Specific Work and/or FSP:

- Volatile organic compounds (VOCs);
- Semi-volatile organic compounds (SVOCs);
- Non-filtered, non-preserved samples (e.g. Polychlorinated byphenols (PCBs), sulfate, etc.);
- Non-filtered, preserved samples (e.g. phenols, nitrogen, cyanide, total metals, etc.);
- Filtered, non-preserved samples;
- Filtered, preserved immediately samples (e.g. dissolved metals); and
- Miscellaneous parameters.

Immediately following collection, samples shall be placed in a cooler with double-bagged ice.

5.7.2 Bailers

In general, groundwater samples shall only be collected from disposable or stainless steel bailers. Groundwater samples shall be collected directly into the laboratory provided sample containers from the bailer. Samples shall be collected in order of analyte stability, as summarized below, unless otherwise specified by the Site-Specific Work and/or FSP:

- VOCs;
- SVOCs;
- Non-filtered, non-preserved samples (e.g. PCBs, sulfate, etc.);
- Non-filtered, preserved samples (e.g. phenols, nitrogen, cyanide, total metals, etc.);
- Filtered, non-preserved samples;
- Filtered, preserved immediately samples (e.g. dissolved metals); and
- Miscellaneous parameters.

Immediately following collection, samples shall be placed a cooler with double-bagged ice.

5.7.3 Quality Control Samples

Quality Control (QC) samples, if required, will be collected consecutively to ensure appropriate duplicate sample collection in accordance with SOP SAS-04-03. Immediately following collection, samples shall be placed in a cooler with double-bagged ice.

5.8 Post-Sample Collection

Non-dedicated and dedicated sampling equipment, which does not remain within the well casing, shall be removed from the monitoring well. The reusable and/or dedicated equipment and instruments shall be decontaminated in accordance with SOP SAS-04-04 or as otherwise specified by the Site-Specific Work and/or FSP. Disposable equipment and supplies shall be disposed of in accordance with procedures outlined in the Site-Specific Work and/or FSP. The sampler shall secure the well casing using a slip or expandable well cap. The flush-mount lid shall be bolted down or the protective cover lid closed and locked, as appropriate.

6.0 DOCUMENTATION

Sample information, labeling, and custody control shall be performed in accordance with requirements specified in SOP SAS-03-01 and SAS-03-02. Sampling activities shall be recorded in the field logbook and/or on the appropriate field form as specified in SOP SAS-01-01 or as required by the Site-Specific Work and/or FSP.

7.0 REFERENCES AND ADDITIONAL RESOURCES

ASTM International, D4448-01 Standard Guide for Sampling Groundwater Monitoring Wells

ASTM International, D5903-96(2001) Standard Guide for Planning and Preparing for a Groundwater Sampling Event

ASTM International, D6089-97(2003)e1 Standard Guide for Documenting a Ground-Water Sampling Event

ASTM International, D6301-03 Practice for the Collection of Samples of Filterable and Nonfilterable Matter in Water

ASTM International, D6452-99(2005) Standard Guide for Purging Methods for Wells Used for Ground-Water Quality Investigations

ASTM International, D6564-00(2005) Standard Guide for Field Filtration of Ground-Water Samples

ASTM International, D6634-01 Guide for the Selection of Purging and Sampling Devices for Ground- Water Monitoring Wells

ASTM International, D6771-02 Practice for Low-Flow Purging and Sampling for Wells and Devices Used for Ground-Water Quality Investigations

USEPA, 2001, Environmental Investigations Standard Operating Procedures and Quality Assurance Manual (EISOPQAM), Region 4, Enforcement and Investigations Branch, SESD, Athens, Georgia, www.epa.gov/region4/sesd/eisopqam/eisopqam.html.

USEPA, 2002, Ground-Water Sampling Guidelines for Superfund and RCRA Project Manager, Region 5 and Region 10, EPA 542-S-02-001.

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/60/B-07/001.

STANDARD OPERATING PROCEDURE
NO. SAS-08-04

AQUIFER TESTING
Revision 0

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for field evaluation of aquifer hydraulic conductivity. Variations in the hydraulic conductivity within or between formations or strata can create irregularities in groundwater flow paths. Formations of high hydraulic conductivity represent areas of greater groundwater flow and, therefore, zones of potential preferred contaminant migration. Further, anisotropy within strata or formations affects the magnitude and direction of groundwater flow. Thus, information on hydraulic conductivities is necessary to evaluate preferential flow paths and groundwater velocity.

Hydrogeologic assessments should contain data on the hydraulic conductivities of the significant formations underlying the site as measured in monitoring wells. It may be beneficial to use numerical or laboratory methods to augment results of field tests. However, field methods provide the best definition of the horizontal hydraulic conductivity in most cases. Field methods differ from laboratory methods which measure vertical hydraulic conductivity, typically in Shelby tube samples.

2.0 EQUIPMENT AND MATERIALS

- Pump (and generator if required) capable of withdrawal at a constant or predetermined variable rate that can meet the designed pumpage rate and lift requirements
- Water pressure transducers and data logger (bring transducers for the pumping well and each observation well as well as extras in case of malfunction)
- A flow meter or other type of water measuring device to accurately measure and monitor the discharge from the pumping well
- Sufficient hose or pipe to convey discharge outside the recharge area of the pumping well and observation wells
- Electric water level indicator(s) capable of measurement to the hundredth of a foot
- Watch or stopwatch with second hand
- Barometer (some groundwater multiprobes include a barometer)

- Tape Measure of appropriate length based on distance to observation wells.
- Flashlights, lanterns, alarm clock, electrical tape
- Semi-log graph paper, pens, and field book

3.0 HEALTH AND SAFETY WARNINGS

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 METHODS

4.1 Field Methods

Varieties of procedures are available for evaluating hydraulic conductivity in the field. ASTM D4043-96(2004) Guide for Selection of Aquifer Test Method in Determining Hydraulic Properties by Well Techniques should be consulted in selecting an appropriate test method. Field methods for collecting hydraulic conductivity data are described in a number of ASTM standard practices:

- D2434-68(2000) Test Method for Permeability of Granular Soils (Constant Head)
- D4044-96(2002) Test Method (Field Procedure) for Instantaneous Change in Head (Slug) Tests for Determining Hydraulic Properties of Aquifers
- D4050-96(2002) Test Method (Field Procedure) for Withdrawal and Injection Well Tests for Determining Hydraulic Properties of Aquifer Systems
- D4104-96(2004) Test Method (Analytical Procedure) for Determining Transmissivity of Nonleaky Confined Aquifers by Overdamped Well Response to Instantaneous Change in Head (Slug Tests)
- D4105-96(2002) Test Method (Analytical Procedure) for Determining Transmissivity and Storage Coefficient of Nonleaky Confined Aquifers by the Modified Theis Nonequilibrium Method
- D4106-96(2002) Test Method (Analytical Procedure) for Determining Transmissivity and Storage Coefficient of Nonleaky Confined Aquifers by the Theis Nonequilibrium Method

- D4511-00 Test Method for Hydraulic Conductivity of Essentially Saturated Peat
- D4630-96(2002) Test Method for Determining Transmissivity and Storage Coefficient of Low-Permeability Rocks by In Situ Measurements Using the Constant Head Injection Test
- D4631-95(2000) Test Method for Determining Transmissivity and Storativity of Low Permeability Rocks by In Situ Measurements Using Pressure Pulse Technique
- D5269-96(2002) Test Method for Determining Transmissivity of Nonleaky Confined Aquifers by the Theis Recovery Method
- D5270-96(2002) Test Method for Determining Transmissivity and Storage Coefficient of Bounded, Nonleaky, Confined Aquifers
- D5472-93(2005) Test Method for Determining Specific Capacity and Estimating Transmissivity at the Control Well
- D5473-93(2000) Test Method for (Analytical Procedure for) Analyzing the Effects of Partial Penetration of Control Well and Determining the Horizontal and Vertical Hydraulic Conductivity in a Nonleaky Confined Aquifer
- D5720-95(2002) Practice for Static Calibration of Electronic Transducer-Based Pressure Measurement Systems for Geotechnical Purposes
- D5785-95(2000) Test Method for (Analytical Procedure) for Determining Transmissivity of Confined Nonleaky Aquifers by Underdamped Well Response to Instantaneous Change in Head (Slug Test)
- D5786-95(2000) Practice for (Field Procedure) for Constant Drawdown Tests in Flowing Wells for Determining Hydraulic Properties of Aquifer Systems
- D5850-95(2000) Test Method for (Analytical Procedure) Determining Transmissivity, Storage Coefficient, and Anisotropy Ratio from a Network of Partially Penetrating Wells
- D5855-95(2000) Test Method for (Analytical Procedure) for Determining Transmissivity and Storage Coefficient of a Confined Nonleaky or Leaky Aquifer by Constant Drawdown Method in a Flowing Well
- D5881-95(2005) Test Method for (Analytical Procedure) Determining Transmissivity of Confined Nonleaky Aquifers by Critically Damped Well Response to Instantaneous Change in Head (Slug)
- D5912-96(2004) Test Method for (Analytical Procedure) Determining Hydraulic Conductivity of an Unconfined Aquifer by Overdamped Well Response to Instantaneous Change in Head (Slug)
- D5920-96(2005) Test Method (Analytical Procedure) for Tests of Anisotropic Unconfined Aquifers by Neuman Method

- D6028-96(2004) Test Method (Analytical Procedure) for Determining Hydraulic Properties of a Confined Aquifer Taking into Consideration Storage of Water in Leaky Confining Beds by Modified Hantush Method
- D6029-96(2004) Test Method (Analytical Procedure) for Determining Hydraulic Properties of a Confined Aquifer and a Leaky Confining Bed with Negligible Storage by the Hantush-Jacob Method
- D6030-96(2002) Guide for Selection of Methods for Assessing Groundwater or Aquifer Sensitivity and Vulnerability
- D6034-96(2004) Test Method (Analytical Procedure) for Determining the Efficiency of a Production Well in a Confined Aquifer from a Constant Rate Pumping Test
- D6391-99(2004) Test Method for Field Measurement of Hydraulic Conductivity Limits of Porous Materials Using Two Stages of Infiltration from a Borehole

4.2 Single Well Tests

Hydraulic conductivity can be determined in the field using a variety of test methods, each addressing specific conditions and/or data collection objectives. These methods are commonly referred to as bail down or slug tests and are performed by adding or removing a slug (known volume) of water from a well and observing the recovery of the water surface to its original level. Similar results can be achieved by pressurizing the well casing, depressing the water level, and suddenly releasing the pressure to simulate removal of water from the well. One method is described by McLane, et. al. (1990) and is contained in references to the Standard Practices.

When reviewing information obtained from single well tests, several criteria should be considered. First, they are run on one well and, as such, the information is limited to the geologic area directly adjacent to the screen. Second, the vertical extent of screening will control the part of the geologic formation that is being analyzed during the test. That part of the column above or below the screen and sand filter pack interval that has not been tested may also have to be tested for hydraulic conductivity. Third, the methods used to collect the information obtained from single well tests should be adequate to accurately measure parameters such as changing static water (prior to initiation, during, and following completion of the test), the amount of water removed from the well, and the elapsed time of recovery. This is especially important in highly permeable formations where pressure transducers and high speed recording equipment may need to be used.

Observation wells in which the well screen intersects the water table (i.e. water table wells) will be tested only by methods involving removal of water from the well in order to minimize the potential for well screen filter pack interference. Addition of water to a monitor well is appropriate only to piezometer installation. However, the addition of water to any monitoring well shall be avoided whenever possible, since the addition may affect water quality in sampling events. In cases where addition of water to a well is unavoidable, it should be of document-able known quality and removed upon completion of the test.

The interpretation of the single well test data should be consistent with the existing geologic information (boring log data). The well screen and filter pack adjacent to the interval under examination should have been properly developed to ensure the removal of fines or correct deleterious drilling effects.

It is important that bail down tests be of sufficient duration to provide representative measures of hydraulic conductivity. Staff should be aware of initial rapid water level recovery during a bail down test which may represent drainage of the filter pack material around the well screen. This is of particular concern in wells screened in silty clay formations. These data points should be ignored when selecting the appropriate data points to establish a water level recovery slope.

4.3 Multiple Well Tests

Multiple well tests, more commonly referred to as pumping tests, are performed by pumping water from one well and observing the resulting drawdown in nearby wells. Tests conducted with wells screened in the same water-bearing formation provide hydraulic conductivity data. Tests conducted with wells screened in different water-bearing zones furnish information concerning hydraulic communication between units. Multiple well tests for hydraulic conductivity are advantageous because they characterize a greater proportion of the subsurface and thus provide a greater amount of detail. Multiple well tests are subject to similar constraints to those listed above for single well tests. Some additional problems that should have been considered in conducting a multiple well test include: (1) storage of potentially contaminated water pumped from the well system, and (2) potential effects of groundwater pumping on existing waste plumes. The geologic constraints should be considered to interpret the pumping test results. Incorrect assumptions regarding geology may translate into incorrect estimations of hydraulic conductivity.

4.4 Laboratory Methods

Laboratory analysis of undisturbed samples (e.g. Shelby tube) provides values of vertical hydraulic conductivity. When laboratory methods are to be used, the specific ASTM Standard Practice shall be referenced in samples provided to subcontractors. ASTM methods shall be consulted to assure that test methods specified are applicable to the sample to be tested.

5.0 CONTROLLED PUMPING TESTS

The most representative method for determining aquifer characteristics is by controlled aquifer pumping tests, because these tests stress a much larger volume of the formation than slug tests and laboratory tests. Pumping tests require a higher level of effort and expense than other types of aquifer tests, and are not always justified. As an example, slug tests may be acceptable for site characterization, whereas pumping tests may be performed to support remedial design or modeling.

Aquifer characteristics that may be obtained from pumping tests include transmissivity (T), hydraulic conductivity (K), specific yield (Sy) for unconfined aquifers, and storage coefficient (S) for confined aquifers. These parameters can be determined by graphical solutions and computerized programs, such as Aqtesolv®.

These are standard (i.e., typically applicable) operating procedures which may be varied or changed as required dependent on site conditions, equipment limitations, or limitations imposed by the procedure. In all instances, the ultimate procedures employed should be documented and associated with the final report.

5.1 Summary

If possible, continuously monitor pre-test water levels at the test site for about one week prior to performance of the pump test. This information allows for the determination of the barometric efficiency of the aquifer, as well as noting changes in head due to recharge or pumping in the area adjacent to the well. Prior to initiating the long-term pump test, a step test (Section 5.5) is performed to estimate the greatest flow rate that may be sustained by the pump well.

After the pumping well has recovered from the step test, the long-term pumping test begins. At the beginning of the test, the discharge rate is set as quickly and accurately as possible. The water levels in the pumping well and observation wells are recorded following a set schedule. The duration of the test is determined by project needs and aquifer properties; typically three days or until water levels becomes constant.

5.2 Interferences and Potential Problems

Prior to conducting a pumping test, efforts should be made to anticipate and resolve interferences and potential problems that could affect the aquifer or the test. These problems could be caused by changing atmospheric conditions, impact of local potable wells, contaminants in the aquifer, etc. Note that if it is necessary for a neighboring well to continue pumping, it should be pumped at a constant rate and not started or stopped for the duration of the test.

5.3 Pumping Discharge

If a pumping test will be conducted in an area with contaminated groundwater, special arrangements must be made for proper handling, treatment, and disposal of the water. The preferred method is to discharge to a sanitary sewer, with prior approval.

Uncontaminated groundwater discharge generated during a pumping test should be sent to storm or sanitary sewers, abiding by all applicable regulations. If there are no sewers in the vicinity of the pumping well, the discharge may be sent to a river or pond. If the previously mentioned discharge options are not available, the groundwater may be discharged to the ground surface under either of the following conditions:

- The aquifer being tested is confined; or
- The end of the discharge hose/pipe is outside of the cone of depression created by the pumping well when testing an unconfined aquifer.

5.4 Pre-Test Procedures

The hydrostratigraphy of the aquifer should be fully characterized prior to performance of the test to identify formation thickness, whether it is confined or unconfined, whether confining layers are leaky and to identify any lateral boundaries that may influence results.

If the pumping test occurs at a site where existing production and/or monitoring wells will be used, confirm that the locations and screened intervals of the wells are within the same aquifer, and meet the requirements of the method of analysis.

If possible, continuously measure water levels in the pumping well and all observation wells for a period at least equal to the length of the test. These measurements will establish a pre-pumping trend. The trend should be similar in all wells. A well with an unusual trend may indicate some local stress in the aquifer.

When barometric records are available, changes in barometric pressure will be recorded during the test in order to correct water levels for any possible fluctuations that may occur due to changing atmospheric conditions. Pre-test water level trends are projected for the duration of the test. These trends and/or barometric changes are used to "correct" water levels during the test so they are representative of the hydraulic response of the aquifer due to pumping of the test well.

5.5 Step Test

The step drawdown test is performed to determine the maximum pumping rate that the pumping well can sustain and the minimum pumping rate necessary to assure drawdown in the observation wells. The pumping and observation wells are equipped with transducers prior to the test. The test is then performed by pumping at a low rate, relative to the expected final rate of pumpage, until drawdown in the pumping well stabilizes. The rate is then increased again until drawdown in the pumping well stabilizes (step 2). A minimum of three steps will be tested; the duration of each step will be similar, and should be between 30 minutes and 2 hours.

The data are then plotted on semi-log paper or on a computer. The minimum sustainable pumping rate that yields drawdown in the closest observation wells will be used as the target-pumping rate for the longterm test. These data may also be used to determine aquifer properties and well loss in the pumping well.

6.0 PUMP TEST

6.1 Time Intervals

Commence the long-term pumping test after the pumping well has fully recovered from the step test.

Place transducers into the observation wells prior to starting the test and allow time for them to equilibrate to the water temperature within the well. At the beginning of the test, the discharge rate should be set as quickly and accurately as possible. Record the pumping and observation well water levels with transducers and a data logger(s) set to record logarithmically. As backup in case of transducer malfunction, manually record water levels on field forms and/or field notebooks according to the schedules in Tables 1 and 2:

Table 1: Time Intervals for Measuring Drawdown in the Pumped Well

Elapsed Time Since Start or Stop of Test (Minutes)	Interval Between Measurements (Minutes)
0-10	0.5-1
10-15	1
15-60	5
60-300	30
300-1440	60
1440-termination	480

Table 2: Time Intervals for Measuring Drawdown in an Observation Well

Elapsed Time Since Start or Stop of Test (Minutes)	Interval Between Measurements (Minutes)
0-60	2
60-120	5
120-240	10
240-360	30
360-1440	60
1440-termination	480

6.2 Water Level Measurements

Water levels will be measured as specified in the SOP SAS-08-01. During the early part of the test, sufficient personnel are required to initiate the pumping test data loggers and assist with manual water level measurements of the pumping well and flow rate measurements. Manual measurements are required as a backup to and verification of the data logger(s). After the first two hours, one to two people are usually sufficient to continue the test. It is not necessary that readings at the wells be taken simultaneously. It is very important that depth to water readings be measured accurately and the exact time of readings is recorded.

During a pumping test, the following data must be recorded accurately on the log book and/or the aquifer test data form.

- Project ID - A number assigned to identify a specific site.
- Well ID - The location of the well in which water level measurements are being taken.
- Distance and Direction from Pumped Well - Distance and azimuth to each observation well from the pumping well in feet.
- Personnel - The personnel conducting the pumping test.
- Pumping Start and End Date/Time - The date when the pumping began, and start time using a 24-hour clock.
- Initial Static Water Level (Test Start) - Depth to water, to the nearest 0.01 feet, in the observation well at the beginning of the pumping test.
- Test End Date/Time - The date and time when water level readings were discontinued.
- Final Static Water Level (Test End) - Depth to water, to the nearest 0.01 feet, in the observation well at the end of the pumping test.
- Target Pumping Rate
- Measurement Methods - Type of pump, type of data logger(s) used to record water levels, transducer ID number, and acquisition rate (i.e. data recorded on a log scale)
- Notes - Appropriate observations or information which has not been recorded elsewhere, including notes on sampling, pH readings, and conductivity readings.
- Elapsed Time (min) - Time of manual measurement record from time 0.00 (start of test) recorded in minutes and seconds.
- Depth to Water (ft) – Manual depth to water measurement, to the nearest 0.01 feet, in the observation well at the time of the water level measurement.

- Flow Rate (gal/min) - Flow rate of pump measured from an orifice, weir, flow meter, container, or other type of water measuring device.

6.3 Test Duration

The duration of the test is determined by the needs of the project and properties of the aquifer. One simple test for determining adequacy of data is when the log-time versus drawdown for the most distant observation well begins to plot as a straight line on the semi-log graph paper. There are several exceptions to this simple rule of thumb; therefore, it should be considered a minimum criterion. Different hydrogeologic conditions can produce straight-line trends on log-time versus drawdown plots. In general, longer tests produce more definitive results. Duration of one to three days is desirable, followed by a similar period of monitoring the recovery of the water level. Unconfined aquifers and partially penetrating wells may have shorter test durations. Knowledge of the local hydrogeology, combined with a clear understanding of the overall project objectives is necessary in judging appropriate test duration. There is no need to continue the test once the water levels in the observation wells stabilize.

The recovery of water levels following pumping phase may be measured and recorded for a period of time equal to the pumping phase. The frequency of the water level measurements should be similar to the frequency of water level measurements during the pumping phase (Table 1).

7.0 POST OPERATION

The following activities are performed after completion of water level recovery measurements:

- Decontaminate and/or dispose of equipment per SOP SAS-04-04.
- When using an electronic data-logger, use the following procedures:
  - Stop logging sequence
  - Check file size, print data, and/or save memory to a reliable storage device (i.e. hard drive or USB drive): Backup the data as soon as possible upon completion of a test!
  - Do not clear the memory of the transducer until the data has been saved onto a hard drive
- Review field forms for completeness.
- Replace testing equipment in storage containers
- Check sampling equipment and supplies. Repair or replace all broken or damaged equipment.
- Interpret pumping/recovery test field results.

8.0 CALCULATIONS

Upload the data from the test into a spreadsheet to be entered into a computerized program, such as Aqtesolv®. Use the information entered into the Data Acquisition Form to complete the computer analysis of the data. There are several accepted methods for determining aquifer properties such as transmissivity, storativity, and conductivity. The appropriate method to use is dependent on the characteristics of the aquifer being tested (confined, unconfined, leaky confining layer etc.). When reviewing pump test data, the following text and/or documents may be used to determine the method most appropriate to your case:

- Analysis and Evaluation of Pumping Test Data (Kruseman and Ridder, 1989)
- Applied Hydrogeology (Fetter, 2000)
- Groundwater and Wells (Driscoll, 1986)
- ASTM D4105-96(2002)
- ASTM D4106-96(2002)

9.0 QUALITY ASSURANCE/ QUALITY CONTROL (QA/QC)

Gauges, transducers, flow meters, and other equipment used in the pumping tests will be calibrated before use at the site. Copies of the documentation of instrumentation calibration will be filed with the test data records. The calibration records will consist of laboratory measurements and, if necessary, any on-site zero adjustment and/or calibration that were performed. Where possible, all flow and measurement meters will be checked on-site using a container of measured volume and stopwatch; the accuracy of the meters must be verified before testing proceeds.

10.0 DATA REDUCTION AND INTERPRETATION

Data collected from single well tests will be analyzed by methods described by Bouwer and Rice (1976). Multiple well data can be analyzed by a variety of methods, depending on the specific geologic and well parameters. Texts such as Driscoll (1986) or other well hydraulics references should be consulted for selection of the proper method of data analysis. In reviewing hydraulic conductivity measurements, the following criteria should be considered to evaluate the accuracy or completeness of information.

- Values of hydraulic conductivity between wells in similar lithologies should generally not exceed one order of magnitude difference.

- Hydraulic conductivity determinations based upon multiple well tests are preferred. Multiple well tests provide more complete information because they characterize a greater portion of the subsurface.
- Use of single well tests will require that more individual tests be conducted at different locations to sufficiently define hydraulic conductivity variation across the site.
- Hydraulic conductivity information generally provides average values for the entire area across a well screen. For more depth discrete information, well screens will have to be shorter. If the average hydraulic conductivity for a formation is required, entire formations may have to be screened, or data taken from overlapping clusters.

It is important that measurements define hydraulic conductivity both vertically and horizontally across the site. Laboratory tests may be necessary to ascertain vertical hydraulic conductivity in saturated formations or strata. Results from boring logs should also be used to characterize the site geology. Zones of high permeability or fractures identified from drilling logs should be considered in the determination of hydraulic conductivity. Additionally, information from boring logs can be used to refine the data generated by single well or pumping tests.

11.0 REFERENCES AND ADDITIONAL RESOURCES

Bouwer, H., and Rice, R.C., "A Slug Test for Determining Hydraulic Conductivity of Unconfined Aquifers with completely or Partially Penetrating Wells", Water Res. Res., 12 p. 423-428, 1976.

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ASTM International, D5472-93(2005) Test Method for Determining Specific Capacity and Estimating Transmissivity at the Control Well

ASTM International, D5473-93(2000) Test Method for (Analytical Procedure for) Analyzing the Effects of Partial Penetration of Control Well and Determining the Horizontal and Vertical Hydraulic Conductivity in a Nonleaky Confined Aquifer

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ASTM International, D6030-96(2002) Guide for Selection of Methods for Assessing Groundwater or Aquifer Sensitivity and Vulnerability

ASTM International, D6034-96(2004) Test Method (Analytical Procedure) for Determining the Efficiency of a Production Well in a Confined Aquifer from a Constant Rate Pumping Test

ASTM International, D6391-99(2004) Test Method for Field Measurement of Hydraulic Conductivity Limits of Porous Materials Using Two Stages of Infiltration from a Borehole

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/60/B-07/001.

STANDARD OPERATING PROCEDURE
NO. SAS-08-05

WELL INTEGRITY INSPECTION, MAINTENANCE, AND REHABILITATION
Revision 0

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for inspecting groundwater monitoring well integrity. The well integrity inspection identifies wells that in their current condition are not suitable for obtaining groundwater/product elevations, water quality and/or hydraulic information, groundwater/product samples and/or other data obtained using the well. The results of the evaluation shall be used to ensure the integrity of wells over extended periods of time by identifying conditions that warrant well maintenance and/or rehabilitation. This SOP also describes well maintenance and rehabilitation.

2.0 EQUIPMENT AND MATERIALS

- Map of well locations;
- Tools and well keys, as required to facilitate access to wells;
- Water level measuring device (electronic water level indicator, interface probe, or weighted steel tape);
- Adjustable rate pump, adjustable rate submersible or positive displacement bladder pump (Note: The Site-Specific Work and/or Field Sampling Plan (FSP) shall specify the type of pump required);
- 1/4 to 3/8-inch Teflon®, polyvinyl chloride (PVC), or polypropylene tubing, if applicable;
- Power source, if applicable;
- Compressed inert gas source (for use with bladder pump), if applicable;
- PVC or stainless steel bailer or solid slug;
- Rope;
- Pressure transducer and automatic data logger, if applicable;
- Container(s) for purge water storage (e.g. 5-gallon buckets, polyethylene storage tank, etc.);
- Existing well boring/construction logs, if available;
- Groundwater elevation table, if available;
- Polyethylene sheeting, as appropriate;

- Camera;
- Personal protection equipment; and
- Field logbook and/or appropriate field forms.

3.0 HEALTH AND SAFETY WARNINGS

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 EXECUTION

Inspections shall be performed at the frequencies described below or as required by the Site-Specific Work Plan to 1) verify the structural integrity of the wells above and below ground, 2) identify significant silt/sediment buildup in wells, and 3) identify biofouling that could contribute to corrosion of structures or decrease in the efficiency of recovery and pumping operations.

4.1 Well Location Verification

The location of each well shall be compared to that given on the site map. If the well location is found to be in error, the well shall be resurveyed and/or re-delineated relative to site features and its position adjusted on the map.

4.2 Aboveground Structural Integrity Inspection

The physical condition of the well will be determined by visually inspecting aboveground components during each monitoring and/or sampling event. Components to be inspected include:

- Protective casing/flush-mount cover;
- Bumper posts, if applicable;
- Concrete pad or apron, if applicable;
- Well cap (expandable or slip);
- Locking mechanism;
- Exposed top of casing; and
- Surface drainage around the wells.

If the aboveground components are damaged, well maintenance or rehabilitation is required (see Section 4.3).

4.3 Below Ground Well Structural Integrity Inspection

4.3.1 General

Total depth measurements shall be obtained annually in accordance with SOP SAS-08-01 and compared to the baseline total depth measurements obtained at the time of well installation, development, and/or start of the project. If a significant amount of silt/sediment is present, well maintenance or rehabilitation is required (see Section 4.3).

4.3.2 Monitoring Wells

A stainless steel or PVC bailer or slug, with a diameter and length equivalent to a sampling pump or bailer, shall be lowered the entire length of the well to identify obstructions or damage to the well casing and screen. If the bailer or slug cannot be lowered to within the screened interval, an obstruction or damage exists that requires well maintenance or rehabilitation (see Section 4.3).

4.3.3 Vapor Extraction Wells

Vacuum and air flow rates shall be measured periodically in accordance with system-specific procedures and compared to previous steady-state measurements and the current operational status of the system. If a significant change in vacuum and/or air flow rates is observed and not substantiated by the current operational status of the system, well maintenance or rehabilitation is required (see Section 4.3).

4.3.4 Recovery Wells

Recovery rates shall be evaluated at least once every quarter and compared to previous measurements. If a significant change in rates is observed and not substantiated by current product/water levels, well maintenance or rehabilitation is required (see Section 4.3).

4.4 Well Maintenance or Rehabilitation

Deficiencies or damage identified during aboveground and below ground well integrity inspections shall be evaluated on a case-by-case basis. Well maintenance or rehabilitation that cannot be implemented at the time of inspection shall be implemented within a reasonable period of time. Well maintenance or rehabilitation may include, but is not limited to, the following:

- Replacement of aboveground components;
- Silt/sediment removal;
- Well surging and redevelopment;
- Biomass removal and/or cleaning with an approved biocide; and
- Equipment (e.g. pumps, etc.) repair or replacement.

If deficiency or damage cannot be corrected through well maintenance or rehabilitation, the well shall be abandoned in accordance with SOP SAS-05-05 and applicable federal, state, and local regulations. Wells critical to site activities and/or operations shall be replaced in accordance with SOPs SAS-05-03 and SAS-05-04, applicable federal, state, and local regulations, and the Site-Specific Work Plan.

4.5 Decontamination

Non-Dedicated and dedicated equipment used for inspection and/or corrective action activities, which does not remain within the well casing, shall be removed from the well. The reusable and/or dedicated equipment and instruments shall be decontaminated in accordance with SOP SAS-04-04 or as otherwise specified by the Site-Specific Work Plan. Disposable equipment and supplies shall be disposed of in accordance with procedures outlined in the Site-Specific Work Plan.

5.0 DOCUMENTATION

Inspection, maintenance, and rehabilitation activities shall be recorded in the field logbook and/or on the appropriate field form as specified in SOP SAS-01-01 or as otherwise required by the Site-Specific Work Plan.

6.0 REFERENCES AND ADDITIONAL RESOURCES

ASTM International, D6089-97(2003) Standard Guide for Documenting a Ground-Water Sampling Event

ASTM International, D4448-01 Standard Guide for Sampling Groundwater Monitoring Wells

USEPA, 2001, Environmental Investigations Standard Operating Procedures and Quality Assurance Manual (EISOPQAM), Region 4, Enforcement and Investigations Branch, SESD, Athens, Georgia, www.epa.gov/region4/sesd/eisopqam/eisopqam.html.

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001.

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STANDARD OPERATING PROCEDURE NO. SAS-08-06

POTABLE WATER WELL SAMPLING Revision 0

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for the collection of water samples from water supply wells. Potable water samples are collected to evaluate the potable water supply. In some cases, potable water samples may be collected to evaluate the delivery system (e.g. well casing, pump, piping, etc.). The sampling guidelines described in the SOP are intended to facilitate the collection of representative samples.

2.0 EQUIPMENT AND MATERIALS

- Hand tools (e.g. crescent wrenches, pipe wrenches, and slip joint pliers), as needed;
- Garden water hose;
- Plastic sheeting;
- Graduated cylinder;
- Stopwatch;
- Sample containers and labels;
- Cooler with ice;
- Chain of custody forms and seals; and
- Personal protective equipment.

3.0 HEALTH AND SAFETY WARNINGS

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 PREPARATIONS

4.1 Sample Location Selection

In general, the installation of a sampling tap to obtain samples shall not be warranted. Potable water samples shall be collected from taps or spigots on the existing delivery system. Prior to sampling, the tap closest to the well shall be identified for sample collection. This location, to the extent practical, should be upstream of any filtration or water treatment device(s). If the location is not upstream of any filtration or water treatment device, the sampler shall recorded the type, manufacturer, and model of each filtration or water treatment device in the field logbook and/or on the appropriate field form. On rare occasions a tap or spigot may not be available for sampling. In these instances, the closest access point to the wellhead shall be selected for sampling. When project objectives include an evaluation of the water delivery, a representative location downstream of filtration or water treatment devices, may be selected. The selected or preferred sample locations shall be described in the Site-Specific Work and/or Field Sampling Plan (FSP).

4.2 Groundwater Elevation and Well Depth Measurements

In general, it is preferred to not obtain groundwater elevations and well depth measurements from public or private water supply wells. In most cases, groundwater elevation and well depth shall be estimated based on the driller's log and/or well completion report. In rare instances it may be necessary to measure groundwater elevation. In these cases, measurements shall be obtained using an electronic water level indicator which has been dedicated for use in potable water wells only and has been properly decontaminated and stored to prevent the introduction of contamination into the well. In addition, the water level indicator shall not be lowered any deeper than is necessary to obtain the groundwater elevation measurement.

4.3 Calculation of the Pre-Sample Purge Volume

When potable water samples are being collected to evaluate the potable water source, all standing/stagnant water shall be purged from the delivery system immediately prior to sample collection. The volume of water contained in the well casing, pressure or holding tanks, and other plumbing and appurtenances (pipes, hoses, etc.) shall be estimated by the sampler. All estimated volumes of water contained in plumbing and appurtenances, assumptions, and calculations shall be recorded in the field logbook and/or on the appropriate field form.

5.0 EXCUTION

5.1 Pre-Sample Purging

If sample(s) are being collected to evaluate the delivery system, a first draw sample shall be collected prior to the purging (see Section 5.3 below). If samples are being collected to evaluate the potable water supply, the system shall then be purged with a minimum of three times the calculated purge volume before sampling commences. If no information regarding well depth is available, purging shall be performed for 10 minutes prior to sampling. Pre-sample purging shall also take into account the following, if known:

- Pump intake level;
- Specific capacity of the aquifer; and
- Well efficiency.

Purged water if discharged to the ground surface shall be done in a manner that prevents icy conditions or damage on the property. In addition, the sampler shall divert purge water at way from the wellhead or building using hoses, plastic sheeting, irrigation pipe, or other appropriate means, to the extent practical. Purge waters shall be disposed at the nearest sump or drain available whenever possible.

If samples are being collected to evaluate the delivery system, the initial/first draw sample shall be collected prior to purging activities.

5.2 Groundwater Quality/Indicator Parameter Monitoring

The Site-Specific Work and/or Sampling Plan(s) shall specify the groundwater quality/indicator parameters to be monitored, which typically include temperature, pH, specific conductance or actual conductivity, oxidation-reduction potential, dissolved oxygen, and turbidity. Parameter monitoring will begin at the start of purging from the delivery system. The sampler shall monitor and record in the field logbook and/or on the appropriate field form parameters every two to three minutes (during continuous purging) until parameters have stabilized. Parameter stabilization is considered to be achieved when three consecutive readings, taken within 2 to 3 minute intervals are within the parameter-specific limit listed in the table below or as specified in the Site-Specific Work and/or Sampling Plan(s).

Parameter	Stabilization Criteria[1]
Conductance, Specific Electrical	+/- 3% S/cm @ 25^{o}C
Conductivity, Actual[2]	+/- 3% S/cm
Dissolved Oxygen	+/- 0.3 mg/L
Oxidation-Reduction Potential	+/- 10 mV
pH	+/- 0.1 standard units
Temperature	+/- 0.5 ^{o}C
Turbidity	+/- 10% NTUs or three consecutive readings less than or equal to 10 NTUs

Once the parameters have stabilized, purging is considered complete and sample collection shall commence, with the exception of the collection of a first draw sample. The first draw sample shall be collected prior to delivery system purging.

5.3 SAMPLING PROCEDURES

The sampler shall collect the potable water sample(s) from a tap or spigot on the existing delivery system, which is closest to the well. This location, to the extent practical, should be upstream of any filtration or water treatment device(s). If the location is not upstream of any filtration or water treatment device, the sampler shall recorded the type, manufacturer, and model of each filtration or water treatment device in the

[1] USEPA, 2002, Ground-Water Sampling Guidelines for Superfund and RCRA Project Managers, EPA 542-S-02-001
[2] Based on the stabilization criteria for specific electrical conductance as published in the documented cited above

field logbook and/or on the appropriate field form. The location, including a sketch, shall also be documented in the field logbook and/or on the appropriate field form.

Following purging activities, the sampling tap shall be shut off. The tap shall be turned on and adjusted to an approximate flow of 100 ml/min using a graduated cylinder and a stopwatch. The flow rate shall be recorded in the field logbook and/or on the appropriate field form. Sample bottles shall be filled in a manner which minimizes aeration. The sample bottles shall be filled as required in order of decreasing volatility. Any pertinent field observations (e.g. odors, discoloration, etc.) shall also be recorded in the field logbook and/or on the appropriate field form.

6.0 POST-SAMPLING PROCEDURES

Following sample collection, any filters, aerators, and/or treatment systems disconnected prior to sampling activities shall be reconnected. In addition, the sampling site shall be cleaned before leaving the vicinity.

7.0 DECONTAMINATION

Following sample collection, all equipment shall be decontamination as described in SOP SAS-04-04 or as otherwise specified by the Site-Specific Work and/or Sampling Plan(s).

8.0 DOCUMENTATION

Sample information, labeling, and custody control shall be performed in accordance with requirements specified in SOP SAS-03-01 and SAS-03-02. Sampling activities, including pertinent field information and observations, shall be recorded in the field logbook and/or on the appropriate field form as specified in SOP SAS-01-01 or as required by the Site-Specific Work and/or FSP including, but not limited to, the following:

- Condition of the well and dedicated equipment;
- Owner’s and occupant’s name(s);
- Facility name and address;
- Sampling location (specific tap or spigot);
- Filtering or treatment systems on delivery systems (if applicable);
- Aerator or filter on sampling tap;
- Pressure on holding tank volume (if applicable);
- Purge flow rate;

- Purge time;
- Total purge volume;
- Sample appearance (odor, color, turbidity, etc.); and
- Calculations for purge volumes.

9.0 REFERENCES AND ADDITIONAL RESOURCES

ASTM International, 1994, D5612-94R03 Guide for Quality Planning and Field Implementation of a Water Quality Measurement Program

ASTM International, 1995, D5851-95R00 Guide for Planning and Implementing a Water Monitoring Program

ASTM International, 2001, D5903-96(2001) Standard Guide for Planning and Preparing for a Groundwater Sampling Event

USEPA, 2001, Environmental Investigations Standard Operating Procedures and Quality Assurance Manual (EISOPQAM), Region 4, Enforcement and Investigations Branch, SESD, Athens, Georgia.

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001.

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STANDARD OPERATING PROCEDURE
NO. SAS-08-07

NON-AQUEOUS PHASE LIQUID SAMPLING
Revision 0

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for the collection of non-aqueous phase liquid (NAPL) samples from monitoring, observation, and/or recovery wells. NAPL samples are collected to support plume characterization and/or treatment/recovery system design. Light and dense NAPL, also referred to as LNAPL and DNAPL, may be collected for physical parameter determination (e.g. density, viscosity, etc.), simulated distillation, fingerprinting, waste characterization, etc.

2.0 EQUIPMENT AND MATERIALS

Equipment and materials may vary based on the type of NAPL being sampled (light or dense). In general, the following equipment and materials shall be required unless otherwise specified by the Site-Specific Work and/or Field Sampling Plan (FSP):

<u>LNAPL Sample Collection</u>:

- Bailer (disposable or dedicated);
- Rope;
- Peristaltic pump;
- Polyvinyl chloride or Teflon tubing (disposable or dedicated), as appropriate; and
- Silicone tubing (disposable or dedicated).

<u>DNAPL Sample Collection</u>:

- Solinst Model 425 Discrete Interval Sampler or equivalent;
- Low density polyethylene (LDPE) tubing;
- Solinst Reel or equivalent;
- High pressure hand pump or compressed air source with regulator; and
- Rope.

General:

- Water and NAPL gauging equipment (see SOP SAS-08-01);
- 5-gallon bucket;
- Approved storage container(s) (55-gallon drum, polyethylene tank, etc.);
- Sample containers and labels;
- Chain of custody forms and seals;
- Decontamination materials/equipment;
- Personal protective equipment; and
- Field logbook and/or appropriate field form.

3.0 HEALTH AND SAFETY

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 EXECUTION

4.1 Preparation

The sampler shall create a work area around the monitoring well to minimize the potential for cross-contamination. Work area preparations may include the placement of polyethylene sheeting prevent sampling equipment from coming in contact with the ground surface. The sampler shall barricade and/or flag the work area, if required by the Site-Specific HASP. The sampler shall also arrange the sampling equipment and supplies to facilitate efficient execution of NAPL sampling procedures.

4.2 Well Gauging

Groundwater and NAPL elevation measurements shall be obtained in accordance with SOP SAS-08-01 or as otherwise specified in the Site-Specific Work and/or FSP. The sampler shall also obtain the total well depth from top of casing (in feet to the nearest 0.01-foot) using a water level indicator, interface probe, or steel tape, as required by the Site-Specific Work and/or FSP or otherwise specified. Total well depths may be obtained prior to the sampling and provided to the sampler. If total well depth is required to be measured immediately prior to sampling, the sampler will take precautions to minimize the displacement of sediments, if present, within the well during gauging activities. Groundwater and NAPL elevation measurements and total well depth measurements shall be recorded in the field logbook and/or on the appropriate field form.

4.3 Standing NAPL Column and Casing Volume Calculations

The sampler shall calculate the standing NAPL column and casing volume using the following formulas:

4.3.1 LNAPL Column

$\text{Standing LNAPL Column}_{\text{(Feet)}} = \text{DTW}_{\text{(FT BTOC)}} - \text{DTP}_{\text{L (FT BTOC)}}$

Where: DTW = Depth to Water
FT BTOC = Feet below top of well casing
DTP_L = Depth to Product (LNAPL)

4.3.2 DNAPL Column

$\text{Standing DNAPL Column}_{\text{(Feet)}} = \text{TD}_{\text{(FT BTOC)}} - \text{DTP}_{\text{D (FT BTOC)}}$

Where: TD = Total Well Depth
FT BTOC = Feet below top of well casing
DTP_D = Depth to Product (DNAPL)

4.3.3 Casing Volume

$\text{Casing Volume}_{\text{(Gallons)}} = \text{Standing NAPL Column}_{\text{(Feet)}} \text{ X Volume per One Foot of Casing}^{\text{WDS}}_{\text{(Gallons/Foot)}}$

Where: $^{\text{WDS}}$ = Well diameter-specific (see table below)

Well Diameter-Specific Volume Per One Foot of Casing				
Well Diameter (Inches)	**Volume Per Foot of Casing** (Gallons)		**Well Diameter** (Inches)	**Volume Per Foot of Casing** (Gallons)
0.25	0.0026		4.0	0.6528
0.50	0.0102		6.0	1.469
0.75	0.0230		8.0	2.611
1.0	0.0408		10.0	4.081
2.0	0.1632		12.0	5.876

The sampler shall recorded calculations in the field logbook and/or on the appropriate field form.

4.4 Bailer/Tubing/Sampler Intake Position Determination

The sampler should determine the position/depth of the bailer/tubing/sampler intake, using the water and NAPL elevation measurements, such that the intake will be positioned within the bottom quarter of the NAPL column. The intake position (depth/elevation) shall be recorded in the field logbook and/or on the appropriate field form. In addition, the sampling equipment shall also be recorded in the field logbook and/or on the appropriate field form.

4.5 Well Evacuation

In order to obtain a representative NAPL sample from an existing well, the product that has stagnated and/or may have chemically changed in the well casing shall be removed prior to sampling. The evacuation will allow fresh NAPL to enter the well from the formation.

4.5.1 LNAPL Evacuation

If using a bailer, the sampler shall slowly lower the bailer to the intake position. The bailer shall be slowly retrieved from the well and the contents emptied into a 5-gallon bucket or an approved storage container. This process shall continue until no measurable amount (< 0.01 foot) of LNAPL remains or one casing volume of LNAPL has been removed, whichever occurs first. If using a peristaltic pump, the sampler shall slowly lower the tubing to the intake position. The pump shall be turned on and the removed LNAPL shall be collected in a 5-gallon bucket or an approved storage container. The pump process shall continue until no measurable amount (< 0.01 foot) of LNAPL remains or one casing volume of LNAPL has been removed, whichever occurs first.

The volume of LNAPL evacuated from the well shall be recorded in the field logbook and/or on the appropriate field form.

4.5.2 DNAPL Evacuation

The discrete interval sampler shall be connected to the tubing and reel. The high pressure hand pump or compressed air shall be connected to the reel. The sampler shall be pressured to the recommended operating pressure for the intake position/depth according to the following unless otherwise specified by the sampler operations manual and/or Site-Specific Work and/or FSP.

Recommended Operating Pressure[1]			
Depth		Pressure	
Feet	Meters	psi	kPa
25	8	20	148
50	15	30	217
100	30	50	364
200	61	95	670
300	90	140	952
500	150	225	1,495

Notes: 1. Operating pressure = (Sample depth in feet X 0.43) + 10 psi
2. Operating pressure = (Sample depth in meters X 9.8) + 70 kPa
3. psi = pounds per square inch
4. kPa = kiloPascals

While pressurized, the sampler shall then be lowered to the intake position/depth. At the desire depth, the pressure shall be released, which will allow the sampler to fill by hydrostatic pressure. The sampler shall then be re-pressurized to the recommended operating pressure. Following, re-pressurization, the sampler shall be

[1] http://www.groundwatersoftware.com/Equipment/solinst_model_425.htm

slowly raised to the surface. The contents shall be transferred to the 5-gallon bucket or approved storage container via the sample release device. This process shall continue until no measurable amount (< 0.01 foot) of DNAPL remains or one casing volume of DNAPL has been removed, whichever occurs first.

4.6 Post NAPL Evacuation Activities

Groundwater and NAPL elevation measurements shall be measured and monitored in accordance with SOP SAS-08-01 or as otherwise specified in the Site-Specific Work and/or FSP. Once the NAPL column has recovered to a level equivalent or greater than the prescribed sample volume, sampling may commence.

4.7 Sample Collection

4.7.1 LNAPL Sample Collection

If using a bailer, the sampler shall slowly lower the bailer to the intake position. The bailer shall be slowly retrieved from the well and the contents emptied into the appropriate sample container(s).

If using a peristaltic pump, the sampler shall slowly lower the tubing to the intake position. The pump shall be turned on and the removed LNAPL shall be emptied into the appropriate sample container(s).

4.7.2 DNAPL Sample Collection

The discrete interval sampler shall be connected to the tubing and reel. The high pressure hand pump or compressed air shall be connected to the reel. The sampler shall be pressured to the recommended operating pressure for the intake position/depth according to the following unless otherwise specified by the sampler operations manual and/or Site-Specific Work and/or FSP (see Section 4.5.2). While pressurized, the sampler shall then be lowered to the intake position/depth. At the desire depth, the pressure shall be released, which will allow the sampler to fill by hydrostatic pressure. The sampler shall then be re-pressurized to the recommended operating pressure. Following, re-pressurization, the sampler shall be slowly raised to the surface. The contents shall be transferred to the appropriate sample container(s) via the sample release device.

4.8 Post Sample Collection

Non-Dedicated and dedicated sampling equipment, which does not remain within the well casing, shall be removed from the monitoring well. The reusable and/or dedicated equipment and instruments shall be decontaminated in accordance with SOP SAS-04-04 or as otherwise specified by the Site-Specific Work and/or FSP. Disposable equipment and supplies shall be disposed of in accordance with procedures outlined in the Site-Specific Work and/or FSP. The sampler shall secure the well casing using a slip or expandable well cap. The flush-mount lid shall be bolted down or the protective cover lid closed and locked, as appropriate.

5.0 Documentation

Sample information, labeling, and custody control shall be performed in accordance with requirements specified in SOP SAS-03-01 and SAS-03-02. Sampling activities shall be recorded in the field logbook and/or on the appropriate field form as specified in SOP SAS-01-01 or as required by the Site-Specific Work and/or FSP.

6.0 REFERENCES AND ADDITIONAL RESOURCES

http://www.groundwatersoftware.com/Equipment/solinst_model_425.htm

USEPA, 2002, Ground-Water Sampling Guidelines for Superfund and RCRA Project Manager, Region 5 and Region 10, EPA 542-S-02-001.

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/60/B-07/001.

SOP SERIES SAS-09
SURFACE WATER SAMPLING AND MEASUREMENT PROCEDURES

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STANDARD OPERATING PROCEDURE NO. SAS-09-01

SURFACE WATER SAMPLING FOR CHEMICAL AND BIOLOGICAL ANALYSIS Revision 0

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for the collection of grab surface water samples for chemical and biological analysis using manual sampling techniques. The collection of composite surface water samples using automatic samplers shall be address in an equipment-specific SOP or the Site-Specific Work Plan, as needed. Surface water samples are utilized for the characterization of surface water and assessment of human and ecological receptors.

2.0 EQUIPMENT AND MATERIALS

Sampling equipment and materials vary by collection method. However, some standard equipment and materials are required regardless of collection method:

- Hip or chest waders, as appropriate;
- Boat and personal floatation devices (PFDs), as needed;
- Sample bottles/containers and labels;
- Field logbook and/or the appropriate field form(s);
- Pens with waterproof, non-erasable ink;
- Chain of custody forms;
- Depth and length measurement devices;
- Survey stakes, flags, or buoys and anchors;
- Decontamination materials;
- Coolers and ice packs/double-bagged ice;
- Personal protective equipment; and
- Camera.

3.0 HEALTH AND SAFETY WARNINGS

Aquatic environments present unique health and safety concerns ranging from accessibility to water depth and velocity to indigenous species. Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Work on water requires that marine health and safety procedures are used in addition to standard health and safety procedures. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 PERMITTING

Sampling performed within navigable waters and critical habitats may fall under the jurisdiction of one or more federal, state, or local agencies, including by not limited to the United States Army Corp of Engineers (USACOE), US Department of Fish and Wildlife, and State Departments of Natural Resources. Prior to the commencement of sampling activities, appropriate permit(s), if applicable, shall be obtained.

5.0 EXECUTION

5.1 General Considerations

The scope or extent of the sampling effort, data quality objectives, type(s) of samples (e.g. surface or depth grab), and sampling technique shall be determined prior to sample site selection and sample collection. In addition, the hydrology and morphometrics of a stream or impoundment shall be determined to the extent practical prior to sample collection. Water quality data (e.g. dissolved oxygen, pH, and temperature, etc.) shall be collected in impoundments prior to sample collection, to the extent practical, to determine if stratification is present. The Site-Specific Work Plan and/or Field Sampling Plan (FSP), as appropriate, shall specify the type(s) of samples to be collected and the collection technique(s).

5.2 Sample Site Selection

An initial reconnaissance shall be performed, to the extent practical, identify suitable sampling locations. Bridges and piers shall generally be deemed acceptable sampling locations since they provide ready access and permit water sampling at any point across the width of the water body. However, data quality objectives (DQOs) must be reviewed prior to final acceptance of these structures as sampling locations, since these structures alter the nature of water flow. When samples will be collected by wading in lakes, ponds, and slow-moving rivers and streams, sampling locations shall be selected that allow the sampler to approach the location from downstream in order to minimize the disturbance of sediments. Sampling station locations shall be selected without regard to other means of access if the stream is navigable by boat. However, other factors including but not limited to the following shall be considered in the sample site selection process:

- Project goals and DQOs;
- Field personnel health and safety;
- Manmade structures that alter the nature of water flow and mixing;
- General water environment characteristics (e.g. flow, depth, stratification, etc.);
- Potential disturbance of threatened or endangered species or critical habitat; and
- Type of water environment: river, streams, creeks; lakes, ponds, impoundments, estuarine, etc.

5.3 Surface Grab Sample Collection Procedures

Surface grab samples shall be collected from the top 12 inches of the water column. Samples shall be collected in a manner that avoids skimming of the surface and disturbance of sediments. If sample collection is performed by wading in the stream, the location shall be approached from a downstream location and efforts shall be made to minimize sediment disturbance, which has the potential to bias the sample. Wading shall be deemed acceptable if a noticeable current is present and the samples can be collected directly into the bottle from a location upstream of the field personnel. The field personnel shall approach the sample location slowly from downstream in order to minimize sediment disruption and sample corruption.

5.3.1 Direct Grab Sampling

Where practical, use of the actual sample container as the collection device is preferred since the same container can be submitted for laboratory analysis. This procedure reduces sample handling and potential loss of analytes or contamination from the sample from other sources. The following procedure shall be used for direct grab sample collection using unpreserved sample containers:

1. Remove the container cap or lid.
2. Slowly submerge the container, opening first, into the water.
3. Invert the container so the opening is upright and pointing towards the direction of water flow (if applicable) and allow water to slowly run into and fill the container.
4. Return the filled container to the surface.
5. If field preservation is required, proceed to Step 6; otherwise, secure the container cap or lid and proceed to Step 10.
6. Pour out a small volume of sample away from and downstream of the sampling location. (Do not use this step for volatile organics or other analytes that require zero headspace.)
7. Add the appropriate volume of the analytical method-prescribed preservative and secure the container cap or lid.
8. Invert the container several times to ensure sufficient mixing of the sample and preservative.
9. Check the preservation of the sample; adjust the pH of the sample with additional preservative, if necessary; and re-secure the cap or lid.
10. Label the sample container in accordance with SOP SAS-03-01 and place in cooler with double-bagged ice for in preparation for transportation to the analytical laboratory.

5.3.2 Sampling with an Intermediate Vessel or Container

If the sample cannot be collected directly in the sample container(s), an unpreserved sample container or an intermediate vessel (e.g. beaker, bucket, or dipper with or without an extension arm) shall be used to obtain the sample using the following procedure:

1. Decontamination the intermediate vessel in accordance with SOP SAS-04-04.
2. Fill the intermediate vessel or container by slowly dipping it into the water with the opening pointing towards the direction of water flow (if applicable);
3. Allow water to slowly run into and fill the intermediate vessel or container in a manner that minimizes agitation of the sample;

4. Remove the sample container lid and fill the sample container(s) from the intermediate vessel or container while avoid direct contact between them;
5. If field preservation is required, follow Step 6 through Step 9 in Section 3.3.1 above; otherwise, proceed to Step 6 below.
6. Secure the sample container lid.
7. Label the sample container in accordance with SOP SAS-03-01 and place in cooler with double-bagged ice for in preparation for transportation to the analytical laboratory.

5.3.3 Sampling with a Pump and Tubing

The following procedure shall be used for the collection of a surface grab sample using a pump and dedicated tubing:

1. Decontaminate the pump in accordance with SOP SAS-04-04, as appropriate.
2. Lower the tubing or pump intake to a depth of 6 to 12 inches below the water surface, where possible. The pump intake or intake tubing shall be maintained below the water surface during sample collection.
3. Pump several tubing volumes through the system prior to collecting the first sample.
4. Fill the sample container(s) from the discharge tubing.
5. If field preservation is required, follow Step 6 through Step 9 in Section 3.3.1 above; otherwise, proceed to Step 6 below;
6. Secure the sample container lid.
7. Label the sample container in accordance with SOP SAS-03-01 and place in cooler with double-bagged ice for in preparation for transportation to the analytical laboratory.

5.4 Depth Grab Sample Collection Procedures

Depth grab samples shall be collected from below the top 12 inches of the water column. Specific sample collection procedures for depth grab samples are presented below. If sample collection is performed by wading in the stream, the location shall be approached from a downstream location and efforts made to minimize sediment disturbance, which has the potential to bias the sample. Wading shall be deemed acceptable if a noticeable current is present and the samples can be collected from a location upstream of the field personnel. The field personnel shall approach the sample location slowly from downstream in order to minimize sediment disruption and sample corruption.

5.4.1 Sampling with Kemmerer, Niskin, or Van Dorn Type Devices

To the extent practical, devices constructed of stainless steel or Teflon or with Teflon-coated surfaces shall be used. Samplers that are constructed of plastic and rubber shall not be used to collect samples for extractable organics or volatile organic compound (VOC) analysis. The following procedure shall be used to collect depth grab samples using these devices:

1. Decontaminate the device in accordance with SOP SAS-04-04;
2. Measure the water column to determine the maximum depth and sampling depths;
3. Mark the line attached to the device with depth increments so that the sampling depth can be accurately recorded;
4. Slowly lower the device to the desired sampling depth in a manner that minimizes sediment disturbance;
5. At the desired depth, send the messenger weight down to trip the closure mechanism;
6. Slowly retrieve the device;
7. Rinse the outside of the device with distilled water;
8. Remove the sample container cap or lid and fill the container via the discharge tube;
9. If field preservation is required, follow Step 6 through Step 9 in Section 3.3.1 above; otherwise, proceed to Step 10 below.
10. Secure the sample container lid.
11. Label the sample container in accordance with SOP SAS-03-01 and place in cooler with double-bagged ice for in preparation for transportation to the analytical laboratory.

5.4.2 Sampling with Double Check-Valve Bailers

If DQOs do not necessitate a sample from a strictly discrete interval of the water column, a double check-valve bailer may be used. The following procedure shall be used to collect a depth grab sample with a double check-valve bailer:

1. Decontaminate the bailer in accordance with SOP SAS-04-04, or use a clean disposable bailer at each sampling location.
2. Measure the water column to determine the maximum depth and sampling depths.
3. Mark the line attached to the bailer with depth increments so that the sampling depth can be recorded.
4. Slowly lower the bailer to the desired sampling depth in a manner that minimize sediment disturbance.
5. Slowly retrieve the bailer.
6. Rinse the outside of the bailer with distilled water.

7. Remove the sample container cap or lid and fill the containers via the discharge port.
8. If field preservation is required, follow Step 6 through Step 9 in Section 3.3.1 above; otherwise, proceed to Step #9 below.
9. Secure the sample container lid.
10. Label the sample container in accordance with SOP SAS-03-01 and place in cooler with double-bagged ice for in preparation for transportation to the analytical laboratory.

5.4.3 Sampling with a Pump and Tubing

The following procedure shall be used for the collection of a depth grab sample using a pump and dedicated tubing:

1. Decontaminate the pump in accordance with SOP SAS-04-04, as appropriate.
2. Measure the water column to determine the maximum depth and sampling depths.
3. Secure the pump intake or intake tubing to a stiff pole or weight.
4. Lower the pump intake or intake tubing to the desire sample depth.
5. Pump several tubing volumes through the system prior to collecting the first sample.
6. Remove the sample container cap or lid and fill the sample container from the discharge tubing.
7. If field preservation is required, follow Step 6 through Step 9 in Section 3.3.1 above; otherwise, proceed to Step 8 below;
8. Secure the sample container lid.
9. Label the sample container in accordance with SOP SAS-03-01 and place in cooler with double-bagged ice for in preparation for transportation to the analytical laboratory.

5.5 Sampling for Biological Analysis

When sampling for biological or bacteriological examination, the procedures described above shall be followed with one exception, unless otherwise specified in the Site-Specific Work and/or FSP. Samples shall be collected in bottles properly sterilized and protected against contamination. As with any sample collection procedure, while the bottle is open, both the bottle and stopper shall be protected against contamination from other sources and the bottle closed at once following sample collection.

6.0 DOCUMENTATION

Sample information, labeling, and custody control shall be performed in accordance with requirements specified in SOP SAS-03-01 and SAS-03-02. Sampling activities shall be recorded in the field logbook and/or on the appropriate field form as specified in SOP SAS-01-01 or as required by the Site-Specific Work and/or FSP.

7.0 REFERENCES

ASTM International, D3977-97 (2002), Standard Test Methods for Determining Sediment Concentration in Water Samples.

ASTM International, D4581-86 (2005), Guide for Measurement of Morphologic Characteristics of Surface Water Bodies.

ASTM International, D5073-02, Practice for Depth Measurement of Surface Water.

Florida Department of Environmental Protection, February 2004, DEP-SOP-001/01 FS 2100 Surface Water Sampling.

USEPA, November 1994, SOP 2013: Surface Water Sampling, Rev. 0.0, Environmental Response Team.

USEPA, July 2002. Standard Operating Procedures for the Collection of Chemical and Biological Ambient Water Samples. Revision 1.

USEPA. 40 CFR Part 136.3 (e) Table II

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001.

STANDARD OPERATING PROCEDURE
NO. SAS-09-02

STREAMFLOW MEASUREMENT
Revision 0

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes guidelines for the calculation of velocity and stream discharge measurements in rivers and streams. Procedures are given for measurements that can be conducted by wading with assistance from other field personnel working from the stream bank. Procedures for measurements of large, deep rivers are beyond the scope of this SOP and will not be discussed further.

2.0 EQUIPMENT AND MATERIALS

- Flow Meter;
- Top-setting wading rod (measured in tenths of a foot);
- Tape measure or tagline (long enough to traverse the stream bed)
- Stakes to anchor tape to shore;
- Mallet or hammer;
- Field logbook and applicable field data sheets;
- Pen(s) with waterproof, non-erasable ink;
- Waders; and
- Personal protective equipment.

3.0 HEALTH AND SAFETY WARNINGS

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Work on water requires that marine health and safety procedures are used in addition to standard health and safety procedures. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 GENERAL PROCEDURES

4.1 Standard Field Procedures

Streamflow measurements shall be conducted only by a trained technician. Field data and observations associated with streamflow measurements shall be documented in accordance with SOP SAS-01-01, if not otherwise specified in this SOP. All activities should be recorded in a field logbook and/or on a streamflow measurement field form.

4.2 Site Selection

The stream transect location is a critical component of streamflow measurement. A site where the stream is most consistent in depth and flow rate across its width is easier to sample and provides more accurate results. Flow sites should be free of eddies, slack water, and excessive turbulence. Avoid areas where islands, ox-bows, piles of debris, aquatic plants or tributaries are present.

4.3 Flow Meter Selection

Several flow meters are available for measuring stream velocity. Some specific meters are the Price Model #1210 (AA); Price Model #1205 (Pygmy) for small, shallow streams; the March-McBirney 201D; and the March-McBirney Flo-Mate 2000. Selection of an appropriate flow meter will depend on the width and depth of the stream being measured, as well as stream features and irregularities. Additional guidance for selection of flow meters may be given in the Site-specific Work Plan.

4.4 Calculation of Stream Discharge

Stream discharge is determined by multiplying the mean stream velocity by the cross sectional area of the flow. The general form of the discharge equation is:

$$Q = A \text{ x } v$$

Where: Q = discharge in cubic feet per second (cfs)
A = cross section area of the channel at the transect in square feet (ft^2)
v = mean water column velocity at the transect in feet per second (ft/s)

To measure discharge (Q), a transect of the stream is divided into subsections and velocity, width and depth measurements are made within each subsection. Discharge of the stream at the transect is calculated by a form of the general equation:

$$Q = \sum_{i=1}^{n} (A_i \, x \, v_i)$$

Where: Q = discharge (cfs)
A_i = cross-sectional area of subsection I (ft^2)
v_i = velocity of subsection (ft/s)

A variation of this equation for mid-section method from Rantz (1982) is presented is Section 7.0 below. Other variations can be found in references listed at the end of this SOP and may be used as specified in the Site-specific Work Plan.

5.0 FIELD MEASUREMENT PROCEDURES

1. Calibrate the flow meter as specified in the manufacturer's instructions.
2. Attach the flow meter to the top set wading rod.
3. Measure the width of the stream at the selected transect location is measured by staking one end of the tape measure or pre-measured and incrementally marked tagline on the right bank. Pull the tape measure across the stream keeping it perpendicular to the flow and stake it on the left bank. Measure the width of the stream from left edge of water (LEW) to right edge of water (REW). LEW is defined as the point where water flow begins on the transect as you face downstream. REW is where water flows ends on the transect.

4. Determine the spacing of transect subsections to be used for velocity measurements. Each subsection should have a width of 5% to 10% of the stream width. For an accurate measurement of discharge, velocity should be measured in 20 to 30 subsections. If inconsistencies in flow rate or streambed topography are present, the number and sizes of subsections can be adjusted to accommodate the differences. Additional guidance on subdividing the transect may be given in the Site-specific Work Plan.
5. Determine the mid-point of each subsection. Use a cumulative measurement. If the stream is 30 feet wide with 20 subsections, the first mid-point is located at 0.75 feet from LEW, the second is located at 2.25 feet from LEW, etc. Draw a rough sketch of the transect with subsections and mid-point measurements in the field logbook and/or on the appropriate field form.
6. Begin the velocity and depth measurements at the first subsection mid-point as measured from the LEW. Measure the total depth of water using the scale on the lower portion of the wading rod. Single indentations on the rod indicate 0.1 foot, double indentations indicate 0.5 foot and triple indentations indicate 1.0 foot. Depending on water depths, velocity measurements will be taken at one or two depths as follows:
    - Depths ≤ 2.5 feet – one measurement is taken at 60% of the total depth when measured from the surface of the water. To set the sensor of the flow meter at 60% of the depth, line up the foot scale on the sliding rod with the tenth scale on the top of the depth gauge rod. For example, if the first subsection is 1.5 feet deep, line up the 1 foot indentation on the sliding rod with the 5 on the tenth scale on the depth gauge rod.
    - Depths > 2.5 feet – two measurements are taken: one at 20% of the total depth and one at 80% of the total depth when measured from the surface of the water. To set the 20% depth point, multiply the depth of the water by two and move the sliding rod so that the foot measurement on it lines up with the tenth of a foot measure on the depth gauge rod. For example, if the first subsection is 2.8 feet deep, twice the depth is 5.6 feet. Line up the number 5 on the sliding rod with the 6 on the depth gauge rod. To set the 80% depth point, divide the depth of the water by two and move the sliding rod to line up with the depth gauge rod based on the results. For example, 2.8 feet divided by 2 equals 1.4 feet. Line up the number 1 on the sliding rod with the 4 on the depth gauge rod. The average of the two velocity measurements are used in the flow calculation.

Take the velocity measurement(s) following the manufacturer's instructions and record them in the field logbook or on the field log form. Proceed to the next subsection of the transect and repeat the procedure across the stream towards the REW.

7. If required, continue to next transect location and repeat the measurement procedures.

6.0 DISCHARGE CALCULATIONS

Calculate the discharge in each transect subsection by multiplying the average velocity (>2.5-foot depth subsection) or single velocity (≤ 2.5-foot depth) by the subsection width and average depth using the equation:

$$Q = \left(\frac{D_1 + D_2}{2}\right)\left(\frac{v_1 + v_2}{2}\right)W_1 + \ldots + \left(\frac{D_m + D_n}{2}\right)\left(\frac{v_m + v_n}{2}\right)W_m$$

Where: Q = discharge (cfs)
v = velocity of subsection (ft/s)
W = width of subsection (ft)

Note: The first and last subsections are located at the edges of the stream and have a depth and velocity of zero (D_1, D_n, v_1 and v_n).

7.0 QUALITY ASSURANCE/QUALITY CONTROL

7.1 Equipment Calibration, Operation, and Maintenance

All field equipment shall be calibrated, operated, and maintained in accordance with SOP SAS-02-01 and manufacturer's instructions.

7.2 Calculations

All calculations shall be checked by another person for correctness and use of appropriate equations. Any corrections required will be made by the person originally performing the calculations. These corrections will be checked for correctness and approved for publication.

8.0 REFERENCES AND ADDITIONAL RESOURCES

Carter, R. W. and Davidian, J., 1969, General Procedure for Gaging Streams: Techniques of Water Resources Investigations of the U.S. Geological Survey, Book 3.

California Department of Pesticide Regulation, Environmental Monitoring Branch, 2004, Standard Operating Procedure for Determining Wadable Stream Discharge with Price Current Meters, SOP Number: FSWA009.01.

Rantz, S.E., 1982, *Measurement and Computation of Streamflow: Volumes 1 and 2*, “Measurement of Stage and Discharge”, U.S. Geological Survey Water-Supply Paper 2175.

Florida Department of Environmental Protection, Bureau of Watershed Management, Watershed Assessment Section, February 2004, FT 1800 Field Measurement of Water Flow and Velocity. DEP-SOP-001/01.

USEPA, Region 6, January 2003, Standard Operating Procedure for Streamflow Measurement.

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001.

SOP SERIES SAS-10
WITHHELD – NOT RELEVANT TO STUDY ACTIVITIES

SOP SERIES SAS-11
SOIL VAPOR SAMPLING AND MEASUREMENT PROCEDURES

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STANDARD OPERATING PROCEDURE
NO. SAS-11-01

SUB-SLAB SAMPLE PORT INSTALLATION, SAMPLING, AND ABANDONMENT
Revision 0

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for installation, sampling, and abandonment of sub-slab sample ports. Soil-gas (soil vapor) sampling is a useful tool to evaluate potential subsurface soil and groundwater impacts that can partition into gas and affect indoor air quality. Sub-slab sampling is conducted directly beneath the building's slab to provide measurements of soil-gas that may potentially enter a building.

2.0 EQUIPMENT AND MATERIALS

- Rotary hammer drill (or equivalent) with a ½-inch diameter bit;
- Hand Tools, including a hammer, needle-nose pliers, and trowel;
- Tubing receptacle;
- Teflon compression fittings to connect sampling points at "T" connection;
- "T" Swagelok (compression) or equivalent fitting;
- 4-way Teflon micro-valve;
- ¼-inch O.D. Teflon tubing;
- Modeling clay or rubber stopper;
- Nitrile gloves;
- Summa canisters with flow controllers, vacuum gauge, and shipping container;
- Sample labels;
- Chain of custody forms and seals;
- Field air monitoring instruments, as specified in the Work Plan (e.g. photo ionization detector, multi-gas monitors, etc.);
- Location markers (e.g. pin flags, wooden stakes, flagging tape, etc.);
- Granular bentonite;

- Asphalt cold patch or cement, as appropriate for site restoration;
- DOT-specified 55-gallon drum; and
- Field logbook and/or appropriate field form(s);

3.0 HEALTH AND SAFETY

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 CONSIDERATIONS

Variations in chemical-specific characteristics, geologic conditions, and atmospheric influences can affect soil-gas sampling results. For this reason, it is important to understand factors the may influence the reported data when collecting soil-gas data. In all cases, site-specific factors should be carefully evaluated prior to initiation of sampling to obtain representative soil-gas data.

Prior to any soil-gas sampling, soil type must be evaluated for suitability of sampling. Soils with smaller grain sizes have smaller pore spaces and are less permeable, which may reduce the ability for soil gas to be released from the subsurface. For example, clays have the smallest grain size and significantly restrict soil gas migration. Soil moisture also limits the ability for soil gas to be released from the subsurface because moisture trapped in the pore space of sediments can inhibit or block soil-gas flow. Seasonal and geographical variations in soil moisture content can affect air permeabilities. In addition, manmade and naturally occurring preferential pathways (e.g. utility corridors, lenses of coarse-grained materials within fine-grained materials, etc.) may also affect soil-gas migration and shall be considered prior to soil-gas sampling.

Reliability of soil-gas sampling may be improved by using fixed probes and by ensuring that leakage of atmospheric air into the samples is avoided during purging or sampling. To avoid dilution of the sampling region from leakage, the minimum purge volume deemed adequate to flush the sampling system should be removed, and soil-gas samples should be collected from the most permeable zones in the vadose zone when possible. Site-specific information concerning soil lithology, grain size analysis, soil moisture, and soil-gas permeability may be obtained by performing three soil borings in the immediate area of the sampling locations in advance of the soil-gas sampling. In addition, previous site investigation sample results, when available, should be used to determine the placement of the soil-gas sampling locations.

Since oxygen, carbon dioxide and nitrogen can be sampled using a multi-gas monitor to give real-time results, parallel analysis of oxygen, carbon dioxide and nitrogen in soil-gas may also be used to help assess the reliability of a given sample result.

5.0 EXECUTION

The active soil-gas sampling approach consists of withdrawing an aliquot of soil gas from the subsurface, followed by the analysis of the withdrawn gas. Active soil-gas systems use mechanical equipment to create a small-diameter hole in the ground and then use a vacuum to "actively" withdraw a soil gas sample through Teflon tubing within the vadose zone. The soil gas sample is collected in a Summa canister and sent to a laboratory for analysis. Samples are analyzed using USEPA's Ambient Air Compendium Method TO-15 (USEPA 1999) for determining organic compounds in ambient air. The results provided by active soil-gas systems are quantitative and are reported in units of concentration per volume (micrograms per cubic meter [$\mu g/m^3$], or parts per billion volume [ppb_v]).

The following active soil-gas sampling methodologies (port installation, sampling, and abandonment) are based on established methods as outlined in the USEPA SOP 2042 (USEPA 1996) and the ASTM International (ASTM) standard guide D 5314-01 (ASTM 2001). Additional guidelines were provided from the San Diego County Site Assessment and Mitigation (SAM) Manual, "Overview of Soil Vapor Survey Methods" (San Diego County 2002 and 2004) and the California Regional Water Quality Control Board (CRWQCB), Los Angeles Region (LARWQCB) (CRWQCB 2002 and 2003) and the Department of Toxic Substances Control (DTSC) guidelines (DTSC 2004 and 2005).

5.1 Summa Canister Preparation, QA/QC, and Set Up

A Summa canister is a stainless steel container which has had its internal surfaces passivated using a “Summa” process. The process uses an electro polishing step in conjunction with chemical deactivation. The overall process results in a chemically inert interior surface of the media which allows for the collection and subsequent analysis of samples containing very low concentrations of volatile organic compounds (VOCs). The Summa media is available in a number of different sizes. Typically, 6-liter Summa media are used for the collection of soil-gas because this volume should allow for low detection limits and facilitate more complex analyses.

Once the laboratory cleaning process is completed per USEPA SOP 1703 (USEPA 1994), the Summa media are prepared by the laboratory for use in the field. Each canister is evacuated to achieve a vacuum pressure of approximately -30 inches of mercury (" Hg). The pressure differential between the canister and atmosphere allows for the Summa media to sample without the use of a separate sample pump. Depending on the project requirements, either grab or integrated samples may be collected. The holding time (shelf life) for Summa canisters that have been prepared for use in the field is 30 days. If the canister has not been used within this time-period, it shall be returned to the contracted laboratory for re-conditioning.

Prior to collection, check all canisters for the proper certification issued by the analytical laboratory, as per USEPA SOP 1703 (USEPA 1994). The sampler shall complete the sample set-up of a Summa (or equivalent) canister prior to sample collection. Each six-liter (6.0 L) Summa (or equivalent) canister shall be fitted with a dedicated sample flow controller (regulator). After verification that the valve on the canister is in the “off” position, the brass cap shall be removed from the canister inlet fitting and the sample flow controller shall be attached to the canister inlet. The brass cap shall then be installed onto the inlet of the flow controller and tighten. *Note: The sample flow controller (regulator) is a complete assembly that shall be attached directly to the canister*. The assembly shall then be leak-checked by opening the canister valve and noting the initial vacuum reading. The vacuum should indicate between -25" Hg and -30" Hg. The canister shall not be used if the starting vacuum is less than -25" Hg. The vacuum may fall a very small amount (1 to 2 " Hg) due to the evacuation of the flow controller and then quickly stabilize. If the vacuum does not stabilize, the flow controller or associated fittings are leaking. If necessary, determine the location of the leak, and repair it accordingly. Any necessary repairs shall be document in the field logbook and/or on the appropriate field form.

5.2 Sampling Port Installation

The sampler shall follow the general procedure for sub-slab sample port installation as detailed below, unless otherwise required by the Site-Specific Work and/or Sampling Plan(s):

1. All subsurface activities shall only be performed following the clearance of each location for underground utilities in accordance with SOP SAS-05-01. In addition, a qualified contractor shall locate and mark private subsurface utilities.
2. Prior to drilling holes through the slab, all floor coverings present shall be neatly removed.
3. A single ½-inch diameter core hole shall be drilled through the slab of the structure. The core hole is typically located in the central portion of the slab, well away from the edges of the foundation where dilution is more likely to occur.
4. Teflon tubing (1/4-inch O.D.) shall be inserted into the core hole to the base of the concrete slab.
5. The core hole shall be immediately sealed with a material such as modeling clay or a rubber stopper to minimize the disturbance of the soil-gas concentrations.

5.3 Pre-Sample Collection Activities

To help ensure a representative soil gas sample is being collected, field screening using a multiple gas detection monitor shall be performed to establish that acceptable sampling conditions have been attained prior to sample collection.

5.4 Sample Collection

Samples shall be collected using a 6-Liter Summa canister. The San Diego County Site Assessment and Mitigation (SAM) Manual, "Overview of Soil Vapor Survey Methods" guidance (San Diego County 2004) requires this rate to be less than 200 milliliter per minute (ml/min). Summa canisters are filled using a flow regulator set at a constant rate within the range of 50 to 200 ml/min. No tubing purge or field screening is performed prior to sampling. The sampler shall follow the step-by-step procedure for sub-slab sampling as outlined below, unless otherwise required by the Site-Specific Work and/or Sampling Plan(s):

1. Attach the purged tubing to a Summa canister.

2. The sampler shall attach an in-line particulate filter to the sample train, if deemed necessary given site conditions.
3. The sampler shall record the initial Summa canister vacuum reading from the line gauge in the field logbook and/or on the appropriate field form.
4. The valve on the Summa canister shall be opened allowing the soil-gas sample to be drawn into the canister by pressure equilibration. Note: If condensation is observed in the sample tubing, the sample shall be discarded and the observation shall be documented in the field logbook and/or on the appropriate field form.
5. When the line gauge reads approximately -4 to -5" Hg remaining, the sampler shall close the Summa canister valve.
6. The sampler shall record the final Summa canister vacuum reading from the line gauge in the field logbook and/or on the appropriate field form.
7. The sampler shall fill out and attach the sample tag to the Summa Canister along with any additional information requested by the laboratory. This information shall also be recorded in the field logbook and/or on the appropriate field form.
8. The sample shall be packaged and shipped under chain of custody to the laboratory for analysis. The samples shall not be chilled during storage or transport to the laboratory. To minimize potential effects on the sample integrity, the sample analysis shall be conducted within 72 hours of the collection time.

5.5 Sample Port Abandonment

After sample collection, the tubing is removed. The core hole shall be filled with a neat cement (coarse aggregate free) mix or asphalt cold patch, as appropriate for site restoration. Any floor covering removed shall be replaced and the area restored to its pre-sampling condition to the extent practicable.

All investigation-derived waste is placed in Department of Transportation (DOT)-specified 55-gallon drums and properly labeled. The drums are placed in a secure on-site location for temporary storage prior to appropriate off-site disposal. Disposable sampling equipment and health & safety materials that are not visibly impacted are double-bagged in plastic trash bags and disposed of in a solid waste disposal location (i.e. trash dumpster or container).

6.0 QUALITY ASSURANCE/QUALITY CONTROL

6.1 Equipment Calibration, Operation, and Maintenance

Field air monitoring instruments, as specified in the Work Plan (e.g. photo ionization detector, multi-gas monitors, etc.) shall be calibrated, operated, and maintained in accordance with SOP SAS-02-01.

6.2 Leak Testing

Leakage during soil vapor sampling may dilute samples with ambient air and produce results that underestimate actual site soil vapor concentrations. Leak testing, if any is required, shall be based on data quality objectives as specified in the Site-Specific Work Plan. The following paragraph describes a direct leak detection method that is suitable for use during soil gas sampling.

Seal integrity can be evaluated directly using an inert tracer gas (e.g. laboratory grade helium). Inert gas selection shall be conducted in conjunction with the laboratory. The sampler shall construct an air tent using polyethylene sheet or assemble a commercially available air tent which encompasses the top of the probe/well casing and the entire sample train. During sampling, the tracer gas shall be allowed to flow around the sample train connections and the bentonite or grout seal at the ground surface. Following sample collection, the air tent shall be dismantled. The soil vapor sample shall be analyzed for inert trace gas in addition to the other requested analysis. If the tracer gas is detected in the soil vapor sample, the seal integrity was compromised and the analytical results, which are not representative of the stratigraphic unit or zone within the stratigraphic unit, shall be considered invalid.

6.3 Decontamination

Equipment decontamination procedures shall be implemented, in accordance with SOP SAS-04-04, to avoid cross-contamination between sampling locations.

All elements of the sample train shall be dedicated to each sampling location to avoid potential cross-contamination. If visible contamination (soil or water) is drawn into the sampling train, it shall be changed immediately.

6.5 Duplicate Samples

If required by the Site-Specific Work and/or Sampling Plan(s), duplicate samples shall be collected with the addition of a “T” splitter being attached to the 4-way micro valve with a Teflon nut, and one canister attached to each end of the “T” Swagelok (compression) or equivalent fitting and in accordance with SOP SAS-04-03.

7.0 REFERENCES AND ADDITIONAL RESOURCES

ASTM International, 2001, ASTM Standard D 5314-92 (2001) Standard Guide for Soil Gas Monitoring in the Vadose Zone.

California Regional Water Quality Control Board, Los Angeles Region, 2002, General Laboratory Testing Requirements for Petroleum Hydrocarbon Impacted Sites.

California Regional Water Quality Control Board, Los Angeles Region, 1997, Interim Guidance for Active Soil Gas Investigation, Advisory issued January 28, 2003.

Department of Toxic Substance Control-California Environmental Protection Agency, 2004, Interim Final Guidance to the Evaluation and Mitigation of Subsurface Vapor Intrusion to Indoor Air, Revised February 7, 2005.

Hartman, Dr. Blayne; June 2002 - LUSTLine #41 Reevaluating the Upward Vapor Migration Risk Pathway, Synopsis: *An Updated Article on Upward Vapor Migration & a Recommended Sampling Protocol.*

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United States Environmental Protection Agency (USEPA), 1994, SOP 1703, Rev. 0.0, Summa Canister Cleaning Procedure.

USEPA, 1995, SOP 1704, Rev. 0.0, Summa Canister Sampling.

USEPA, 1996, SOP 2042, Rev. 0.0, Soil Gas Sampling

USEPA, 1999, 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) in *Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air,* 2nd Ed., EPA Publication 625/R-96/010b.

USEPA, 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001.

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STANDARD OPERATING PROCEDURE
NO. SAS-11-02

POST-RUN TUBING SYSTEM SAMPLING
Revision 0

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for Post-Run Tubing (PRT) System sampling. Soil-gas (soil vapor) sampling is a useful tool to evaluate potential subsurface soil and groundwater impacts that can partition into gas and affect indoor air quality. PRT sampling is conducted above the water table at a depth of five feet below ground surface (bgs) or deeper to provide measurements of soil-gas that may potentially enter a building and affect indoor air quality.

2.0 EQUIPMENT AND MATERIALS

- Rotary hammer drill (or equivalent) with a 1 3/8-inch diameter bit;
- Retractable gas vapor tip (GVP);
- Expendable GVP replacements;
- Hand Tools, including a hammer, needle-nose pliers, and trowel;
- Tubing receptacle;
- Teflon compression fittings to connect sampling points at “T” connection;
- “T” Swagelok (compression) or equivalent fitting;
- Gas sampling pump capable of extracting 200 milliliters per minute (mL/min);
- 4-way Teflon micro-valve;
- 1/4-inch O.D. Teflon tubing;
- VOC-free caulk;
- Nitrile gloves;
- Summa canisters with flow controllers, vacuum gauge, and shipping container;
- Sample labels;
- Chain of custody forms and seals;
- Field air monitoring instruments, as specified in the Work Plan (e.g. photo ionization detector, multi-gas monitors, etc.);

- Location markers (e.g. pin flags, wooden stakes, flagging tape, etc.);
- Granular bentonite;
- Asphalt cold patch or cement, as appropriate for site restoration;
- Decontamination materials;
- DOT-specified 55-gallon drum; and
- Field logbook and/or appropriate field form(s);

3.0 HEALTH AND SAFETY

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 CONSIDERATIONS

Variations in chemical-specific characteristics, geologic conditions, and atmospheric influences can affect soil-gas sampling results. For this reason, it is important to understand factors the may influence the reported data when collecting soil-gas data. In all cases, site-specific factors should be carefully evaluated prior to initiation of sampling to obtain representative soil-gas data.

Prior to any soil-gas sampling, soil type must be evaluated for suitability of sampling. Soils with smaller grain sizes have smaller pore spaces and are less permeable, which may reduce the ability for soil gas to be released from the subsurface. For example, clays have the smallest grain size and significantly restrict soil gas migration. Soil moisture also limits the ability for soil gas to be released from the subsurface because moisture trapped in the pore space of sediments can inhibit or block soil-gas flow. Seasonal and geographical variations in soil moisture content can affect air permeabilities. In addition, manmade and naturally occurring preferential pathways (e.g. utility corridors, lenses of coarse-grained materials within fine-grained materials, etc.) may also affect soil-gas migration and shall be considered prior to soil-gas sampling.

Reliability of soil-gas sampling may be improved by using fixed probes and by ensuring that leakage of atmospheric air into the samples is avoided during purging or sampling. To avoid dilution of the sampling region from leakage, the minimum purge volume deemed adequate to flush the sampling system should be removed, and soil-gas samples should be collected from the most permeable zones in the vadose zone when possible. Site-specific information concerning soil lithology, grain size analysis, soil moisture, and soil-gas permeability may be obtained by performing three soil borings in the immediate area of the sampling locations in advance of the soil-gas sampling. In addition, previous site investigation sample results, when available, should be used to determine the placement of the soil-gas sampling locations.

Since oxygen, carbon dioxide and nitrogen can be sampled using a multi-gas monitor to give real-time results, parallel analysis of oxygen, carbon dioxide and nitrogen in soil-gas may also be used to help assess the reliability of a given sample result.

5.0 EXECUTION

The active soil-gas sampling approach consists of withdrawing an aliquot of soil gas from the subsurface, followed by the analysis of the withdrawn gas. Active soil-gas systems use mechanical equipment to create a small-diameter hole in the ground and then use a vacuum to “actively” withdraw a soil gas sample through stainless steel or Teflon tubing within the vadose zone. The soil gas sample is collected in a Summa canister and sent to a laboratory for analysis. Samples are analyzed using USEPA’s Ambient Air Compendium Method TO-15 (USEPA 1999) for determining organic compounds in ambient air. The results provided by active soil-gas systems are quantitative and are reported in units of concentration per volume (micrograms per cubic meter [$\mu g/m^3$], or parts per billion volume [ppb_v]).

The following active soil-gas sampling methodologies (emplacement, purging, sampling, leak testing, field screening, and abandonment) are based on established methods as outlined in the USEPA Standard Operating Procedure (SOP) Number 2042 (USEPA 1996) and the ASTM International (ASTM) standard guide D 5314-01 (ASTM 2001). Additional guidelines were provided from the San Diego County Site Assessment and

Mitigation (SAM) Manual, "Overview of Soil Vapor Survey Methods" (San Diego County 2002 and 2004) and the California Regional Water Quality Control Board (CRWQCB), Los Angeles Region (LARWQCB) (CRWQCB 2002 and 2003) and the Department of Toxic Substances Control (DTSC) guidelines (DTSC 2004 and 2005).

5.1 Summa Canister Preparation, QA/QC, and Set Up

A Summa canister is a stainless steel container which has had its internal surfaces passivated using a "Summa" process. The process uses an electro polishing step in conjunction with chemical deactivation. The overall process results in a chemically inert interior surface of the media which allows for the collection and subsequent analysis of samples containing very low concentrations of volatile organic compounds (VOCs). The Summa media is available in a number of different sizes. Typically, 6-liter Summa media are used for the collection of soil-gas because this volume should allow for low detection limits and facilitate more complex analyses.

Once the laboratory cleaning process is completed per USEPA SOP 1703 (USEPA 1994), the Summa media are prepared by the laboratory for use in the field. Each canister is evacuated to achieve a vacuum pressure of approximately -30 inches of mercury (" Hg). The pressure differential between the canister and atmosphere allows for the Summa media to sample without the use of a separate sample pump. Depending on the project requirements, either grab or integrated samples may be collected. The holding time (shelf life) for Summa canisters that have been prepared for use in the field is 30 days. If the canister has not been used within this time-period, it shall be returned to the contracted laboratory for re-conditioning.

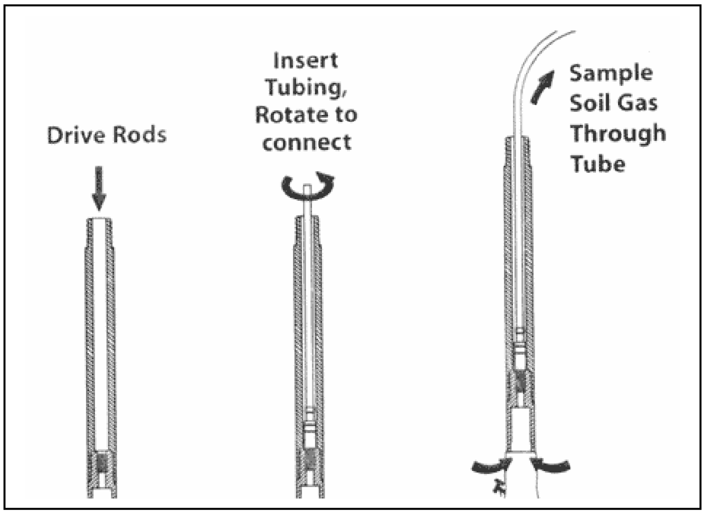
Prior to collection, check all canisters for the proper certification issued by the analytical laboratory, as per USEPA SOP 1703 (USEPA 1994). The sampler shall complete the sample set-up of a Summa (or equivalent) canister prior to sample collection. Each six-liter (6.0 L) Summa (or equivalent) canister shall be fitted with a dedicated sample flow controller (regulator). After verification that the valve on the canister is in the "off" position, the brass cap shall be removed from the canister inlet fitting and the sample flow controller shall be attached to the canister inlet. The brass cap shall then be installed onto the inlet of the flow controller and tighten. *Note: The sample flow controller (regulator) is a complete assembly that shall be attached directly to the canister.* The assembly shall then be leak-checked by opening the canister valve and noting the initial vacuum reading. The vacuum should indicate between -25" Hg and -30" Hg. The canister shall not be used if the starting vacuum is less than -25" Hg. The vacuum may fall a very small amount (1 to 2" Hg) due to the evacuation of the flow controller and then quickly stabilize. If the vacuum does not stabilize, the flow controller or associated fittings are leaking. If necessary, determine the location of the leak, and repair it accordingly. Any necessary repairs shall be document in the field logbook and/or on the appropriate field form.

5.2 Temporary Soil-Gas Probe Emplacement

The PRT system sampling methodology (see Figure below) shall be utilized to collect soil-gas samples within the vadose zone at a minimum sampling depth of 5 feet bgs.

FIGURE 1

PRT System Soil Gas Sampling



The sampler shall follow the general procedure for PRT system sampling as detailed below, unless otherwise required by the Site-Specific Work and/or Sampling Plan(s):

1. All subsurface activities shall only be performed following the clearance of each location for underground utilities in accordance with SOP SAS-05-01. In addition, a qualified contractor shall locate and mark private subsurface utilities.
2. Prior to drilling, the sampler shall clear vegetation or remove any floor coverings present, as appropriate.

3. If concrete or asphalt is present, a 1 3/8-inch diameter core hole shall be drilled through the entire thickness of the material until bare soil is reached.
4. Utilizing direct push technology, the sampler shall advance the 1.1-inch outer diameter (O.D.) expendable drive point attached to the 1.25-inch O.D. hollow push rods to target depth, which shall be a minimum of 5 feet bgs. Sample depths shall be chosen to minimize the transient effects of changes in barometric pressure, temperature, precipitation or breakthrough of ambient air from the surface to ensure that representative samples are collected. Sample depths shall be specified in the Site-Specific Work and/or Sampling Plan(s). No soil-gas sampling shall be conducted within 48 hours of a rainfall/irrigation event, due to excessive soil moisture content anticipated in the exposed surfaces.
5. Once the target depth is reached, the sampler shall insert the PRT and pull back the tool string approximately 3 inches (0.25 feet) thereby exposing the vapor inlet.
6. The sampler shall extend the 1/4-inch O.D. Teflon tubing through the slotted opening of the extension driver adapter, leaving 4 feet of tubing extending beyond the ground surface.
7. The sampler shall seal the end of the tubing with a protective cap to prevent air infiltration.
8. The sampler shall seal around the drive rods at the ground surface with hydrated bentonite slurry to prevent ambient air intrusion from occurring.
9. The sampler shall record the date and probe emplacement time in addition to the sample location in the field logbook and/or on the appropriate field form.

5.3 Pre-Sample Collection Activities

To help ensure a representative soil gas sample is being collected, the PRT system shall be purged of all ambient air and field screening shall be performed using a multiple gas detection monitor to establish that acceptable sampling conditions have been attained prior to sample collection. During probe emplacement, subsurface conditions are disturbed. To allow subsurface conditions to equilibrate, the sample system purge and soil gas screening shall not be conducted for at least 20 minutes following probe emplacement.

5.3.1 PRT System Purge

For a representative soil gas sample to be obtained, enough air shall be withdrawn prior to sample collection to purge the sampling system of all ambient air. The purge volume or “dead space volume” shall be estimated based on the internal volume of the tubing used and the annular space around the probe tip. Only the volume of air sufficient to flush the probe and sampling line shall be extracted before collecting the sample. The air contained in the Teflon tubing, vapor point holder and fittings forming the "sampling train" shall be evacuated using an air-sampling pump set at a rate not to exceed 200 ml/min. for the calculated period of time. System purging shall be performed consistently at each sampling location. An example of typical purge volumes and times is shown below.

Purge Volumes for PRT System

		5-foot Sample Depth	10-foot Sample Depth
One Purge Volume	**Volume**	46.14 ml	68.44 ml
	Time	13.8 sec	20.5 sec

The sampler shall calculate the volume of ambient air to be purged using the following factors and equations:

<u>Purge Calculation Factors</u>

1. Tubing (0.25-inch O.D., 0.17-inch I.D.) Volume = 4.46 ml per foot internal volume
2. Vapor Point Holder and Post Run Tubing Adapter Volume = 6 ml internal volume
3. Calculations assume a 4-foot section of tubing extends from the boring surface to the canister.

<u>Volume Equation:</u>

A x ((B x C) + D) = E

Where:
- A = Number of Purge Volumes
- B = 1 foot of tubing, 4.46 ml
- C = Depth
- D = Point Holder Volume, 6 ml
- E = Volume to be purged

<u>Time Equation:</u>

(E ÷ F) x G = H

Where:
- E = Volume to be purged
- F = Purge Rate, 200 ml/min.
- G = 60 seconds
- H = Purge Time in seconds at 200 ml/min.

5.3.2 Screening with Field Instruments

Analysis of oxygen, carbon dioxide and nitrogen in soil-gas samples can often be used to help assess the reliability of a given sample result. It is recommended that one or all of the aforementioned analytes be monitored using a multiple gas detector. After completion of the system purge, the monitoring instrument shall be connected at the "T" connection using the 0.25-inch O.D. Teflon tubing. When the monitoring instrument readings are stable or peak, the values shall be recorded in the field logbook and/or on the appropriate field form.

5.4 Sample Collection

After the sampling train has been adequately purged and field screened; samples shall be collected using a 6-liter Summa canister. Due to the disruption of soil gas equilibrium during purging and field screening, a period of equilibrium (at least 20 minutes in length) shall be allowed for subsurface conditions to equilibrate. To minimize the potential desorption of contaminants from the soil, Summa canisters should be filled at a rate that minimizes the vacuum applied to the soil and the turbulent flow at the probe tip. The San Diego County Site Assessment and Mitigation (SAM) Manual, "Overview of Soil Vapor Survey Methods" guidance (San Diego County 2004) requires this rate to be less than 200 ml/min. Summa canisters shall be filled using a flow regulator set at a constant rate within the range of 50 to 200 ml/min. The sampler shall follow the step-by-step procedure for PRT system sampling as outlined below, unless otherwise required by the Site-Specific Work and/or Sampling Plan(s):

1. The sampler shall attach an in-line particulate filter to the sample train, if deemed necessary given site conditions.
2. The sampler shall record the initial Summa canister vacuum reading from the line gauge in the field logbook and/or on the appropriate field form.
3. The valve on the Summa canister shall be opened allowing the soil-gas sample to be drawn into the canister by pressure equilibration. If condensation is observed in the sample tubing, the sample shall be discarded and the observation shall be documented in the field logbook and/or on the appropriate field form.
4. When the line gauge reads approximately -4 to -5" Hg remaining, the sampler shall close the Summa canister valve.
5. The sampler shall record the final Summa canister vacuum reading from the line gauge in the field logbook and/or on the appropriate field form.
6. The sampler shall fill out and attach the sample tag to the Summa Canister along with any additional information requested by the laboratory. This information shall also be recorded in the field logbook and/or on the appropriate field form.

7. The sample shall be packaged and shipped under chain of custody to the laboratory for analysis. The samples shall not be chilled during storage or transport to the laboratory. To minimize potential effects on the sample integrity, the sample analysis shall be conducted within 72 hours of the collection time.

5.5 Temporary Probe Removal and Borehole Abandonment

After sample collection, both the drive rod and tubing shall be removed. Soil-gas probes shall then be sealed using granular bentonite to fill the annular space of the hole. Soil-gas probes performed within residential or industrial/commercial structures shall also be filled with granular bentonite to the base of the core hole and a 1-inch thick caulk vapor seal shall be applied at the base of the core hole. The remainder of the core hole shall be filled with a neat cement (coarse aggregate free) mix or asphalt cold patch, as appropriate for site restoration. Any floor covering removed shall be replaced and the area restored to its pre-sampling condition to the extent practicable.

All investigation-derived waste is placed in Department of Transportation (DOT)-specified 55-gallon drums and properly labeled. The drums are placed in a secure on-site location for temporary storage prior to appropriate off-site disposal. Disposable sampling equipment and health & safety materials that are not visibly impacted are double-bagged in plastic trash bags and disposed of in a solid waste disposal location (i.e. trash dumpster or container).

6.0 QUALITY ASSURANCE/QUALITY CONTROL

6.1 Equipment Calibration, Operation, and Maintenance

Field air monitoring instruments, as specified in the Work Plan (e.g. photo ionization detector, multi-gas monitors, etc.) shall be calibrated, operated, and maintained in accordance with SOP SAS-02-01.

6.2 Leak Testing

Leakage during soil vapor sampling may dilute samples with ambient air and produce results that underestimate actual site soil vapor concentrations. Leak testing, if any is required, shall be based on data quality objectives as specified in the Site-Specific Work Plan. The following paragraph describes a direct leak detection method that is suitable for use during soil gas sampling.

Seal integrity can be evaluated directly using an inert tracer gas (e.g. laboratory grade helium). Inert gas selection shall be conducted in conjunction with the laboratory. The sampler shall construct an air tent using polyethylene sheet or assemble a commercially available air tent which encompasses the top of the probe/well casing and the entire sample train. During sampling, the tracer gas shall be allowed to flow around the sample train connections and the bentonite or grout seal at the ground surface. Following sample collection, the air tent shall be dismantled. The soil vapor sample shall be analyzed for inert trace gas in addition to the other requested analysis. If the tracer gas is detected in the soil vapor sample, the seal integrity was compromised and the analytical results, which are not representative of the stratigraphic unit or zone within the stratigraphic unit, shall be considered invalid.

6.3 Decontamination

Equipment decontamination procedures shall be implemented, in accordance with SOP SAS-04-04, to avoid cross-contamination between sampling locations.

6.3.1 Sample Probe Decontamination

Sample probe contamination shall be checked between each sample by drawing ambient air through the probe via a gas sampling pump and checking the response of the PID. If readings are higher than background, replacement or decontamination shall be necessary. Sample probes shall be decontaminated simply by drawing ambient air through the probe until the PID reading is at background. More persistent contamination shall be washed out using methanol and water, and then air drying. For persistent volatile contamination, use of a portable propane torch may be needed. If use of a portable propane torch is deemed necessary, the sampler shall use a pair of pliers to hold the probe while running the torch up and down the length of the sample probe for approximately 1 to 2 minutes. The probe shall be allowed cool before handling. When using this method, the sampler shall wear gloves that are capable of preventing burns. Having more than one probe per sample team is advisable as it will reduce lag times between sample stations while probes are decontaminated.

6.3.2 Drive Rod Decontamination

After each use, drive rods and other reusable components are properly decontaminated to prevent cross contamination in accordance with SOP SAS-04-04.

6.3.3 Sample Train Decontamination

All elements of the sample train shall be dedicated to each sampling location to avoid potential cross-contamination. If visible contamination (soil or water) is drawn into the sampling train, it shall be changed immediately.

6.4 Duplicate Samples

If required by the Site-Specific Work and/or Sampling Plan(s), duplicate samples shall be collected with the addition of a "T" splitter being attached to the 4-way micro valve with a Teflon nut, and one canister attached to each end of the "T" Swagelok (compression) or equivalent fitting and in accordance with SOP SAS-04-03.

7.0 REFERENCES AND ADDITIONAL RESOURCES

ASTM International, 2001, ASTM Standard D 5314-92 (2001) Standard Guide for Soil Gas Monitoring in the Vadose Zone.

California Regional Water Quality Control Board, Los Angeles Region, 2002, General Laboratory Testing Requirements for Petroleum Hydrocarbon Impacted Sites.

California Regional Water Quality Control Board, Los Angeles Region, 1997, Interim Guidance for Active Soil Gas Investigation, Advisory issued January 28, 2003.

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USEPA, 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001.

STANDARD OPERATING PROCEDURE
NO. SAS-11-03

INSTALLATION OF PROBES/WELLS FOR SVE SYSTEM EFFECTIVENESS AND VAPOR MIGRATION MONITORING
Revision 0

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for the installation of semi-permanent to permanent soil vapor monitoring probes/wells for the evaluation of Soil Vapor Extraction (SVE) system effectiveness and subsurface vapor migration. This SOP also describes selection, including advantages and disadvantages, of drilling methods, probe/well materials and construction/configuration.

2.0 EQUIPMENT AND MATERIALS

- Drilling equipment and supplies (Drilling method specific);
- Well casing and screen materials (See Sections 4.3 & 4.4 below);
- Filter pack sand;
- Bentonite;
- Grout (optional);
- Portland cement;
- Asphalt (as necessary for surface restoration);
- Stick-up or flush-mount protective well covers;
- 4-way micro-valve (Probe/well less than 1 inch in diameter);
- Zip ties (Probe/well less than 1 inch in diameter);
- ¼-inch outside diameter (OD) silicone, Tygon, or Teflon tubing (Probe/well less than 1 inch in diameter);

- Expandable well cap retrofitted with a with a 1/8-Inch, NPT, chrome-plated brass, non-valved, coupling insert (herein referred to as “coupling insert”) and vinyl slip cap (Probe/wells 1 inch or more in diameter);
- Metal well ID tag (optional);
- Probe/well location maps;
- Miscellaneous tools;
- Chain of custody forms and seals; and
- Field logbook and/or appropriate field form.


Coupling Insert

3.0 HEALTH AND SAFETY

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

Underground utilities, whether private, commercial, or public, shall be cleared in accordance with SOP ENV-05-01 prior to commencing drilling activities.

4.0 PROBE/WELL INSTALLATION

4.1 Considerations

Prior to the selection of drilling method(s), materials and diameters, screen length(s), and configuration, and installation of probes/wells, several key factors must be considered.

4.1.1 Project Objectives and Costs

Short- and long-term objectives shall be defined in the early stages of the project with respect to the type of data required, purpose, and mean(s) of evaluating the data. The project objectives shall define whether probes/wells shall be utilized for purposes other than SVE system effectiveness and vapor migration monitoring. While multiple purpose probes/wells can reduce drilling costs, effects on data quality shall be evaluated with respect to project objectives.

4.1.2 Site Conditions and Access

Site conditions and access shall also be considered to prevent project delays, increased project costs, and deviations from project objectives.

4.1.3 Surface and Subsurface Geological and Hydrologic Conditions

Geologic and hydrologic conditions are critical factors in the selection of drilling method(s), materials and diameters, screen length(s), and configuration, and installation of probes/wells. To the extent practical, surface and subsurface geologic and hydrologic conditions shall be characterized prior to probe/well material and construction/configuration selection and installation. Soil materials, variability within stratigraphic units, preferential pathways, confined/unconfined conditions, actual or potential perched water conditions, water table elevation and variability, and presence of constituents of concern or free phase product shall be considered prior to selection of probe/well material, diameter, screen length and configuration. If geologic and hydrologic conditions cannot be characterized prior to probe/well installation, anticipated conditions shall be discussed with the field staff prior to the commencement of field activities.

4.2 Drilling Method Selection

Common drilling methods include auger, rotary, and direct push technologies. Both hollow-stem and solid-stem auger methods can be used in unconsolidated soils and semi-consolidated (e.g. weathered rock) soils, but not in competent rock. Each method can be employed without introducing foreign materials (e.g. drilling fluids, etc.) into the borehole, thus minimizing the potential for cross contamination. This method consists of a drill pipe or drill stem coupled to a drilling bit that rotates and cuts through soils and competent rock. The cuttings produced from the rotation of the drilling bit are transported to the surface by drilling fluids (e.g.

water, drilling mud, or air) in all cases except for sonic rotary. Sonic rotary methods do not require the addition of any fluids in unconsolidated material because the vibration of the sonic rotary head allows the drill bit to cut without fluids. Consolidated materials may require some water to cool the drill bit. Direct push technology (DPT) use a hydraulic system to advance a 2- or 4-foot stainless steel sampler with a liner, typically acetate, attached to small-diameter, hollow drill rods into the subsurface. The sampler can be configured to allow for discrete interval sampling. Since the sampler is advanced hydraulically, soil cuttings generated by this method are minimal. DPT can be employed without introducing foreign materials (e.g. drilling fluids, etc.) into the borehole and in locations not accessible to most drill rigs. This method can be used in most unconsolidated soils, but not depositions consisting primarily of coarse gravel, cobbles, and/or weathered bedrock. Boreholes can be augured to depths of 40 feet or more (depending on the Geoprobe™ size and stratigraphy), but generally boreholes are advanced to depths of less than 30 feet. Due to the borehole diameter, probe/well installation is limited to small-diameter materials.

In general, air, water, and mud rotary drilling methods shall not be selected for probe/well installation since they introduce foreign materials into the borehole that have the potential to alter or inhibit vapor migration in the immediate vicinity of the probe/well and inhibit vapor migration into the probe/well screen. Table 1 (see Attachment A) shall be used as a guide in selecting drilling method(s).

4.3 Selection of Probe/Well Material and Diameter

Material and diameter selection shall be primarily based on well purpose (single or multiple uses), geologic and hydrologic conditions, and the anticipated probe/well construction/configuration. In general, well diameters greater than four inches, regardless of material, shall be deemed unsuitable due to the volume of air required to purge prior to sample collection. Table 2 (see Attachment B) shall be used as a guide in selecting probe/well materials and diameters.

4.4 Probe/Well Screen Length Selection

Screen length selection shall be based on probe/well purpose (single or multiple uses), geologic and hydrologic conditions, and type of data desired (discrete or composite). Single use probes/wells, those dedicated to SVE system effectiveness and vapor migration monitoring, generally offer more flexibility in screen length selection. Multiple use probes/wells generally offer less flexibility in screen length selection and typically require longer screen lengths to fulfill its various functions. Geologic and hydrologic conditions (e.g. zones of increased permeability/preferential contamination migration or groundwater pathways within a stratigraphic unit, variability in groundwater elevation, etc.) combined with the type of data desired strongly influence screen length selection.

Shorter screen lengths, generally one half to two feet in length, shall be preferred for the monitoring of zones of increased permeability/preferential pathways or discrete intervals with a stratigraphic unit, or the entire thickness of a thinner layer of soil material. Shorter screen lengths are generally preferred for single use probes/wells because they minimize 1) the potential to screen more than one stratigraphic unit or preferential pathway and 2) purge volumes required prior to sampling.

Medium screen lengths, generally two to ten feet in length, shall be preferred for the monitoring of the entire thickness of a stratigraphic unit or stratigraphic units prone to perched water and/or relatively moderate to high fluctuations in groundwater elevation. Medium screen lengths are generally preferred for multi-use probes/wells because they minimize the potential to screen more than one stratigraphic unit.

Long screen lengths, general ten feet or more in length, shall be preferred for multi-use probes/wells intended for regular groundwater and/or product monitoring and/or sampling, especially when relatively moderate to high fluctuations in groundwater elevation are anticipate. In general, probes/wells with screen lengths fifteen feet or longer shall not be deemed adequate for SVE system effectiveness and vapor migration monitoring because they 1) increase the potential to screen more than stratigraphic unit, 2) may not allow for the collection of a sample representative of the entire screened interval, and 3) require a larger purge volume prior to soil vapor sample collection.

4.5 Probe/Well Configuration Selection

The vertical and horizontal configuration of probes/wells shall be a function of their intended purpose(s). Probes/wells intended to evaluate vapor migration across a plane/boundary or within area may be installed within the anticipated radius of influence (ROI) of one or more soil vapor extraction wells. Probes/wells intended to evaluate the actual ROI of a soil vapor extraction well shall be, to the extent possible, installed within the anticipated ROI of only the soil vapor extraction well to be evaluated. In both cases, probes/wells shall generally be installed at set horizontal distances from soil vapor extraction well(s) (e.g. distances equivalent to ½, ¾, and/or the anticipated ROI). Single probes/wells, nested probes/wells, or a combination thereof shall be utilized to achieve project and data quality objectives. Single probes/wells are utilized to monitor one stratigraphic unit or one zone of increased permeability/preferential contamination migration or groundwater pathways within a stratigraphic unit. Nested probes/wells are utilized to monitor multiple stratigraphic units or zones of increased permeability/preferential contamination migration or groundwater pathways within a stratigraphic unit.

4.6 Execution

4.6.1 General

Probes/wells intended for SVE system effectiveness and vapor migration monitoring shall be installed in a manner similar to the installation of wells intended for groundwater monitoring/sampling with the following exceptions:

1. Water shall not be utilized to settle the filter pack (especially in confined stratigraphic units);
2. Bentonite grout shall generally be preferred over placing and then hydrating bentonite pellets/chips;
3. Probe/well screens and associated filter pack shall not, to the extent possible, extend into more than one stratigraphic unit;
4. Probe/well screens and associated filter pack shall not, to the extent possible, extend into more than one confining unit (e.g. clay layer);
5. To the extent possible, a minimum of five (5) feet of bentonite should be placed between the screens and filter packs of individual probes/wells that have been nested within the same borehole to prevent short-circuiting between probes/wells;

6. Probes/wells installed within or adjacent to utility corridors or building foundations shall be protected, to the extent possible, against short-circuiting with the ground surface.
7. Probes/wells installed with screens and/or filter pack within five (5) feet of ground surface shall be protected with impermeable materials (e.g. geotextile, plastic blankets, etc), to the extent possible, against short-circuiting with the ground surface; and
8. Probes/wells shall generally be installed using hollow-stem auger, sonic rotary, or direct push technology methods, unless otherwise required by the Site-Specific Work Plan or the Engineer of Record for the SVE System.

4.6.2 SVE System Effectiveness Monitoring

Probes/wells intended for SVE system effectiveness monitoring shall undergo pre-system start up (a.k.a. baseline) monitoring following the procedures described SOP SAS-11-04) establish a representative set of baseline data and 2) facilitate a defensible evaluation of post-system start up data set.

5.0 REFERENCES AND ADDITIONAL RESOURCES

ASTM International, 2001, ASTM Standard D 5314-92 (2001) Standard Guide for Soil Gas Monitoring in the Vadose Zone.

USEPA, 1994, SOP # 1703, Rev #: 0.0, Summa Canister Cleaning Procedure.

USEPA, 1995, SOP #1704, Rev. #: 0.0, Summa Canister Sampling.

USEPA, 1996, SOP # 2042, Rev. #: 0.0, Soil Gas Sampling

USEPA, 1999, 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) in *Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air*, 2nd Ed., EPA Publication 625/R-96/010b.

USEPA, 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001.

ATTACHMENT A
TABLE 1 – DRILLING METHOD SELECTION

TABLE 1
Drilling Method Selection

SOP SAS-11-03 - ATTACHMENT A

DRILLING METHOD	ADVANTAGES	DISADVANTAGES	NOTES
Hollow-Stem Auger	• Can be used in unconsolidated and semi-consolidated soils • No Introduction of foreign materials into the borehole • Suited for soils that tend to collapse • Probe/well can be installed inside the auger • Can facilitate the installation of larger diameter probes/wells • Can facilitate the installation of more than one small diameter probe/well in a single borehole • Boreholes can be drilled to depths of 100 feet or more	• Cannot be used in competent rock • Retracting augers in caving sand conditions can be extremely difficult • Generates large amounts of soil cuttings	• Generally deemed suitable for the installation of probes/wells, intended for SVE system effectiveness and vapor migration monitoring, in unconsolidated and semi-consolidated soils • Preferred drilling method for the installation of probes/wells with a diameter equal to or greater than one inch and/or nested probes/wells in a single borehole in unconsolidated and semi-consolidated soils
Solid-Stem Auger	• Can be used in unconsolidated and semi-consolidated soils • No Introduction of foreign materials into the borehole • Can facilitate the installation of larger diameter probes/wells • Can facilitate the installation of more than one small diameter probe/well in a single borehole • Boreholes can be drilled to depths of 150 feet or more	• Cannot be used in competent rock • Not suited for soils that tend to collapse • Generates large amounts of soil cuttings	• Generally deemed suitable for the installation of probes/wells, intended for SVE system effectiveness and vapor migration monitoring, in unconsolidated and semi-consolidated soils

TABLE 1
Drilling Method Selection

SOP SAS-11-03 - ATTACHMENT A

DRILLING METHOD	ADVANTAGES	DISADVANTAGES	NOTES
Air Rotary	• Can be used in unconsolidated and semi-consolidated soils and rock • Can facilitate the installation of larger diameter probes/wells • Can facilitate the installation of more than one small diameter probe/well in a single borehole • Boreholes can be drilled to depths of 150 feet or more	• Introduces foreign materials into the borehole • Generates large amounts of soil cuttings • Conventional method does not control the blowing of cuttings out of the borehole	• Generally deemed unsuitable for the installation of probes/wells intended for SVE system effectiveness and vapor migration monitoring
Water Rotary	• Can be used in unconsolidated and semi-consolidated soils and rock • Can facilitate the installation of larger diameter probes/wells • Can facilitate the installation of more than one small diameter probe/well in a single borehole • Boreholes can be drilled to depths of 150 feet or more	• Introduces foreign materials into the borehole • Generates large amounts of soil cuttings • Drilling fluids can carry contamination from a contaminated zone to an uncontaminated zone	• Generally deemed unsuitable for the installation of probes/wells intended for SVE system effectiveness and vapor migration monitoring
Mud Rotary	• Can be used in unconsolidated and semi-consolidated soils and rock • Can facilitate the installation of larger diameter probes/wells • Can facilitate the installation of more than one small diameter probe/well in a single borehole • Boreholes can be drilled to depths of 150 feet or more	• Introduces foreign materials into the borehole • Generates large amounts of soil cuttings • Drilling fluids can carry contamination from a contaminated zone to an uncontaminated zone	• Generally deemed unsuitable for the installation of probes/wells intended for SVE system effectiveness and vapor migration monitoring

TABLE 1
Drilling Method Selection

SOP SAS-11-03 - ATTACHMENT A

DRILLING METHOD	ADVANTAGES	DISADVANTAGES	NOTES
Sonic Rotary	• Can be used in unconsolidated and semi-consolidated soils and rock • Minimal smearing of formation materials • Can facilitate the installation of larger diameter probes/wells • Can facilitate the installation of more than one small diameter probe/well in a single borehole • Boreholes can be drilled to depths of 150 feet or more	• Requires large open spaces for rig and support equipment • Expensive compared to other methods • In flowing sands, introduction of a foreign materials (potable water) is required	• Generally deemed suitable for the installation of probes/wells intended for SVE system effectiveness and vapor migration monitoring • Preferred drilling method for the installation of probes/wells with a diameter equal to or greater than one inch and/or nested probes/wells in a single borehole in competent rock
Direct Push Technologies	• Can be used in unconsolidated and semi-consolidated soils and rock • No Introduction of foreign materials into the borehole • Can access locations not accessible by other drilling equipment • Generates minimal amounts of soil cuttings	• Cannot be used in depositions consisting of coarse gravel, cobbles, and/or weathered or competent rock • Cannot facilitate the installation of larger diameter probes/wells • Cannot facilitate the installation of more than one small diameter probe/well in a single borehole • Drilling depth is limited compared to other drilling methods	• Generally deemed suitable for the installation of small-diameter probes/wells intended for SVE system effectiveness and vapor migration monitoring • Preferred drilling method for the installation of probes/wells with a diameter less than one inch in unconsolidated and semi-consolidated soils
Hand Auger	• Can be used in unconsolidated soils • No Introduction of foreign materials into the borehole • Can access locations not accessible by other drilling equipment • Generates minimal amounts of soil cuttings	• Cannot be used in depositions consisting of coarse gravel, cobbles, and/or weathered or competent rock • Cannot facilitate the installation of larger diameter probes/wells • Cannot facilitate the installation of more than one small diameter probe/well in a single borehole • Drilling depth is limited compared to other drilling methods	• Generally deemed suitable for the installation of shallow, small-diameter probes/wells intended for SVE system effectiveness and vapor migration monitoring, but is not the preferred drilling method

ATTACHMENT B
TABLE 2 – PROBE/WELL MATERIAL AND DIAMETER SELECTION

TABLE 2
Probe/Well Material and Diameter Selection

SOP SAS-11-03 - ATTACHMENT B

WELL MATERIAL	WELL DIAMETER	ADVANTAGES	DISADVANTAGES	NOTES
Polyvinyl Chloride (PVC)	1-Inch I.D.	• Suitable for single probe/well construction in small to large diameter boreholes • Suitable for nested probes/wells in medium to large diameter boreholes • Relatively low purge volume per foot of casing/screen • Can be fitted with various screen lengths (1, 5, and 10 foot screens) • Allows for fluid level gauging to confirm well screen masking by fluids • Limited suitability for other purposes (e.g. groundwater/product gauging and sampling) • Relatively inexpensive material	• Unsuitable for nested probes/wells in small diameter boreholes • Limited suitability for other purposes	• Generally deemed suitable for the installation of single or nested probes/wells, intended for SVE system effectiveness and vapor migration monitoring, in unconsolidated and semi-consolidate soils and competent rock. • Preferred material and diameter for monitoring within most depositional environments including fine grained materials, confined conditions, and the caprillary fringe
Polyvinyl Chloride (PVC)	2-Inch I.D.	• Suitable for single probe/well construction in large diameter boreholes • Can be fitted with various screen lengths (1, 5, and 10 foot screens) • Allows for fluid level gauging to confirm well screen masking by fluids • Suitable for other purposes (e.g. groundwater/product gauging and sampling) • Relatively inexpensive material	• Limited suitability for single probe/well construction in small and medium diameter boreholes • Generally, unsuitable for nested probes/wells • Relatively moderate purge volume per foot of casing/screen	• Generally deemed suitable for the installation of single or nested probes/wells, intended for SVE system effectiveness and vapor migration monitoring, in unconsolidated and semi-consolidate soils and competent rock. • Preferred material and diameter for probes/wells intended for multiple uses in most depositional environments

TABLE 2
Probe/Well Material and Diameter Selection

SOP SAS-11-03 - ATTACHMENT B

WELL MATERIAL	WELL DIAMETER	ADVANTAGES	DISADVANTAGES	NOTES
Polyvinyl Chloride (PVC)	4-Inch I.D.	• Suitable for single probe/well construction in large diameter boreholes • Can be fitted with various screen lengths (5, and 10 foot screens) • Allows for fluid level gauging to confirm well screen masking by fluids • Suitable for other purposes (e.g. groundwater/product gauging and sampling) • Relatively inexpensive material	• Unsuitable for nested probes/wells • Relatively high purge volume per foot of casing/screen	• Generally deemed unsuitable for SVE system effectiveness and vapor migration monitoring due to the high purge volume per foot of casing/ screen • Limited suitability for vacuum/ pressure gauging
Stainless Steel	1/8-Inch O.D.	• Suitable for single probe/well construction in small to large diameter boreholes • Suitable for nested probe/well construction in small to large diameter boreholes • Minimal purge volume per foot of casing/screen	• Does not allow for fluid level gauging to confirm well screen masking by fluids • Generally limited to a 0.5-foot well screen • Extremely difficult to rehabilitate the well, when necessary • Unsuitable for other purposes	• Generally deemed suitable for the installation of single or nested probes/wells, intended for SVE system effectiveness and vapor migration monitoring, in unconsolidated and semi-consolidate soils and competent rock. • Preferred material and diameter for monitoring within depositional environments characterized by fine-grained materials and unconfined conditions well above the water table

TABLE 2
Probe/Well Material and Diameter Selection

SOP SAS-11-03 - ATTACHMENT B

WELL MATERIAL	WELL DIAMETER	ADVANTAGES	DISADVANTAGES	NOTES
Stainless Steel	1/4-Inch O.D.	• Suitable for single probe/well construction in small to large diameter boreholes • Suitable for nested probe/well construction in small to large diameter boreholes • Minimal purge volume per foot of casing/screen	• Does not allow for fluid level gauging to confirm well screen masking by fluids • Generally limited to a 0.5-foot well screen • Extremely difficult to rehabilitate the well, when necessary • Unsuitable for other purposes	• Generally deemed suitable for the installation of single or nested probes/wells, intended for SVE system effectiveness and vapor migration monitoring, in unconsolidated and semi-consolidate soils and competent rock. • Preferred material and diameter for monitoring within depositional environments characterized by fine-grained materials and unconfined conditions well above the water table
Stainless Steel	2-Inch I.D.	• Suitable for single probe/well construction in medium to large diameter boreholes • Can be fitted with various screen lengths (1, 5, and 10 foot screens) • Allows for fluid level gauging to confirm well screen masking by fluids • Suitable for other purposes (e.g. groundwater/product gauging and sampling)	• Limited suitability for single probe/well construction in small diameter boreholes • Generally, unsuitable for nested probes/wells • Relatively moderate purge volume per foot of casing/screen • Relatively expensive material	• Generally deemed suitable for the installation of single or nested probes/wells, intended for SVE system effectiveness and vapor migration monitoring, in unconsolidated and semi-consolidate soils and competent rock. • Preferred diameter for probes/wells intended for multiple uses in most depositional environments

TABLE 2
Probe/Well Material and Diameter Selection

SOP SAS-11-03 - ATTACHMENT B

WELL MATERIAL	WELL DIAMETER	ADVANTAGES	DISADVANTAGES	NOTES
Stainless Steel	4-Inch I.D.	• Suitable for single probe/well construction in large diameter boreholes • Can be fitted with various screen lengths (5, and 10 foot screens) • Allows for fluid level gauging to confirm well screen masking by fluids • Suitable for other purposes (e.g. groundwater/product gauging and sampling)	• Unsuitable for nested probes/wells • Relatively high purge volume per foot of casing/screen • Relatively expensive material	• Generally deemed unsuitable for SVE system effectiveness and vapor migration monitoring due to the high purge volume per foot of casing/ screen • Limited suitability for vacuum/ pressure gauging

STANDARD OPERATING PROCEDURE
NO. SAS-11-04

SVE SYSTEM EFFECTIVENESS AND VAPOR MIGRATION MONITORING
Revision 0

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for the monitoring of semi-permanent to permanent soil vapor monitoring probes/wells for the evaluation of Soil Vapor Extraction (SVE) system effectiveness and subsurface vapor migration. This SOP also describes field measurements and soil vapor collection methods, and quality assurance procedures.

2.0 EQUIPMENT AND MATERIALS

- Digital manometer (Dwyer Series 475 Mark III Digital Manometer or equivalent) or magnehelic differential pressure gauge (0-20 inches of water);
- Digital manometer (Dwyer Series 475 Mark III Digital Manometer or equivalent)or magnehelic differential pressure gauge (0-200 inches of water);
- 1-liter Tedlar™ bags;
- Tygon™ or silicone tubing (cut to length);
- ¼-inch OD Teflon™, Polyethylene, or PVC tubing (cut to length);
- GeoTech Peristaltic Pump or equivalent;
- BIOS DC-LITE flow calibrator, calibrated rotometer, or equivalent;
- 60-mL syringe for purging (Probe/well less than 1 inch in diameter);
- Stainless-steel manual pump for purging (Probe/well equal to or greater than 1 inch in diameter);
- Extra vinyl slip covers;
- Clean (dedicated) 3/16-Inch hose barb, chrome-platted brass, non-valved, in-line coupling body (herein referred to as “coupling body”);
- New or dedicated 4-way valves for purging and sampling;
- Summa (or equivalent) canisters;
- Sample flow controller;


Coupling Body

- ¼-inch OD Teflon sample line;
- ¼-inch OD Teflon or stainless-steel compression fittings;
- Probe/well location maps;
- Miscellaneous tools (i.e. socket set to remove well/probe caps);
- Chain of custody forms and seals; and
- Field logbook and/or appropriate field form.

3.0 HEALTH AND SAFETY

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 EXECUTION

Probes/wells intended for SVE system effectiveness monitoring shall undergo pre-system start up (a.k.a. baseline) monitoring to 1) establish a representative set of baseline data and 2) facilitate a defensible evaluation of post-system start up data set. Procedures for baseline and post-system start up monitoring are described in the following sections.

4.1 Vacuum/Pressure Gauging

In order to evaluate the degree of influence that a soil vapor extraction (SVE) wells have on surrounding area, vacuum measurements shall be collected from designated monitoring locations prior to any soil vapor sampling. The Dwyer digital manometer or magnehelic differential pressure gauge or equivalent (herein referred to as the “gauging instrument”) shall be used for this measurement. Immediately prior to use, the gauging instrument shall be zeroed at atmospheric pressure. Vacuum/pressure measurements shall be obtained using the of the following probe/well diameter-specific procedures.

4.1.1 Probe/Well Diameters Less Than One Inch

At probes/wells with a diameter of less than one-inch, the positive fitting on the gauging instrument shall be connected to the 4-way valve, previously installed to the top of the well riser, using small diameter silicone tubing of appropriate size. The negative fitting on the gauging instrument shall remain open to the atmosphere. The 4-way valve shall be opened to the well and closed to the atmosphere. The gauging instrument shall be allowed a maximum of thirty (30) minutes to stabilize before the vacuum/pressure is recorded. If the gauging instrument does not stabilize within the 30-minute period, the range in which the vacuum/pressure reading fluctuates over an additional one (1) minute period will be documented in the field logbook and/or on the appropriate field form. The highest reading observed within the observed range will be recorded in the field logbook and/or on the appropriate field form as the primary measurement. (*Please note: If the gauging instrument reading fluctuates between two vacuums, the lowest/weakest vacuum observed will be recorded as the primary measurement. If the gauging instrument reading fluctuates between a vacuum and a pressure, the highest pressure observed will be recorded as the primary measurement. If the manometer reading fluctuates between two pressures, the highest/strongest pressure observed will be recorded as the primary measurement. In all cases, the range in the gauging instrument readings over the additional one-minute period will be recorded in the field logbook and/or on the appropriate field form.)* The vacuum/pressure measurement shall be recorded to the nearest hundredth of an inch of water column in the field logbook and/or on the appropriate field form first, followed by any secondary data entry devices (i.e. PDA, laptop, etc.). Please note a field form, if used, is considered the record document. Immediately following the recording of the vacuum/pressure measurement, the 4-way valve shall be closed to the well and open to the atmosphere and the gauging instrument shall be detached from the silicone tubing and 4-way valve *(see Attachment A: Guide to the 4-Way Micro-Valve)*.

A picture of a typical vacuum/pressure gauging set-up is provided below.

4.1.2 Probe/Well Diameters Equal to or Greater Than One Inch

At probes/wells with a diameter equal to or greater than one-inch, the positive fitting on the gauging instrument shall be connected to a dedicated coupling body using silicone (or equivalent) tubing. The negative fitting on the gauging instrument shall remain open to the atmosphere. The coupling body shall then be connected to the coupling insert located on the expandable well cap, which will open the well to the gauging instrument. The gauging instrument shall be allowed a maximum of thirty (30) minutes to stabilize before the vacuum/pressure is recorded. If the gauging instrument does not stabilize within the 30-minute period, the range in which the vacuum/pressure reading fluctuates over an additional one (1) minute period will be documented in the field logbook and/or on the appropriate field form. The highest reading observed within the observed range will be recorded as the primary measurement. (*Please note: If the gauging instrument reading fluctuates between two vacuums, the lowest/weakest vacuum observed will be recorded as the primary measurement. If the gauging instrument reading fluctuates between a vacuum and a pressure, the highest pressure observed will be recorded as the primary measurement. If the manometer reading fluctuates between two pressures, the highest/strongest pressure observed will be recorded as the primary measurement. In all cases, the range in the gauging instrument readings over the additional one-minute period will be recorded in the field logbook and/or on the appropriate field form.)* The vacuum/pressure measurement shall be recorded to the nearest hundredth of an inch of water column in the field logbook and/or on the appropriate field form first, followed by any secondary data entry devices (i.e. PDA, laptop, etc.). Please note a field form, if used, is considered the record document. Immediately following the recording of the vacuum/pressure measurement, the coupling body shall be disconnected from the coupling insert, which will close the well to the gauging instrument and the atmosphere. The gauging instrument and associated tubing shall then be detached from the dedicated coupling body.

4.2 Probe/Well Purging

Upon completion of any vacuum / pressure measurements and prior to soil vapor sample collection, each probe/well shall be purged a predetermined volume (in Liters or milliliters) based on the volume of the probe/well riser and screen. The purge volume shall be equivalent to a minimum of three probe/well volumes. The actual purge volume removed shall be recorded in the field logbook and/or on the appropriate field form. If the probe/well would not yield the full purge volume or water and/or product are encountered during purging, this observation shall be documented in the field logbook and/or on the appropriate field form.

4.2.1 Probe/Well Diameters Less Than One Inch

To purge the monitoring locations with a diameter less than one-inch, a 60-ml plastic syringe shall be attached to the 4-way valve, previously installed to the top of the well riser and the valve shall be configured (opened to the well and closed to the atmosphere) to allow the removal of the required purge volume. The syringe plunger shall be drawn back to evacuate a purge volume. The valve gate shall then be configured (closed to the well and opened to the atmosphere) and the syringe plunger shall be pushed in allowing the purged volume to be expelled to atmosphere. This process shall continue until a minimum of three probe/well volumes have been removed from the monitoring location. Care shall be taken to prevent the purged air from being reintroduced into the probe/well. At the completion of purging, the 4-way valve shall remain attached to the monitoring location with the valve configured so that the well is closed to atmosphere. Failure to close the 4-way valve to atmosphere prior to attaching the Tedlar™ bag or Summa canister will result in a volume of ambient air infiltrating back into the well riser and subsequently being collected as a sample *(see Attachment A: Guide to the 4-Way Micro-Valve)*.

4.2.2 Probe/Well Diameters Equal to or Greater Than One Inch

Purging probes/wells with diameters equal to or greater than one inch requires the use of a stainless steel hand pump in conjunction with silicone (or equivalent) tubing and a dedicated coupling body. The hand pump shall be tested prior to each sampling event by attaching a 1-liter Tedlar™ test bag to the hand pump outlet. The inlet of the hand pump shall remain open to atmosphere. Two strokes of a properly working hand pump should fill a 1-liter bag to approximately 75-percent of capacity. The 1-liter bag should not be completely filled because the bags are typically oversized in order to allow for expansion of the sample during shipment, storage, etc. The hand pump shall be rebuilt in accordance with manufacturer specifications if the hand pump fails to adequately fill the test bag.

The stainless steel hand pump shall be used in conjunction with silicone (or equivalent) tubing and a dedicated coupling body. The vacuum side of the hand pump shall be attached to a dedicated coupling body using silicone (or equivalent) tubing. The dedicated coupling body shall then be connected to the coupling insert located on the expandable well cap, which will allow for the removal of purge volumes from the probe/well. The hand pump has an internal one-way valve and, therefore, manipulation of the coupling body and coupling insert shall not be necessary. The purged volume is expelled to atmosphere from the positive side of the hand pump with every downward stroke of the pump handle (piston). Every upward stroke of the pump handle should remove approximately ½-liter of the purge volume from the well. Care shall be taken to fully extend the hand pump handle to ensure that the appropriate volume is removed from the probe/well with each pump stroke. When a minimum of three well volumes have been removed from the monitoring location, the coupling body shall be disconnected from the coupling insert, which closes the probe/well to atmosphere.

4.3 Soil Vapor Sample Collection

Upon completion of probe/well purging (evacuation of a minimum of three probe/well volumes of air), soil vapor sample collection using Tedlar™ sample media and/or summa (or equivalent) canisters shall commence. If water and/or product are encountered during sample collection, this observation shall be documented in the field logbook and/or on the appropriate field form.

4.3.1 Tedlar™ Bag Sample Media

Soil vapor samples for on-site analysis/field screening shall be collected using a Tedlar™ bag media and a peristaltic pump. For probes/wells with a diameter less than one-inch, the peristaltic pump shall be attached to a 4-way plastic micro valve using a combination of Tygon™ and silicone (or their respective equivalent) tubing. The valve, which was used for the well purging, should already be attached to the top of the well riser. For probes/wells with a diameter greater than or equal to one-inch, the peristaltic pump shall be attached to the dedicated coupling body using a combination of Tygon™ and silicone (or their respective equivalent) tubing. The outlet of the peristaltic pump shall be attached to the inlet side of the flow calibrator (or rotometer) using a combination of Tygon™ and silicone (or their respective equivalent) tubing. Prior to flow rate adjustment and sample collection, the sample identification, date, time, and vacuum/pressure reading (if applicable) shall be clearly documented on the Tedlar™ Bag.

4.3.1.1 Flow Rate Adjustment

The flow calibrator or calibrated rotometer shall be used to adjust the flow rate of the peristaltic pump to allow a flow rate of less than 200 mL/minute. For probes/wells with a diameter less than one-inch, this adjustment shall be performed by 1) configuring the micro valve to allow for sample removal from the well, 2) depressing the read button on the flow meter and noting the rate of sample flow or if a calibrated rotometer is used, simply observe the flow rate indicated by the ball height, and 3) quickly adjusting the peristaltic pump to allow a flow rate of 200-ml/minute or less. For probes/wells with a diameter greater than or equal to one-inch, this adjustment shall be performed by 1) connecting the coupling body to the coupling insert to allow for sample removal from the well, 2) depressing the read button on the flow meter and noting the rate of sample flow or if a calibrated rotometer is used, simply observe the flow rate indicated by the ball height, and 3) quickly adjusting the peristaltic pump to allow a flow rate of 200-ml/minute or less. *Notes: The initial settings on the pump should be set to allow for the minimum flow possible. It is important to set the flow rate as quickly as possible in order to minimize the amount of additional sample volume. An advantage that the use of a rotometer has over a flow meter is that an instantaneous flow reading will be displayed, allowing for a much quicker flow-rate adjustment to the peristaltic pump.* After setting the sample flow, sample collection shall be immediately initiated. Care shall be taken at this time to avoid unintentionally adjusting (by bumping or handling) the pump speed control.

4.3.1.2 Sample Collection

After setting the sample flow, the flow calibrator or calibrated rotometer shall be removed from the sample train and a new, clean, pre-labeled, one-liter Tedlar™ bag shall be connected to the tubing exiting from the positive-pressure (output) side of the peristaltic pump. A wire tie shall be used, if necessary, to make the connection between the bag and the pump a leak proof fitting. Immediately open the valve on the Tedlar™ bag approximately one turn. *Please note: Unless a vacuum/pressure reading was not collected, the sample time is the same time as the acquisition of the primary vacuum/pressure measurement. If a vacuum/pressure measurement was not collected, the sample-start time shall be documented in the field logbook and/or on the appropriate field form.* Based on the flow rate to collect a 1-liter vapor sample, the peristaltic pump shall be allowed approximately five (5) minutes to collect the sample. Total sample collection time, which may exceed five (5) minutes, is dependent on the soil characteristics of the stratigraphic unit (a.k.a. stratum) from which the sample is being collected. Upon retrieval of the one-liter sample volume, the valve on the Tedlar™ bag shall be closed and the peristaltic pump turned off. The micro valve shall then be configured such that the valve is closed to the well and open to the atmosphere (well diameters less than one-inch) or the coupling body shall be disconnected from the coupling insert (well diameters greater than or equal to one-inch). The sample bag shall be placed in a black trash bag or container that will not allow sunlight to pass through.

Duplicate samples shall be collected by repeating the preceding procedure detailed above. The duplicate sample shall be collected immediately after the first sample (original/main sample) has been collected. Due to the nature of the coarse-adjustment valves that are typically installed on Tedlar™ bags, the use of a sample splitter is not recommended since this will often result in the collection of unequal sample volumes.

4.3.1.3 Post-Sample Collection

The sample train shall be dismantled and all non-dedicated lines used for sample collection shall be disposed of. New sample lines at each sample location shall be used, except for dedicated equipment (4-way micro valves, fittings, and coupling bodies, etc.). The micro valve shall remain attached to probes/wells with a well diameter less than one-inch, however; the valve shall be configured so that the probe/well is closed to atmosphere *(see Attachment A: Guide to the 4-Way Micro-Valve)*. For probes/wells with a diameter equal to or greater than one inch, the vinyl slip cover shall be fitted over the coupling insert on the expandable well cap following sampling collection. The dedicated equipment (coupling body) used for the monitoring locations with a probe/well diameter equal to or greater than one-inch shall be placed into a labeled, re-sealable bag. Non-dedicated, reusable equipment shall be cleaned / decontaminated in accordance with SOP ENV-04-04 or as otherwise required by the Site-Specific Work Plan.

4.3.2 Summa™ Canister Sample Media

Soil vapor samples for commercial laboratory analysis shall be obtained using Summa™ or equivalent canisters. For probes/wells with a diameter less than one-inch, the Summa (or equivalent) canister shall be attached directly to a 4-way plastic micro valve using silicone tubing. The valve, which was used for the well purging, should already be attached to the top of the well riser. For probes/wells with a diameter greater than or equal one-inch, the Summa™ (or equivalent) canister shall be attached directly to the dedicated coupling body located on the expandable well cap using silicone tubing.

4.3.2.1 Canister Preparation and QA/QC

A Summa canister is a stainless steel container which has had its internal surfaces passivated using the "Summa" process. The process uses an electro polishing step in conjunction with chemical deactivation. The overall process results in a chemically inert interior surface of the media which allows for the collection and subsequent analysis of samples containing very low concentrations of VOCs. The Summa media is available in a number of different sizes. Typically, 6-liter Summa canisters are used for the collection of soil vapor samples because this volume should allow for low detection limits and facilitate more complex analyses.

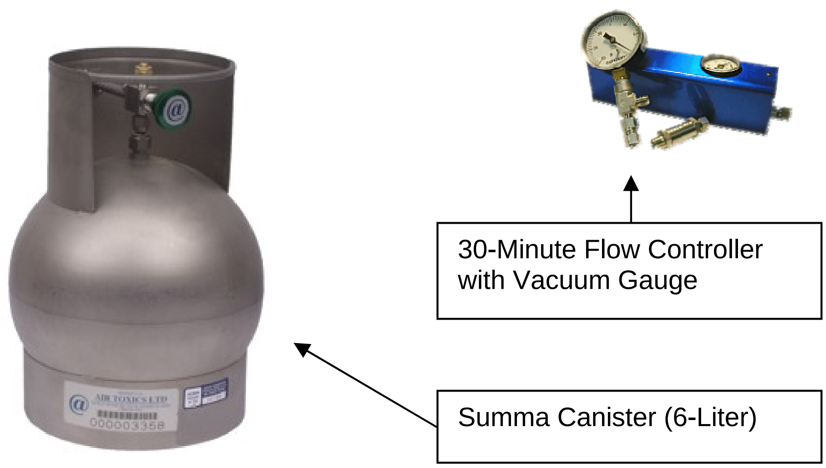
Once the laboratory cleaning process is completed, the Summa canisters are prepared by the laboratory for use in the field. Each canister is evacuated to achieve a vacuum pressure of approximately 30-inches of mercury. The pressure differential between the canister and atmosphere allows for the Summa canister to sample without the use of a separate sample pump. Depending on the project requirements, either grab or integrated samples may be collected. The holding time (shelf life) for Summa canisters that have been prepared for use in the field is 30-days. If the canister has not been used within this time-period, it shall be returned to the contracted laboratory for re-conditioning.

Summa canisters undergo either an individual or batch certification process. The individual certification process requires that each canister undergo a comprehensive Quality Assurance/Quality Control (QA/QC) procedure that results in analysis documentation for each canister, verifying that there are no residual compound concentrations above a pre-determined level. Typically, individually certified canisters are used for ambient air sampling programs that require a high level of QA/QC. Batch certified canisters undergo the same re-conditioning process as the individually certified canisters. However, only 5-percent of randomly chosen canisters are analyzed for residual constituents. If any of the selected canisters do not meet specific certification criteria, all of the canisters in that batch are required to undergo the entire cleaning and QA/QC process again. This process is repeated until all QA/QC re-conditioning criteria are met.

4.3.2.2 Sample Set Up

Field sampling staff shall complete the sample set-up of a Summa (or equivalent) canister prior to sample collection. Each six-liter (6.0 L) Summa (or equivalent) canister shall be fitted with a dedicated sample flow controller (regulator). After verification that the valve on the canister is in the "off" position, the brass cap shall be removed from the canister inlet fitting and the sample flow controller shall be attached to the canister inlet. The brass cap shall then be installed onto the inlet of the flow controller and tighten. *Note: The 30-minute sample flow controller (regulator) is a complete assembly that shall be attached directly to the canister.* The assembly shall then be leak-checked by opening the canister valve and noting the initial vacuum reading. The vacuum should indicate between 20 and 30-inches of mercury. The canister shall not be used if the starting vacuum is less than 20-inches of mercury. The vacuum may fall a very small amount (1 to 2-inches) due to the evacuation of the flow controller and then quickly stabilize. If the vacuum does not stabilize, the flow controller or associated fittings are leaking. If possible, determine the location of the leak, and repair it accordingly. Any necessary repairs shall be document in the field logbook and/or on the appropriate field form. If the leak cannot be quickly identified and repaired, the Summa canister and flow controller shall not be used.

A picture of a typical 6-liter Summa canister and a 30-minute sample flow controller are provided below.



4.3.2.3 Sample Collection

Upon completion of sample set up, soil vapor sample collection shall begin. A short length of dedicated Teflon™ tubing shall then be installed onto the top of the flow regulator with a Teflon™ Swagelok fitting or equivalent to form a leak proof connection. The Summa (or equivalent) canister shall be connected via the Teflon™ tubing and a small length of silicon tubing to the 4-way micro valve (probes/wells with a diameter less than one-inch or the dedicated coupling body (probes/wells with a diameter equal to or greater than one inch). If necessary, a wire tie shall be used on each connection where different tubing attaches to form a leak-proof seal. For probes/wells with a diameter less than one-inch, the 4-way micro valve shall then be configured to allow sample collection (valve open to the well and sample flow controller / regulator and closed to the atmosphere) and the valve on the canister opened approximately two (2) turns. For probes/wells with a diameter greater than or equal to one-inch, the coupling body shall be connected to the coupling insert located on the expandable well cap and the valve on the canister opened approximately two (2) turns. The sample start time and beginning canister vacuum (inches of mercury [Hg]) shall be recorded in the field logbook and/or on the appropriate field form. *Note: The typical initial canister vacuum is between 20 and 30 inches of Hg.*

A picture of a typical 6-liter Summa canister, 30-minute sample flow controller, and sample train is provided below for a probe/well with a diameter less than one-inch.

When the sampler has identified a minimum change/decrease of 15 inches of Hg in canister vacuum (Initial Vacuum – Final Vacuum) and the final canister vacuum is equal to or below five (5) inches of Hg, but above two (2) inches of Hg, the valve to the canister shall be closed. For probes/wells with a diameter less than one inch, the 4-way micro valve shall then be configured to be closed to the probe/well, sample flow controller / regulator, and the atmosphere. For probes/wells with a diameter equal to or greater than one inch, the coupling body shall be disconnected from the coupling insert. *NOTE: Based on the approximate flow rate (200 milliliters per minute [mL/min], approximately thirty (30) minutes is required to collect the specified sample volume.* The sample time, canister number, and sample flow controller / regulator number shall be recorded on the chain of custody and the final canister vacuum and sample end time recorded in the field logbook and/or on the appropriate field form. The sample flow controller / regulator shall be removed from the canister and the Teflon™ sample tubing shall be discarded after a single use to prevent cross-contamination between samples. Finally, the brass cap (used earlier) shall be attached to the inlet fitting on the Summa canister and a sample identification tag/label attached to the canister.

Duplicate samples shall be collected by repeating the procedure detailed above, with the addition of a “T” splitter, and one canister attached to each end of the “T” Swagelok (compression) or equivalent fitting.

A picture of a typical set-up for the collection of a duplicate sample at a probe/well with a diameter of less than one-inch is provided below.

4.3.2.4 Post-Sample Collection

The sample train shall be dismantled and all non-dedicated lines used for sample collection shall be disposed of. New sample lines at each sample location shall be used, except for dedicated equipment (4-way micro valves, fittings, and coupling bodies, etc.). The micro valve shall remain attached to probes/wells with a well diameter less than one-inch, however; the valve shall be configured so that the probe/well is closed to atmosphere *(see Attachment A: Guide to the 4-Way Micro-Valve)*. For probes/wells with a diameter equal to or greater than one inch, the vinyl slip cover shall be fitted over the coupling insert on the expandable well cap following sampling collection. The dedicated equipment (coupling body) used for the monitoring locations with a probe/well diameter equal to or greater than one-inch shall be placed into a labeled, re-sealable bag. Non-dedicated, reusable equipment shall be cleaned / decontaminated in accordance with SOP ENV-04-04 or as otherwise required by the Site-Specific Work Plan.

4.4 Soil Vapor Sample Handling

Tedlar™ bag samples shall be transported to the onsite field screening location. Field screening shall be performed in accordance with the SOP SAS-11-05. The holding time for a Tedlar™ bag sample shall not exceed thirty-six (36) hours.

Summa canisters samples shall be shipped to the contracted laboratory under strict chain of custody procedures for offsite laboratory analysis. The holding time for a Summa sample shall not exceed fourteen (14) days.

5.0 Quality Assurance/Quality Control

5.1 Leak Testing

Leakage during soil vapor sampling may dilute samples with ambient air and produce results that underestimate actual site soil vapor concentrations. Leak testing can be conducted using direct and indirect methods to evaluate seal integrity. The type of leak testing, if any, shall be based on data quality objectives as specified in the Site-Specific Work Plan.

5.1.1 Direct

Seal integrity can be evaluated directly using an inert tracer gas (e.g. laboratory grade helium). Inert gas selection shall be conducted in conjunction with the laboratory. The sampler shall construct an air tent using polyethylene sheet or assemble a commercially available air tent which encompasses the top of the probe/well casing and the entire sample train. During sampling, the tracer gas shall be allowed to flow around the sample train connections and the bentonite or grout seal at the ground surface. Following sample collection, the air tent shall be dismantled. The soil vapor sample shall be analyzed for inert trace gas in addition to the other requested analysis. If the tracer gas is detected in the soil vapor sample, the seal integrity was compromised and the analytical results, which are not representative of the stratigraphic unit or zone within the stratigraphic unit, shall be considered invalid.

5.1.2 Indirect

Seal integrity can be evaluated indirectly by measuring oxygen and carbon dioxide levels in the soil vapor sample. Oxygen and carbon dioxide levels shall be compared to levels in ambient air, project-specific criteria, and/or data trend(s). If the soil vapor sample levels are comparable to ambient air and/or project-specific criteria and/or do not fit data trend(s), the sample results shall be considered suspect. If soil vapor analysis is being performed by an offsite laboratory, this data shall be qualified appropriately. If soil vapor analysis is being performed onsite (either by a mobile laboratory or as field screening), then the probe/well shall be re-sampled within 24 to 36 hours of the original sample. The duplicate and original sample results shall be compared and evaluated based on project-specific criteria and data trend(s) to determine if the seal integrity was compromised and validity of the data collected. The reasons supporting the qualification or invalidation of data shall be documented in the field logbook and/or on the appropriate field form or as otherwise required by the Site-Specific Work Plan or Quality Assurance Project Plan (QAPP).

6.0 REFERENCES AND ADDITIONAL RESOURCES

ASTM International, 2001, ASTM Standard D 5314-92 (2001) Standard Guide for Soil Gas Monitoring in the Vadose Zone.

USEPA, 1994, SOP # 1703, Rev #: 0.0, Summa Canister Cleaning Procedure.

USEPA, 1995, SOP #1704, Rev. #: 0.0, Summa Canister Sampling.

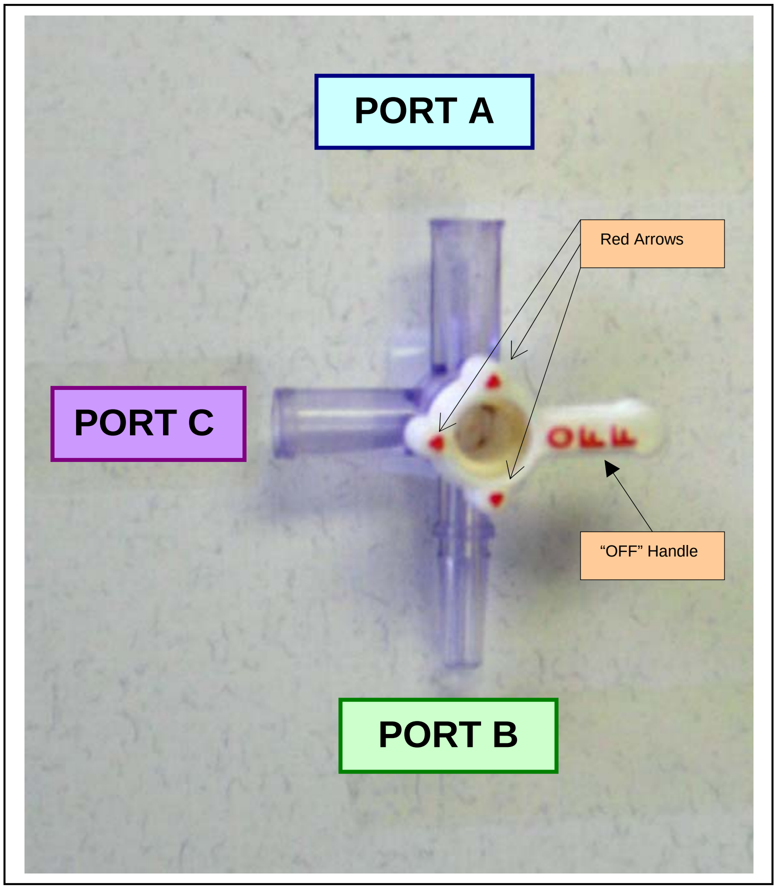
USEPA, 1996, SOP # 2042, Rev. #: 0.0, Soil Gas Sampling

USEPA, 1999, 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) in *Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air*, 2nd Ed., EPA Publication 625/R-96/010b.

USEPA, 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001.

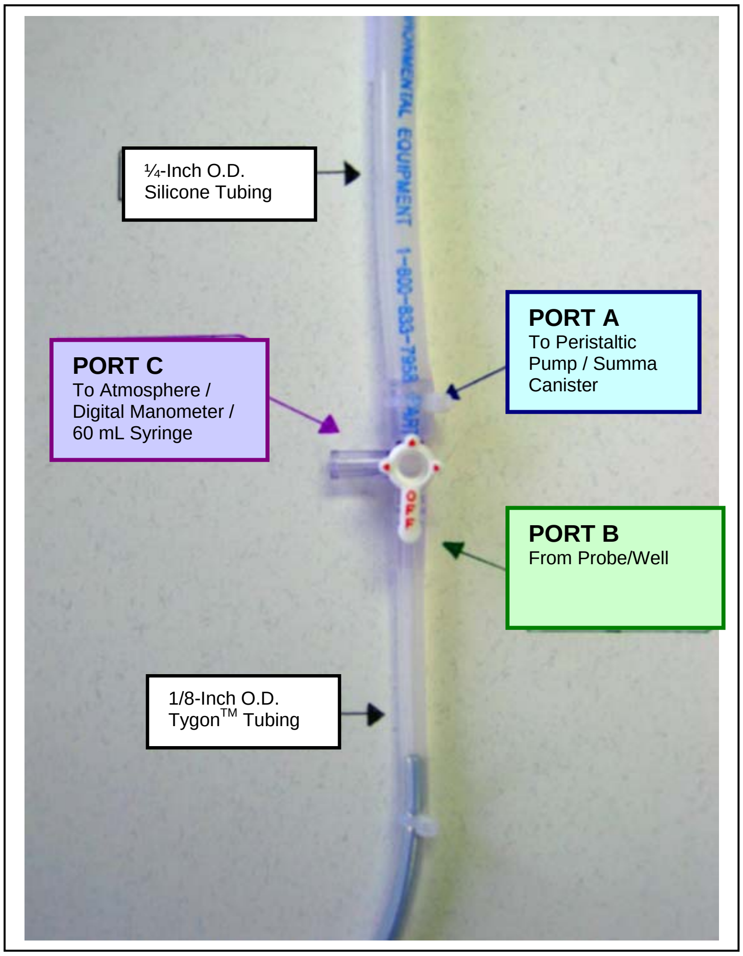
ATTACHMENT A
GUIDE TO THE 4-WAY MICRO-VALVE

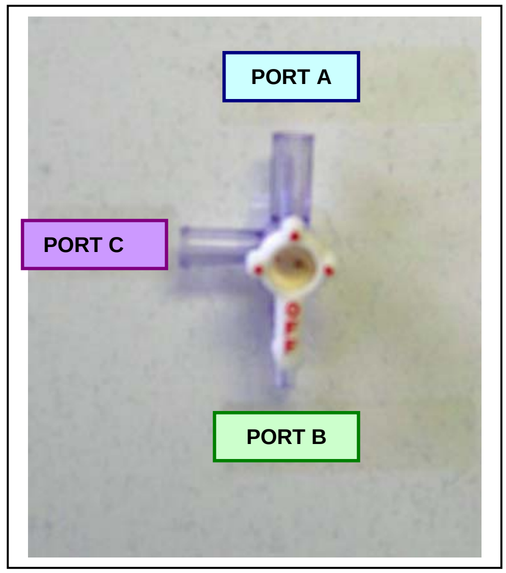
GUIDE TO THE 4-WAY MICRO-VALVE



Notes:
1. Red arrows on the 4-way micro-valve indicate the ports that are currently open.
2. The "OFF" handle indicates the port that is currently closed.
3. The designation of ports is alphabetical from the top (opposite the probe/well) going in a clockwise direction.

Valve Position #1: Closed to Probe/Well





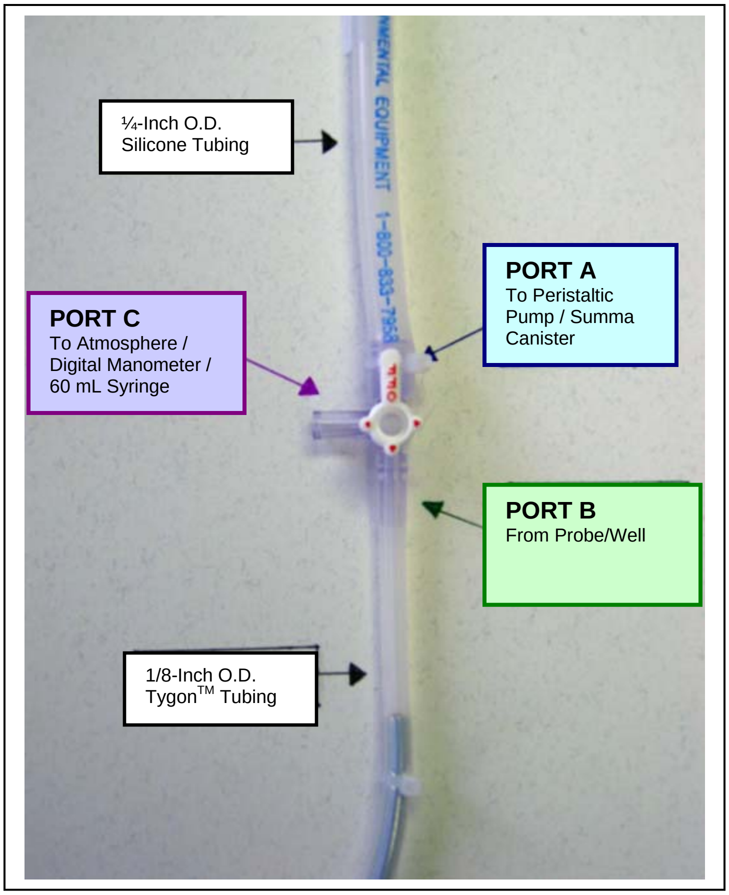
Valve Position #1:

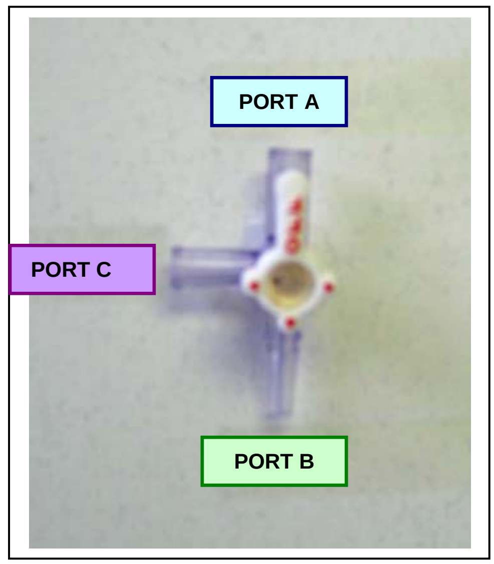
Closed to Port B (Probe/Well);
Open to Port A (Peristaltic Pump / Summa Canister)
Open to Port C (Atmosphere / Digital Manometer / 60 mL Syringe)

The "OFF" handle is turned in such a way that it is directly over Port B. The three small, red arrows opposite the "OFF" handle indicate which ports are open (Ports A & C).

In this valve position, the probe/well is not open to the atmosphere and, therefore, will not vent. If the valve is not in this position prior to the start of the monitoring (vacuum/pressure gauging, Tedlar™ bag sample collection, and/or summa canister sample collection, set the valve to Position #1 and return to this location at least 30 minutes later.

Valve Position #2: Open for Vacuum/Pressure Gauging & Purging





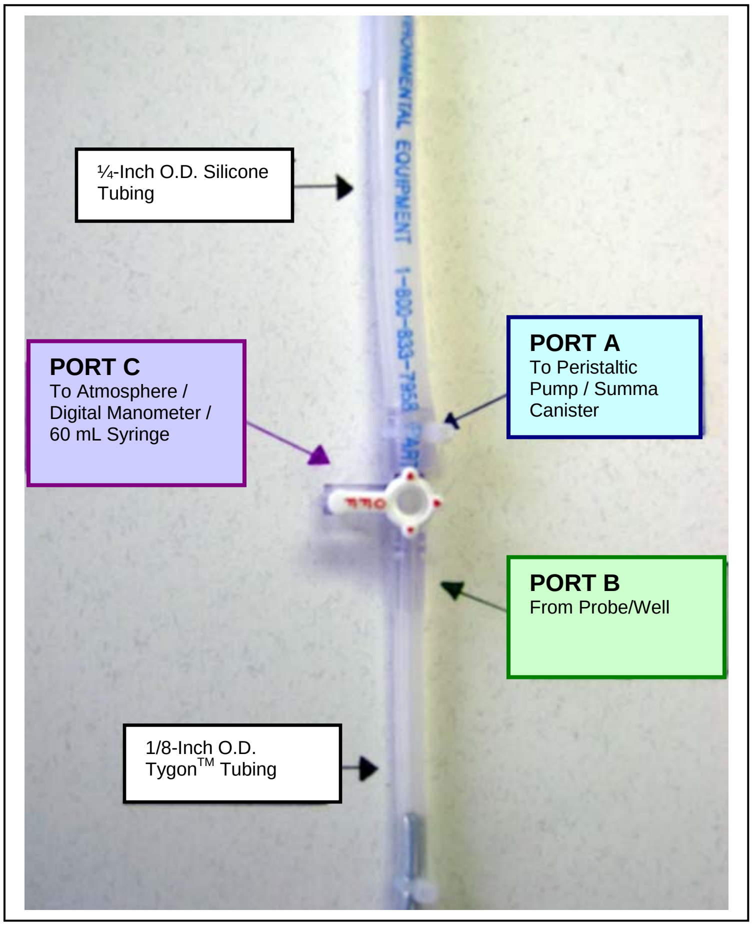
Valve Position #2:

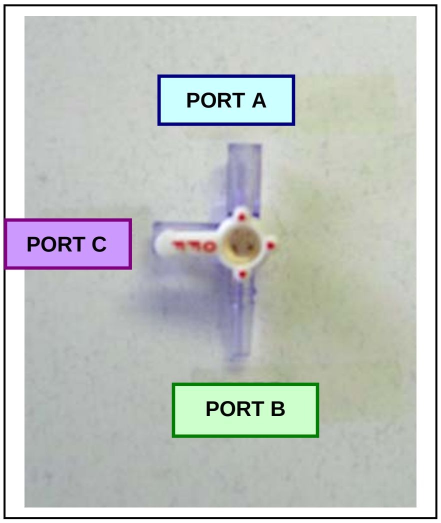
Closed to Port A (Peristaltic Pump / Summa Canister);
Open to Port B (Probe/Well)
Open to Port C (Atmosphere / Digital Manometer / 60 mL Syringe)

The "OFF" handle is turned in such a way that it is directly over Port A. The three small, red arrows opposite the "OFF" handle indicate which ports are open (Ports B & C).

In this valve position when the digital manometer is connected to Port C, a vacuum/pressure reading can be obtained from the probe/well. If the valve is in this position prior to the start of the monitoring (vacuum/pressure gauging, Tedlar™ bag sample collection, and/or summa canister sample collection, set the valve to Position #1 and return to this location at least 30 minutes later.

Valve Position #3: Open for Soil Vapor Sample Collection





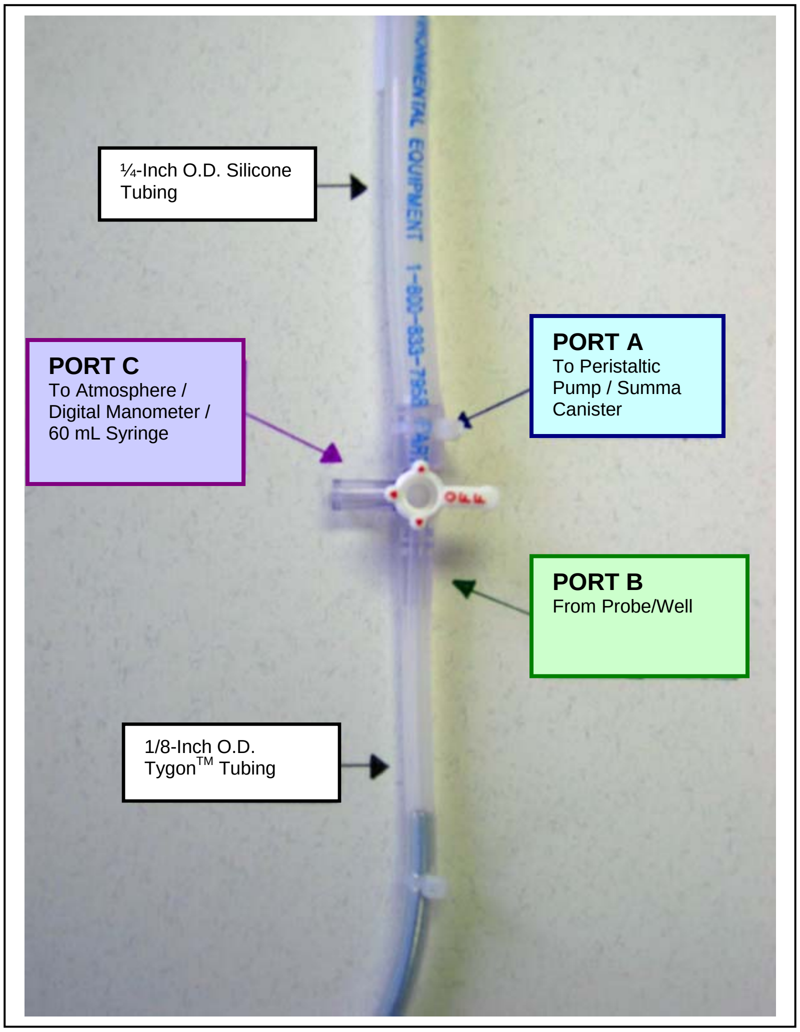
Valve Position #3:

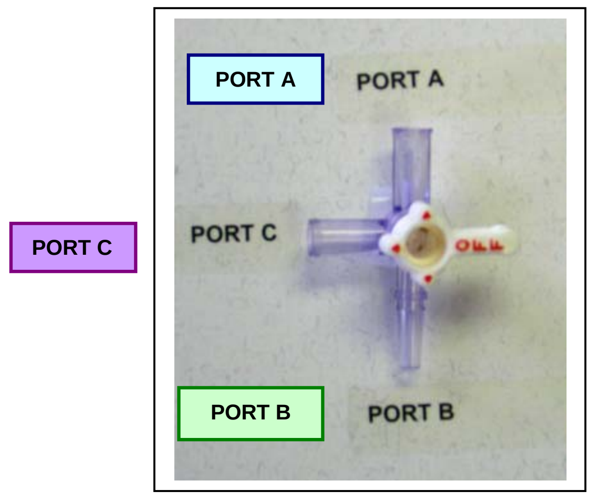
Closed to Port C (Atmosphere / Digital Manometer / 60 mL Syringe);
Open to Port A (Peristaltic Pump / Summa Canister)
Open to Port B (Probe/Well)

The “OFF” handle is turned in such a way that it is directly over Port C. The three small, red arrows opposite the “OFF” handle indicate which ports are open (Ports A & B).

In this valve position, a soil vapor sample can be collected from the probe/well using the peristaltic pump and Tedlar™ bag or a summa canister. If the valve is in this position prior to the start of the monitoring (vacuum/pressure gauging, Tedlar™ bag sample collection, and/or summa canister sample collection, set the valve to Position #1 and return to this location at least 30 minutes later.

Valve Position #4: Improper Valve Position





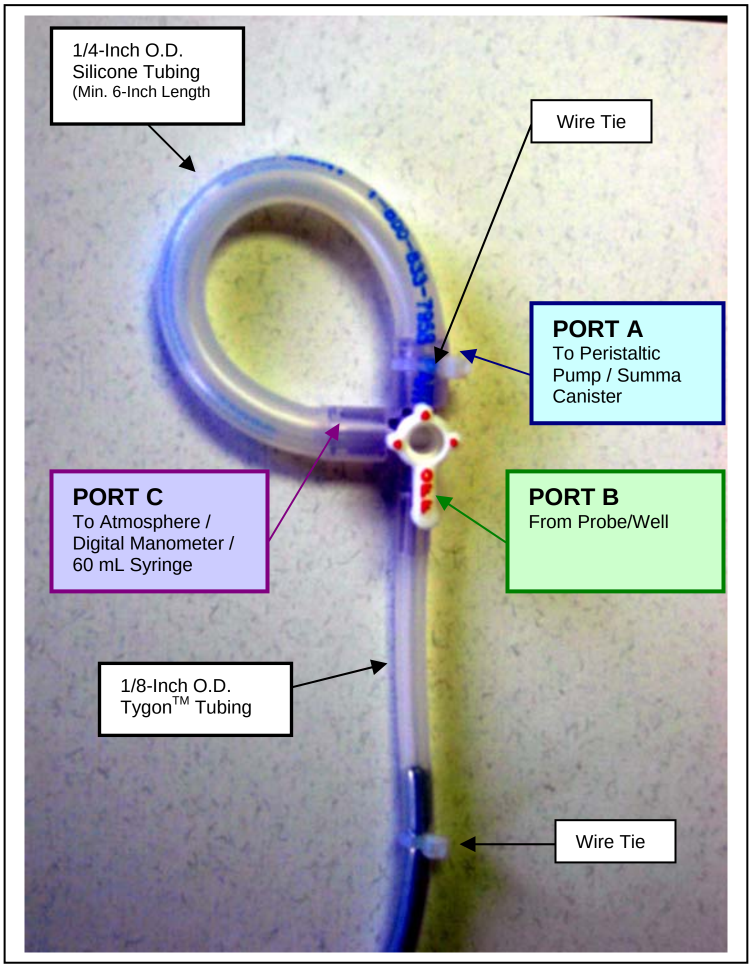
Valve Position #4:

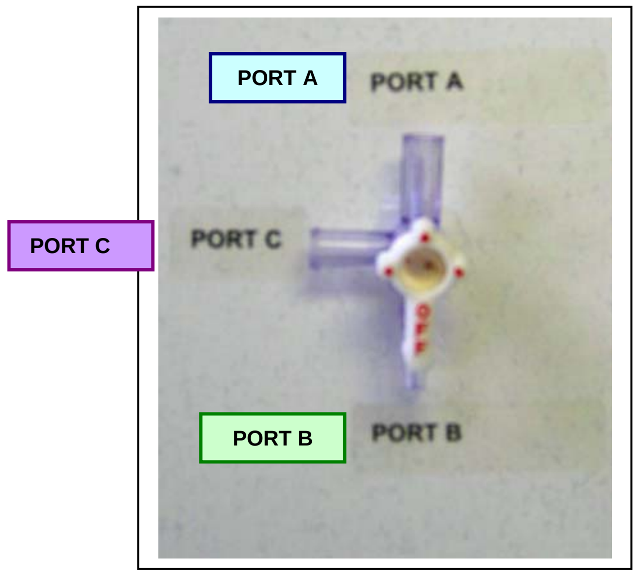
Open to Port A (Peristaltic Pump / Summa Canister);
Open to Port B (Probe/Well)
Open to Port C (Atmosphere / Digital Manometer / 60 mL Syringe)

The "OFF" handle is turned in such a way that it is opposite of Port C. The three small, red arrows opposite the "OFF" handle indicate all ports are open (Ports A, B & C).

In this valve position, the probe/well is open to the atmosphere and, therefore, will vent. In addition, this valve position will allow ambient air into the sample train and invalidate the data. If the valve is in this position prior to the start of the monitoring (vacuum/pressure gauging, Tedlar™ bag sample collection, and/or summa canister sample collection, set the valve to Position #1 and return to this location at least 30 minutes later. The valve should never be in this position.

Post-Monitoring Valve and Tubing Configuration





Post-Monitoring Valve and Tubing Configuration:

Closed to Port B (Probe/Well)
Open to Port A (Peristaltic Pump / Summa Canister);
Open to Port C (Atmosphere / Digital Manometer / 60 mL Syringe)

The 4-way micro-valve is set to position #1. The "OFF" handle is turned in such a way that it is directly over Port B. The three small, red arrows opposite the "OFF" handle indicate which ports are open (Ports A & C). In addition, the silicone tubing (minimum length of six (6) inches) is configured such that it forms a loop between Port A and Port C and a wire tie is used to secure the silicone tubing to Port A.

In this configuration, the probe/well is not open to the atmosphere and, therefore, will not vent. In addition, this configuration minimizes the water infiltration into the 4-way micro-valve. The valve and tubing should be placed in this configuration following vacuum/pressure gauging and soil vapor sample collection**.**

STANDARD OPERATING PROCEDURE
NO. SAS-11-05

FIELD SCREENING FOR FIXED GASES AND SOIL VAPOR CONCENTRATIONS
Revision 0

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for conducting the field screening soil vapor samples collected using Tedlar™ bag media. The field screening consists of instrument calibration, real-time determination of fixed gases (oxygen and carbon dioxide) levels, percent of lower explosive limit (% LEL), and soil vapor concentrations (as determined using a photoionization detector [PID] and flame ionization detector [FID]), and documentation of field screening results.

2.0 EQUIPMENT AND MATERIALS

- LandTec GA-90 Landfill Gas Analyzer or equivalent
- RAE Systems ppbRAE continuous monitoring PID or equivalent
- Thermo Electron TVA 1000B PID and FID or equivalent
- Calibration Gases:
    - Zero Gas – Hydrocarbon (HC) Free Air
    - Carbon dioxide (CO_2) at 35% by volume
    - Oxygen (O_2) at 4% by volume
    - Isobutylene at 0.5% by volume
    - Methane (CH_4) at 3.25% by volume
    - Isobutylene in air at concentrations of 10, 50 and 1,000 ppmv
    - Methane (CH_4) in air at concentrations of 50, 500, and 5,000 ppmv
- Regulators for gas cylinders
- 1-liter Tedlar™ bag sample media
- ¼-inch outer diameter (OD) Teflon™ or Tygon™ tubing cut to length
- Thermo Electron Dilutor Orifice 10:1 (a.k.a. 10-to-1 dilution probe)
- Thermo Electron Dilutor Orifice 25:1 (a.k.a. 25-to-1 dilution probe)

- Thermo Electron Dilutor Orifice 50:1 (a.k.a. 50-to-1 dilution probe)
- Metering valves
- Field Screening Calibration Forms
- Field Screening Spreadsheet and/or Forms
- Miscellaneous tools

3.0 HEALTH AND SAFETY

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 CONSIDERATIONS

- Calibration gas cylinders shall be stored in accordance with OSHA and site-specific regulations/guidelines.
- Field screening instruments shall be stored between uses and maintained in accordance with manufacturer guidelines.
- Field screening shall be performed at a fixed location, when practical, with adequate ventilation.
- A ppbRAE or equivalent may be used as an optional screening tool to confirm low level volatile organic compound (VOC) concentrations.

5.0 INSTRUMENT SPECIFICATIONS

Instrument specifications are intended as general guidelines only. Instruments may be substituted based on project/task specific needs.

5.1 LandTec GA-90 or Equivalent

A LandTec GA-90 or equivalent shall be used to measure O_2 and CO_2 levels as percent by volume (%) in soil vapor samples. If required by project/task specific requirements, this instrument may be used to measure the % LEL in soil vapor samples.

5.2 ppbRAE or Equivalent

A ppbRAE or equivalent may be used as an optional screening tool to measure and confirm low level VOCs in soil vapor samples. The ppbRAE or equivalent, when used, shall measure VOCs as parts per billion by volume (ppbv) and/or parts per million by volume (ppmv).

5.3 TVA 1000B or Equivalent

A Toxic Vapor Analyzer (TVA 1000B) or equivalent shall be used to measure low to high level VOCs as ppmv in soil vapor samples. The TVA 1000B or equivalent shall also be used to measure low to high level total hydrocarbons (THC) as ppmv or percent by volume ($\%_V$) in soil vapor samples.

6.0 INSTRUMENT CALIBRATION

In order to ensure the collection of valid levels of fixed gases, O_2 and CO_2, and soil vapor concentrations as total hydrocarbons (THC), proper calibration of the instruments is important. Instruments shall be calibrated prior to field screening in accordance with the manufacturers recommended procedures. Calibration gases shall be introduced directly at a rate of 0.5 liters per minute to the LandTec GA-90 or equivalent since the instrument pump is not required for calibration. Calibration standard gases shall be introduced to the ppbRAE, TVA 1000B PID, and TVA 1000B FID using Tedlar™ bag media which will allow the instrument pump to draw in the calibration gas at the appropriate flow. Following screening activities each day, a post-screening calibration check shall be performed. If the screening instruments are to be used continuously throughout the workday, mid-screening calibration checks shall also be performed. One-point bump calibration checks shall also be performed on the TVA 1000B or equivalent and associated dilution probe(s) at a frequency of one per two-hours of field screening. Calibration gases with concentrations within the linear range of the instrument shall be used for the pre-screening calibration and post-screening calibration check in addition to the mid-screening and one-point bump calibration checks, when required.

6.1 Pre-Screening Calibration

6.1.1 LandTec GA-90 or equivalent

Prior to the start of field screening, the LandTec GA-90 or equivalent shall be calibrated in accordance with the manufacturers recommended procedures using 4.0% $_V$ O_2 and 35% $_V$ CO_2 standard gases (see Attachment A). The pre-screening calibration shall be documented on the appropriate instrument calibration form (see Attachment A).

6.1.2 ppbRAE or equivalent

Prior to the start of optional, confirmatory low level PID field screening, the ppbRAE or equivalent shall be calibrated in accordance with the manufacturers recommended procedures using hydrocarbon free air (0 ppmv THC by volume) and 10 ppmv isobutylene standard gas (see Attachment A). The pre-screening calibration shall be documented on the appropriate instrument calibration form (see Attachment A).

6.1.3 TVA 1000B or equivalent

Prior to the start of field screening, the PID portion of the TVA 1000B or equivalent shall be calibrated in accordance with the manufacturers recommended procedures using hydrocarbon free air (0% $_V$ THC) and 50 and 1,000 ppmv isobutylene standard gases. The FID portion of the TVA 1000 or equivalent shall be calibrated in accordance with the manufacturers recommended procedures using hydrocarbon free air (0% $_V$ THC) and 50, 500, and 5,000 ppmv methane standard gases (see Attachment A). The pre-screening calibration shall be documented on the appropriate instrument calibration form (see Attachment A).

6.1.4 Dilution Probes

Following the calibration of the TVA 1000B PID and FID, each dilution probe shall be calibrated by adjusting the associated metering valve until the concentration displayed on the instrument is within (+/-) 15% of the target concentration of the designated calibration gases. The following table summarizes the type and concentration of calibration gas, target displayed concentration, and acceptable range for each dilution probe and instrument. The pre-screening calibration shall be documented on the appropriate instrument calibration form (see Attachment A).

Instrument	Dilution Probe	Calibration Gas		Concentration Displayed on Instrument	
		Type	Concentration	Target (ppmv)	Acceptable Range (ppmv)
TVA 1000B PID	10-to-1	Isobutylene	0.5 $\%_V$	500	425 – 575
TVA 1000B FID	10-to-1	Methane	3.25$\%_V$	3,250	2,762 – 3,738
	25-to-1	Methane	3.25$\%_V$	1,300	1,105 – 1,495
	50-to-1	Methane	3.25$\%_V$	650	552 – 748

6.2 Mid- and Post-Screening Calibration Checks

Properly calibrated instruments may drift during the field screening period. In order to ensure the collection of valid data, calibration accuracy checks will be conducted at the conclusion of the field screening each day. If the screening instruments are to be used throughout the workday, mid-screening calibration checks shall also be performed.

6.2.1 LandTec GA-90 or equivalent

The calibration of the LandTec GA-90 or equivalent shall be checked using 4.0 $\%_V$ O_2 and 35$\%_V$ CO_2 standard gases. If the observed concentration/level is within (+/-) 15% of the standard gases, the calibration shall be considered adequate. If the observed concentration/level is outside that range, the LandTec GA-90 or equivalent shall be recalibrated. Data obtained since the previous calibration check shall be flagged as estimated values. The following table summarizes the type and concentration of calibration gas, target displayed concentration, and acceptable range for each fixed gas. The calibration checks shall be documented on the appropriate instrument calibration form (see Attachment A).

Fixed Gas	Calibration Gas		Concentration Displayed on Instrument	
	Type	Concentration	Target (%)	Acceptable Range (%)
Oxygen	O_2 Standard	4.0%$_V$	4.0	3.4 – 4.6
Carbon Dioxide	CO_2 Standard	35.0%$_V$	35.0	29.75 – 40.25

6.2.2 ppbRAE or equivalent

The calibration of the ppbRAE or equivalent shall be checked using hydrocarbon free air (0 ppmv THC by volume) and 10 ppmv isobutylene standard gases, if the observed concentration/level is within (+/-) 15% of the calibration gases, the calibration shall be considered adequate. If the observed concentration/level is outside that range, the ppbRAE or equivalent shall be recalibrated. Data obtained since the previous calibration check shall be flagged as estimated values. The following table summarizes the type and concentration of calibration gas, target displayed concentration, and acceptable range for the ppbRAE. The calibration checks shall be documented on the appropriate instrument calibration form (see Attachment A).

Instrument	Calibration Gas		Concentration Displayed on Instrument	
	Type	Concentration	Target (ppmv)	Acceptable Range (ppmv)
ppbRAE	HC Free Air	0.0 ppmv	0.0	0.08 – 0.15
	Isobutylene	10.0 ppmv	10.0	8.5 – 11.5

6.2.3 TVA 1000B or equivalent

Given the wide range of hydrocarbons anticipated, the linearity of the PID response shall be checked using hydrocarbon free air (0%$_V$ THC) and 50 and 1,000 ppmv isobutylene standard gases. The FID response shall be checked using 50, 500, and 5000 ppmv methane standard gases. If the observed concentration/level is within (+/-) 15% of the standard gases, the calibration shall be considered adequate. If the observed concentration/level is outside that range, the TVA 1000B or equivalent shall be recalibrated. Data obtained since the previous calibration check shall be flagged as estimated values. The following table summarizes the type and concentration of calibration gases, target displayed concentration, and acceptable range for each instrument. The calibration checks shall be documented on the appropriate instrument calibration form (see Attachment A).

Instrument	Dilution Probe	Calibration Gas		Concentration Displayed on Instrument	
		Type	Concentration	Target (ppmv)	Acceptable Range (ppmv)
TVA 1000B PID	None	HC Free Air	0.0 ppmv	0.0	0.08 – 0.15
		Isobutylene	50.0 ppmv	50.0	42.5 – 57.5
			1,000 ppmv	1,000	850 – 1150
TVA 1000B FID	None	HC Free Air	0.0 ppmv	0.0	0.08 – 0.15
		Methane	50.0 ppmv	50.0	42.5 – 57.5
			500 ppmv	500	425 – 575
			5,000 ppmv	5,000	4250 – 5750

6.2.4 Dilution Probes

Following the calibration check of the TVA 1000B PID and FID, each dilution probe and associated metering valve shall be shall be verified using designated type and concentration of standard gas. The dilution probe calibration is considered adequate if the concentration displayed on the instrument is within (+/-) 15% of the target concentration of the designated calibration gas. The following table summarizes the type and concentration of calibration gas, target displayed concentration, and acceptable range for each dilution probe and instrument. The calibration checks shall be documented on the appropriate instrument calibration form (see Attachment A)

Instrument	Dilution Probe	Calibration Gas		Concentration Displayed on Instrument	
		Type	Concentration	Target (ppmv)	Acceptable Range (ppmv)
TVA 1000B PID	10-to-1	Isobutylene	$0.5\%_V$	500	425 – 575
TVA 1000B FID	10-to-1	Methane	$3.25\%_V$	3,250	2,762.5 – 3,737.5
	25-to-1	Methane	$3.25\%_V$	1,300	1,105 – 1,495
	50-to-1	Methane	$3.25\%_V$	650	552.5 – 747.5

6.3 Periodic Bump Calibration Checks

Due to the negligible (< 5%) instrument drift throughout a day, the LandTec GA-90 and ppbRAE or equivalent(s) will not undergo periodic bump calibration checks. Given the wide range of hydrocarbons anticipated, one-point, calibration bump checks shall be performed on the TVA 1000B PID and FID, dilution probes, and associated metering valves or equivalents. The period bump calibration check shall be performed at a frequency of one per two-hours of field screening. The calibration is considered adequate if the concentration displayed on the instrument is within (+/-) 15% of the target concentration of the designated calibration gas. If the observed concentration is outside this range, the instrument and/or dilution probe and metering valve shall be recalibrated as appropriate. Data obtained since the previous bump calibration check shall be flagged as estimated values. The following table summarizes the type and concentration of calibration gas, target displayed concentration, and acceptable range for each dilution probe and instrument. The calibration checks shall be documented on the appropriate instrument calibration form (see Attachment A).

Instrument	Dilution Probe	Calibration Gas		Concentration Displayed on Instrument	
		Type	Concentration	Target (ppmv)	Acceptable Range (ppmv)
TVA 1000B PID	None	Isobutylene	50.0 ppmv	50.0	42.5 – 57.5
	10-to-1	Isobutylene	0.5% $_V$	500	425 – 575
TVA 1000B FID	None	Methane	5,000 ppmv	5,000	4250 – 5750
	10-to-1	Methane	3.25% $_V$	3,250	2,762 – 3,738
	25-to-1	Methane	3.25% $_V$	1,300	1,105 – 1,495
	50-to-1	Methane	3.25% $_V$	650	552 – 748

7.0 SAMPLE SCREENING

Soil vapor samples collected in Tedlar™ bags shall be screened at a fixed location, whenever practical. Since samples may have 1) concentrations above the measurement range of the instrument or 2) insufficient oxygen content to analyze reliably, the order of the screening is important to the identification of these situations. The screening order is also dictated by the sample flow rates, which vary by instrument, and the sample volume.

7.1 Screening Procedures

Prior to field screening, the well/sample ID, sample date, and sample time shall be recorded on the appropriate field form and/or spreadsheet (see Attachment C). Once the screening data and time have also been recorded on the appropriate field form and/or spreadsheet (see Attachment C), the field screening shall commence. The soil vapor samples shall be analyzed in the following order:

- Fixed gases (O_2 and CO_2)
- Percent of lower explosive limit (% LEL) - If required by the project or task
- Soil vapor concentrations (VOCs) as determined using a PID
- Soil vapor concentrations (THC) as determined using a FID

The field screening shall adhere to the procedure outlined in the Field Screening Procedure Flow Chart provided in Attachment B. Following screening the Tedlar™ bag sample media shall be discarded.

7.2 Reporting

Field screening results as observed on the instruments, fixed gases levels (O_2 & CO_2), percent lower explosive limit, and soil vapor concentrations, as determined using a PID and FID, shall be recorded in the appropriate spreadsheet or on the appropriate field form (see Attachment C). The use of a dilution probe shall also be documented in the appropriate spreadsheet or on the appropriate field form (see Attachment C). *Please note: Concentrations as determined using a PID and FID shall be corrected for the use of dilution probe(s)*. If the concentration of the vapor sample exceeds the operating range of the instrument, with or without the use of a dilution probe, it shall be marked as “estimated”. If a flame-out of the FID occurs, “FO” shall be recorded as the default value for the affected sample. If the flame-out was not the result of 1) insufficient sample flow, 2) FID capsule contamination, or 3) insufficient oxygen in the sample (<14% when adjusted to account for the use or absence of a dilution probe), the upper dynamic range of the instrument, which has been adjusted for the use of or absence of a dilution probe, shall be used as the corrected FID reading. In this case, the reading shall be flagged as estimated. These situations shall be documented in the appropriate spreadsheet or on the appropriate field form.

8.0 SAMPLE HOLD TIMES

Soil vapor samples collected using Tedlar™ bag media shall be field screened at a fixed location, if practical, within thirty-six (36) hours of sample collection.

9.0 REFERENCES AND ADDITIONAL RESOURCES

Field Environmental Instruments, LANDTEC GA-90 Gas Analyzer Specifications and Features.

LANDTEC, GA-90 Landfill Gas Analyzer Operation Manual, Version MK2C1.12.

RAE Systems, 1999, Portable Continuous ppb VOC Detector Monitor Specifications and Features.

RAE Systems, 1999, Using the MiniRAE 2000 & ppbRAE plus.

Thermo Electron Corporation, 2003, Product Overview TVA-1000B Toxic Vapor Analyzer.

Thermo Electron Corporation, 2003, TVA-1000B Toxic Vapor Analyzer Instruction Manual P/N BK3500, December.

USEPA, 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001.

ATTACHMENT A
INSTRUMENT CALIBRATION FORMS

ATTACHMENT A-1
LANDTEC GA-90 LANDFILL GAS ANALYZER OR EQUIVALENT

FIELD SCREENING INSTRUMENT CALIBRATION FORM
LandTec GA-90 or Equivalent

Form Revision 0

PROJECT INFORMATION

Project Name: ______________________ **Task Name:** ______________________
Project Number: ______________________ **Task/Project Manager:** ______________________

FIELD SCREENING TEAM INFORMATION	INSTRUMENT INFORMATION
Date: ______________	**Make:** ______________
Screener: ______________	**Model:** ______________
Assistant: ______________	**Serial #:** ______________

CALIBRATION GAS INFORMATION

Manufacturer	Cal. Gas Type	Lot Number	Expiration Date

CALIBRATION AND CALIBRATION CHECK INFORMATION

Time	Type of Calibration or Calibration Check	Calibration Standard		Instrument Response	Response within Tolerances (circle one)	Comments
		Type	Conc.			
	Pre-Screening Calibration[R]	O2	4.0%		Yes / No	
		CO2	35.0%		Yes / No	
	Mid-Screening Calibration Check*	O2	4.0%		Yes / No	
		CO2	35.0%		Yes / No	
	Post-Screening Calibration Check[R]	O2	4.0%		Yes / No	
		CO2	35.0%		Yes / No	
	Mid-Screening Recalibration*	O2	4.0%		Yes / No	
		CO2	35.0%		Yes / No	
	Mid-Screening Recalibration*	O2	4.0%		Yes / No	
		CO2	35.0%		Yes / No	

Notes: 1. [R] = Required 2. * = If necessary 3. % = percent by volume

ATTACHMENT A-2
ppbRAE or EQUIVALENT

FIELD SCREENING INSTRUMENT CALIBRATION FORM
ppbRAE or Equivalent

Form Revision 0

PROJECT INFORMATION

Project Name: ______________________ Task Name: ______________________
Project Number: ______________________ Task/Project Manager: ______________________

FIELD SCREENING TEAM INFORMATION	INSTRUMENT INFORMATION
Date: ______________________	Make: ______________________
Screener: ______________________	Model: ______________________
Assistant: ______________________	Serial #: ______________________

CALIBRATION GAS INFORMATION

Manufacturer	Cal. Gas Type	Lot Number	Expiration Date

CALIBRATION AND CALIBRATION CHECK INFORMATION

Time	Type of Calibration or Calibration Check	Calibration Standard Type	Calibration Standard Conc.	Instrument Response	Response within Tolerances (circle one)	Comments
	Pre-Screening Calibration[R]	Free Air	0.0 ppmv		Yes / No	
		Isobutylene	10.0 ppmv		Yes / No	
	Mid-Screening Calibration Check*	Free Air	0.0 ppmv		Yes / No	
		Isobutylene	10.0 ppmv		Yes / No	
	Post-Screening Calibration Check[R]	Free Air	0.0 ppmv		Yes / No	
		Isobutylene	10.0 ppmv		Yes / No	
	Mid-Screening Recalibration*	Free Air	0.0 ppmv		Yes / No	
		Isobutylene	10.0 ppmv		Yes / No	
	Mid-Screening Recalibration*	Free Air	0.0 ppmv		Yes / No	
		Isobutylene	10.0 ppmv		Yes / No	
	Mid-Screening Recalibration*	Free Air	0.0 ppmv		Yes / No	
		Isobutylene	10.0 ppmv		Yes / No	

Notes: 1. [R] = Required 2. * = If necessary 3. ppmv = parts per million by volume

ATTACHMENT A-3
TVA-1000B TOXIC VAPOR ANALYZER OR EQUIVALENT

FIELD SCREENING INSTRUMENT CALIBRATION FORM
TVA 1000 (FID) or Equivalent

Form Revision 0

PROJECT INFORMATION

Project Name: ______________________ **Task Name:** ______________________
Project Number: ______________________ **Task/Project Manager:** ______________________

FIELD SCREENING TEAM INFORMATION	INSTRUMENT INFORMATION
Date: ______________	**Make:** ______________
Screener: ______________	**Model:** ______________
Assistant: ______________	**Serial #:** ______________

CALIBRATION GAS INFORMATION

Manufacturer	Cal. Gas Type	Lot Number	Expiration Date

CALIBRATION AND CALIBRATION CHECK INFORMATION

Time	Type of Calibration or Calibration Check	Calibration Standard		Instrument Response				Response(s) within Tolerances (circle one)	Comments
		Type	Conc.	w/o Dilution Probe	w/ 10-to-1 Dilution Probe	w/ 25-to-1 Dilution Probe	w/ 50-to-1 Dilution Probe		
	Pre-Screening Calibration[R]	Free Air	0.0 ppmv		N/A	N/A	N/A	Yes / No	
		Methane	50.0 ppmv		N/A	N/A	N/A	Yes / No	
		Methane	500 ppmv		N/A	N/A	N/A	Yes / No	
		Methane	5,000 ppmv		N/A	N/A	N/A	Yes / No	
		Methane	32,500 ppmv	N/A				Yes / No	
	Mid-Screening Calibration Check*	Free Air	0.0 ppmv		N/A	N/A	N/A	Yes / No	
		Methane	50.0 ppmv		N/A	N/A	N/A	Yes / No	
		Methane	500 ppmv		N/A	N/A	N/A	Yes / No	
		Methane	5,000 ppmv		N/A	N/A	N/A	Yes / No	
		Methane	32,500 ppmv	N/A				Yes / No	

CALIBRATION AND CALIBRATION CHECK INFORMATION (Continued)

Time	Type of Calibration or Calibration Check	Calibration Standard		Instrument Response				Response(s) within Tolerances (circle one)	Comments
		Type	Conc.	w/o Dilution Probe	w/ 10-to-1 Dilution Probe	w/ 25-to-1 Dilution Probe	w/ 50-to-1 Dilution Probe		
	Post-Screening Calibration Check[R]	Free Air	0.0 ppmv		**N/A**	**N/A**	**N/A**	**Yes / No**	
		Methane	50.0 ppmv		**N/A**	**N/A**	**N/A**	**Yes / No**	
		Methane	500 ppmv		**N/A**	**N/A**	**N/A**	**Yes / No**	
		Methane	5,000 ppmv		**N/A**	**N/A**	**N/A**	**Yes / No**	
		Methane	32,500 ppmv	**N/A**				**Yes / No**	
	Mid-Screening Recalibration*	Free Air	0.0 ppmv		**N/A**	**N/A**	**N/A**	**Yes / No**	
		Methane	50.0 ppmv		**N/A**	**N/A**	**N/A**	**Yes / No**	
		Methane	500 ppmv		**N/A**	**N/A**	**N/A**	**Yes / No**	
		Methane	5,000 ppmv		**N/A**	**N/A**	**N/A**	**Yes / No**	
	Mid-Screening Recalibration*	Free Air	0.0 ppmv		**N/A**	**N/A**	**N/A**	**Yes / No**	
		Methane	50.0 ppmv		**N/A**	**N/A**	**N/A**	**Yes / No**	
		Methane	500 ppmv		**N/A**	**N/A**	**N/A**	**Yes / No**	
		Methane	5,000 ppmv		**N/A**	**N/A**	**N/A**	**Yes / No**	
	Bump Calibration Check*	Free Air	0.0 ppmv		**N/A**	**N/A**	**N/A**	**Yes / No**	
		Methane	5,000 ppmv		**N/A**	**N/A**	**N/A**	**Yes / No**	
		Methane	32,500 ppmv	**N/A**				**Yes / No**	
	Bump Calibration Check*	Free Air	0.0 ppmv		**N/A**	**N/A**	**N/A**	**Yes / No**	
		Methane	5,000 ppmv		**N/A**	**N/A**	**N/A**	**Yes / No**	
		Methane	32,500 ppmv	**N/A**				**Yes / No**	
	Bump Calibration Check*	Free Air	0.0 ppmv		**N/A**	**N/A**	**N/A**	**Yes / No**	
		Methane	5,000 ppmv		**N/A**	**N/A**	**N/A**	**Yes / No**	
		Methane	32,500 ppmv	**N/A**				**Yes / No**	
	Bump Calibration Check*	Free Air	0.0 ppmv		**N/A**	**N/A**	**N/A**	**Yes / No**	
		Methane	5,000 ppmv		**N/A**	**N/A**	**N/A**	**Yes / No**	
		Methane	32,500 ppmv	**N/A**				**Yes / No**	
	Bump Calibration Check*	Free Air	0.0 ppmv		**N/A**	**N/A**	**N/A**	**Yes / No**	
		Methane	5,000 ppmv		**N/A**	**N/A**	**N/A**	**Yes / No**	
		Methane	32,500 ppmv	**N/A**				**Yes / No**	

Notes: 1. [R] = Required 2. * = If necessary 3. ppmv = parts per million by volume 4. N/A = Not Applicable

FIELD SCREENING INSTRUMENT CALIBRATION FORM
TVA 1000 (PID) or Equivalent

Form Revision 0

PROJECT INFORMATION	
Project Name: ______	Task Name: ______
Project Number: ______	Task/Project Manager: ______

FIELD SCREENING TEAM INFORMATION	INSTRUMENT INFORMATION
Date: ______	Make: ______
Screener: ______	Model: ______
Assistant: ______	Serial #: ______

CALIBRATION GAS INFORMATION

Manufacturer	Cal. Gas Type	Lot Number	Expiration Date

CALIBRATION AND CALIBRATION CHECK INFORMATION

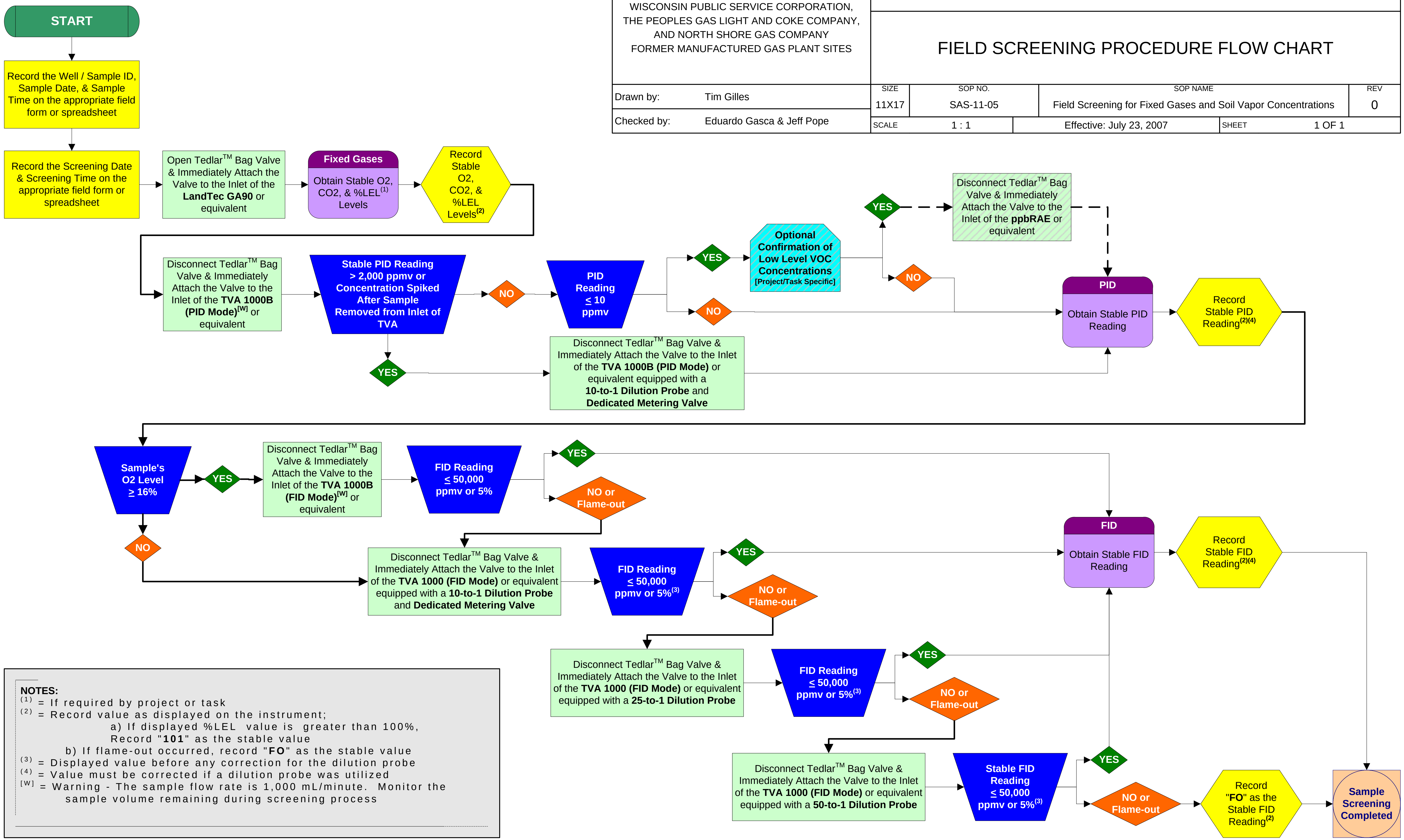
Time	Type of Calibration or Calibration Check	Calibration Standard		Instrument Response		Response within Tolerances (circle one)	Comments
		Type	Conc.	w/o Dilution Probe	w/ 10-to-1 Dilution Probe		
	Pre-Screening Calibration[R]	Free Air	0.0 ppmv		N/A	Yes / No	
		Isobutylene	50.0 ppmv		N/A	Yes / No	
		Isobutylene	1,000 ppmv		N/A	Yes / No	
		Isobutylene	5,000 ppmv	N/A		Yes / No	
	Mid-Screening Calibration Check*	Free Air	0.0 ppmv		N/A	Yes / No	
		Isobutylene	50.0 ppmv		N/A	Yes / No	
		Isobutylene	1,000 ppmv		N/A	Yes / No	
		Isobutylene	5,000 ppmv	N/A		Yes / No	
	Post-Screening Calibration Check[R]	Free Air	0.0 ppmv		N/A	Yes / No	
		Isobutylene	50.0 ppmv		N/A	Yes / No	
		Isobutylene	1,000 ppmv		N/A	Yes / No	
		Isobutylene	5,000 ppmv	N/A		Yes / No	

CALIBRATION AND CALIBRATION CHECK INFORMATION (Continued)							
Time	Type of Calibration or Calibration Check	Calibration Standard		Instrument Response		Response within Tolerances (circle one)	Comments
		Type	Conc.	w/o Dilution Probe	w/ 10-to-1 Dilution Probe		
	Mid-Screening Recalibration*	Free Air	0.0 ppmv		**N/A**	**Yes / No**	
		Isobutylene	50.0 ppmv		**N/A**	**Yes / No**	
		Isobutylene	1,000 ppmv		**N/A**	**Yes / No**	
		Isobutylene	5,000 ppmv	**N/A**		**Yes / No**	
	Mid-Screening Recalibration*	Free Air	0.0 ppmv		**N/A**	**Yes / No**	
		Isobutylene	50.0 ppmv		**N/A**	**Yes / No**	
		Isobutylene	1,000 ppmv		**N/A**	**Yes / No**	
		Isobutylene	5,000 ppmv	**N/A**		**Yes / No**	
	Single-Point Bump Calibration Check*	Isobutylene	50.0 ppmv		**N/A**	**Yes / No**	
		Isobutylene	5,000 ppmv	**N/A**		**Yes / No**	
	Single-Point Bump Calibration Check*	Isobutylene	50.0 ppmv		**N/A**	**Yes / No**	
		Isobutylene	5,000 ppmv	**N/A**		**Yes / No**	
	Single-Point Bump Calibration Check*	Isobutylene	50.0 ppmv		**N/A**	**Yes / No**	
		Isobutylene	5,000 ppmv	**N/A**		**Yes / No**	
	Single-Point Bump Calibration Check*	Isobutylene	50.0 ppmv		**N/A**	**Yes / No**	
		Isobutylene	5,000 ppmv	**N/A**		**Yes / No**	
	Single-Point Bump Calibration Check*	Isobutylene	50.0 ppmv		**N/A**	**Yes / No**	
		Isobutylene	5,000 ppmv	**N/A**		**Yes / No**	
	Single-Point Bump Calibration Check*	Isobutylene	50.0 ppmv		**N/A**	**Yes / No**	
		Isobutylene	5,000 ppmv	**N/A**		**Yes / No**	
	Single-Point Bump Calibration Check*	Isobutylene	50.0 ppmv		**N/A**	**Yes / No**	
		Isobutylene	5,000 ppmv	**N/A**		**Yes / No**	
	Single-Point Bump Calibration Check*	Isobutylene	50.0 ppmv		**N/A**	**Yes / No**	
		Isobutylene	5,000 ppmv	**N/A**		**Yes / No**	
	Single-Point Bump Calibration Check*	Isobutylene	50.0 ppmv		**N/A**	**Yes / No**	
		Isobutylene	5,000 ppmv	**N/A**		**Yes / No**	
	Single-Point Bump Calibration Check*	Isobutylene	50.0 ppmv		**N/A**	**Yes / No**	
		Isobutylene	5,000 ppmv	**N/A**		**Yes / No**	

Notes: 1. R = Required　　2. * = If necessary　　3. ppmv = parts per million by volume

ATTACHMENT B
FIELD SCREENING PROCEDURE FLOW CHART

WISCONSIN PUBLIC SERVICE CORPORATION, THE PEOPLES GAS LIGHT AND COKE COMPANY, AND NORTH SHORE GAS COMPANY FORMER MANUFACTURED GAS PLANT SITES	SOP SAS-11-05 ATTACHMENT B			
	FIELD SCREENING PROCEDURE FLOW CHART			
Drawn by: Tim Gilles	SIZE 11X17	SOP NO. SAS-11-05	SOP NAME Field Screening for Fixed Gases and Soil Vapor Concentrations	REV 0
Checked by: Eduardo Gasca & Jeff Pope	SCALE 1 : 1		Effective: July 23, 2007	SHEET 1 OF 1



NOTES:

(1) = If required by project or task

(2) = Record value as displayed on the instrument;
a) If displayed %LEL value is greater than 100%, Record "**101**" as the stable value
b) If flame-out occurred, record "**FO**" as the stable value

(3) = Displayed value before any correction for the dilution probe

(4) = Value must be corrected if a dilution probe was utilized

[W] = Warning - The sample flow rate is 1,000 mL/minute. Monitor the sample volume remaining during screening process

ATTACHMENT C
FIELD SCREENING RESULTS SPREADSHEET/FORM

FIXED GASES AND SOIL VAPOR CONCENTRATION FIELD SCREENING DATA

PROJECT INFORMATION		GENERAL INSTRUMENT INFORMATION		SCREENER INFORMATION	
Project Name:		Fixed Gases:		Screener's Name:	
Project Number:		PID (Low Level Confirmation):		Screener's Title:	
Task Name:		PID (Low-High Level):		Assistant's Name:	
Task/Project Manager:		FID (Low-High Level):		Assistant's Title:	

FIELD SCREENING RESULTS

WELL ID or SAMPLE ID	SAMPLE DATE	SAMPLE TIME (24-Hour)	SCREENING DATE	SCREENING TIME (24-Hour)	Observed Field Screening Values[(1)], Units, and Dilution Values[(2)]									Corrected Value[(3)]		COMMENTS
					O_2 (%)	CO_2 (%)	% LEL[(4)] (%)	PID	PID UNITS (circle one)	PID Dilution Value[(2)] (circle one)	FID	FID UNITS (circle one)	FID Dilution Value[(2)] (circle one)	PID (ppmv)	FID (ppmv)	
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
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									ppbv ppmv %	1 10		ppmv %	1 10 25 50			

FIELD SCREENING RESULTS

WELL ID or SAMPLE ID	SAMPLE DATE	SAMPLE TIME (24-Hour)	SCREENING DATE	SCREENING TIME (24-Hour)	Observed Field Screening Values[1], Units, and Dilution Values[2]									Corrected Value[3]		COMMENTS
					O_2 (%)	CO_2 (%)	% LEL[4] (%)	PID	PID UNITS (circle one)	PID Dilution Value[2] (circle one)	FID	FID UNITS (circle one)	FID Dilution Value[2] (circle one)	PID (ppmv)	FID (ppmv)	
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
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FIELD SCREENING RESULTS

					Observed Field Screening Values[1], Units, and Dilution Values[2]									Corrected Value[3]		
WELL ID or SAMPLE ID	SAMPLE DATE	SAMPLE TIME (24-Hour)	SCREENING DATE	SCREENING TIME (24-Hour)	O_2 (%)	CO_2 (%)	% LEL[4] (%)	PID	PID UNITS (circle one)	PID Dilution Value[2] (circle one)	FID	FID UNITS (circle one)	FID Dilution Value[2] (circle one)	PID (ppmv)	FID (ppmv)	COMMENTS
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
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									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			

Notes: [1] = As observed on the instrument's display; If flame-out occurs, record "FO" as the default value.

[2] = Dilutions Values (Dilution Probe Specific): No Dilution Probe Used - Circle "1"; 10-to-1 Dilution Probe Used - Circle "10"; 25-to-1 Dilution Probe Used - Circle "25"; 50-to-1 Dilution Probe Used - Circle "50"

[3] = Calculated based on the units and dilution value or, in the case of a flame-out when sufficient oxygen is present, the upper dynamic range of the instrument multiplied by the dilution value.

[4] = If required by project or task

E = Estimated Value: Corrected value exceeds the upper dynamic range of the instrument or flame-out due to concentrations above the instruments range occurred.

ppbv = Parts per billion volume

ppmv = Parts per million volume

% = Percent by volume

N/A = Not Applicable

FO = Instrument Flame Out (FID Only)