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7. Abstract


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Part 1

# CONTENTS


1.0 INTRODUCTION . . . . . 1
- 1.1 PURPOSE AND SCOPE . . . . . 1
- 1.2 BACKGROUND . . . . . 1
- 1.3 SITE SETTING . . . . . 3

2.0 TECHNOLOGY DESCRIPTION . . . . . 5
- 2.1 BACKGROUND ON SENSOR TECHNOLOGY . . . . . 5
- 2.2 BASIC SENSOR SYSTEM . . . . . 7
- 2.3 PAWS OFFGAS SYSTEM . . . . . 8
- 2.4 IN SITU SYSTEM FOR VADOSE ZONE MONITORING WELLS . . . . . 9

3.0 DEMONSTRATION OBJECTIVES AND MEASURES OF MEETING OBJECTIVES . . . . . 11
- 3.1 CARBON TETRACHLORIDE MONITORING IN VADOSE ZONE WELLS . . . . . 11
  - 3.1.1 Objectives . . . . . 11
  - 3.1.2 Measures of Meeting the Objectives . . . . . 12
- 3.2 REAL-TIME, ON-LINE MONITORING OF SVE OFFGAS . . . . . 12
  - 3.2.1 Objectives . . . . . 13
  - 3.2.2 Measures of Meeting Objectives . . . . . 13

4.0 REGULATORY COMPLIANCE . . . . . 14
- 4.1 NATIONAL ENVIRONMENTAL POLICY ACT (NEPA) . . . . . 15
- 4.2 CERCLA . . . . . 15
- 4.3 RCRA . . . . . 15
- 4.4 CULTURAL RESOURCES REVIEW . . . . . 16

5.0 HANFORD COMPLIANCE . . . . . 16
- 5.1 SAFETY . . . . . 16
- 5.2 QUALITY ASSURANCE . . . . . 16
- 5.3 TRAINING . . . . . 16

6.0 ORGANIZATION AND RESPONSIBILITIES . . . . . 17
- 6.1 DEMONSTRATION OPERATIONS . . . . . 17
- 6.2 PROJECT ENGINEER . . . . . 17
- 6.3 FIELD TEAM LEADER . . . . . 17
- 6.4 PRINCIPAL INVESTIGATOR . . . . . 17

7.0 DESCRIPTION OF TASKS AND PROCEDURES . . . . . 19
- 7.1 CARBON TETRACHLORIDE MONITORING IN VADOSE ZONE WELLS . . . . . 19
- 7.2 REAL-TIME, ON-LINE MONITORING OF SVE OFFGAS . . . . . 20

# CONTENTS

8.0 SITE SERVICES REQUIREMENTS ..... 20
8.1 CARBON TETRACHLORIDE MONITORING IN VADOSE ZONE WELLS ..... 20
8.2 REAL-TIME, ON-LINE MONITORING OF SVE OFFGAS ..... 21

9.0 DEMONSTRATION SCHEDULE ..... 21

10.0 REFERENCES ..... 22

APPENDIXES:

A - PROCEDURE FOR CARBON TETRACHLORIDE MONITORING IN VADOSE ZONE WELLS ..... A-1

B - PROCEDURE FOR REAL-TIME, ON-LINE MONITORING OF SVE OFFGAS ..... B-1

C - WELLS FOR PAWS MONITORING ..... C-1

FIGURES:

1. Hanford Site Map and Location of the 200 West Area ..... 2
2. Site Map of the 200 West Area ..... 4
3. Schematic of Surface Acoustic Wave (SAW) Sensor with Absorptive Polymer Coating ..... 6
4. Expected Application of the In Situ Probe for Monitoring in Vadose Zone Wells ..... 10
5. Field Demonstration Organization ..... 18

TABLE:

1. Task/Milestone Summary for PAWS Sensor System ..... 21

# 1.0 INTRODUCTION

## 1.1 PURPOSE AND SCOPE

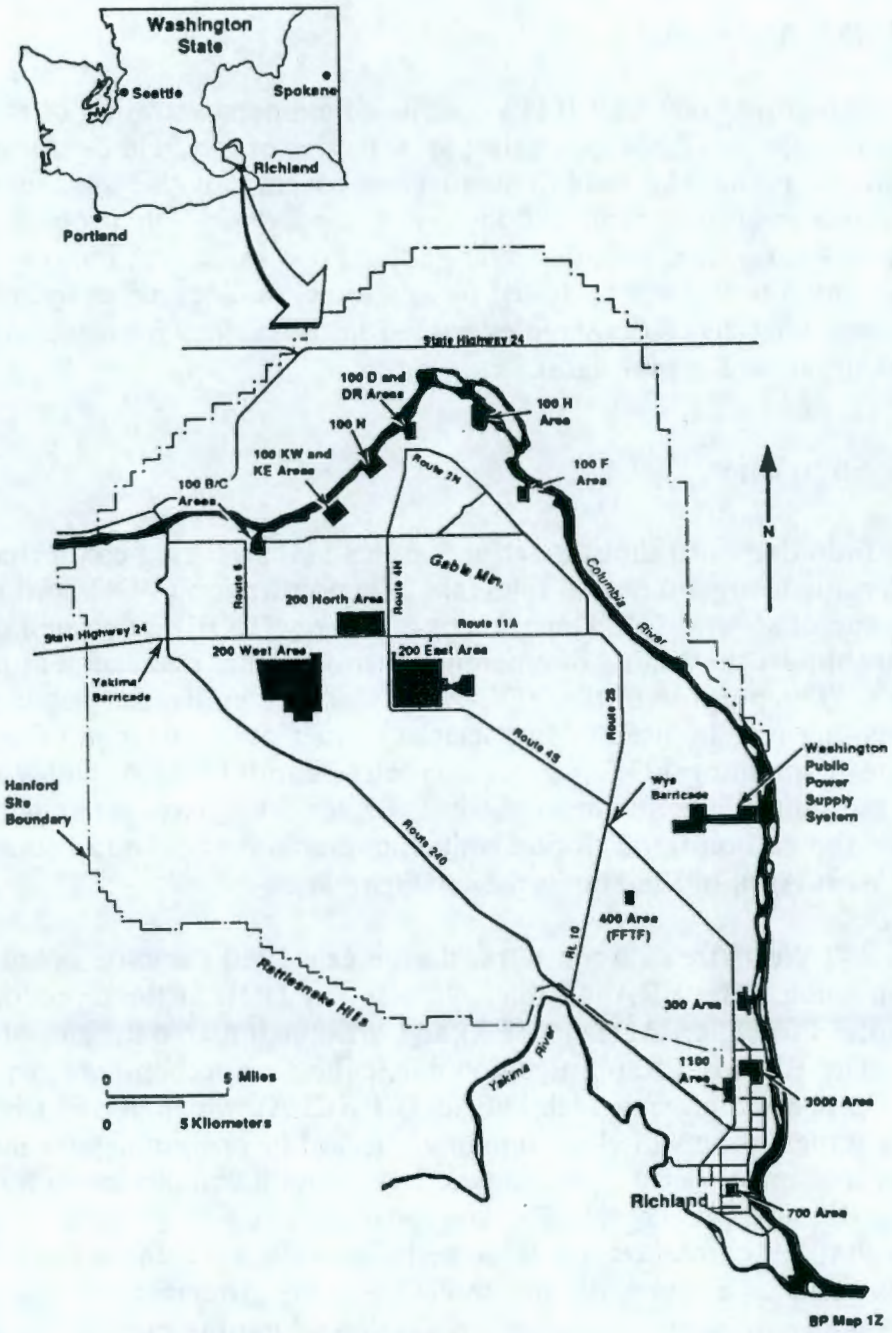
This integrated test plan (ITP) describes field demonstration of two Portable Acoustic Wave Sensor (PAWS) systems; all activities of the field demonstration will comply with this plan. This field demonstration covers only the tasks identified herein. The field demonstration for this ITP involves using a down hole probe for in situ monitoring in 4- , 6- , and 8-in. diameter vadose zone wells. An improved system for aboveground monitoring will be tested for real-time, on-line, offgas monitoring as well as for comparison analysis of gas samples pushed to the surface from the in situ probe (to compare to the in situ sensor data).

## 1.2 BACKGROUND

The field demonstrations described in this ITP are being conducted as part of the Volatile Organic Compound-Arid Integrated Demonstration (VOC-Arid ID). The VOC-Arid ID is one of several U.S. Department of Energy (DOE) integrated demonstrations designed to support the testing of emerging environmental management and restoration technologies. The purpose of the VOC-Arid ID is to identify, develop, and demonstrate technologies that may be used to characterize, remediate, and/or monitor arid or semiarid sites containing VOC (e.g., carbon tetrachloride) with or without associated metal and radionuclide contamination. Initially, the VOC-Arid ID activities will focus primarily on the carbon tetrachloride contamination and associated contamination found in the 200 West Area of the Hanford Site (Figure 1).

The 200 West Area carbon tetrachloride expedited response action (ERA) is currently on-going. The ERA is being conducted by DOE at the direction of the U.S. Environmental Protection Agency (EPA) and Washington Department of Ecology (Ecology). The ERA is a removal action under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), which allows ERA to be taken where early remediation will abate imminent hazard or prevent significantly increased degradation that might occur if action was delayed until completion of a remedial investigation/feasibility study (RI/FS) and record of decision (ROD). The ERA is based on concern that the carbon tetrachloride residing in the soils under the 200 West Area continues to serve as a source of contamination to the groundwater. Thus, the purpose of the ERA is to minimize contaminant migration within the unsaturated soils in the 200 West Area by removing the carbon tetrachloride. The proposed action for removing the carbon tetrachloride is to use soil vapor extraction (SVE) with aboveground treatment, using a vacuum system and a network of soil vapor extraction vadose wells.

Figure 1. Hanford Site Map and Location of the 200 West Area.



Although the VOC-Arid ID and the ERA are separate projects, by conducting VOC-Arid ID demonstrations at the ERA site, both projects benefit. The ERA site provides a large source of contaminant at a controlled, characterized location. The VOC-Arid ID provides for additional characterization of the contaminant site as well as producing better, faster, and/or cheaper environmental restoration technologies. By combining these two projects, the cost effectiveness of each project rises significantly.

## 1.3 SITE SETTING

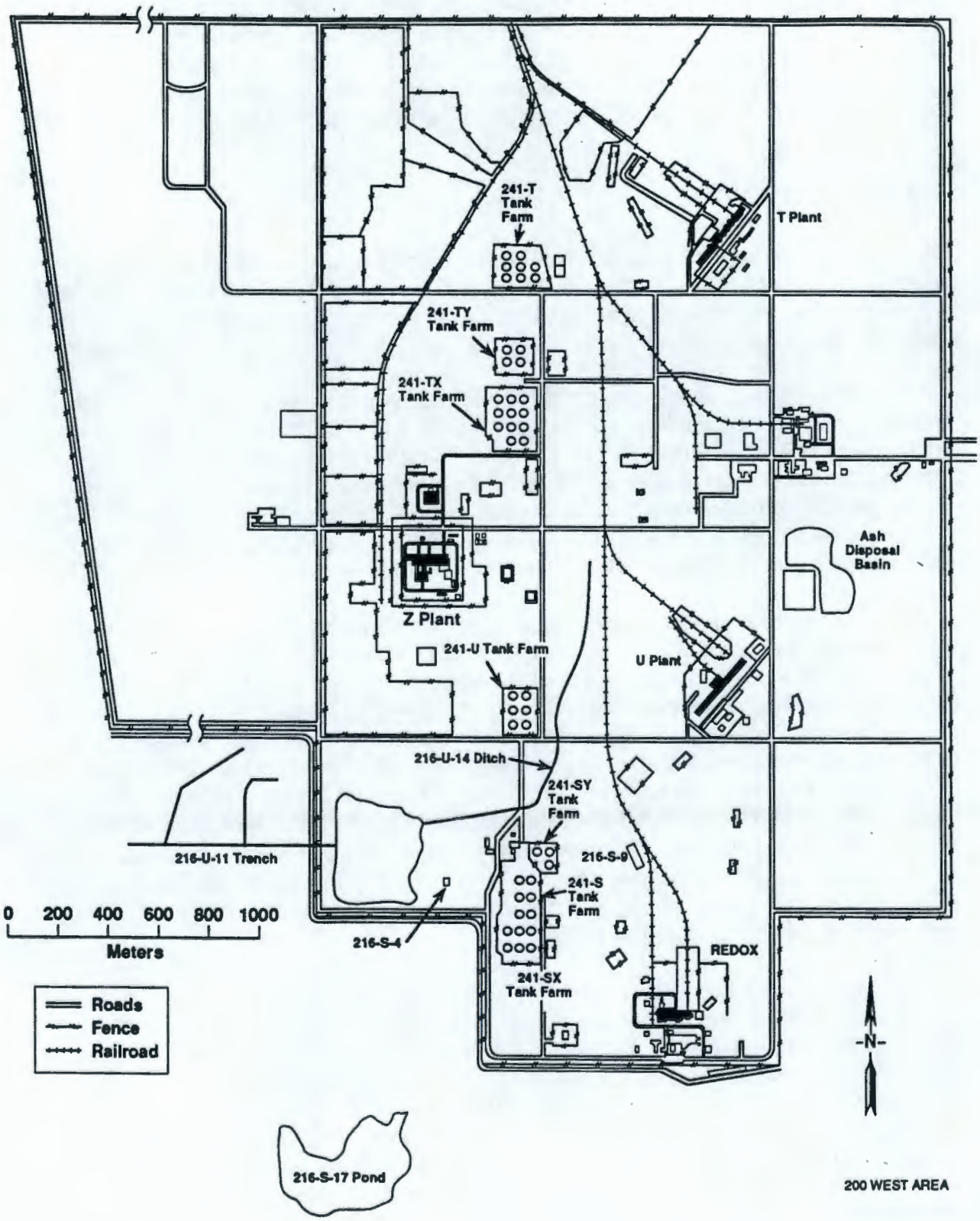
Field testing will be conducted in the vicinity of three carbon tetrachloride disposal sites (216-Z-1A Tile Field, 216-Z-9 Trench, and 216-Z-18 Crib). This field demonstration involves using a downhole probe for in situ monitoring in 4- , 6- , and 8-in. diameter vadose zone wells.

The upper geologic unit of the 200 West Area consists of two facies: (1) coarse-grained sand and granule to boulder gravel from which matrix is commonly lacking, and (2) fine- to coarse-grained sand and silt that commonly displays normally graded rhythmites a few centimeters to several decimeters thick. In general, this unit is composed of approximately 50% sands and gravels, 45% cobbles, and 5% boulders. This unit ranges in thickness from 6 to >60 m in the 200 West Area. It is underlain by 1.5 to 18 m of silts and fine sands, which in turn are underlain by another gravel unit.

Carbon tetrachloride vapor concentrations observed throughout the 200 West Area in 1991 ranged from less than detectable to several hundred parts per million by volume in the vadose zone. Observed concentrations are highest in the vicinity of, and west of, three sites (216-Z-9 Trench, 216-Z-1A Tile Field, and 216-Z-18 Crib) where carbon tetrachloride was discharged to the soil column (Figure 2). However, the observed vapor concentrations may vary with time and appear to be influenced by fluctuations in the barometric pressure (DOE-RL 1991). Carbon tetrachloride breakdown products, chloroform and methylene chloride, have also been observed in soil samples in trace amounts. Other substances that have been identified, in trace amounts, in at least one soil sample from the 200 West Area include benzene; fluoromethane; 1,1-dichloroethylene; trans-1,2-dichloroethylene; trichlorofluormethane; methyl isobutyl ketone; and toluene (DOE-RL 1991).

Many of the liquid waste streams discharged to the soil column in the 200 West Area since 1944 contained radionuclides. The primary radionuclide components of the aqueous and organic liquids discharged to the three carbon tetrachloride disposal sites were plutonium and americium. The plutonium contamination extends approximately 30 m beneath the 216-Z-1A Tile Field; the lateral spread is limited within a 9-m-wide zone around the perimeter of the tile field. Other radionuclides, such as radioactive isotopes of cesium, cobalt, hydrogen, iodine, strontium, and technetium, have been discharged to the soil column beneath the 200 West Area. In addition, radon gas occurs naturally in Hanford soils.

Figure 2. Site Map of the 200 West Area.



# 2.0 TECHNOLOGY DESCRIPTION

## 2.1 BACKGROUND ON SENSOR TECHNOLOGY

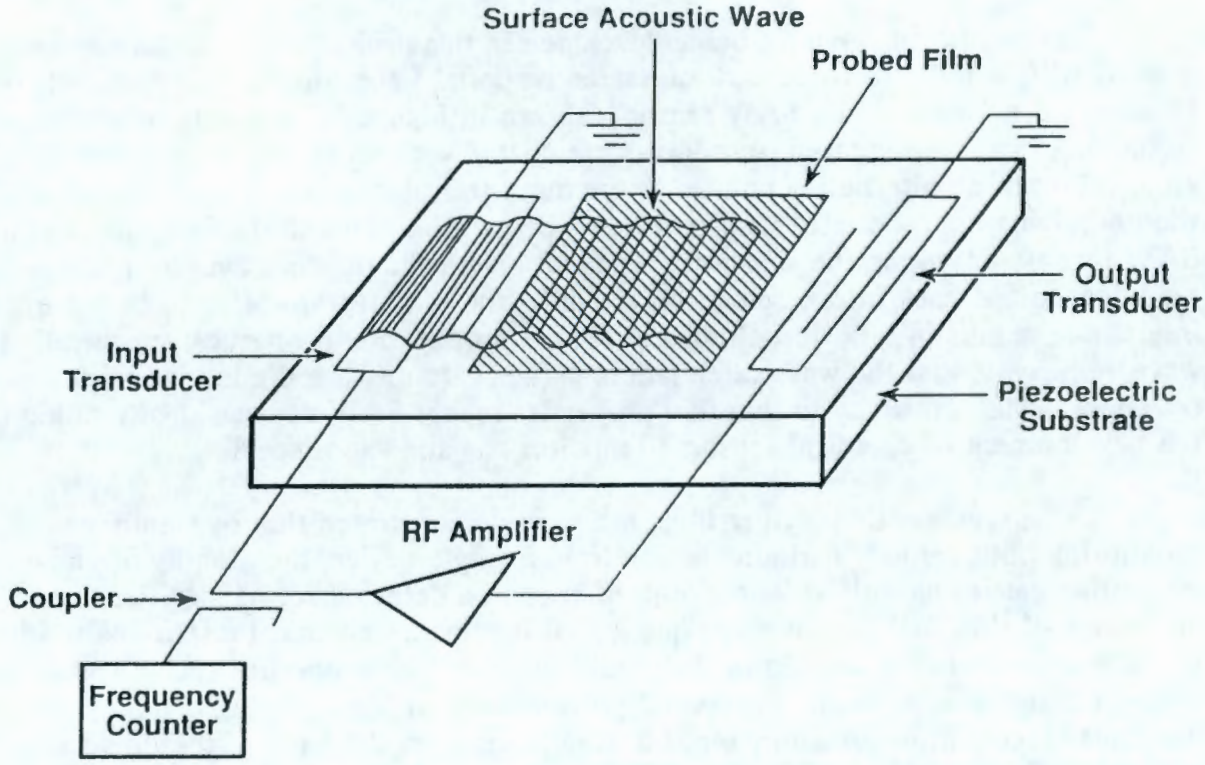
The monitoring systems being developed in this project utilize surface acoustic wave (SAW) sensors (a trademark of Sandia National Laboratories, Albuquerque, New Mexico). A schematic of a SAW sensor is shown in Figure 3. A quartz substrate containing two interdigitated transducers are coated with an absorptive polymer film. Application of an alternating voltage to the input transducer generates a strain field in the underlying quartz due to its piezoelectric properties. This strain field launches a SAW that travels along the substrate, interacting with the polymer overlayer, before being converted back into an electrical signal by the output transducer. The wave/film interaction results in a perturbation of the wave propagation properties, specifically the wave velocity, v, and the wave attenuation, $\alpha$ (i.e., rate of wave diminution with distance). This sensitivity to thin film properties makes SAW devices ideally suited for the development of chemical sensors to monitor gas and vapor species.

Using viscoelastic polymer films, we have demonstrated that by simultaneously monitoring both velocity and attenuation from a single device, the identity of an isolated molecular species as well as its concentration can be determined. A significant advantage of this dual output technique is that it provides chemical discrimination based on differences between species in the modification of film properties such as mass and viscoelasticity. For example, for several polymers tested (e.g., polyisobutylene), this molecular recognition capability tends to discriminate on the basis of the liquid density of the absorbing species. This makes these films ideally suited for discriminating relatively high density chlorinated hydrocarbons (1.4 to 1.6 g/mL) from lower density nonchlorinated species (0.6 to 1.0 g/mL). A patent on this unique capability was granted on December 31, 1991 (see References below).

In practice, these two responses are measured by using the SAW device as the feedback element of an oscillator circuit. In this configuration, relative frequency changes ($\Delta f/f$ where f is frequency) are proportional to relative velocity changes ($\Delta v/v$), enabling a frequency counter to be used to monitor velocity. Wave velocity can be resolved to an accuracy of approximately 0.01 ppm (1 Hz noise out of 97 MHz operating frequency). Insertion loss can be evaluated by measuring the power level after the SAW device using a detector to convert the RF power to a DC voltage (not shown in Figure 1). Noise levels as low as 0.0004 dB have been measured using this technique.

By utilizing elastomeric polymers (e.g., polyisobutylene) as the absorptive layers for these sensors, the rapid diffusional properties result in rapid (few second) and reversible sensor responses. This enables the sensors to be used online to continuously monitor concentration with time. The reversibility of the absorption enables sensor baseline to be evaluated on line by periodically removing the chemical from the gas stream using a carbon-based scrubber. Minimum detection limits for typical chlorinated hydrocarbons are approximately 10 to 50 ppmv using this scrubber method to evaluate baseline.

Figure 3. Schematic of Surface Acoustic Wave Sensor with Absorptive Polymer Coating.



## 2.2 BASIC SENSOR SYSTEM

The basic PAWS system consists of two SAW devices contained in a test case and configured with appropriate oscillator circuitry, data acquisition and control electronics, and environmental sampling. The system can be configured with a single, polymer-coated device in the test case acting as an independent sensor or dual-coated devices with one being the sensor and the other acting as a reference. When using reference devices, each SAW component is part of a separate oscillator with the sensing device exposed to the chemical while the reference is isolated. The resultant frequency from the sensor oscillator is mixed with the reference frequency to obtain a difference frequency that is compensated for temperature-induced baseline drift. The sensor device is challenged with known concentrations of the chemical of interest to determine the calibration coefficient. Wave velocity and attenuation for the device are measured. Either response can be used to determine chemical concentration while the ratio of responses can be used to verify the identity of an isolated chemical species.

Other elements of the radio frequency (RF) oscillator electronics are high-gain, low-noise amplifiers, a low-pass filter, impedance matching for the SAW transducers, and couplers to remove RF signals for frequency and power measurements. Since the viscoelastic properties used to obtain the two independent device responses also change with temperature, some thermal control is required to overcome the resulting temperature sensitivity. Thermal stability is provided by an electronic feedback system to control absolute and relative temperature fluctuations in the test case and frequency mixing to remove (to first order) temperature-dependent response in the two similar devices. Accurate temperature monitoring is possible from resistance measurements directly on the SAW devices or from thermistors mounted in the test case. Bridge circuits are added to convert resistance into voltage for measurement. All components of the oscillator electronics, the thermal management and measurement system, and the device test case itself are integrated onto two personal computer boards.

The environmental sampling system consists of a pump to move the gaseous species across the sensor, a bypass line with a pressure relief valve to provide constant pressure on the sensing line, and a three-way solenoid valve to direct the chemical through a carbon-based scrubber. The scrubber is used to establish sensor baseline on demand and in place. When the gas containing the chemical is passed through the scrubber, the volatile organic species to be detected is removed but with little perturbation to the line pressure or relative humidity. System stability (i.e., drift rate) dictates how often the sensor baseline must be reevaluated.

Data acquisition and system control is provided by a digital electronic board and computing system linked via a serial interface. The digital board contains (1) a frequency counter to monitor oscillation or mixed frequency, (2) multiplexed 16-bit, analog-to-digital conversion for measuring up to eight voltages from RF detectors and temperature sensors; (3) digital outputs (maximum of eight) used to activate relays for pump power and solenoid valve switching; (4) a control microprocessor and associated random access memory (RAM) programmed for single command data acquisition of all relevant parameters; and (5) a serial communications port capable of RS-232 or RS-422 protocol. A DOS-based computer is used to communicate with the digital electronic board,

analyze the data, and display the pertinent parameters in real-time. Software routines are written in the LabWindows (a trademark of National Instruments) domain. The system, which uses a simple setup routine, automatically turns on pumps and scrubbers, acquires and stores data, computes chemical concentrations based on frequency shifts or attenuations and the related calibration coefficients, and analyzes frequency to attenuation ratios. Software corrections for temperature compensation are also implemented. A small notebook computer is adequate for PAWS system implementation.

## 2.3 PAWS OFFGAS SYSTEM

For offgas monitoring, the SAW sensor and oscillator circuitry, data acquisition and control electronics, environmental sampling hardware, and associated power conditioners are housed in a single modular package with a total volume of approximately 0.4 $ft^3$. Communication to a notebook computer uses an RS-232 serial interface since drive requirements are small. The power conditioning enables any 12-V power source, including a battery (e.g., car battery) for those sites where alternating current (AC) line power is not available, to be used to power the PAWS module.

Gas inlet and outlet ports with 1/8-in. Swagelock (a trademark of Swagelock) connections are provided on the front of the module. Gas is delivered to the PAWS system through tubing plumbed directly into the existing vacuum extraction or wellhead lines. Exhaust following chemical detection can be recirculated back into the original gas stream, treated to remove the contaminant (e.g., with GAC), or released to the atmosphere as appropriate. Onsite calibration of the sensor is possible through use of bottled gasses containing calibrated concentrations. Comparisons to other measurement techniques, such as grab sampling and gas chromatograph (GC) analysis, are possible through simple plumbing reconfigurations.

The operating temperature range of the electronics can be quite severe for this phase of the program. Outdoor temperatures can range from approximately -10$^{o}$C to 40$^{o}$C. Of greatest importance are the gas and SAW device temperatures. Ideally, the two should be very close together to avoid thermal transients; however, the sensor needs to be maintained a few degrees above the gas to avoid condensate forming on the polymer. As temperature increases, vapor species become more volatile and their absorption is reduced resulting in a loss of sensitivity. Typically, this sensitivity loss is about a factor of two per 10$^{o}$C.

Offgas monitoring has been previously performed for 100 to 1,600 ppm concentrations of carbon tetrachloride using SAW devices coated with polyisobutylene. This polymer has a reasonable but not large affinity for the carbon tetrachloride; however, its low sensitivity to water vapor makes it particularly useful for well monitoring. Also, with the PAWS system thermal stability and noise characteristics, detection of carbon tetrachloride with such a device is precise and accurate.

The computational portions of the PAWS system can easily be integrated into existing hardware at offgas monitoring sites; however, some modifications for differences

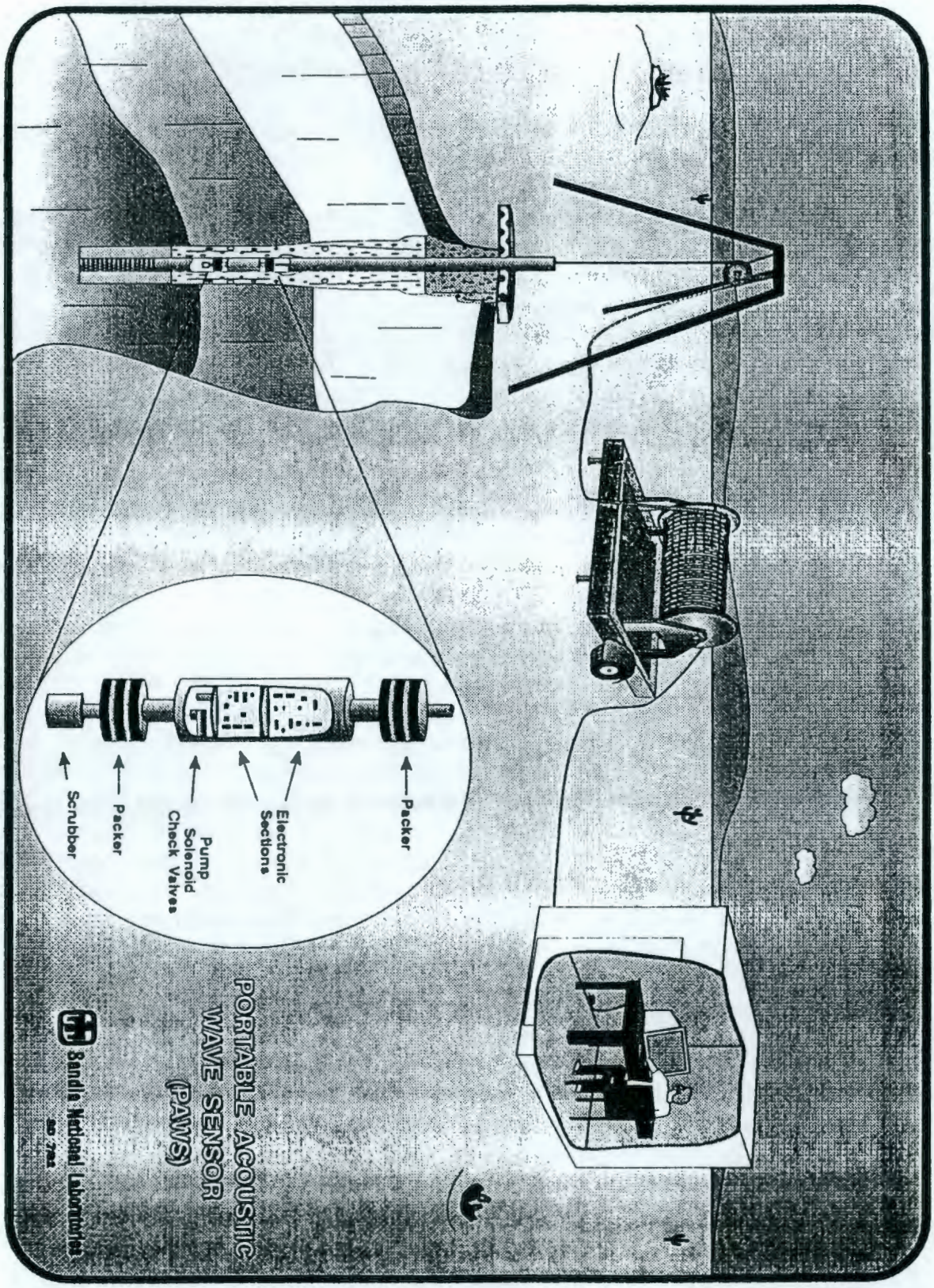
in computer architecture and display capability may be required. The PAWS system also lends itself to simple digital readout of chemical concentration as a function of time with only minor rearranging of software.

## 2.4 IN SITU SYSTEM FOR VADOSE ZONE MONITORING WELLS

Vadose zone monitoring can be implemented in one of two ways: (1) packaging the sensor, electronics, and gas handling hardware and inserting them into the monitoring well at a point above the ground water for in situ analysis; or (2) pulling a gas sample from the well through a long tube and delivering it to an aboveground sensor package. This project focuses on the former; however, this in situ system is configured to enable a sample to be pushed to the surface for comparison with aboveground analysis (e.g., PAWS offgas system, portable GC).

The PAWS downhole system is illustrated in the cartoon in Figure 4. The probe, constructed so that it can be placed into 4-in. and larger wells, houses the same components as the PAWS module used for off-gas monitoring (see Section 2.3). RF oscillator electronics and data acquisition/control electronics are placed in separate, shielded compartments within the probe to reduce interference during measurements. All environmental sampling hardware is contained in a third isolated section. This sampling system is configured to enable a portion of the sample gas to be sent to the surface using a 1/8-in. teflon tube. The probe superstructure consists of a 2.5-ft long anodized aluminum cylinder with the three isolated internal regions. An anodized aluminum cover protects the electronic components. Access to the well environment is achieved with ports at the top and bottom that contain frits to prevent particulate contamination inside the chamber. Packers are attached above and below the main section and are sealed against the well by application of 25 to 50 $lb/in^2$ on a gas line from the surface. The bottom packer can be separated from the main section using a long gas line and tether to enable longer sections of screened wells to be packed off. The pressurized line from the surface has a quick-connect to the probe while a pressure regulated 12-V pump is used to inflate the packers. The gas handling equipment also contains a purge system consisting of a pump attached to a fritted port above the bottom packer, a one-way valve, and a port that exits the probe above the top packer. A small purge pump can be housed in the main probe section or a larger pump can be housed in a separate section that is connected to the main probe by a gas line (to go to the vent above the top packer), a pair of wires for power, and a tether. Having a separate section enables higher capacity pumps to be used for larger diameter wells. This separate purge pump section can be used to push 10 to 20 L/min out of the well to purge the well prior to analysis. The probe is lowered into the well using a portable tripod, a 12-V electric winch, and a braided cable. Connections to the computing system and power supply at the surface use a cable containing four twisted shielded pairs. The serial communications between the probe and the up-hole computer requires use of the RS-422 interface as long line lengths may be necessary. Both RS-232 and RS-422 interface capability is designed into the data acquisition electronics.

Figure 4. Expected Application of the In situ Probe for Monitoring in Vadose Zone Wells.



# 3.0 DEMONSTRATION OBJECTIVES AND MEASURES OF MEETING OBJECTIVES

## 3.1 CARBON TETRACHLORIDE MONITORING IN VADOSE ZONE WELLS

### 3.1.1 Objectives

The test objectives for the field demonstration of the PAWS downhole system for carbon tetrachloride are presented below. Overall system performance will be compared to existing baseline technologies.

A. Evaluate performance of PAWS downhole system.

1. Determine ease of system transport to site and setup.
2. Evaluate problems with lowering probe into target monitoring wells to depths of interest.
3. Evaluate ability to achieve full operation of system including ability to pack off individual screened intervals for isolation, purge isolated zone, and acquire sensor responses during testing.
4. Evaluate PAWS downhole system effectiveness for in situ monitoring of carbon tetrachloride concentrations.
5. Determine capability of PAWS downhole system to push a sample to the surface for comparative monitoring.

B. Determine time requirements for PAWS downhole system.

1. Determine time required to perform a single downhole measurement including times to lower probe into well, pack off desired region, purge isolated region, achieve effective sensor operation (e.g., achieve stable device temperature), perform the measurement, and remove probe from well.
2. Evaluate ability of downhole PAWS system to provide real-time response to vapor concentrations.
3. Determine maximum time limit between baseline evaluations.

### 3.1.2 Measures of Meeting the Objectives

The following parameters will be measured to demonstrate the test objectives have been met.

A. Measure performance of PAWS downhole system.

1. Record any problems associated with system transport to site and set up.

2. Record any problems with lowering probe into target monitoring wells (4- , 6- , and 8-in. diameter) to the depths of interest. Identify appropriate solutions.
3. Record any problems associated with packing off screen intervals and purging the isolated zones. Record sensor responses (frequency shift, attenuation, and temperature).
4. Identify sensor baseline through use of scrubber and measure sensor drift rates. Confirm that the minimum detectable limit for carbon tetrachloride concentration is less than 100 ppm.
5. Record any problems associated with pushing a sample to the surface for comparative monitoring. Achieve an agreement within 20% between the PAWS downhole measurement of carbon tetrachloride concentration and an independent PAWS surface measurement as well as independent verification by an accepted baseline method.

B. Record time requirements for PAWS downhole system.

1. Measure time required to lower probe into well, pack desired region, purge isolated region, achieve effective sensor operation (e.g., achieve stable device temperature), record sensor responses, and remove probe from the well. Achieve completion of all operations in <2 hr.
2. Record response delay times of system after baseline evaluations. Real-time response is achieved if delays to full signal are <10 sec.
3. Measure maximum time limit between baseline evaluations. Achieve a minimum of 10 min between baseline evaluations.

## 3.2 REAL-TIME, ON-LINE MONITORING OF SVE OFFGAS

### 3.2.1 Objectives

The PAWS system test objectives for monitoring carbon tetrachloride vapors in the SVE off-gas stream are to:

A. Evaluate performance of PAWS system.

1. Determine the ability of PAWS sensor system to interface into the offgas stream and achieve full operation.
2. Evaluate the effectiveness of PAWS system for on-line analysis of the offgas stream.
3. Determine the system capability to accurately evaluate the concentrations of carbon tetrachloride vapors and determine the sensitivity levels.

4. Determine any modifications to the system that may be needed to make it a complete, portable, real-time monitoring instrument for onsite use by Hanford personnel.

B. Determine total cost of a field-usable PAWS system.

C. Determine time requirements for PAWS operations.

1. Evaluate the ability of the PAWS system to gather real-time information and to operate continuously without significant problems.
2. Determine the maximum time limit between baseline evaluations.
3. Determine the time required to make any system modifications and finalize hardware for a field-usable instrument.

### 3.2.2 Measures of Meeting the Objectives

The following parameters will be recorded or measured to demonstrate that the test objectives have been met.

A. Measure the performance of PAWS system in the SVE offgas stream.

1. Identify and record any changes that need to be performed to integrate and operate the PAWS system with the offgas stream.
2. Record the operations of the system an ensure that it responds only to changes in chemical concentrations (periodically reevaluate baseline). Fluctuations in environmental parameters should have little effect on sensor response. Record any anomalies.
3. Measure the concentrations of the carbon tetrachloride vapors in the offgas stream. Achieve agreement within 20% between independently measured concentrations and PAWS data. Measure the PAWS baseline noise and the drift in the sensor baseline.
4. Record information about modifications that could improve performance of PAWS system. Special attention should be paid to system robustness and user-friendly operations. Solicit help from the field team leaders.

B. Record the costs required to fabricate a complete PAWS system for off-gas monitoring.

C. Measure and record times for PAWS operations and estimate time needed of hardware modifications.

1. Record PAWS response delay time following baseline evaluations. Measure time lengths for continuous PAWS operation.

2. Observe the sensor baseline drift rate and measure the maximum time limit between baseline evaluations.
3. Estimate the time required for hardware modifications of the PAWS system before a complete instrument can be transferred for Hanford use.

# 4.0 REGULATORY COMPLIANCE

This section identifies the regulatory compliance requirements for this field demonstration. The major requirements for the demonstration are derived from the National Environmental Policy Act (NEPA); the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA); and the Resource Conservation and Recovery Act (RCRA). Because of the limited nature of residuals from this demonstration, no requirements under the Clean Air Act, Clean Water Act, or other federal or state environmental laws are specifically applicable.

## 4.1 NATIONAL ENVIRONMENTAL POLICY ACT

The NEPA, 42 USC 4321 et seq., is the basic federal charter for protecting the nation's environment. NEPA's focus is to ensure that federal agencies such as DOE give appropriate consideration to environmental impacts in their decisionmaking.

On April 30, 1992, DOE determined that VOC-Arid ID sensor development and demonstration activities fit within a typical class of action currently available for a categorical exclusion listed in Subpart D of DOE's NEPA implementing procedures, 10 CFR 1021. The testing and demonstration of the PAWS technology as described in this integrated test plan are specifically discussed in the Information Bulletin supporting that categorical exclusion approval and the minimal environmental impacts that may be caused by these activities are clearly within the range of impacts assumed in DOE's categorical exclusion approval. Accordingly, no further NEPA compliance documentation is required for demonstration of the PAWS technology.

## 4.2 CERCLA

The CERCLA, 42 USC 9601 et seq., is designed to manage the unplanned, uncontrolled releases of hazardous substances. In particular, CERCLA is the governing framework for the ERA being conducted in the 200 West Area at Hanford to remove carbon tetrachloride from the soil vadose zone.

This PAWS field demonstration will be conducted around the ERA site and in coordination with ERA activities. The ERA is described in document (DOE-RL 1991).

Depending on test results, some of the data generated may contribute to ERA site characterization. The objectives and quality objectives for ERA site characterization are detailed in the ERA site characterization work plan (Rohay 1991a for FY92, and Rohay et al 1993 for FY93).

### 4.3 RCRA

Subtitle C of RCRA, 42 U.S.C. 6921-6939b, establishes a comprehensive program to regulate newly generated hazardous waste. Administered by Ecology and EPA, RCRA Subtitle C requirements are contained in Washington Administrative Code (WAC) Chapter 173-303, and in 40 CFR Parts 260 through 272 and apply to the generation, accumulation, treatment, storage, and disposal of hazardous waste. No solid, hazardous, or mixed wastes are expected to be generated by this test. In the event such wastes are generated, they will be managed in accordance with applicable RCRA requirements, including Westinghouse Hanford Company (WHC) Environmental Investigation Instruction (EII) 4.2, Interim Control of Unknown, Suspected Hazardous, and Mixed Waste and EII 4.3, Control of CERCLA and Other Past Practice Investigation Derived Waste.

### 4.4 CULTURAL RESOURCES REVIEW

The test sites were determined to have no historic properties as discussed in Cultural Resources Review, #89-600-014.

## 5.0 HANFORD COMPLIANCE

This section identifies Hanford compliance areas for this field demonstration.

### 5.1 SAFETY

Activities under this integrated test plan will be governed by the existing site-specific health and safety plan for the Arid ID well characterization.

### 5.2 QUALITY ASSURANCE

All work on the Hanford Site is subject to the requirements of DOE Order 5700.6C, Quality Assurance (DOE-RL 1991), which establishes broadly applicable quality assurance (QA) program requirements.

To ensure that the field demonstration activities are consistent with DOE-RL Order 5700.6C, Quality Assurance, all work will be performed in compliance with Westinghouse Hanford's QA manual (WHC 1988) and with applicable procedures outlined in the QA program plan (WHC 1990). This QA program plan describes the various plans, procedures, and instructions that will be used by WHC to implement the requirement of DOE-RL Order 5700.6C.

The objective of the test plan and the appendices is to ensure that the data obtained and the conclusions drawn are sufficiently accurate and reliable to support decisions associated with the evaluation of the demonstration.

### 5.3 TRAINING

With the exception of high carbon tetrachloride concentrations, no special health and safety considerations are expected. No special training will be required; however, standard training, including the Occupational Safety and Health Administration (OSHA) training for personnel working at hazardous waste sites (40-hr hazardous waste worker training), participation in a medical surveillance program, plus all relevant training required to be on the Hanford Site, will be required for any personnel entering the exclusion zone. Should conditions warrant the use of supplied air, appropriate training (e.g., equipment and mask fit) and qualifications will be required.

Safety training requirements are listed in the site-specific health and safety plan. Security requirements are consistent with those needed for visitor access to the test site.

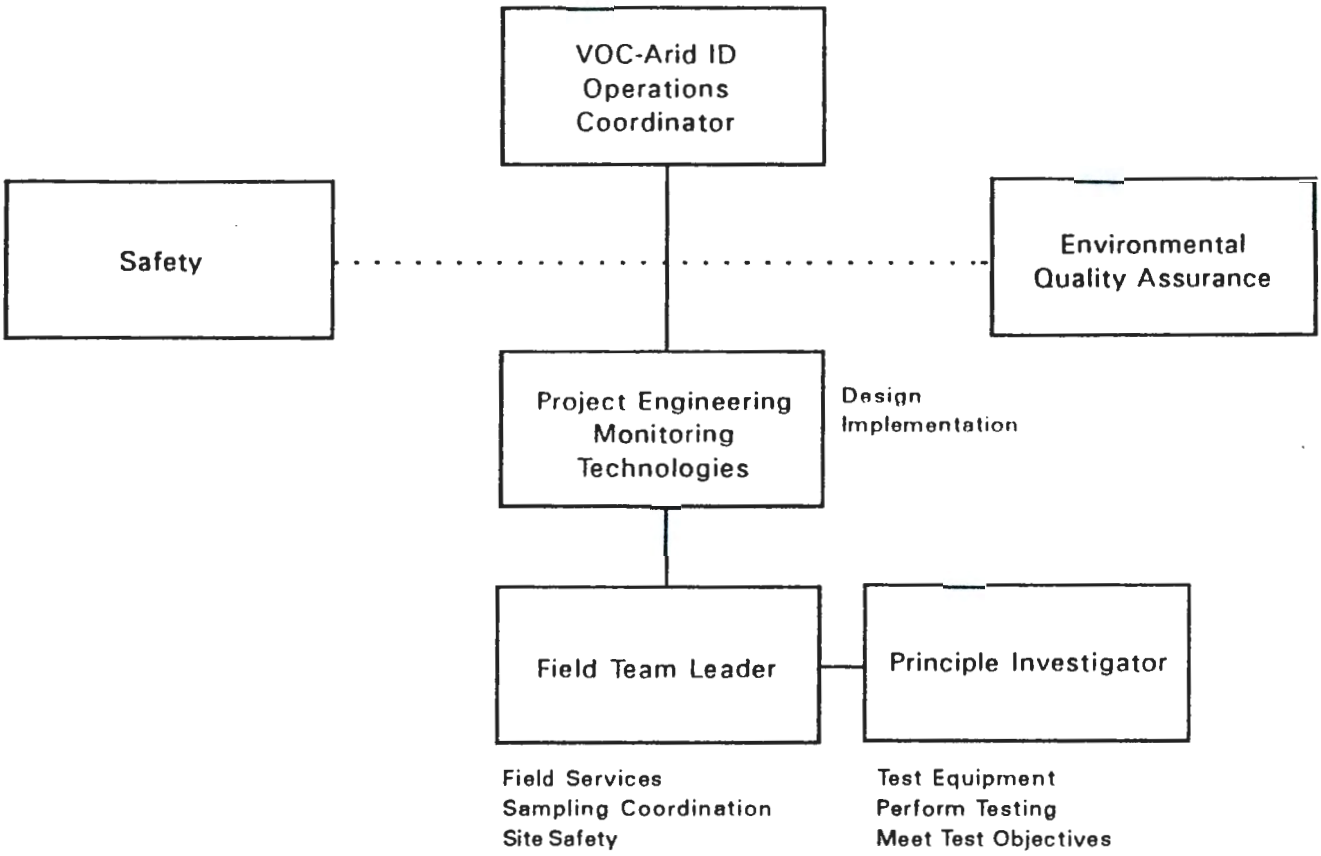
## 6.0 ORGANIZATION AND RESPONSIBILITIES

The field test will be performed by Demonstration Operations working with the principal investigator (Figure 5). General organization and responsibilities for the VOC-Arid ID, Demonstration Operations and the ERA can be found in their respective Project Management Plans. Organization for the field demonstration is shown in Figure 5. General responsibilities and specific responsibilities for the field demonstration follow.

### 6.1 DEMONSTRATION OPERATIONS

Demonstration Operations is responsible for site characterization, engineering and conduct of field demonstrations. Demonstration Operations ensures regulatory and DOE/Hanford compliance for field demonstration activities.

Figure 5. Field Demonstration Organization.



## 6.2 PROJECT ENGINEER

The project engineer is responsible for coordinating with the principal investigators and the field team leaders and ensuring the availability of needed equipment and materials.

## 6.3 FIELD TEAM LEADER

The field team leader is responsible for overall technical field management of the project and control of site access. All onsite personnel report through the onsite field team leader to accomplish their work.

## 6.4 PRINCIPAL INVESTIGATOR

The principal investigator will:

- ensure that the test objectives are met
- conduct the testing through coordination with the field team leader
- provide all monitoring equipment to be tested
- provide personnel to set up the equipment, perform the test, and analyze the results
- prepare a performance evaluation report that reviews the results of the testing related to each objective.

# 7.0 DESCRIPTION OF TASKS AND PROCEDURES

Activities of this integrated test plan include testing of the sensor system for offgas monitoring and testing of the downhole probe for in situ monitoring in vadose zone monitoring wells. The description of tasks is in the sequence in which the tests will be performed. The test site will be restored after the field demonstration. Restoration will include removal of all equipment and temporary services not necessary for other activities either ongoing or anticipated at the test site.

## 7.1 CARBON TETRACHLORIDE MONITORING IN VADOSE ZONE WELLS

At least six wells with one or more screened intervals in the vadose zone have been identified by the project engineer and field team leader prior to initiation of the field demonstration. These wells have carbon tetrachloride as the major contaminant, with concentrations in excess of 100 ppm (variable with site conditions). At least one well each with diameters of 4, 6, and 8 in. has been selected. In addition, wells with

multiple screened intervals have been chosen to test the systems ability to monitor screened intervals that are not at the bottom of the well. To prevent any possibility of contamination of the probe during this test, wells outside of the exclusion zone were preferred. If possible, baseline information from previous grab sample analysis on concentrations of carbon tetrachloride and the various co-contaminants in the selected wells will be provided to the principal investigator prior to testing. In addition, comparison testing (e.g., based on access to a GC for analysis of samples pushed to the surface by the probe) during the field demonstration would be helpful to verify the accuracy of the acoustic wave sensor.

A detailed procedure for the actual field demonstration tasks is provided in Appendix A. This downhole in situ test will involve the system described in Section 2.4. This system will be calibrated in the laboratory at Sandia Laboratories and then disassembled for transport to the Hanford Site. Upon arrival at Hanford, the major components (e.g., probe and packer module, cabling and plumbing, computer and power supplies) will be reassembled. Assembly includes attaching the purge pump section (if used) and packers to the main probe section, attaching the electrical and gas connections to the probe using the quick-connections, and attaching the electrical cable to the power supply box and to the RS-232 to RS-422 converter attached to the computer. The well will be opened and tested for contaminant concentrations above the action level in the vicinity of the well. If needed, personnel working near the wellhead will put on protective gear. The tripod will be set up over the well and the probe will be attached to the cabling of the winch system and lowered into the well to the desired depth. The gas line will be attached to the air compressor and the packers will be inflated to seal off a section of the well. The purge system will be activated and operated for sufficient time to purge the gas in the well bore. The sensor line may be operating during this purge to monitor the rise in contaminant concentration. The sensor line will always be operated after the purge is completed to monitor the concentration achieved after the purge cycle. For some runs, a gas sample will be sent to the surface for comparison with the in situ analysis. After completion of the test cycle, the packers will be deflated and the probe will either be moved to a new depth (for wells with multiple-screened intervals) or will be removed from the well and prepared for testing in a new well.

After completion of all tests, the probe will be tested for contamination and, if declared free of contamination, disassembled and prepared for transport back to Sandia Laboratories. The results of the test will be documented in a data package describing the activities and basic test results. This document will be submitted to demonstration operations within 1 mo of completion of the demonstration. In addition, an evaluation of the field demonstration based on the objectives and measures of success from Section 3.1 will be prepared and submitted by July 31, 1993 to the VOC-Arid ID technology coordinator.

## 7.2 REAL-TIME, ON-LINE MONITORING OF SVE OFFGAS

A detailed procedure for the actual field demonstration tasks is provided in Appendix B. This SVE offgas test will involve the PAWS system described in Section 2.3. Hardware for the offgas testing will be calibrated in the laboratory at Sandia and then transported to the Hanford Site. After the simple setup procedure is completed, the system will be operated using ambient air to verify integrity. The gas line from the SVE will be connected to the PAWS gas inlet while valved off. Exhaust gas from the PAWS module will be returned to the purge or bypass lines used at the site or exhausted to the atmosphere either with or without granular-activated carbon treatment. Once the SVE line is opened, monitoring for contaminant leakage in the site support trailer will be performed. Several days of continuous monitoring of the offgas stream is planned. During this period, large amounts of data can be acquired to verify the performance of the sensor system and its ability to quantify the concentration of carbon tetrachloride. Data from comparison techniques such as the on-line Odyssey systems or grab samples analyzed by GC will be compiled with the PAWS sensor data.

Following actual field testing, the PAWS system will be disconnected from the off-gas lines and disassembled in preparation for shipping. These procedures require little time as the PAWS system is designed for ease of use and quick operations. Results from the test will be documented in a data package describing the activities and basic test results. This document will be submitted to Demonstration Operations within 1 mo of completion of the demonstration. In addition, an evaluation of the field demonstration based on the objectives and measures of success from Section 3.2 will be prepared and submitted by July 31, 1993 to the VOC-Arid ID technology coordinator.

# 8.0 SITE SERVICES REQUIREMENTS

## 8.1 CARBON TETRACHLORIDE MONITORING IN VADOSE ZONE WELLS

Standard 110-Vac power may be required for the computer and the power supplies for the downhole probe. Generator power is acceptable for this demonstration; a generator that can be made available in at least 2 hr should be identified prior to the field test. A tape with a length of 250 ft will be needed for measuring the depth of the probe in wells. Use of an organic vapor monitor or other portable instrument will be required to monitor contaminant concentrations in the vicinity of the well. Since the concentrations in the vicinity of the well may be high enough to prevent safe operation by personnel, access to protective equipment including a source of supplied air will be needed during the field demonstration. Access to a gas chromatograph for analysis of samples sent to the surface by the probe will be needed for comparison to the in situ results.

A map of the wells for vadose monitoring and the specific well numbers can be found in Appendix C.

## 8.2 REAL-TIME, ON-LINE MONITORING OF SVE OFFGAS

Access to the onsite support trailer and its 110-Vac power supply will be required. In addition, access to a gas line from the SVE system prior to the treatment system will be required. Use of an organic vapor monitor or other instrument to verify that no contamination is leaking into the support trailer will be required. Baseline results on the concentration of carbon tetrachloride and other contaminants in the offgas stream at the time of the field demonstration will be needed for comparison. These baseline results could be from the on-line Odyssey systems and/or from gas chromatographic analysis of grab samples.

# 9.0 DEMONSTRATION SCHEDULE

The task/milestone schedule for this demonstration is shown in Table 1.

Table 1. Task/Milestone Summary for PAWS Sensor System.

| | July | August | |
|---|---|---|---|
| Field Demonstration | A---- | | |
| Data Package Submission | | B | |
| Evaluation Report Submission | | | C |

Task/Milestone Description:

A: Field demonstration of the in situ system in vadose zone wells and the above ground system for offgas monitoring will start on or about July 12, 1993. The demonstration will run one to two weeks.

B: Provide demonstration operations with a data package from the demonstration within one month of completing the demonstration. Package will include brief overview of the demonstration activities and findings. Also provide a critique of demonstration operations support.

C: Provide the VOC-Arid Technology Coordinator with a performance evaluation report in accordance with guidance by August 30, 1993.

## 10.0 REFERENCES

DOE-RL 1991, Expedited Response Action Proposal (EE/CA & EA for 200 West Area Carbon Tetrachloride Plume, DOE/RL-91-32, Draft B, U.S. Department of Energy, Richland Field Office, Richland, Washington.

Frye, G. C., and R. W. Cernosek, 1992, FY 1993 Technical Test Plan - PAWS Down Hole Liquid/Vapor Phase, TTP AL-2211-04, Rev. 6, November 1992.

Frye, G. C. and S. J. Martin, Dual Output Acoustic Wave Sensor for Molecular Discrimination, U.S. Patent #5,076,094, Dec. 31, 1991.

Rohay, V. J., 1991a, 200 West Carbon Tetrachloride Expedited Response Action Phase II Site Evaluation Work Plan, WHC-SD-EN-AP-059, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Rohay, V. J., 1991b, Electric Cone Penetrometer Test at the 200 West Area, WHC-SD-EN-TP-004, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

WHC 1988, Quality Assurance, WHC-CM-4-2, Westinghouse Hanford Company, Richland, Washington.

WHC 1990, Environmental Engineering, Technology, and Permitting Function Quality Assurance Program Plan, WHC-EP-0383, Environmental Engineering Group, Westinghouse Hanford Company, Richland, Washington.

# APPENDIX A

## PROCEDURE FOR CARBON TETRACHLORIDE MONITORING IN VADOSE ZONE WELLS

Operation of the PAWS downhole probe will be done in accordance with the following procedure:

1. Transport probe, purge pumps, packers, cable, gas lines, air compressor, power supply (if needed), and computer to the Hanford Site. Access to a power generator (if needed) should be provided at the site by Hanford personnel.

2. Reassemble the probe including the purge pump section and the packers.

3. Make electrical connections between the computer and the power supplies and the probe pigtail cable. If operating on a car or other battery (expected mode), attach the computer power cord and the probe power lines to the battery. If operating with a generator, plug in the computer and power supply to the generator and start up the generator. Turn on the computer and initiate the software routine.

4. Electrically connect the probe to the spooled power cable and connect the gas line for the packers. Connect the probe to the support cable from the winch. If comparison testing with aboveground instrument(s) is to be performed, attach the 1/8-in. teflon tube to the probe.

5. Open the well to be tested and monitor the air concentrations in the vicinity to determine if concentrations are above action limits. Place the portable tripod with winch over the well and manually place the probe into the top of the well so that it is suspended from the support cable.

6. Using the electric winch, lower the probe into the well to the desired depth. The electrical and gas lines will be fed manually while the winch lowers the probe.

7. Attach the main probe power cable to the pigtail cable. Supplying power to the probe will turn on the sample pump.

8. Attach the air compressor to the gas line of the probe and pressurize to 50 $lb/in^2$ to set the packers. If comparison testing with an above-ground PAWS system, attach the 1/8-in. sample tube from the probe to the PAWS system, then attach a carbon-based scrubber canister to the exit gas port from the instrument to collect the contaminant.

9. For wells where a pre-purge value is to be determined, the sensor system will be operated prior to purging.

10. Operating the sensor system involves setting up the parameters for the run (e.g., scrub time, number of cycles, calibration coefficient) in the software, initiating the run and noting the concentration values determined during the run, and plotting out the results upon completion of the run. Runs will be repeated if possible.

11. When comparison testing is being performed, the aboveground PAWS system will be run simultaneously with the in situ system. Gas samples will be drawn at known times for analysis by GC by onsite personnel.

12. Using the software routine, turn on the pump that purges the packed off region. Pump long enough to pull at least two well volumes from the well and then turn off the purge pump. If possible (i.e., noise from the purge pump is not a problem), the sensor system will be operated (see steps 10 and 11) during the purge to monitor in real-time the changes in contaminant concentration with volume purged.

13. The sensor system will be operated after purging (see steps 10 and 11) to determine the contaminant concentration in the formation.

14. Disconnect the main electrical cable from pigtail cable. Release the pressure on the line to deflate the packers and then disconnect the gas line from the air compressor.

15. Repeat steps 6 to 14 for each of the well depths to be tested.

16. When testing on a given well is complete, pull the probe up using the winch while manually respooling the electrical and gas lines. Disconnect the electrical cable, the gas line and the winch line from the probe.

17. Move the various components to a new well and repeat steps 4 to 14 for each well to be tested. If changing to a different well diameter, the packers and sometimes the purge pump section will need to be changed.

18. After testing is completed, have the probe and associated hardware tested for contamination.

19. Prepare for transportation of system hardware back to Sandia Laboratories.

# APPENDIX B

## PROCEDURE FOR REAL-TIME, ON-LINE MONITORING OF SVE OFFGAS

1. Transport PAWS module, power supplies, interface cable, and computer to the Hanford site.

2. Set up module in the support trailer and verify that all components are working properly.

3. With the gas line from the SVE system closed, attach the PAWS gas inlet to this gas line. As directed by the field team leader, attach the PAWS gas outlet to a gas line returning to the SVE system or to a line venting to the atmosphere either with or without an in-line scrubber.

4. Verify that no leakage of contamination is occurring in the trailer using an organic vapor monitor provided by onsite personnel.

5. Perform a variety of tests including at least one long run (2 to 8 hr). A PAWS test involves setting up the parameters for the run (e.g., scrub time, number of cycles, calibration coefficient) in the software, initiating the run and noting the concentration values determined during the run, and plotting out the results upon completion of the run.

6. Compile the results from the PAWS tests (i.e., carbon tetrachloride concentration versus time) and results from baseline analyses (e.g., Odyssey measurements, GC analysis).

7. When all testing is completed, turn off the gas from SVE system. With the sample pump running, disconnect the SVE gas line from the PAWS inlet line and let run for at least 3 min. to fully purge out the lines. This should include at least one minute with the scrubber turned on to purge out this sample line as well.

8. Perform at least one run with the ambient air being sampled to determine the baseline offset when no contaminant is present.

9. Turn the sample pump off and disconnect the line connected to the exit from the PAWS module. Turn off the PAWS module and computer, disconnect the serial communication line and power supply lines, and pack up the hardware for transport.

# APPENDIX C

## WELLS FOR PAWS MONITORING

The following is a list of wells for the PAWS test (Table C-1). Also included is a map showing well locations see Figure C-1.

Table C-1. Wells for PAWS Monitoring.

| Well | Diameter (in.) | Completion |
|---|---|---|
| W15-6 | 6 | Perforated: 175 to 408 ft |
| W15-9 | 4 (liner) | Perforated: 186 to 189 ft |
| W15-82 | 8 | Open at bottom of casing: 101 ft |
| W15-85 | 8 | Open at bottom: 106 ft |
| W15-95 | 8 | Open at bottom: 100 ft |
| W15-216 | 4 | Two screens: 70 to 80 ft, 175 to 185 ft |
| W15-217 | 4 | Screen: 106 to 121 ft |
| W15-218 | 4 | Two screens: 98.5 to 113.5 ft, 180.5 to 195.5 ft |
| W18-2 | 8 (w/6-in. screen) | Perforated: 200 to 278 ft, screen: 205 to 254.5 ft |
| W18-6 | 6 (linear) | Perforated: 190 to 298 ft |
| W18-9 | 6 (w/5-in. screen) | Perforated: 180 to 218 ft, screen: 182 to 212 ft |
| W18-12 | 6 (w/5-in. screen) | Perforated: 180 to 218 ft, screen: 194 to 214 ft |
| W18-85 | 6 | Open at bottom: 150 ft |
| W18-86 | 6 | Open at bottom: 150 ft |
| W18-153 | 8 | Open at bottom: 110 ft |
| W18-157 | 8 | Open at bottom: 110 ft |
| W18-246 | 4 | Two screens: 120 to 130 ft, 165 to 175 ft |
| W18-247 | 4 | Two screens: 119 to 129 ft, 162 to 172 ft |
| W18-248 | 4 | Screen: 123 to 138 ft |
| W18-249 | 4 | Screen: 122 to 137 ft |

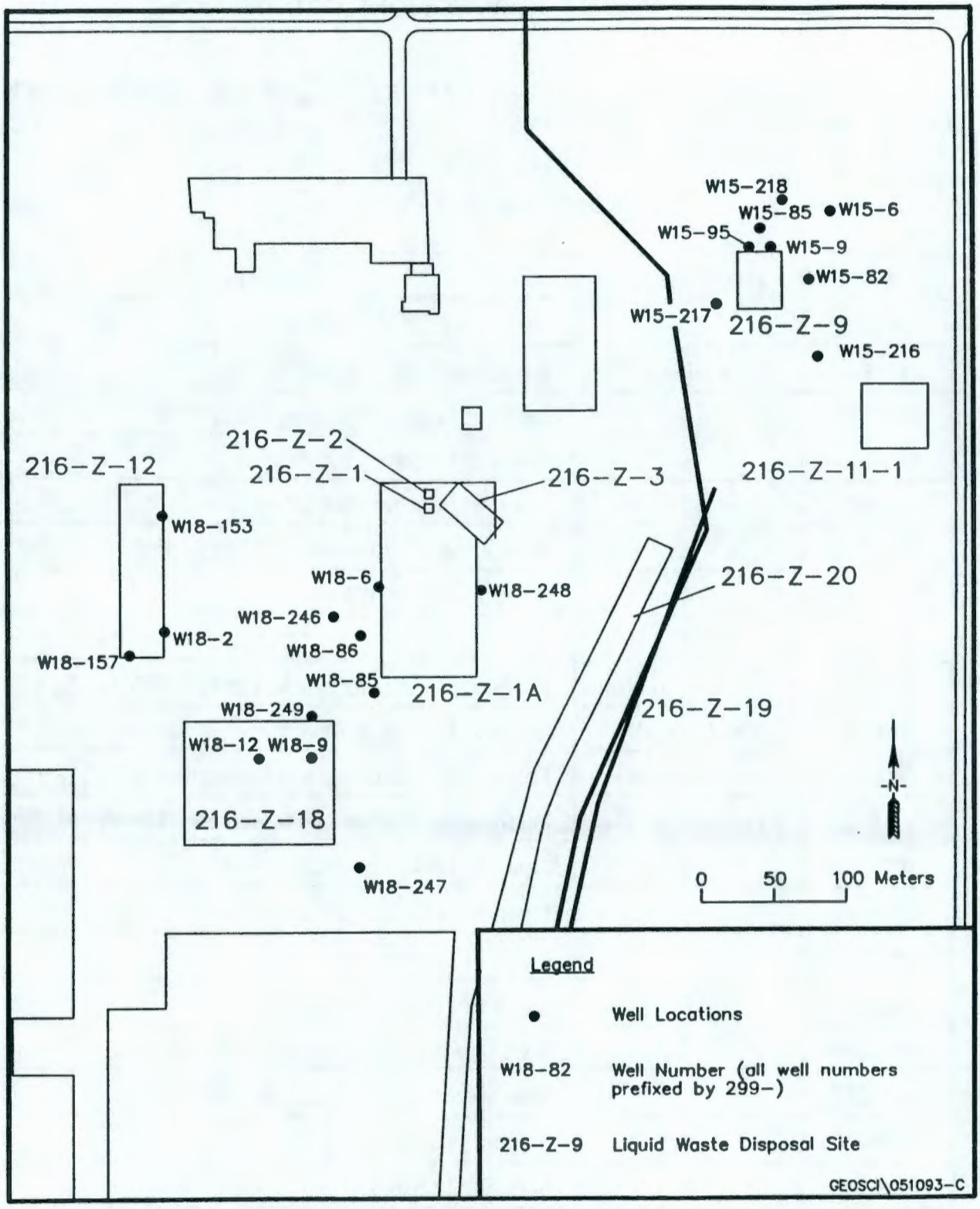



Figure C-1. Well Field.