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# Environmental Technology Verification Program

# Verification Test Plan

# Evaluation of Groundwater Sampling Technologies in Small-Diameter Direct Push Wells

Sandia
National
Laboratories



ETV ETV ETV

February 2002

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## Verification Test Plan

## Evaluation of Groundwater Sampling Technologies in Small Diameter Direct Push Wells

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## APPROVAL SIGNATURES

*This document is intended to ensure that all aspects of the verification are documented, scientifically sound, and that operational procedures are conducted within quality assurance/quality control specifications and health and safety regulations.*

*The signatures of the individuals below indicate concurrence with, and agreement to operate compliance with, procedures specified in this document.*

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## EXECUTIVE SUMMARY

The US EPA created the Environmental Technology Verification (ETV) Program to facilitate the deployment of innovative technologies through performance verification and information dissemination. The goal of the ETV Program is to further environmental protection by substantially accelerating the acceptance and use of improved and cost-effective technologies. The ETV Program is intended to assist and inform those involved in the design, distribution, permitting, and purchase of environmental technologies. The verification study described in this test plan will be conducted by the Advanced Monitoring Systems Center (AMS), one of six Centers of the ETV program. The AMS Center is administered by the EPA's National Exposure Research Laboratory. Sandia National Laboratories will serve as the verification organization for the test. The verification test will evaluate commercially available groundwater sampling technologies that can be deployed in small diameter (< 2") direct push wells. The technologies will be tested under both controlled and "real-world" conditions. First, the samplers will be deployed in an aboveground standpipe at the John C. Stennis Space Center in southwestern Mississippi. The standpipe will be filled with spiked tap water containing known concentrations of six volatile organic compounds (VOCs), including trichloroethene, benzene, ethyl benzene, cis-1,2-dichloroethene, vinyl chloride, and methyl-tertiary-butyl ether (MTBE), and five inorganic cations (calcium, iron, magnesium, potassium, and sodium). Secondly, the samplers will be deployed in six groundwater monitoring wells at Tyndall Air Force Base in Panama City, FL. Historical data and results from pre-test samples from these 1.0" direct push wells indicated that the target organic and inorganic analytes are present in the wells at concentrations ranging from non-detect to approximately 2,000 μg/L for the VOCs and 70,000 μg/L for the inorganic cations.

## ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| AMS | Advanced Monitoring Systems Center, ETV |
| ASTM | American Society for Testing and Materials |
| DoD | Department of Defense |
| DP | direct push (groundwater well) |
| EPA | U. S. Environmental Protection Agency |
| ESH&Q | Environmental Safety, Health, and Quality |
| ESTCP | Environmental Security Technology Certification Program, U.S. DoD |
| ETV | Environmental Technology Verification Program |
| ETVR | Environmental Technology Verification Report |
| GC/MS | gas chromatography/mass spectrometry |
| HASP | Health and Safety Plan |
| HIF | Hydrologic Instrumentation Facility |
| ICP-AES | inductively coupled plasma-atomic emission spectrometry |
| MTBE | methyl-tertiary-butyl ether |
| NERL | National Exposure Research Laboratory, U.S. EPA |
| ORNL | Oak Ridge National Laboratory |
| PPE | personal protective equipment |
| QA | quality assurance |
| QAPP | Quality Assurance Project Plan |
| QAS | ORNL Quality Assurance Specialist |
| QC | quality control |
| RPD | relative percent difference |
| RSD | relative standard deviation |
| SNL | Sandia National Laboratories |
| SSC | John C. Stennis Space Center |
| TAFB | Tyndall Air Force Base |

# 1. INTRODUCTION

This chapter discusses the purpose of the verification and the verification test plan, describes the elements of the verification test plan, and provides an overview of the Environmental Technology Verification (ETV) Program and the technology verification process.

## 1.1. Verification Test Objectives

The purpose of this verification test is to evaluate the performance of commercially available field sampling technologies for collection of representative groundwater samples for selected volatile organic compounds and metals. Specifically, this plan defines the following elements of the verification test:

Roles and responsibilities of verification test participants;

Procedures governing verification test activities such as sample collection, preparation, analysis, data collection, and interpretation;

Experimental design of the verification test;

Quality assurance (QA) and quality control (QC) procedures for conducting the verification and for assessing the quality of the data generated from the verification; and,

Health and safety requirements for performing the verification test.

## 1.2. What is the Environmental Technology Verification Program?

The U.S. Environmental Protection Agency (EPA) created the Environmental Technology Verification Program (ETV) to facilitate the deployment of innovative or improved environmental technologies through performance verification and dissemination of information. The goal of the ETV Program is to further environmental protection by substantially accelerating the acceptance and use of improved and cost-effective technologies. ETV seeks to achieve this goal by providing high-quality, peer-reviewed data on technology performance to those involved in the design, distribution, financing, permitting, purchase, and use of environmental technologies.

ETV works in partnership with recognized standards and testing organizations and stakeholder groups consisting of regulators, buyers, and vendor organizations, with the full participation of individual technology vendors. The program evaluates the performance of innovative technologies by developing verification test plans that are responsive to the needs of stakeholders, conducting field or laboratory tests (as appropriate), collecting and analyzing data, and preparing peer-reviewed reports. All evaluations are conducted in accordance with rigorous quality assurance (QA) protocols to ensure that data of known and adequate quality are generated and that the results are defensible.

ETV is a voluntary program that seeks to provide objective performance information to all of the participants in the environmental marketplace and to assist them in making informed technology decisions. ETV does not rank technologies or compare their performance, label or list technologies as acceptable or unacceptable, seek to determine “best available technology,” or approve or disapprove technologies. The program does not evaluate technologies at the bench or pilot scale and does not conduct or support research. Rather, it conducts and reports on testing designed to describe the performance of technologies under a range of environmental conditions and matrices.

The program now operates six Centers covering a broad range of environmental areas. ETV began with a 5-year pilot phase (1995–2000) to test a wide range of partner and procedural alternatives in various pilot areas, as well as the true market demand for and response to such a program. In the Centers, EPA utilizes the expertise of partner “verification organizations” to design efficient processes for conducting performance tests of innovative technologies. These expert partners are both public and private organizations, including federal laboratories, states, industry consortia, and private sector entities. Verification organizations oversee and report verification activities based on testing and QA protocols developed with input from all major stakeholder/customer groups associated with the technology area.

The verification test described in this plan will be administered by the Advanced Monitoring Systems (AMS) Center, with Sandia National Laboratories serving as the verification organization. (To learn more about ETV, visit ETV's Web site at **http://www.ornl.gov**. The AMS Center is administered by EPA's National Exposure Research Laboratory (NERL).

### 1.3. The Technology Verification Process

The technology verification process is intended to serve as a template for conducting technology verifications that will generate high quality data which can be used to verify technology performance. Four key steps are inherent in the process:

- Needs identification and technology selection;
- Verification test planning and implementation;
- Report preparation;
- Information distribution.

#### *1.3.1. Needs Identification and Technology Selection*

The first step in the technology verification process is to determine technology needs of the user-community (typically state and Federal regulators and the regulated community). Each Center utilizes stakeholder groups. Members of the stakeholder groups come from EPA, the Departments of Energy and Defense, industry, and state regulatory agencies. The stakeholders are invited to identify technology needs and to assist in finding technology vendors with commercially available technologies that meet the needs. Once a technology need is established, a search is conducted to identify suitable technologies. The technology search and identification process consists of reviewing responses to Commerce Business Daily announcements, searches of industry and trade publications, attendance at related conferences, and leads from technology vendors. The following criteria are used to determine whether a technology is a good candidate for the verification:

- Meets user needs
- May be used in the field or in a mobile laboratory
- Applicable to a variety of environmentally impacted sites
- High potential for resolving problems for which current methods are unsatisfactory
- Costs are competitive with current methods
- Performance is better than current methods in areas such as data quality, sample preparation, or analytical turnaround
- Uses techniques that are easier and safer than current methods
- Is commercially available and field-ready.

#### *1.3.2. Verification Planning and Implementation*

After a vendor agrees to participate, EPA, the Verification Organization, and the vendor meet to discuss each participants responsibilities in the verification process. In addition, the following issues are addressed:

- Site selection. Identifying sites that will provide the appropriate physical or chemical environment, including contaminated media
- Determining logistical and support requirements (for example, field equipment, power and water sources, mobile laboratory, communications network)
- Arranging analytical and sampling support
- Preparing and implementing a verification test plan that addresses the experimental design, sampling design, QA/QC, health and safety considerations, scheduling of field and laboratory operations, data analysis procedures, and reporting requirements

### *1.3.3. Report Preparation*

Innovative technologies are evaluated independently and, when possible, against conventional technologies. The technologies being verified are operated by the vendors in the presence of independent observers. The observers are EPA staff, technical panel staff and from a independent third-party organization. The data generated during the verification test are used to evaluate the capabilities, limitations, and field applications of each technology. A data summary and detailed evaluation of each technology are published in an Environmental Technology Verification Report (ETVR). The original complete data set is available upon request.

An important component of the ETVR is the Verification Statement, which consists of three to five pages, using the performance data contained in the report, are issued by EPA and appear on the ETV Internet Web page. The Verification Statement is signed by representatives of EPA and the verification organization.

### *1.3.4. Information Distribution*

Producing the ETVR and the Verification Statement represents a first step in the ETV outreach efforts. ETV gets involved in many activities to showcase the technologies that have gone through the verification process. The Program is represented at many environmentally-related technical conferences and exhibitions. ETV representatives also participate in panel sessions at major technical conferences. ETV maintains a traveling exhibit that describes the program, displays the names of the companies that have had technologies verified, and provides literature and reports.

Web technology is utilized by the ETV program to the fullest extent possible and ETVRs and Verification Statements are available for downloading in Portable Document Format (pdf) on the ETV Web site (http://www.epa.gov/etv).

## 1.4. Purpose of this Verification Test Plan

The purpose of the verification test plan is to describe the procedures that will be used to verify the performance goals of the technologies participating in this verification. This document incorporates the QA/QC elements needed to provide data of appropriate quality sufficient to reach a credible position regarding performance. This is not a method validation study, nor does it represent every environmental situation which may be appropriate for these technologies. But it will provide data of sufficient quality to make a judgement about the application of the technology under conditions similar to those encountered in the field under normal conditions.

## 2. VERIFICATION RESPONSIBILITIES AND COMMUNICATION

This section identifies the organizations involved in this verification test and describes the primary responsibilities of each organization. It also describes the methods and frequency of communication that will be used in coordinating the verification activities.

### 2.1. Verification Organization and Participants

Participants in this verification are listed in Table 2-1. The specific responsibilities of each verification participant are discussed in Section 2.3 Sandia National Laboratories (SNL) is the verification organization for this test, with Oak Ridge National Laboratory (ORNL), also an ETV Verification Organization, providing technical assistance. The Advanced Monitoring Systems Center of ETV is administered through EPA's Office of Research and Development, National Exposure Research Laboratory.

**Table 1** ***Verification Participants in the Groundwater Sampling Technology Verification Test***

| Organization | Point(s) of Contact | Role |
|---|---|---|
| **Sandia National Laboratories**<br>PO Box 5800, MS-0755<br>Albuquerque, NM 87185-0755 | **Program Manger**: Wayne Einfeld<br>phone: (505) 845-8314<br>fax: (505) 844-0116<br>weinfel@sandia.gov | verification organization |
| **U. S. EPA**<br>National Exposure Research Laboratory<br>Environmental Science Division<br>P.O. Box 93478<br>Las Vegas, NV 89193-3478 | **Project Officer:** Eric Koglin<br>phone: (702) 798-2332<br>fax: (702) 798-2107<br>koglin.eric@epa.gov | EPA project management |
| **Geoprobe Systems**<br>601 N. Broadway<br>Salina, KS 67401 | **Contact:** Wes McCall<br>phone: (785) 825-1842<br>fax: (785) 825-6983<br>mccallw@geoprobesystems.com | technology vendor |
| **U.S. Geological Survey**<br>Hydrologic Instrumentation Facility<br>Building 2101<br>Stennis Space Center, MS 39529-6000 | **Contact:** Bill Davies<br>phone: (228) 688-2108<br>fax: (228) 688-1577<br>wjdavies@usgs.gov | Stennis Site Contact |
| **AFRL/MLQL**<br>139 Barnes Dr., Suite 2<br>Building 1117<br>Tyndall AFB, FL 32403-5323 (Stop 37) | **Contact:** Marlene Cantrell<br>phone: (850)-283-6003<br>Marlene.Cantrell@tyndall.af.mil | Tyndall Site Contact |
| **DataChem**<br>4388 Glendale-Milford Road<br>Cincinnati, Ohio 45242 | **Contact:** Dixie Yockey<br>phone: (513) 733-5336<br>fax: (513) 733-5347<br>dyockey@datachemlabs.com | analytical laboratory |

## 2.2. Organization

An organizational chart depicting the lines of communication for the verification is shown in Figure 2-1.

## 2.3. Responsibilities

The following is a delineation of each participant's responsibilities for the verification test. In this section, the term "vendor" applies to Geoprobe Systems who is participating with two technologies. The Vendor, in consultation with SNL and EPA, is responsible for the following elements of this verification test:

- Contribute to the design and preparation of the verification test plan;
- Provide detailed procedures for using the technology;
- Prepare field-ready technology for verification;
- Operating the technology during the verification test;
- Documenting the methodology and operation of the technology during the verification;
- Logistical, and other support, as required.

SNL has responsibility for:

- Preparing the verification test plan;
- Developing a quality assurance project plan (QAPP) (Section 6 of the verification test plan);
- Preparing a health and safety plan (HASP) (Section 7 of the verification test plan) for the verification activities;
- Developing a test plan for the verification;
- Acquiring the necessary laboratory analysis data;
- Performing sample preparation activities (including purchasing, labeling, and distributing).

SNL and EPA have coordination and oversight responsibilities for:

- Providing needed logistical support, establishing a communication network, and scheduling and coordinating the activities of all verification participants, including the technical panel;
- Auditing the on-site sampling activities;
- Managing, evaluating, interpreting, and reporting on data generated by the verification;
- Evaluating and reporting on the performance of the technologies;
- Other logistical information and support needed to coordinate access to the site for the field portion of the verification, such as waste disposal.

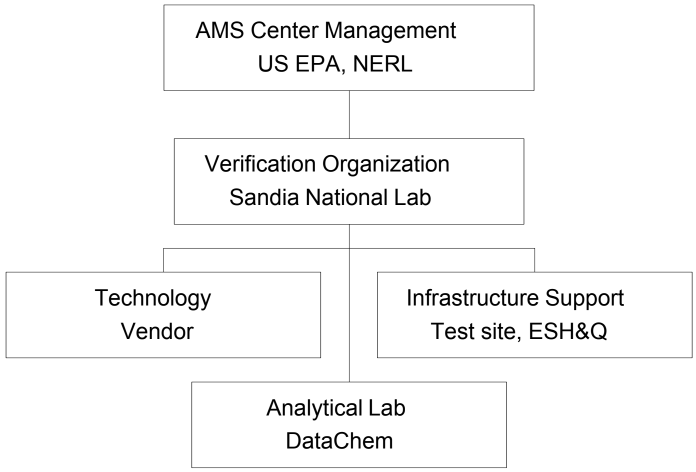


**Figure 1** *Organizational chart for the Ground Water Sampling Technologies Verification Test.*

# 3. TECHNOLOGY DESCRIPTIONS

This section provides descriptions of the technologies participating in the verification test. These descriptions were provided by the technology vendors, with minimal editing by the verification organization.

## 3.1. Background

Geoprobe Systems began development and design of direct push probing machines and the affiliated tooling in the late 1980s. The initial application for the direct push machines and tools was for collection of soil gas samples. Because of the effectiveness and efficiency of the direct push method, it was soon applied to soil sampling and groundwater sampling for environmental investigations. More recently, Geoprobe Systems has developed the equipment and methods to install small diameter monitoring wells for use in environmental water quality investigations. Because of the small diameter of the direct push installed temporary groundwater sampling tools and monitoring wells smaller diameter sampling pumps are needed. Additionally, research has found that low-flow sampling rates are usually required to obtain representative water quality samples [1]. This is especially true for volatile organic compounds that are sensitive to pressure and temperature changes and inorganic analytes, such as iron and chromium, that may be affected by elevated levels of turbidity in the sampled ground water.

The direct-push installed, small diameter, temporary ground water sampling tools are used for site assessments and investigations for many geo-environmental projects [2]. These temporary sampling devices are installed, samples are collected, and the sampling devices are removed for decontamination and multiple re-use. These temporary installations provide an efficient and cost effective method for site characterization. Additionally, small diameter wells installed by direct push methods are substantially growing in use and gaining wider regulatory acceptance as permanent installations for water quality monitoring [3]. Traditionally, these small diameter tools and wells were sampled with peristaltic pumps, inertial pumps (or check valves), and mini-bailers. Each of these sampling methods has significant limitations and often may not provide representative samples [1]. Because of the need for a cost effective, small-diameter ground water sampling device that can provide high-quality, representative samples from these direct-push tools and wells, Geoprobe Systems has developed a simple mechanically operated bladder pump. Bladder pumps have been found acceptable for sampling of all environmental parameters [4].

## 3.2. Geoprobe Systems Model XXXX Mechanical Bladder Pump

The first of two technologies to be tested in a recently developed bladder pump that is applicable for use in direct push well installations.

### *3.2.1. Device Design*

The mechanical bladder pump uses a concentrically corrugated bladder that is open on both ends (Figure XXX). This bladder is alternately compressed and expanded by actuation of the inner concentric tube to pump fluid to the surface. The bladder is fabricated of FEP Teflon® with cuffs on each end that allow for attachment to an upper and lower bladder adapter. The bladder adapters are barbed so the bladder cuffs stay mechanically attached. The lower bladder adapter is attached to the pump body so that it is anchored and can not move during the pump cycle. The upper bladder adapter slides freely inside the pump body and attaches the bladder to the inner tubing adapter and inner tubing so it may be actuated from the surface. A compression spring is installed above the upper bladder adapter and is held in position with a spring retainer located near the top of the pump body. This spring assists in compressing the bladder and with return of the inner tubing during the down (or supply) stroke of the pump. The outer tubing attaches directly to the upper end of the pump body. This tube may be fabricated of high density polyethylene

(HDPE), Polypropylene, Kynar® (PVDF), FEP Teflon® or other suitable materials as required by the data quality objectives of the sampling program. The outer tube is held in place at the surface as the inner tube is alternately lowered and raised to operate the pump. The inner tube also may be fabricated of high density polyethylene (HDPE), Polypropylene, Kynar® (PVDF), FEP Teflon® or other suitable materials as required by the data quality objectives of the sampling program. For purposes of the ETV field tests the outer tubing material will be HDPE or polypropylene and the inner tubing material will be FEP. The chemically inert character of FEP for many environmental contaminants is well documented and known by the regulators and regulated community. However, at least two studies [5,6] found that Kynar® (PVDF) tubing may be less sorptive than FEP for several of the halogenated compounds, particularly chlorinated volatiles. As Kynar® tubing is more rigid than FEP it may prove to be a better material, both mechanically and for chemical inertness, to use as the inner tube component of the mechanical pump. Also, if the mechanical bladder pump is to be used as a portable sampling device during site characterization with temporary ground water sampling tools it may be preferable to use less expensive materials for the corrugated bladder and concentric tubing. The bladder and inner tube could be made of polypropylene, which is much less expensive than FEP or Kynar®. Polypropylene is almost as chemically inert as FEP, making it an attractive substitute when the tube and bladder will be used once and discarded for portable applications.

The pump body, check balls and all other metal components of the mechanical bladder pump are fabricated from #304 stainless steel. This material is resistant to corrosion under most groundwater geochemical conditions [7,8] and is recommended for use in the construction and fabrication of well screens and groundwater sampling tools [7] especially when organic contaminants are the primary analytes of interest.

#### *3.2.2. Field Operation*

The mechanical bladder pump can be operated manually, with nothing other than your two hands. Manual operation is accomplished by using one hand to hold the outer tube in position and the other had to oscillate the inner tube up and down repeatedly. A simple hand crank mounted on the well head can be used to make the physical work easier and help maintain a more consistent flow rate for sampling activities. Additionally, an electric motor may be used to do the work of oscillating the inner-tube up and down, minimizing the physical work required and providing a consistent and adjustable flow rate for sampling and purging activities.

The pump is appropriately decontaminated and then assembled according to the manufacturer's instructions. Next the concentric inner and outer tubes are attached to the inner tubing adapter and top of the pump body respectively. Accurate measurement is made and the tubing set is cut at the desired length so the pump intake will be positioned at the desired depth in the well. The pump is lowered into position (Figure 3-2). The outer tube is held or anchored in position as the inner tube is oscillated up and down to operate the pump and purge water from the well. Water is discharged from the inner tube which may be attached to an in-line flow cell to monitor water quality parameters such as pH, temperature, specific conductance, dissolved oxygen content and oxidation-reduction potential. The discharge flow from the inner tube may be directed into properly preserved sample containers for sample collection.

#### *3.2.3. Advantages and Limitations*

A brief summary of the advantages and limitations of the mechanical bladder pump is provided below. The features of the mechanical bladder pump are discussed relative to other pump designs commonly used for environmental water quality sampling activities.

***Advantages:***

- The pump is small, light weight, and very portable.
- Can be operated manually.
- Does not require an air compressor, pump or supply of compressed gas from cylinders to operate.
- Can be operated with a simple hand crank to make flow rate more consistent and level of effort for operation lower.
- When operated manually or with mechanical crank no generator or line current for operation is required.
- Can be operated with an electric motor driven crank to automate and minimize physical effort required for operation. This will also provide adjustable, consistent flow rates. Can be powered from vehicle battery, generator, or line current.
- Flow rate can be adjusted to provide the desired flow to meet the stringent low flow sampling criteria. For the ½" pump, flows can be varied from less than 100 mL/min to over 500 mL/min.
- Ability to provide low flow sampling minimizes the amount of pre-sample purge water generated, reducing waste handling and disposal costs.
- Since an air compressor and compressed air is not required for operation there are no problems with moisture condensation in line affecting pump operation.
- Since compressed air is not used to operate the pump testing for air leaks is not required.
- Since there are a limited number of moving parts and no electrical motor or electrical components in the pump generation of heat down hole is essentially eliminated. Excess heat generated by motor driven pumps can raise the temperature of the water being sampled potentially altering the water quality and resulting in loss of volatile constituents.
- Cost of the pump is 25% to 50% lower than conventional gas driven bladder pumps.
- The pump can be operated as a long term dedicated pump or a portable pump.
- Simple construction makes assembly and operation easy.
- Simple construction makes disassembly for decontamination quick and easy.
- Bladders are quickly and easily replaced in the field, especially important when operated as a portable pump and bladders are changed for each sample location.
- Maintenance requirements are minimal and may be easily conducted in the field.
- FEP Teflon® bladders and tubing, and stainless steel construction make this pump acceptable for essentially all environmental water quality sampling requirements.
- For portable sampling activities bladders and tubing of low cost polypropylene or HDPE may be substituted for the more expensive FEP Teflon® components.
- The mechanical bladder pump provides an inexpensive and efficient method for obtaining high quality samples from DP installed temporary ground water sampling tools during initial site characterization activities.

***Limitations:***

- When operated in manual mode maintaining consistent flow rates is difficult to document. Human error can become a factor in flow rates and as such could impact sample quality.
- These small pumps are not designed to provide high flow rates (e.g. several gallons per minute) but usually are operated at flows of a few hundred milliliters per minute or less.
- In deeper wells (50 feet or more in depth) friction between the inner and outer tubing can hinder efficient operation of the pump.
- When FEP tubing is used as the inner tube in deeper wells (50 feet or deeper) elongation of the tubing during the pump cycle can decrease efficiency of the pump. This limitation can be minimized by using a more rigid material for the inner tube (e.g. Kynar /PVDF).

### 3.3. Geoprobe Systems Model XXX Pneumatic Bladder Pump

The second pump to be tested is also a Geoprobe bladder pump that is pneumatically driven.

### *3.3.1. Device Design*

The pneumatic bladder pump uses a Teflon™ PTFE bladder that is open on both ends (Figure XXX). Concentric tubes are used to connect the pump to a controller and gas supply at the surface (Figure XXX). For purposes of the ETV field test the outer tubing material will be HDPE or polypropylene and the inner tubing material will be FEP. The pump controller is pneumatically operated and no electrical supply or batteries are required for its operation. The outer-tube is used to supply gas pressure down hole and the inner-tube is the sample return line. The bladder is alternately compressed and expanded by application of pressure and then pressure release to the exterior surface of the flexible FEP bladder. There is no contact between the pressurizing gas and the water being sampled. During the positive pressure stroke of the pump fluid in the bladder is pushed out of the bladder and up the sample return line, ultimately to the surface. During the pressure release stroke, water from the well enters the pump inlet under hydrostatic pressure and fills the bladder. If the pump is near the static water level there may not be sufficient hydrostatic pressure to fill the bladder. Under these conditions vacuum may be applied to the exterior of the bladder to actively open it and draw water in from the well. The pump controller with this system includes a vacuum assist option just for this situation.

These pneumatic bladder pumps are available in two sizes. The smaller pump is 0.50 inches in OD by 26.5 inches long and can be used in nominal ½" PVC or larger casing, including DP drive rods. The larger pump is 0.75 inches in OD by 20 inches long and can be used in nominal ¾" PVC or larger casing. Each pump may be equipped with a sintered stainless steel inlet filter to minimize pump clogging and sample turbidity. The flow rate that can be achieved by either pump is a function of at least three parameters. These are:

- the depth pump is submerged below the static water level;
- the distance from ground surface to the static water level; and
- the maximum pressure of the supply gas.

Under optimum flow conditions the 0.5-inch pump has been found to provide flow rates between 100 mL/min to 120 mL/min. Like wise, the 0.75-inch bladder pump has provided flow rates ranging between 300 mL/min to 500mL/min under optimal conditions. The flow rates provided by these pumps are well within those specified by the low flow sampling method [1]. The 0.5-inch pump has been operated in wells with a static water level between 95 and 120 feet below grade. Under these difficult conditions flow rates of 20 mL/min to 30 mL/min were obtained.

As noted above the bladder used during the ETV field test will be made of PTFE Teflon™. The chemically inert character of Teflon™ for many environmental contaminants is well documented and known by the regulators and regulated community. However, at least two studies [5,6] found that Kynar™ (PVDF) tubing may be less sorptive than FEP Teflon™ for several of the halogenated VOCs, and particularly the chlorinated hydrocarbons. As Kynar™ tubing is more rigid than FEP it may prove to be a better material, both mechanically and for chemical inertness, to use as the inner tube component of the pneumatic bladder pump. Also, if the pneumatic bladder pump is to be used as a portable sampling device during site characterization with temporary ground water sampling tools it may be preferable to use less expensive materials for the concentric tubing. The inner tube could be made of polypropylene, which is much less expensive than FEP or Kynar™. Polypropylene is almost as chemically inert as FEP, making it an attractive substitute when the tube will be used once and discarded, as for portable applications.

The pump body, check balls and all other metal components of the pneumatic bladder pump are fabricated from #304 stainless steel. This material is resistant to corrosion under most groundwater geochemical conditions [7,8]. The #304 stainless steel is recommended for use in the construction and fabrication of well screens and groundwater sampling tools [5,6] especially when organic contaminants are the primary analytes of interest.

### 3.3.2. Field Operation

The pneumatic bladder pumps can be operated with a portable compressor or compressed gas cylinder to supply the pressurized gas required for operation. If a compressor is used a portable generator or other power supply will be needed to operate it. Minimum recommendations for the compressor are to supply 1.5 cubic feet per minute flow rate per 20 feet of tube. The pump is assembled and attached to the concentric tubing set and lowered to the desired depth in the well (Figure 3-4). The following steps outline the field operation procedure.

- The concentric tubing from the pump is attached to the pump head. If pump is being installed for dedicated operation the pump head is fitted on to the well casing.
- The air supply hose from the pneumatic pump controller is attached to the pump head.
- The controller is attached to the gas supply with the quick connect hose.
- Inlet gas pressure is adjusted to optimal operating range. Usually between 60 psi to 90 psi.
- The pump is turned on.
- The duration of the pump "on time" and "off time" cycles are adjusted to optimize pump flow to the desired rate.
    - On time – controls how long the gas pressure valve is open to supply pressure to the exterior of the bladder. Longer 'on time' increases maximum pressure but results in slower pump cycle.
    - Off time – controls how long the gas pressure is left off. Longer 'off time' gives the bladder more time to open and fill with water but again results in slower pump cycle.
- The vacuum assist option may be operated if the pump is near the static water level and pump recharge is slow. This will speed up opening and filling of the bladder and so decrease to 'off time' duration.
- The sample return line may be attached to an inline flow cell to monitor ground water quality parameters (e.g. pH, DO, ORP, etc.) if desired.
- Water from the sample return line is collected in appropriately preserved containers for the analyses of interest.

If the pump is used as a portable sampling device it should be appropriately decontaminated and then re-assembled according to the manufacturers instructions before use at the next well or sampling location.

### 3.3.3. Advantages and Limitations

A brief summary of the advantages and limitations of the pneumatic bladder pump is provided below. The features of the mechanical bladder pump are discussed relative to other pump designs commonly used for environmental water quality sampling activities.

***Advantages:***

- The pump is small, light weight, and very portable.
- Can be operated without an electrical power supply.
- Can be operated with an air compressor or compressed gas cylinders.
- Flow rate can be adjusted to provide the desired flow to meet the stringent low flow sampling criteria. For the ½" pump, flows can be varied from less than 30 ml/min to over 100 ml/min depending on field conditions.
- Ability to provide low flow sampling minimizes the amount of pre-sample purge water generated, reducing waste handling and disposal costs.

- Since there are a limited number of moving parts and no electrical motor or electrical components in the pump generation of heat down hole is essentially eliminated. Excess heat generated by motor driven pumps can raise the temperature of the water being sampled potentially altering the water quality and resulting in loss of volatile constituents.
- The pump can be operated as a long term dedicated pump or a portable pump.
- Simple construction makes operation easy.
- Bladders may be replaced in the field.
- Maintenance requirements are minimal.
- FEP Teflon™ bladders and tubing, and stainless steel construction make this pump acceptable for essentially all environmental water quality sampling requirements.
- For portable sampling activities tubing of low cost polypropylene or HDPE may be substituted for the more expensive FEP Teflon™ components.
- The small pneumatic bladder pump makes it possible to obtain high quality samples from small diameter DP installed wells or temporary ground water sampling tools during initial site characterization activities.

***Limitations:***

- These small pumps are not designed to provide high flow rates (e.g. several gallons per minute) but usually are operated at flows of tens to a few hundred milliliters per minute or less.
- In wells with a deeper static water level (e.g. 50+ ft) it will be difficult, at best, to achieve the higher flow rates.
- Operation of the pneumatic bladder pump requires a pump controller, compressor and power supply or compressed gas cylinder. This increases the initial purchase cost and significantly adds to the level of effort required for field mobilization.
- A moisture trap (or bowl) must be used on the compressor to prevent build up of moisture in the supply line and around the bladder. Build up of moisture around the bladder can significantly reduce operating efficiency.
- Fines can plug the small pore size in the sintered stainless steel filter.

## 4. VERIFICATION TEST DESIGN

This section discusses the objectives and design of the verification test, the factors that must be considered to meet the performance objectives, and the information that the verification organization will use to evaluate the results of the verification.

### 4.1. Test Objectives

The purpose of this test is to evaluate the performance of groundwater sampling technologies that can be deployed in small-diameter (less than 1.5-inch internal diameter) direct-push installed wells. This test will follow a similar experimental design as verification testing on samplers for conventional 2" and 4" wells that was conducted in 1999 [9]. The three primary objectives of this verification are:

1. Evaluate the performance of the groundwater sampling equipment in a controlled environment where the water is spiked with known amounts of target analytes;
2. Assess how each technology performs when deployed in actual direct push wells, and
3. Determine the logistical and economic resources necessary to operate the technology in the field.

### 4.2. Site Descriptions

The test will be conducted at two sites. First, the samplers will be tested in a standpipe containing spiked tap water at a United States Geological Survey (USGS) facility at Stennis Space Center in Western Mississippi. Secondly, the samplers will be deployed in actual direct push (DP) wells at Tyndall Air Force Base in Panama City, Florida.

#### *4.2.1. USGS Standpipe Facility*

The John C. Stennis Space Center in southwest Mississippi is one of ten NASA field centers in the United States. It is NASA's primary center for testing and flight certifying rocket propulsion systems for the Space Shuttle and future generations of space vehicles. Over the years, SSC has evolved into a multi-agency, multi-disciplinary center for federal, state, academic and private organizations engaged in space, oceans, environmental programs and national defense. The USGS is a one of the resident agencies at the NASA-Stennis complex and operates a number of testing facilities as a part of its Hydrologic Instrumentation Facility (HIF). This facility supports USGS agency-wide hydrologic data-collection activities through the identification of agency needs, development of technical specifications, and testing and evaluation.

One of the HIF test centers is known as the Standpipe Facility. The facility was designed by Doreen Tai, a HIF chemical engineer, and is housed in a Saturn V rocket storage building at the Stennis complex. A schematic diagram of the standpipe and accessories is shown in Figure 2. The standpipe is an above-ground, 100-foot long, 5-inch diameter, stainless steel pipe with numerous external sampling ports along its length. Two large tanks at the top of the standpipe are used to prepare solutions that can then be drained into the standpipe. The tanks are equipped with motor-driven mixing propellers and floating lids to minimize loss of volatile compounds during solution mixing and transfer. An external standpipe fill line at the bottom of the pipe enables the pipe to be filled from the bottom up, thereby minimizing flow turbulence and volatile analyte losses in the prepared solutions. The external access ports allow reference samples to be taken simultaneously with the collection of technology samples inside the pipe. The indoor facility has six levels of access, including the ground floor, and a freight elevator services all levels.

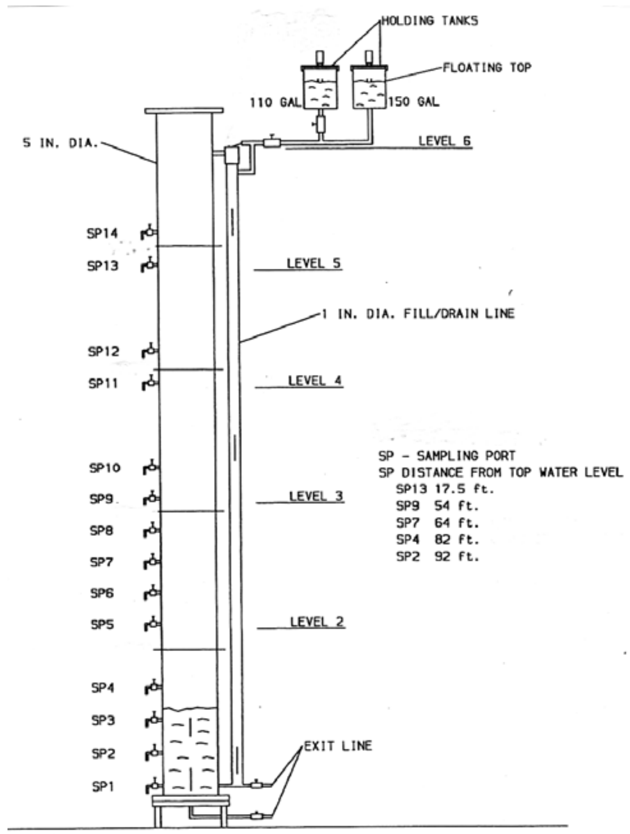


**Figure 2** *The standpipe located at USGS Hydrologic Instrumentation Facility at the NASA Stennis Space Center.*

### *4.2.2. Tyndall Air Force Base*

Tyndall Air Force Base (TAFB) is located near Panama City, Florida. Tyndall is one of many Department of Defense (DoD) facilities with extensive soil and groundwater contamination resulting from military/industrial activities that have occurred on the base over the past decades. A project was funded in FY01 by DoD's Environmental Security Technology Certification Program (ESTCP) to study the comparability of conventional hollow-stem-auger-installed wells with the more recent direct-push installed wells. Specifically, the study is aimed at determining whether statistically significant differences exist between co-located pairs of conventional and direct push wells under long term monitoring scenarios. The ESTCP study involves five DoD sites including TAFB. As a part of the study, a number of new direct push wells were been installed at Tyndall and are selected for use in this ETV test. Two different styles of new direct-push wells are now in existence including eight 1.5-inch diameter wells installed with the Army Corps of Engineer's Cone Penetrometer Testing rig and eight 1.0-inch diameter wells installed using a Geoprobe system. Historical analytical data for these wells from the ESTCP study has been made available to the ETV program to assist with the well selection process as a part of test planning.

### 4.3. Experimental Design

The verification test design consists of two basic components. The first is a test matrix, consisting of several trials, conducted under controlled sampling conditions at the USGS standpipe. These trials enable the determination of vendor sampler performance parameters such as precision and comparability to reference samples. The second part of the test consists of a series of field trials conducted with inherently less experimental control. These field trials present an opportunity to observe the technology in actual field use in conditions very similar to those that would be encountered in routine use. Together, these two study components offer a data set that is adequate for an overall performance assessment of these groundwater-sampling technologies for applications specifically involving the sampling of contaminated groundwater from small-diameter wells.

The target analyte list includes two broad categories of contaminants normally sampled with ground water sampling devices. A selection of non-volatile cations that are commonly encountered in ground water, are included in the test matrix and are listed in Table 2. An additional set of volatile organic compounds, also shown in Table 2, are included in the test matrix as well. The volatile organic compounds include three basic categories of compounds commonly encountered in ground water characterization or remediation efforts: methyl-teritary-butyl-ether (MTBE), trichlorethene (TCE) and a few of its degradation byproducts, as well as benzene and ethyl benzene as indicators of gasoline contamination. The laboratory reporting limit is also shown in Table 2. Target concentrations are selected well in excess of these lab limits to assure the best lab precision and accuracy in the reported results.

**Table 2** ***Target Analyte List***

| Volatile Organic Compound | Laboratory Reporting Limit (µg/L) | Inorganic Cation | Laboratory Reporting Limit (µg/L) |
|---|---|---|---|
| Benzene | 5 | Calcium | 500 |
| cis-1,2-Dichloroethene | 5 | Iron | 500 |
| Ethyl Benzene | 5 | Magnesium | 500 |
| Methyl-tertiary-butyl ether (MTBE) | 5 | Potassium | 500 |
| Trichloroethene | 5 | Sodium | 500 |
| Vinyl Chloride | 5 | | |

#### *4.3.1. USGS Standpipe Trials*

The USGS standpipe enables the preparation of water mixtures containing the target analytes in a range of concentration levels. Since the pipe is above-ground, easy access is possible for the various sampling depths specified in the test. The eight standpipe trials are summarized in Table 3. The inorganic target compound concentrations will include a low (1000 µg/L) and a high (5000 µg/L) level. One volatile organic compound concentration level of 100 µg/L will be used. In both cases, at least two sampling depths will be investigated with the sampling technologies.

##### 4.3.1.1. Standpipe Cleanliness Check

Prior to the start of testing, the standpipe will be filled, drained, and re-filled with tap water. Two samples will be collected from each of the three sampling ports to be used during the testing to ascertain that the standpipe does not contain any of the target analytes above detectable levels. These samples will be analyzed at an on-site laboratory (GB Tech). Testing will not begin until the results from these blank tests are received from the on-site laboratory.

#### 4.3.1.2. Spike Solutions

Spike solutions of both non-volatile and volatile organic compounds will be prepared using custom stock solutions that have been specially prepared for use in this test. To prepare the solutions, a volume of the spiking solution will be added to a known volume of tap water in the standpipe mixing tank. The solution will be gently mixed for 5 minutes prior to draining into the standpipe. Previous studies at the pipe with volatile organic compounds [9] revealed volatile losses of target compounds during mixing and standpipe filling. Consequently, the theoretical value of the mixed concentrations drained into the pipe will not be used as a reference value in this study. Alternatively, reference samples will be collected simultaneously with all vendor samples collected.

#### 4.3.1.3. Reference Samples

The collection of samples from standpipe external sampling ports will serve as reference against which the technology samples can be compared. The port samples will be collected directly into analysis vials with no intervening pumps, filters, or other devices that could potentially affect the sample. The port samples will be collected at the same time that each technology sample is collected from the standpipe. The standpipe trials (Table 3, Trial 1) will include a blank test, where replicate samples will be collected from tap water in the standpipe. This test will be conducted to assess whether the materials of construction in the various samplers are a possible source of contamination. Trials 2 - 8 will entail deploying the samplers are varying depths and concentrations of both volatile and non-volatile target compounds. The use of multiple, sequentially collected samples (i.e., four replicates) will allow the determination of sampler precision. Precision in this context incorporates the variability of the technology and the port sample in combination with the common analytical method used on both sample types. A simple reference sampler (described in “TAFB Field Trials” section below) will also be evaluated in this suite of trials in the standpipe along with the vendor technologies in order to establish its baseline performance. These data will be used to substantiate the performance of the reference sampler as applied in the field trials in the second phase of the study.

Table 3 *Summary of Standpipe Trials*

| Trial | Analyte | Target Analyte Conc. (ppb) | Sampling Port Number | Depth (feet) | Technology Samples | Reference Port Samples |
|---|---|---|---|---|---|---|
| Pre-test [a] | VOC/Inorganic | - | 5, 12, 14 | 17, 35, 76 | - | 2 |
| 1 | VOC/Inorganic | - | 12 | 35 | 4 | 4 |
| 2 | Inorganic | 1000 | 14 | 17 | 4 | 4 |
| 3 | Inorganic | 1000 | 12 | 35 | 4 | 4 |
| 4 | Inorganic | 5000 | 14 | 17 | 4 | 4 |
| 5 | Inorganic | 5000 | 12 | 35 | 4 | 4 |
| 6 [b] | VOC | 100 | 5 | 76 | 4 | 4 |
| 7 | VOC | 100 | 14 | 17 | 4 | 4 |
| 8 | VOC | 100 | 12 | 35 | 4 | 4 |
| Total | | | | | 32 | 38 |

*Notes:*
[a] *This trial is used to ascertain that the standpipe is clean before testing begins.*
[b] *This trial will be conducted with the pipe only half full in order to test the hydraulic lift capacity of the pumps being tested.*

### 4.3.2. Tyndall AFB Field Trials

The use of TAFB monitoring wells in the second phase of the study poses a technical challenge for the collection of data with which to compare the technology data. The use samples collected simultaneously in adjacent co-located wells in the well cluster was explored as an option, however historical sampling data reveal that side-by-side wells do not yield data that is comparable at the level desired for this relatively high precision test. The other option for a reference sample is the collection of a co-located sample simultaneously with the technology sample. Furthermore, the reference sample should minimize surface adsorption loss, sample handling loss, turbulence and other factors that can cause loss of non-volatile or volatile components in the sample. Finally, if the reference sampler is to be deployed alongside the technology, it must have a very small cross-sectional area so that it can be slipped alongside the deployed technology in these narrow diameter wells.

#### 4.3.2.1. Co-located Reference Sampler

In light of these considerations, a very simple tube sampler hereafter referred to as the “Sipper Sampler” was designed and built for use in this test. This sampler consists of a length of 5/8-inch internal diameter Teflon tubing to which a 1-foot length of 1-8-inch external diameter tubing is connected at the down-hole end. Complete specifications and sampler operation procedures are included in Appendix C. At the surface end, a length of peristaltic pump tubing is attached to the 5/8-inch tubing. The tubing assembly is then inserted into the well alongside the deployed technology. A peristaltic pump is used to purge this length of tubing. Following tubing purge, the water column in the tube is held in place via a vacuum applied at the top of the tubing length and the tubing is withdrawn from the well. The entire tubing assembly is withdrawn from the well and water samples are then dispensed into VOA vials from the bottom of the tubing length. The top third of the water column is discarded and only the bottom two-thirds of the water column is used for sample. The top section of the column has the potential for volatile loss by virtue of the air-water interface at the top of the top whereas the bottom section of the water column is less susceptible to losses since no air-water interface exists.

#### 4.3.2.2. Reference Sampler Preliminary Performance Data

This Sipper Sampler design was tested at a number of Tyndall wells in August 2002, in order to assess the sampler's precision for both volatile and non-volatile analytes. In this test, the Teflon tubing string and a peristaltic pump was used to purge the well (1.0 L purge at ~200 mL/min). Water samples for cation analysis were then collected at the outlet of the peristaltic pump. Samples for VOC analysis were collected by dispensing samples from the bottom of the tube in the manner described in the previous paragraph. Summaries of the pre-test sampling results from seven TAFB wells are presented in Tables 4 and 5. Both 1.5" (Table 4) and 1.0" (Table 5) wells were sampled in this preliminary trial. The average concentrations (in µg/L) and corresponding percent relative standard deviations (RSD) are presented for three replicate samples collected using the Sipper Sampler. The results indicated that the reference system reproducibly collected water samples for VOCs, with an average RSD value of 13% (the range was 2% to 43%). The system was even more precise for collecting water samples for the inorganic target cations with an average RSD of 4% (the range was 0% to 27%). Additional verification studies on the performance of the Sipper Sampler will also be carried out during the standpipe phase of the experiments to provide technical data substantiating its use as a reference method in the field.

**Table 4** ***Pre-Test Summary Results from Tyndall Air Force Base 1.5" Wells***

| Analyte | MW-2-P15 | | MW-8-P15 | | MW-5-P15 | |
|---|---|---|---|---|---|---|
| | avg conc (µg/L) | RSD (%) | avg conc (µg/L) | RSD (%) | avg conc (µg/L) | RSD (%) |
| Vinyl Chloride | ND | ND | ND | ND | ND | ND |
| cis-1,2-Dichlroethene | ND | ND | 187 | 8 | ND | ND |
| Benzene | 343 | 2 | ND | ND | ND | ND |
| Trichloroethene | ND | ND | 50 | 3 | 2167 | 12 |
| 1,1,2-Trichloroethane | ND | ND | ND | ND | ND | ND |
| Ethylbenzene | 2 J | ND | ND | ND | ND | ND |
| Boron | 95 | 2 | ND | ND | ND | ND |
| Calcium | 760 | 3 | 20667 | 3 | 23000 | 4 |
| Iron | 1900 | 5 | 3167 | 16 | 733 | 17 |
| Magnesium | 1867 | 3 | 1500 | 0 | 1100 | 0 |
| Manganese | ND | ND | ND | ND | 22 | 11 |
| Potassium | 2500 | 0 | 2300 | 0 | 1967 | 3 |
| Sodium | 6300 | 0 | 2433 | 2 | 1833 | 3 |

**Table 5** ***Pre-Test Summary Results from Tyndall Air Force Base 1.0" Wells***

| Analyte | MW-8-P10 | | MW-9-P10 | | MWD-11-P10 | | T6-5-P10 | |
|---|---|---|---|---|---|---|---|---|
| | avg conc (µg/L) | RSD (%) | avg conc (µg/L) | RSD (%) | avg conc (µg/L) | RSD (%) | avg conc (µg/L) | RSD (%) |
| Vinyl Chloride | ND | ND | ND | ND | ND | ND | 10 | 6 |
| cis-1,2-Dichlroethene | 373 | 12 | ND | ND | 13 | 43 | ND | ND |
| Benzene | ND | ND | 1433 | 4 | ND | ND | 67 | 6 |
| Trichloroethene | 150 | 31 | ND | ND | ND | ND | ND | ND |
| 1,1,2-Trichloroethane | ND | ND | ND | ND | ND | ND | ND | ND |
| Ethylbenzene | ND | ND | 133 | 4 | 8 | 18 | 25 | 14 |
| Boron | ND | ND | ND | ND | ND | ND | ND | ND |
| Calcium | 14333 | 4 | 8900 | 0 | 15000 | 0 | 64667 | 1 |
| Iron | 1330 | 27 | 517 | 2 | ND | ND | ND | ND |
| Magnesium | 1433 | 4 | 813 | 1 | 2500 | 0 | 5333 | 1 |
| Manganese | ND | ND | ND | ND | ND | ND | 52 | 2 |
| Potassium | 2300 | 0 | 2200 | 0 | 5600 | 2 | 1567 | 4 |
| Sodium | 3467 | 3 | 2933 | 2 | 11000 | 0 | 3533 | 6 |

#### 4.3.2.3. Vendor and Reference Co-located Sampling Procedures

During field sampling events, the Sipper Sampler will be co-located in the well alongside the vendor sampler in order to provide simultaneous co-located reference samples from the well. Once both the reference system and vendor technology are deployed in the well, water quality parameters will be monitored through the reference system and optionally from the vendor system, using a flow-through system that enables the measurement of such parameters as turbidity, pH, temperature, dissolved oxygen and redox potential. A low-flow purge protocol will be used for all sampling events during the field trials. The parameters will be monitored through both the reference and vendor system for at least two wells to confirm that comparable conditions are achieved through both systems. If the ground water physical parameters are comparable (as specified in the protocol in Appendix A and B) through both reference and vendor systems for two wells, the groundwater parameters will be monitored only through the reference system for the remaining four wells. The procedure for low-flow, minimal draw down sampling and groundwater parameter monitoring is presented in detail in Appendicies A and B.

Once the conditions have stabilized, samples will be simultaneously collected from both the vendor and reference systems. Samples for cation analysis will be collected first, followed by the collection of samples for VOC analysis. The Sipper Sampler pumping rate will be on the order to 100 to 200 mL/minute and the vendor technology will employ a similar pumping rate. All samples will be collected from 1.0-inch internal diamters wells. A summary of the wells, depths to be sampled, and number of VOC and inorganic replicates to be collected is provided in Table 6.

**Table 6** ***Direct Push Wells to be Sampled at Tyndall Air Force Base***

| Well | Depth to center of screened interval (feet) | Number of Samples | | | |
|---|---|---|---|---|---|
| | | Reference System | | Each Vendor System | |
| | | VOC | Inorganic | VOC | Inorganic |
| MW-2-P10 | 31 | 4 | 4 | 4 | 4 |
| MW-5-P10 | 8 | 4 | 4 | 4 | 4 |
| MW-8-P10 | 8 | 4 | 4 | 4 | 4 |
| MW-9-P10 | 10 | 4 | 4 | 4 | 4 |
| MWD-11-P10 | 17 | 4 | 4 | 4 | 4 |
| T6-5-P10 | 13 | 4 | 4 | 4 | 4 |
| **Total** | - | 24 | 24 | 24 | 24 |

### *4.3.3. Sample Analyses*

All analyses of reference and technology samples will be conducted by DataChem Laboratories (Cincinnati, Ohio). As mentioned above, an on-site laboratory at Stennis (GB Tech) will be utilized to measure the spiked concentrations in the standpipe, but these results will only be used for field confirmation purposes. All subsequent data analysis efforts will be concentrated on the DataChem laboratories results.

### *4.3.4. Laboratory Selection*

DataChem was initially selected based on its good reputation and also as a result of the verification organization's experience and confidence in this laboratory's abilities. As a final qualifying step, DataChem was sent samples from a pre-test study at TAFB. The precision of the results were satisfactory, all internal quality control requirements were met, and the laboratory data package was complete, thereby substantiating the selection of DataChem as the reference laboratory.

### *4.3.5. Sample Collection and Analysis*

The samples from Stennis and Tyndall will be collected and analyzed for specific target analytes, both VOCs and inorganic cations as noted in Table XX. Samples will be collected in containers (40-mL vials for VOCs and 250 mL bottles for inorganics) supplied by DataChem, pre-spiked with the appropriate acid preservative (0.5 mL 1:1 hydrochloric acid:distilled water for VOCs and 1.0 mL concentration nitric acid for inorganics). Samples will be kept at temperatures near 4 ºC until they are shipped by overnight delivery to DataChem for analysis.

#### 4.3.5.1. VOC Method

The preparation/analytical method for the 40-mL VOC vials will be EPA SW-846 Method 8260B, purge-and-trap gas chromatography/mass spectrometry [10]. A copy DataChem's standard operating procedure is included in Appendix B.

#### 4.3.5.2. Inorganic Method

The preparation method for the 250-mL inorganic vials will be EPA SW-846 Method 3010A, hydrochloric and nitric acid digestion [11], followed by inductively coupled plasma-atomic emission spectrometry (ICP-AES) analysis, EPA SW-846 Method 6010B [12]. The inorganic preparation and analytical procedures, as supplied by DataChem, can also be found in Appendix B.

### 4.4. Summary of Verification Activities

The verification test will be conducted the week of February 24, 2003 The test will begin at Stennis on Monday, February 24, 2003. Trials at Stennis are expected to last two days. The group will then travel the ~300 miles to Tyndall AFB by rental vehicles. Sampling will begin at Tyndall on Thursday February 27 or earlier as the schedule permits. Six DP wells will be sampled at TAFB over two days of testing with scheduled completion on Friday February 28. In keeping with program-wide ETV policy, vendors will operate their own equipment. Verification partner personnel will observed the operation of the vendor technology and compile field notes that will be used to document the sections of the report dealing with operational issues and field logistics associated with the use of the vendor technology in the field.

# 5. QUALITY ASSURANCE PROJECT PLAN (QAPP)

The QAPP for this verification test specifies procedures that will be used to ensure data quality and integrity. Careful adherence to these procedures will ensure that data generated from the verification will meet the desired performance objectives and will provide sound analytical results.

## 5.1. Purpose and Scope

The primary purpose of this section is to outline steps that will be taken to ensure that data resulting from this verification is of known quality and that a sufficient number of critical measurements are taken. This section is written in compliance with SNL's ETV Quality Management Plan which is a joint document with ORNL [13].

## 5.2. Quality Assurance Responsibilities

The implementation of the verification test plan must be consistent with the requirements of the study and routine operation of the technology. The SNL program manager is responsible for coordinating the preparation of the QAPP for this verification and for its approval by EPA and the SNL QA Manager. The SNL program manager will ensure that the QAPP is implemented during all verification activities. SNL's QA manager will review and approve the QAPP. The EPA project manager and EPA QA manager will review and approve this plan.

## 5.3. Field Operations

The following paragraphs outline the procedures to be carried out in the field to insure sample custody and documentation of field observations.

### *5.3.1. Sample Management*

All sampling activities will be documented by SNL field technicians using chain-of-custody forms. To save sample handling time and minimize sample labeling errors in the field, redundant portions of the chain-of-custody forms and all sampling labels will be pre-printed prior to the field demonstration.

### *5.3.2. Communication and Documentation*

Field notes will be taken by observers during the standpipe and groundwater well sampling trials. The notes include a written chronology of sampling events, as well as written observations of the performance characteristics of the various technologies tested during the demonstration. Field documentation will include field logbooks, photographs, field data sheets, and chain-of-custody forms.

## 5.4. Performance and System Audits

The following audits will be performed during this verification.

### *5.4.1. Technical Systems Audit*

The SNL program manager will perform a technical systems audit to ensure that this test plan is being implemented appropriately. Any deviations to the test plan will be documented. If the EPA project manager and/or QA manager is on-site for the testing, EPA will conduct independent technical systems audits.

### *5.4.2. Data quality audit of the laboratory*

Because of the verification organization's extensive experience with DataChem and the lab's acceptable performance on the pre-test samples, a data quality audit is not required.

#### *5.4.3. Surveillance of Technology Performance*
During verification testing, SNL staff will observe the operation of the vendor technologies, such as observing the vendor operations and photo-documenting the test site activities. The observations will be documented in a laboratory notebook. The verification report will contain the exact protocols used by the vendors during testing.

### 5.5. Quality Assurance Reports
QA reports provide the necessary information to monitor data quality effectively. It is anticipated that the following types of QA reports will be prepared as part of this verification.

#### *5.5.1. EPA QA Manager Surveillance Report*
If the EPA QA manager is on-site during testing, a report will be prepared for the EPA project manager.

#### *5.5.2. Status Reports*
SNL will regularly inform the EPA project manager of the status of the verification. Project progress, problems and associated corrective actions, and future scheduled activities associated with the verification test will be discussed. When problems occur, the vendor and SNL will discuss them, estimate the type and degree of impact, describe the corrective actions taken to mitigate the impact and to prevent a recurrence of the problems, and discuss with EPA, as necessary. Major problems will be documented in the field logbook.

### 5.6. Corrective Actions
Routine corrective action may result from the surveillance and quality control activities. If the problem identified is technical in nature, the individual vendors will be responsible for seeing that the problem is resolved. If the issue is one that is identified by SNL or EPA, the identifying party will be responsible for seeing that the issue is properly resolved. All corrective actions will be documented. Any occurrence that causes discrepancies from the verification test plan will be noted in the technology verification report.

### 5.7. Laboratory Quality Control Checks
Internal quality control (QC) samples will be analyzed by DataChem to indicate whether or not the samples were analyzed properly. A summary of QC samples include: initial calibration, continuing calibration verification, and analysis of known samples. This data will be reviewed by SNL as part of the data validation process. Discrepancies will be noted in the data validation records.

### 5.8. Data Management
Because all of the samples will be analyzed by a common analytical laboratory, SNL will be responsible for overseeing sample submission and data reporting.

### 5.9. Data Reporting, Validation, and Analysis
To maintain good data quality, specific procedures will be followed during data reduction, review, and reporting. These procedures are detailed below.

#### *5.9.1. Data Reporting*
Data reduction refers to the process of converting the raw results into a concentration which will be used for evaluation of performance. The procedures to be used will be sample dependent, but the following is required for data reporting:

- The concentration unit for the VOC and inorganic samples will be µg/L (parts per billion).

- If a target analyte is not detected, the concentration will be reported as less than the reporting limits of the method, with the reporting limits stated (e.g., < 5 μg/L). A result reported as "0" will not be accepted.

### *5.9.2. Data Validation*

Validation determines the quality of the results relative to the end use of the data. SNL will be responsible for validating the laboratory data. Several aspects of the data (listed below) will be reviewed. The findings of the review will be documented in the validation records. As appropriate, the ETVR will describe instances of failure to meet quality objectives and the potential impact on data quality.

### *5.9.3. Completeness of Laboratory Records*

This qualitative review ensures that all of the samples that were sent to the laboratory were analyzed, and that all of the applicable records and relevant results are included in the data package.

### *5.9.4. Holding Times*

The samples require refrigeration and acid preservation. The method requirement is that the VOC samples are to be prepared within 14 days of sample collection, while the inorganic samples can be stored with refrigeration and preservation for 6 months.

### *5.9.5. Correctness of Data*

So as not to bias the assessment of the technology's performance, errors in the laboratory data will be corrected as necessary. Corrections may be made to data that has transcription errors, calculation errors, and interpretation errors. These changes will be made conservatively, and will be based on the guidelines provided in the method used. The changes will be justified and documented in the validation records.

### *5.9.6. Evaluation of QC Results*

QC samples will be analyzed by the NLLAP-laboratory with every batch of samples to indicate whether or not the samples were analyzed properly. Performance on these samples will be reviewed and major findings will be noted in the validation records.

### *5.9.7. Evaluation of Spiked Sample Results*

Approximately 20 VOC and inorganic samples will be spiked at concentrations less than 200 μg/L. These will be sent to DataChem along with the collected groundwater samples. This will allow for an independent assessment of the laboratory's method precision so that the variability inherent to the analytical method can be accounted for separately from the sampler precision.

## 5.10. Data Analysis for Verification Factors

This section contains a list of the four primary performance verification factors to be evaluated for both the reference and field sampling technologies.

### *5.10.1. Precision*

Sampler precision will be computed for the range of sampling conditions included in the test matrix by the incorporation of replicate samples from both the standpipe and the groundwater monitoring wells in the study design. The relative standard deviation will be used as the parameter to estimate precision. The percent relative standard deviation (RSD) is defined as the sample standard deviation divided by the sample mean times 100, as shown below:

$$RSD = \frac{\sqrt{\frac{\sum (X_i - X_{mean})^2}{n-1}}}{X_{mean}} \bullet 100$$

Here $X_i$ is one observation in a set of n replicate samples, where $X_{mean}$ is the average of all observations, and n is the number of observations in the replicate set of samples. The technology RSD will be reported along with the reference RSD. We will also use a statistical test to assess whether observed differences between the reference sample precision and the technology sample precision are statistically significant. Specifically, the F-ratio test compares the variance (square of the standard deviation) of the two groups to provide a quantitative assessment as to whether the observed differences between the two variances are the result of random variability or the result of a significant influential factor in either the reference or technology sample groups [14].

### *5.10.2. Comparability*

The inclusion of reference samples, collected simultaneously with technology samples from the external sampling port of the standpipe allows the computation of a comparability-to-reference parameter. We will use relative percent difference (RPD) to represent sampler comparability for each of the target compounds in the sampling trials at the standpipe. RPD is defined as follows:

$$RPD = \frac{\left| X_{tech} - X_{ref} \right|}{\frac{\left[ X_{tech} + X_{ref} \right]}{2}} \bullet 100$$

where $X_{tech}$ is the concentration of a technology sample and $X_{ref}$ is the corresponding concentration for the reference sample. We will also use the statistical t-test for two sample means to assess observed differences between the reference and technology mean values for each sampling trial [15]. The t-test gives the confidence level associated with the assumption that the observed differences between technology and reference mean values are the result of random effects among a single population only and that no significant bias between technology and reference is observed.

### *5.10.3. Sampler Versatility*

The versatility of the technology will be evaluated by summarizing its performance over the volatility and concentration range of the target compounds as well as the range of sampling depths encountered in both the standpipe and the groundwater monitoring well trials. A sampler that is judged to be versatile operates with acceptable precision and comparability with reference samples over the range of experimental conditions included in this study. Acceptable levels are < 20% RSD and between 75% and 125% RPD values. Those samplers judged to have low versatility may not perform with acceptable precision or comparability for some of the compounds or at some of the sampling depths.

### *5.10.4. Field Deployment Logistics*

This final category refers to the relative ease of deployment of the sampler under its intended scope of application. This is also a less objective category and incorporates field observations such as personnel numbers and training required for use, ancillary equipment requirements, portability, and others.

## 6. Health and Safety Plan
This sections describes the specific health and safety procedures that will be used during the field work at both Stennis Space Center and Tyndall Air Force Base.

### 6.1. Contact Information
The SNL program manager is Wayne Einfeld, (505) 845-8314.
The Stennis Space Center standpipe facility contact is Bill Davies, (228-688-2108).
The GB Tech laboratory contact for on-site analysis is Al Watkins, (228-688-1447).
The Tyndall Air Force Base contact for well access is Chris Antworth, (850-283-6026).

### 6.2. Health and Safety Plan Enforcement
The SNL program manager will ultimately be responsible for ensuring that all verification participants understand and abide by the requirements of this HASP.

### 6.3. Site Access
At both Stennis and Tyndall, all visitors must sign-in and be badged. No specific site training will be necessary prior to testing.

### 6.4. Waste Generation
A limited amount of aqueous waste is expected to be generated. At Stennis, the VOC spiked tap water will be disposed as waste. This will be coordinated by the Stennis site contact (Bill Davies). At Tyndall, the waste will mostly be generated by well purgings and equipment decontamination. The Tyndall site contact (Chris Antworth) has agreed to handle the disposition of this waste.

### 6.5. Personal Protection
Personal protective equipment (PPE) is appropriate to protect against known and potential health hazards encountered during routine operation of the technology systems. For this verification, Level D PPE is required. Level D provides minimal protection against chemical hazards. Level D PPE will be supplied by the individual technology vendor. It consists only as a work uniform, with gloves worn, where necessary. The only requirement for this verification test is appropriate work clothes, with no shorts or open-toed shoes. The verification team will use disposable gloves when collected the reference samples, as the sample collection vials will contain small quantities of acid preservative.

### 6.6. Physical Hazards
Physical hazards associated with field activities present a potential threat to on-site personnel. Dangers are posed by unseen obstacles, noise, and poor illumination. Injuries may result from the following:

- Accidents due to slipping, tripping, or falling
- Improper lifting techniques
- Moving or rotating equipment
- Improperly maintained equipment

Injuries resulting from physical hazards can be avoided by adopting safe work practices and by using caution when working with machinery. Electrical cables represent a potential tripping hazards. When practical, cables will be placed in areas of low pedestrian travel. If necessary, in high pedestrian travel areas, covers will be installed over cables.

### 6.7. Medical Support
Both Stennis and Tyndall have on-site medical facilities that can be utilized in the event one of the verification team or the vendors need medical assistance.

### 6.8. Environmental Surveillance
The SNL program manager will be responsible for surveying the site before, during, and after the verification test. Appropriate safety and health personnel will be contacted to assist with any health or safety concerns.

### 6.9. Safe Work Practices
Each vendor will provide the required training and equipment for their personnel to meet safe operating practice and procedures. The individual technology vendor and their company are ultimately responsible for the safety of their workers.

The following safe work practices will be implemented at the site for worker safety:
- Eating, drinking, chewing tobacco, and smoking will be permitted only in designated areas;
- Wash facilities will be utilized by all personnel before eating, drinking, or toilet facility use;
- PPE requirements (See Section 6.5) will be followed.

### 6.10. Complaints
All complaints should be filed with the SNL technical lead. All complaints will be treated on an individual basis and investigated accordingly.

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## *APPENDIX A*

### *GROUNDWATER PARAMETER MONITORING PROCEDURES*

*Supplied by: Sandia National Laboratories*

*APPENDIX B*

***LABORATORY STANDARD OPERATING PROCEDURES***
*Supplied by: DataChem (Cincinnati, Ohio)*