O

FEB 01 1994

ENGINEERING DATA TRANSMITTAL

Page 1 of 1

1. EDT 602498

2. To: (Receiving Organization) Distribution	3. From: (Originating Organization) Geosciences	4. Related EDT No.: N/A
5. Proj./Prog./Dept./Div.: Volatile Organic Compounds - Arid Integrated Demonstration	6. Cog. Engr.: S. M. Narbutovskih H6-06	7. Purchase Order No.: N/A
8. Originator Remarks: Volatile Organic Compounds - Arid Integrated Demonstration. Please review and approve as indicated. Initial Release as Rev. 0		9. Equip./Component No.: N/A
		10. System/Bldg./Facility: N/A
11. Receiver Remarks:		12. Major Assm. Dwg. No.: N/A
		13. Permit/Permit Application No.: N/A
		14. Required Response Date: 1/4/94

15. DATA TRANSMITTED					(F)	(G)	(H)	(I)
(A) Item No.	(B) Document/Drawing No.	(C) Sheet No.	(D) Rev. No.	(E) Title or Description of Data Transmitted	Impact Level	Reason for Trans- mittal	Origina- tor Dispo- sition	Receiv- er Dispo- sition
1	WHC-SD-EN-TP-039		0	Integrated Test Plan for Crosswell Compressional and Shear Wave Seismic Tomography for Site Characterization at the VOC Arid Site	4	1/2	1	

16. KEY		
Impact Level (F)	Reason for Transmittal (G)	Disposition (H) & (I)
1, 2, 3, or 4 (see MRP 5.43)	1. Approval 4. Review 2. Release 5. Post-Review 3. Information 6. Dist. (Receipt Acknow. Required)	1. Approved 4. Reviewed no/comment 2. Approved w/comment 5. Reviewed w/comment 3. Disapproved w/comment 6. Receipt acknowledged

(G)	(H)	17. SIGNATURE/DISTRIBUTION (See Impact Level for required signatures)						(G)	(H)
Reason	Disp.	(J) Name	(K) Signature (M) MSIN	(L) Date	(J) Name	(K) Signature (M) MSIN	(L) Date	Reason	Disp.
1/2	1	Cog. Eng. S. M. Narbutovskih	<i>S. M. Narbutovskih</i>	H6-06	A. J. Knepp	<i>A. J. Knepp</i>	1/12/94	3/4	
1/2	1	Cog. Mgr. J. W. Fassett	<i>J. W. Fassett</i>	H6-06	K. R. Simpson	<i>K. R. Simpson</i>	H6-06	3/4	
4		R. L. Hand	<i>R. L. Hand</i>	H4-16	R. F. Raidl	<i>R. F. Raidl</i>	H6-06	3/4	
1	1	Safety N. R. Kerr	<i>N. R. Kerr</i>	H4-67	K. J. Koegler	<i>K. J. Koegler</i>	H6-05	1	1
3		Env. EPIC (2)		H6-08	Central Files (2)		L8-04	3	
3		IRA (2)		H4-17	Unclassified Document Control			3	
1	1	S. Tomich	<i>S. Tomich</i>	H6-08	*C.E. Heiden	<i>C.E. Heiden</i>	1/12/94	H6-04	6

18. S. M. Narbutovskih Signature of EDT Originator 1/12/94	19. Authorized Representative Date for Receiving Organization	20. J. W. Fassett Cognizant/Project Engineer's Manager 1/12/94	21. DOE APPROVAL (if required) Ltr. No. [ ] Approved [ ] Approved w/comments [ ] Disapproved w/comments

Date Received: 12/22/93		INFORMATION RELEASE REQUEST		Reference: WHC-CM-3-4
Complete for all Types of Release				
Purpose ☐ Speech or Presentation ☐ Full Paper ☐ Summary ☐ Abstract ☐ Visual Aid ☐ Speakers Bureau ☐ Poster Session ☐ Videotape		(Check only one suffix) ☒ Reference ☒ Technical Report ☐ Thesis or Dissertation ☐ Manual ☐ Brochure/Flier ☐ Software/Database ☐ Controlled Document ☐ Other		ID Number (include revision, volume, etc.) WHC-SD-EN-TP-039, Rev. 0 List attachments. Date Release Required January 10, 1994
Title: Integrated Test Plan for Crosswell Compressional and Shear Wave Seismic Tomography for Site Characterization at the VOC Arid Site			Unclassified Category UC-	Impact Level 4
New or novel (patentable) subject matter? ☒ No ☐ Yes If "Yes", has disclosure been submitted by WHC or other company? ☐ No ☐ Yes Disclosure No(s).		Information received from others in confidence, such as proprietary data, trade secrets, and/or inventions? ☒ No ☐ Yes (Identify)		
Copyrights? ☒ No ☐ Yes If "Yes", has written permission been granted? ☐ No ☐ Yes (Attach Permission)		Trademarks? ☒ No ☐ Yes (Identify)		
Complete for Speech or Presentation				
Title of Conference or Meeting			Group or Society Sponsoring	

Date(s) of Conference or Meeting	City/State	Will proceedings be published? Will material be handed out?	☐ Yes ☐ No ☐ Yes ☐ No

Title of Journal
N/A

CHECKLIST FOR SIGNATORIES				
Review Required per WHC-CM-3-4	Yes	No	Reviewer - Signature Indicates Approval	
			Name (printed)	Signature Date
Classification/Unclassified Controlled Nuclear Information	☐	☒	}	SW BERLIN <i>[Signature]</i> 12/30/93
Patent - General Counsel	☒	☐		
Legal - General Counsel	☒	☐		
Applied Technology/Export Controlled Information or International Program	☐	☒		
WHC Program/Project	☐	☒		
Communications	☐	☒		
RL Program/Project	☒	☐	L. S. Mamiya <i>[Signature]</i> 1/3/94	
Publication Services	☒	☐	L. S. Hermann <i>[Signature]</i> 1/4/94	
Other Program/Project	☐	☒		
Information conforms to all applicable requirements. The above information is certified to be correct.				

<table style="width:100%;"> <tr> <td style="width: 50%;">References Available to Intended Audience</td> <td style="width: 10%; text-align: center;">Yes</td> <td style="width: 10%; text-align: center;">No</td> <td style="width: 30%;"></td> </tr> <tr> <td>Transmit to DOE-HQ/Office of Scientific and Technical Information</td> <td style="text-align: center;">☒</td> <td style="text-align: center;">☐</td> <td></td> </tr> <tr> <td>Author/Requestor (Printed/Signature)</td> <td></td> <td></td> <td>Date</td> </tr> <tr> <td colspan="4">S. M. Narbutovskih <i>[Signature]</i> 12/22/93</td> </tr> <tr> <td colspan="4">Intended Audience</td> </tr> <tr> <td colspan="4"> ☐ Internal ☐ Sponsor ☒ External </td> </tr> <tr> <td colspan="4">Responsible Manager (Printed/Signature)</td> </tr> <tr> <td colspan="4">J. W. Fassett <i>[Signature]</i> 12/22/93</td> </tr> </table>	References Available to Intended Audience	Yes	No		Transmit to DOE-HQ/Office of Scientific and Technical Information	☒	☐		Author/Requestor (Printed/Signature)			Date	S. M. Narbutovskih <i>[Signature]</i> 12/22/93				Intended Audience				☐ Internal ☐ Sponsor ☒ External				Responsible Manager (Printed/Signature)				J. W. Fassett <i>[Signature]</i> 12/22/93				<table style="width:100%;"> <tr> <th colspan="2" style="text-align: center;">INFORMATION RELEASE ADMINISTRATION APPROVAL STAMP</th> </tr> <tr> <td colspan="2">Stamp is required before release. Release is contingent upon resolution of mandatory comments.</td> </tr> <tr> <td colspan="2" style="text-align: center;"> </td> </tr> <tr> <td>Date Cancelled</td> <td>Date Disapproved</td> </tr> </table>	INFORMATION RELEASE ADMINISTRATION APPROVAL STAMP		Stamp is required before release. Release is contingent upon resolution of mandatory comments.				Date Cancelled	Date Disapproved
References Available to Intended Audience	Yes	No																																							
Transmit to DOE-HQ/Office of Scientific and Technical Information	☒	☐																																							
Author/Requestor (Printed/Signature)			Date																																						
S. M. Narbutovskih <i>[Signature]</i> 12/22/93																																									
Intended Audience																																									
☐ Internal ☐ Sponsor ☒ External																																									
Responsible Manager (Printed/Signature)																																									
J. W. Fassett <i>[Signature]</i> 12/22/93																																									
INFORMATION RELEASE ADMINISTRATION APPROVAL STAMP																																									
Stamp is required before release. Release is contingent upon resolution of mandatory comments.																																									
Date Cancelled	Date Disapproved																																								

SUPPORTING DOCUMENT		1. Total Pages 24
2. Title Integrated Test Plan for Crosswell Compressional and Shear Wave Seismic Tomography for Site Characterization at the VOC Arid Site		3. Number WHC-SD-EN-TP-039
		4. Rev No. 0
5. Key Words remediation monitoring, vadose zone, leak detection APPROVED FOR PUBLIC RELEASE <i>V. Birkhead 4/4/94</i>		6. Author Name: S. M. Narbutovskih <i>[Signature]</i> Signature 10-22-93 Organization/Charge Code 81234/HB15A
7. Abstract Elbring, G.J. and S.M. Narbutovskih, 1994, <i>Integrated Test Plan for Crosswell Compressional and Shear Wave Seismic Tomography for Site Characterization at the VOC Arid Site</i> , WHC-SD-EN-TP-039, Rev. 0, Westinghouse Hanford Company, Richland, Washington.		
8. PURPOSE AND USE OF DOCUMENT - This document was prepared for use within the U.S. Department of Energy and its contractors. It is to be used only to perform, direct, or integrate work under U.S. Department of Energy contracts. This document is not approved for public release until reviewed. PATE ~~N~~ T STATUS - This document copy, since it is transmitted in advance of patent clearance, is made available in confidence solely for use in performance of work under contracts with the U.S. Department of Energy. This document is not to be published nor its contents otherwise disseminated or used for purposes other than specified above before patent approval for such release or use has been secured, upon request, from the Patent Counsel, U.S. Department of Energy Field Office, Richland, WA. DISCLAIMER - This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, nor any of their contractors, subcontractors or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or any third party's use or the results of such use of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof or its contractors or subcontractors. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.		10. RELEASE STAMP OFFICIAL RELEASE (11) BY WHC DATE FEB 01 1994 <i>Station #12</i>
9. Impact Level 4		

CONTENTS

1.0	INTRODUCTION	1
1.1	PURPOSE AND SCOPE	1
1.2	BACKGROUND	1
1.3	SITE SETTING	2
2.0	TECHNOLOGY DESCRIPTION	3
2.1	SEISMIC TOMOGRAPHY	3
2.2	DOWNHOLE EQUIPMENT	8
2.2.1	Sandia Pneumatic Vertical Vibrator Source	8
2.2.2	Bolt Pneumatic Acoustic Repeater	8
2.2.3	Oyo-Conoco Orbital Vibrator Source	8
2.2.4	Oyo-Sandia Three-Component Downhole Receiver	8
2.3	SURFACE EQUIPMENT	9
2.3.1	Winches	9
2.3.2	Tripods	9
2.3.3	Field Truck	9
3.0	DEMONSTRATION OBJECTIVES AND PARAMETERS	9
3.1	DEMONSTRATION OBJECTIVES	9
3.2	DEMONSTRATION PARAMETERS	10
3.3	ANALYTICAL PROCEDURES	11
4.0	REGULATORY COMPLIANCE	12
4.1	OVERVIEW OF SYSTEM RESIDUALS	12
4.2	NEPA	12
4.3	CERCLA	13
4.4	RCRA	13
4.5	CULTURAL RESOURCES REVIEW	13
5.0	HANFORD COMPLIANCE	13
5.1	SAFETY	13
5.2	QUALITY ASSURANCE	14
5.3	TRAINING	14
6.0	ORGANIZATION AND RESPONSIBILITIES	14
6.1	DEMONSTRATION OPERATIONS	14
6.2	PROJECT ENGINEER	15
6.3	FIELD TEAM LEADER	15
6.4	PRINCIPAL INVESTIGATOR	15
7.0	DESCRIPTION OF TASKS AND PROCEDURES	15
8.0	DEMONSTRATION SCHEDULE	17
9.0	REFERENCES	18
	APPENDIX: PROCEDURES	A-1

CONTENTS (cont.)

FIGURES:

1. Hanford Site Map	4
2. Location Map, 100-F Area	5
3. Location Map, 200 West Area	6
4. Site Specific Map Showing Location of Demonstration at 200 West Area	7
5. Field Demonstration Organization	16

1.0 INTRODUCTION

1.1 PURPOSE AND SCOPE

This integrated test plan describes the demonstration of the crosswell acoustic tomography technique as part of the Volatile Organic Compounds - Arid Integrated Demonstration (VOC-Arid ID). The purpose of this demonstration is to image the subsurface seismic velocity structure and to relate the resulting velocity model to lithology and saturation. In fiscal year (FY) 1994 an initial fielding will test three different downhole sources at two different sites at the Hanford U.S. Department of Energy facility (Figure 1) to identify which sources will provide the energy required to propagate between existing steel-cased wells at these two sites. Once this has been established, a second fielding will perform a full compressional and shear wave tomographic survey at the most favorable site. Data reduction, analysis, and interpretation of this full data set will be completed by the end of this fiscal year. Data collection for a second survey will be completed by the end of the fiscal year, and data reduction for this data set will be completed in FY 1995.

The specific need is detailed subsurface characterization with minimum intrusion. This technique also has applications for long term vadose zone monitoring for both Resource Conservation and Recovery Act (RCRA) waste storage facilities and for remediation monitoring. Images produced are continuous between boreholes. This is a significant improvement over the single point data derived solely from core information. Saturation changes, either naturally occurring (e.g., perched water tables) or remediation induced (e.g., water table mounding from injection wells or during inwell air sparging) could be imaged. These crosswell data allow optimal borehole placement for groundwater remediation, associated monitoring wells and possibly evaluation of the effective influence of a particular remediation technique.

The scope of this demonstration includes borehole testing of two downhole compressional wave sources (i.e., an acoustic pneumatic repeater and an orbital vibrator) and one shear wave source (i.e., a vertical shear vibrator). Only one type of receiver will be employed (i.e., a clamped three-component geophone) that senses acoustic arrivals at one location in the borehole for any given source shot. The distances between the source and receiver boreholes has been kept to a conservative 178 ft and 136 ft.

There are numerous tomographic techniques that employ different seismic parameters and many numerical codes available to analyze the data. For this demonstration, traveltime tomography will be employed and the Bureau of Mines traveltime tomography code developed by Tweeton (1988) will be used to produce the final velocity tomograms. Also, both compressional and shear wave data will be collected. These two independent data sets help to identify fully saturated regions within the vadose zone.

1.2 BACKGROUND

Crosswell seismic imaging involves the fielding of a downhole seismic

source and a downhole receiver in boreholes on either side of the region to be imaged. The time it takes the seismic energy to travel from the source to the receiver is measured for a large number (>500) of source-receiver location pairs. These travel times are then inverted into a two-dimensional velocity model through a method known as traveltime tomography. The region between the boreholes is divided into a grid of cells or nodes, each with a velocity assigned to it. Seismic travel times are then calculated through this model and compared to the observed times. The velocities for each cell are adjusted until the difference between the observed and calculated travel times is minimized. Finally the resulting velocity model is interpreted in terms of geology.

Seismic sources generate primarily shear or compressional waves. Shear waves travel slower than compressional waves. These velocities are dependent not only on intrinsic rock properties but also, in the vadose zone, on the degree of saturation. By comparing the different velocity structures obtained from these separate data sets, additional information on rock properties and fluid content can be obtained.

The state-of-practice baseline for this technology is mapping between wells based on correlation of well log information and cores. In the baseline technology, all data between the boreholes is assumed, since there is no direct information. Crosswell imaging, on the other hand, provides a continuous velocity model between the boreholes based on the acoustic traveltime variations. This velocity tomogram reflects the indirect effect of the medium's acoustic properties on the arrival times of the propagating waves and as such, provides information on subsurface properties between the holes.

Surface seismic techniques and crosswell electromagnetic or resistivity tomography are other possible geophysical imaging methods. Each method provides additional information about conditions in the subsurface and the choice on when to apply one method, either alone or in combination together, will be site specific. Crosswell acoustic methods tend to be higher resolution than surface techniques, especially as depth to the target increases. However, high resolution, surface reflection techniques provide more extensive coverage. Electromagnetic and resistivity imaging provide information on the conductivity structure of the subsurface and thus are more sensitive to migrating fluids especially if there is a distinct change in conductive properties. Unfortunately, these potential fields methods are inherently more ambiguous than the seismic techniques. Consequently, for the most accurate, detailed understanding of subsurface fluid migration paths and plume locations, an integrated program is best combining multiple geophysical data sets with borehole geologic control.

1.3 SITE SETTING

Initial requirements for selection of two wells included a maximum separation between the two wells of 200 ft, with the inside diameter (ID) greater than 6 in. for the receiver hole and no less than 5 in. for the source hole. In addition, it must be possible to fill the hole with water to provide acoustic coupling for the non-clamped sources. It is also desirable to conduct these initial tests above and below the groundwater since results are expected to be quite different. Compressional velocities are faster in saturated porous media. Also, there are many potential applications for this

technology ranging from remediation evaluation and monitoring to detailed, subsurface characterization for future planning of drilling projects. Consequently, two very different sites were selected.

Sites for the initial testing of source coupling and energy transmission include the 200 West Area and the 100-F Area (Figure 1). Phase I testing will begin between wells 199-F8-1 and 199-F8-2 (Figure 2). Then tests will be continued at the VOC-Arid ID Site near Z Plant at the 200 West Area (Figure 3). The two wells are 299-W15-10 and 299-W15-11 (Figure 4). These are deep wells that may be used for monitoring an in-well air sparging demonstration. All 4 wells are single cased with carbon steel and have IDs in excess of 6 in. The site chosen for Phase II of this demonstration will depend on the results of the initial source testing of Phase I.

2.0 TECHNOLOGY DESCRIPTION

2.1 SEISMIC TOMOGRAPHY

The use of tomography in the geosciences has its basis in medical imaging and borrows heavily from techniques used in x-ray CAT scan processing. Tomography refers to the inversion process to convert measured values into a model, imaging the distribution of the characteristic that determines the measured value. There are several tomographic techniques, but the one that will be used for this study will be the simultaneous iterative reconstruction technique (SIRT) (Tweeton 1988). There are several other tomographic methods, further details on which can be found in Nolet (1987).

To apply this technique, a data set is collected that contains the travel times of the seismic energy between a large number of source-receiver locations with the source in one borehole and the receiver in a second borehole some distance away. The region between the boreholes to be modeled is then divided up into cells or pixels. Linear equations are set up relating the velocity in the individual pixels to the experimental travel times. An initial guess is made for the velocity in each pixel. The corresponding travel times for the ray paths between the source and receiver locations are then calculated and compared with the experimental data. The differences between the calculated and measured travel times are used in calculating correction factors to be applied to the initial velocity guesses. In SIRT, these correction factors are calculated for all ray paths simultaneously. This procedure is then repeated until some convergence or limit criterion is reached.

In collecting the data, the source is positioned at pre-determined depth in one of the wells. While the source is held stationary, the receiver is moved to each of its pre-determined positions in the second well, and the source signal is recorded for each of these positions. This process is repeated for numerous equally spaced source positions.

Once the data is recorded, different data processing flows are used depending on the source used to generate the data. The ultimate outcome of the processing is good signal-to-noise seismic sections with well characterized wavelets. From such seismic sections, reliable travel times can be picked to invert with the tomography code.

Figure 1. Hanford Site Map.

Figure 2. Location Map, 100-F Area.

Figure 3. Location Map, 200 West Area.

200 WEST AREA

Figure 4. Site-Specific Map Showing Location of Demonstration at 200 West Area.

GEOSCI\121793-K

As stated before, both compressional and shear wave velocity models will be generated. These velocities vary as a function of saturation, but in different ways (Domenico 1976; Gregory 1976). By comparing the ratio of these two velocities, changes in saturation can be imaged to identify perched water tables.

Equipment can be classified as either downhole or surface equipment.

2.2 DOWNHOLE EQUIPMENT

2.2.1 Sandia Pneumatic Vertical Vibrator Source

This is a pneumatically powered source (150 psi) that is run by compressed air through high-pressure and electrical lines from the surface. It produces primarily vertically polarized shear waves. The tool is designed to fit into boreholes 4 in. in diameter and is 14 ft long. The source rigidly clamps to the borehole wall and has only been used in uncased holes in hard rock formations and in steel-cased holes. The clamp has not been tested in polyvinyl chloride (PVC) or fiberglass casing to determine whether these casings would be damaged by the clamp. Control of the source is done electronically from the surface. Air will be exhausted to the borehole.

2.2.2 Bolt Pneumatic Acoustic Repeater

This source is a pneumatic device that has an adjustable high-pressure chamber (2,000 psi) that rapidly discharges to form a pressure pulse in the hole that couples into the ground as a compressional wave. This source is approximately 3 ft long and is designed to operate in holes down to 3 in. in diameter, but can be used in much larger holes. Compressed air is supplied from the surface via a high-pressure line. The release of the pressure is controlled electronically from a firing unit on the surface. The source couples through the borehole fluid and thus requires a fluid-filled borehole to function properly. Air will be exhausted to the borehole.

2.2.3 Oyo-Conoco Orbital Vibrator Source

The orbital vibrator is an electronically powered source that spins an offset mass to create vibrations to couple into the formation. This produces both compressional waves and horizontally polarized shear waves. Like the pneumatic repeater, this is an unclamped source and requires coupling through the borehole fluid and thus requires a fluid-filled borehole. It is 4 in. in diameter and requires at least a 5-in.-ID casing. It is 2 ft 6 in. long and is fielded on a standard seven-conductor wireline.

2.2.4 Oyo-Sandia Three-Component Downhole Receiver

The receiver is a three-component accelerometer group housed in a tool approximately 2 ft long and 4 in. in diameter, requiring a 6-in.-ID casing. The tool clamps rigidly to the borehole wall and can be used in larger casing

holes by adding extension pads to the clamp foot. It communicates with the surface via a standard seven-conductor wireline.

2.3 SURFACE EQUIPMENT

2.3.1 Winches

The largest surface component are the seven-conductor wireline winches that are needed to field the downhole equipment. These winches are skid mounted and weigh several hundred pounds each with a footprint of approximately 6 ft by 4 ft, but can be positioned some distance (<200 ft) from the hole if necessary. The smaller winch runs on 110-V power with a pulling capacity of 1,000 lb, while the larger winch runs off 220-V power and pulls up to 2,500 lb. The winches are the most cumbersome component of the field equipment and will be brought by truck. A forklift is needed for unloading the winches and initial positioning. Repositioning can be done by dragging the skids with our truck-mounted winch. Storage space for the winches is required between field tests in January and May 1994.

2.3.2 Tripods

Tripods are required above the holes, a steel tripod rated at 2 tons for use with the large winch and an aluminum tripod rated at 1 ton for the smaller winch. The tripods have a maximum height of 20 ft, with the horizontal distance between the legs at the base not to exceed 75% of the height (i.e., 15 ft at the maximum height). Appropriate pulleys are provided. One of these pulleys must be mounted at the base of the tripod to change the direction of pull from horizontal to vertical. This base pulley must be attached by wire rope or chain to a strong, firmly planted object. Usually, it is attached to the well head when the well is steel-cased and extends sufficiently above the surface. Storage space for the tripods (collapsed) is required between January and May 1994.

2.3.3 Field Truck

SNL will provide, a four-wheel drive van with a personnel box (14 ft long x 5 ft wide x 6 ft high) mounted in the rear. The vehicle has a maximum height of 10 ft 6 in. This will contain the remainder of the equipment, including source and winch controls, a recording system, and various electronic and mechanical tools for in-field repairs. Storage space for the field truck is required between January and May 1994.

3.0 DEMONSTRATION OBJECTIVES AND PARAMETERS

3.1 DEMONSTRATION OBJECTIVES

- Determine how well the technology performs its intended function.

- Determine the reliability of the technology and the nature and extent of any operational problems.
- Determine the technology's ease of use.
- Determine versatility of the technology in other media, locations, and any limits on operating conditions.
- Determine ease of procuring the technology or critical components.
- Determine operating and maintenance costs.
- Determine speed or rate of technology performance to acquire the data.
- Determine time required for the technology to complete its task.

3.2 DEMONSTRATION PARAMETERS

Determination of data quality will be done by evaluating factors that affect wave propagation and amplitudes. Besides evaluating the data for noise content, clarity of first arrivals, and effective lateral and vertical resolution limits, shot-to-shot energy variations of the sources, source-to-formation coupling factors, source radiation pattern effects, variations in receiver sensitivities, and receiver-to-formation coupling factors will be addressed to determine overall success of the data acquisition capabilities of the technique.

- Determination of technology performance will be done through the creation of synthetic data sets derived from known geologic models. These data sets will be inverted using similar raypath coverage to the actual field data, and the final velocity models obtained will be compared with the models used to generate the data to determine the reliability, approximate error bounds, and performance of the method. The effect of noisy data and time picking errors will also be examined with the synthetic data with results applied in the interpretation of the experimental results.
- To examine reliability of the technology, the actual downtime of the instrumentation, as a function of the number of source-receiver pair traveltimes measured, will be monitored. In addition, the nature and resulting time costs of any operational problems will be documented.

- Ease of use between the different sources will be compared and monitored both in a subjective sense (operator feedback) and in the average number of source-receiver pairs that can be recorded per unit time.
- Determination of technology versatility will be subjective. However, comparisons of the data collected at Westinghouse Hanford Company (WHC) can be directly compared in terms of signal-to-noise ratio and frequency content with data previously collected at Westinghouse Savannah River (Elbring 1992) and conclusions will be drawn concerning the effect of the different geologic media on the performance of the technique.
- Ease of procurement of the commercially available sources will be documented. Commercialization will be worked on to improve the ease with which source and receiver instrumentation can be obtained and also to improve access to the whole crosswell imaging service by attempting to get an industrial partner to take over the service.
- Operating and maintenance costs will be tracked and expressed as a function of cost per square foot imaged.
- Attempt to improve the efficiency of the technology performance through improved fielding techniques, the application of multiple receiver strings, and the use of unclamped sources whenever possible with no degradation of the data. Record duration of work elements to optimize the technique.
- Attempt to reduce turn-around time to complete tomography task by improving the processing flow of the field data, the most time-consuming part of the whole technology. This will be done by employing improved tape playback processes and streamlining processing codes.

3.3 ANALYTICAL PROCEDURES

Tomography refers to the numeric process used to invert observed data into a model imaging the distribution of the varying material property characteristic of the subsurface. There are several seismic tomographic techniques that have been developed each beginning with a different acoustic property. The numerical code used for this study (SIRT) (Tweeton 1988) employs a traveltime technique that assumes straight ray paths. Obviously, ray paths are bent when subsurface conditions change, i.e., lateral or vertical changes in seismic velocity. This assumption will become less valid as the ray path length increases. Although this critical length is not known, this assumption should be kept in mind when interpreting the data.

To apply this analytical procedure, the arrival time of each first direct traveling wave must be discernable. This requires a good signal to noise ratio (S/N) to determine this time. The tomography numeric process is sensitive to the quality of the acquisition conditions. For example, the ability of the source and receivers to couple to the medium and to repeatedly

produce the same data is important. Also, the data should have a high signal to noise ratio. Sources of noise may be coherent or incoherent but will be identified and if possible removed in the analytical process.

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 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 OVERVIEW OF SYSTEM RESIDUALS

The borehole equipment, as described previously, will be run in and out of the wells, but no water, air, or soil will be extracted from the wells. The gas source will be clean, breathable air; therefore, small amounts of vented compressed air will be emitted to the borehole. Otherwise, there are no system residuals associated with this technique.

4.2 NEPA

The National Environmental Policy Act (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 the DOE, give appropriate consideration to environmental impacts in their decision-making.

NEPA compliance for this demonstration is achieved by reference to two currently existing DOE grants of NEPA categorical exclusions for certain activities at the Hanford Site. For the first grant, on December 4, 1992, DOE determined that characterization and environmental monitoring activities on the Hanford Site fit within a typical class of action currently available for Categorical Exclusion (CX) in Subpart D of the U.S. DOE NEPA Implementing Procedures, 10 CFR 1021. The seismic tomography demonstration, as part of this test, is within the scope of activities envisioned in that CX approval. The seismic tomography equipment will produce data that will be useful for the characterization of the Hanford Site, which is the primary purpose of the activities for which the CX was approved. The minimal impacts to the environment that will be caused by this test are clearly within the range of impacts assumed in DOE's CX approval. Accordingly, no further NEPA compliance documentation is required for demonstration of the seismic tomography technique.

For the second grant, on April 30, 1992 DOE determined that VOC-Arid ID's sensor development and demonstration activities fit within a typical class of action then available for categorical exclusion in section D of the U.S. DOE NEPA guidelines. The acoustic equipment used to acquire crosswell data is similar in type to the sensor technologies discussed in the

Information Bulletin supporting that CX approval. Furthermore, this demonstration's minimal environmental impacts will be within the range of impacts assumed in that approval. Accordingly, no further NEPA compliance documentation is required for this demonstration.

4.3 CERCLA

The *Comprehensive Environmental Response, Compensation, and Liability Act* (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 Environmental Restoration at Hanford Site. Depending on test results, some of the data generated may contribute to environmental restoration site characterization.

4.4 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 Chapter 173-303, Washington Administrative Code (WAC 173-303), and in 40 CFR Parts 260 through 272 (40 CFR 260-272), 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 WHC Environmental Investigations Instruction (EII) 4.2, "Interim Control of Unknown, Suspected Hazardous, and Mixed Waste" (WHC 1988a).

4.5 CULTURAL RESOURCES REVIEW

Since this demonstration does not involve disturbing the ground surface and the boreholes are preexisting, there is no excavation permit needed to conduct field operations. Consequently, a cultural resources review is not required.

5.0 HANFORD COMPLIANCE

This section identifies Hanford compliance areas for this field demonstration.

5.1 SAFETY

Activities under this integrated test plan (ITP) will be governed by the Site-Specific Health and Safety Plan for the VOC-Arid ID site and the Radiation Work Procedure (RWP) Number D-072.

All equipment lowered into wells will be wiped and screened by a Health Physics Technician (HPT) before transport from the 100-F Area to the 200 West

Area and again before transporting to the storage location. Decontamination procedures will follow EII 5.4, Rev. 4, "Field Decontamination of Drilling, Well Development and Sampling Equipment" (WHC 1988a) and all borehole equipment will be decontaminated prior to emplacement in another borehole.

5.2 QUALITY ASSURANCE

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

To ensure that the field demonstration activities are consistent with DOE Order 5700, *Quality Assurance*, all work will be performed in compliance with WHC's QA manual, WHC-CM-4-2 (WHC 1988b) and with applicable procedures outlined in the QA Program Plan, WHC-EP-0383 (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 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

No special training will be required for personnel not entering radiological zones. However, standard training, including the Occupational Health and Safety Administration (OSHA) training for personnel working at hazardous waste sites, plus all relevant training required for specific radiological zones, will be required for any personnel entering these zones.

General training, medical, and security requirements for access to the Hanford Site and field demonstration site can be found in the *Field Access Guide for Visitors of the VOC-Arid Integrated Demonstration Site* (McDonald-McNamar 1993). Specific training and medical requirements to get into certain radiological zones are given in RWP Number D-072.

6.0 ORGANIZATION AND RESPONSIBILITIES

The field test will be performed by Demonstration Operations personnel working with the principal investigator (PI). General organization and responsibilities for the VOC-Arid ID, Demonstration Operations is shown in Figure 5. General and specific responsibilities to 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.

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 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

Initiation of the field data collection begins with raising of the tripods over the wells to be used. This is a three-person operation with each leg of the tripod being raised incrementally using the leg releases and safety pegs included with the tripod assembly. The safety lashing (wire rope) is threaded through the tripod legs before any load is applied. The upper and lower sheaves are then connected to the tripod and well head respectively. The wireline cable is then run out from each of the winches and threaded through the sheaves, completing the rigging of the tripods.

The desired source and receiver are attached to the cable head with a standard seven-conductor cable head. For the pneumatic sources, the high-pressure hose rated to 2,000 psi is also laid out on the ground and attached to the source. The source and receiver are then lowered to their first depth positions. Operation of the winches and lowering of the sources requires three workers. One worker operates the electronic controls within the field van, always in visual contact with a second worker at the winch itself. This second person monitors the winch operation for good level-wind and any

Figure 5. Field Demonstration Organization.

Typical Field Demonstration Organization

emergency situations. Each winch is equipped with an electronic emergency shut-off switch. In addition, the larger winch has a hand-operated drum brake. The third worker is located at the well head and monitors the progress of the tools as they move downhole. In addition, for the pneumatic sources where a separate air line is involved, this person attaches the air line to the wireline with cable ties on the way down, and cuts these cable ties on the way up.

Pneumatic sources are supplied with pressurized air from high-pressure tanks at the surface. Pressure within the tools is controlled by regulators at these surface tanks, controlling both the air line pressure and the tool pressure. Couplings in the air line are anchored to prevent whipping hoses in the event of coupling failure. Pressure safety release valves are also placed in the line to prevent pressures in excess of the maximum allowable working pressure.

The source and receiver are then clamped at the desired depths if the source is a clamped source and the source is operated for a standard signal. In the case of the vibratory sources, a sweep is run that lasts 8 s. For the acoustic repeater, a single dump of air is released into the hole. The energy received at the receiver is recorded and the receiver or source is moved to its next position.

Removal of the source and receiver is simply the reverse of lowering the equipment to the first location.

8.0 DEMONSTRATION SCHEDULE

Documentation will be completed by late January to early February 1994. This documentation will include the conceptual and integrated test plan, Sandia-required safety and operating procedures for the specific site, and the equipment to be used.

The demonstration will begin in mid- to late February with approximately 1 week of fielding to test possible sites for seismic coupling and attenuation (Phase 1). Results from Phase 1 will be documented in a brief, informal report within 1 month of the completion of the field work. This report will include results of the test and recommendations for the most favorable site for the full tomographic survey. Results will include a near- and far-field power spectrum of each successful source to evaluate resolution and to estimate discernable target size. A second fielding of 2 to 3 weeks to acquire data for a full tomographic survey is planned for May or June 1994 (Phase 2) assuming results from Phase 1 are satisfactory. The analysis and interpretation of these data will be completed, and a final report on both the Phase 1 and Phase 2 results will be written by the end of September 1994. WHC personnel will assist with the interpretation of the tomogram. An additional survey will be run in August 1994 at another site (Phase 3). The purpose of this survey is to collect baseline data to map the water injection mound associated with an in-well air sparging demonstration. These data will be analyzed in FY 1995.

9.0 REFERENCES

- DOE, 1991, *Quality Assurance*, DOE Order 5700.6C, U.S. Department of Energy, Washington, D.C.
- Domenico, S. N., 1976, "Effect of Brine-Gas Mixture on Velocity in an Unconsolidated Sand Reservoir," *Geophysics*, pp. 41, 882-894.
- Elbring, G. J., 1992, *Crosshole Shear-Wave Seismic Monitoring of an In-Situ Air Stripping Waste Remediation Process*, Sandia Report, SAND91-2742, Sandia National Laboratories, Albuquerque, New Mexico, p. 55.
- Gregory, A. R., 1976, "Fluid Saturation Effects on Dynamic Elastic Properties of Sedimentary Rocks," *Geophysics*, pp. 41, 895-921.
- McDonald McNamar, M. A., 1993, *Field Access Guide for Visitors of the Volatile Organic Compound-Arid Integrated Demonstration*, WHC-SD-EN-AR-002, Rev. 1, Westinghouse Hanford Company, Richland, Washington.
- Nolet, G. (ed.), 1987, *Seismic Tomography with Applications in Global Seismology and Explorations*, Geophysics, D. Reidel Publishing Co., p. 386.
- Tweeton, D. R., 1988, *A Tomographic Computer Program with Constraints to Improve Reconstructions for Monitoring In-Situ Mining Leachate*, U.S. Bureau of Mines Report of Investigations, RI-159, p. 70.
- WAC 173-303, 1990, "Dangerous Waste Regulations," *Washington Administrative Code*, as amended.
- WHC, 1988a, *Environmental Investigations and Site Characterization Manual*, WHC-CM-7-7, Westinghouse Hanford Company, Richland, Washington.
- WHC, 1988b, *Quality Assurance Manual*, WHC-CM-4-2, Westinghouse Hanford Company, Richland, Washington.
- WHC, 1990, *Environmental Engineering Technology and Permitting Function Quality Assurance Program Plan*, WHC-EP-0383, Westinghouse Hanford Company, Richland, Washington.

**APPENDIX
PROCEDURES**

PROCEDURE FOR TRIPODS

1. Tripod is assembled flat on the ground with top of tripod as close as possible to the well head. Legs are attached to top in their fully collapsed configuration with leg release and safety pegs fully engaged.
2. With one worker at each leg, raise tripod to its standing position by walking legs in toward center.
3. With tripod standing, run wire rope lashing through the base of each leg and connect ends of the lashing together.
4. Raise legs, one hole at a time. This is done by having two people hold the leg above the leg release. The third person disengages the leg release, the leg is raised one hole, and the leg release is engaged at the new position. The safety peg is then disengaged, moved up one hole, and engaged completely at the new position. **AT NO TIME DURING THIS PROCESS SHOULD THE LEG BE HELD BETWEEN THE LEG RELEASE AND THE SAFETY PEG!**
5. Legs are raised one hole at a time, moving from leg to leg, to keep the leg lengths as equal as possible.
6. When the tripod has reached its required height, legs are adjusted to make each side of the triangle formed by the tripod as equal as possible with the distance between the legs at the base not to exceed 75% of the height of the tripod.
7. Lashing around the base of the tripod is adjusted to be fairly tight, but not to the extent that it is off the ground creating a tripping hazard.
8. An appropriately rated anchor shackle is used to attach the top sheave to the top eyebolt of the tripod.
9. A second sheave is attached to the well head by means of wire rope lashed around the well head below the flange. The wire rope should be long enough to provide 3 or 4 ft between the well head and the second sheave to permit some motion of the sheave.

PROCEDURE FOR WINCHES

1. Inspect wireline for any signs of kinking, splitting, or weakening of the wireline itself.
2. Lubricate all nipples on winch at the beginning of any field operation and at least once every two days during operation.
3. Make sure all sheaves used in the rigging are the right diameter for the size wire rope used.
4. Make sure all weight-bearing components have capacities equal to or greater than the maximum pulling power of the winch.

5. When a tool is hung on the wireline, **NEVER** disengage the clutch and allow the drum to free-wheel.
6. When winch is not in motion, **ALWAYS** set the drum brake to prevent accidental free-wheeling.
7. During operation, one person must always be at the winch itself to monitor the level-wind and to be able to operate the emergency shut-off switch if necessary.
8. During operation, winch control personnel must be in constant visual and audible contact with the person manning the winch.

DATE

FILMED

3 / 25 / 94

END