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**Stakeholder Acceptance Analysis:
In-Well Vapor Stripping, In-Situ
Bioremediation, and Gas Membrane
Separation System**

T.S. Peterson

December 1995

Prepared for the U.S. Department of Energy's
Office of Technology Development
under Contract DE-AC06-76RLO 1830

Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
by Battelle Memorial Institute

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STAKEHOLDER ACCEPTANCE ANALYSIS

**IN-WELL VAPOR STRIPPING
IN-SITU BIOREMEDIATION
GAS MEMBRANE SEPARATION SYSTEM (MEMBRANE SEPARATION)**

Prepared by

**Todd Peterson
Battelle Seattle Research Center**

**for
U.S. Department of Energy
Office of Technology Development**

December 1995

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Patti Warden

INTRODUCTION

Stakeholders based final evaluations of three innovative technologies in the Volatile Organic Compounds in Arid Soils Integrated Demonstration (VOC-Arid ID) on results of field demonstrations. However, field tests for two technologies, In-Well Vapor Stripping and In-Situ Bioremediation, were not complete at the time of final evaluation. As a result, this report offers stakeholder evaluation of the acceptability of these technologies based on assessments gathered during a focus group and workshop with 33 stakeholders associated with the Hanford site in Washington State and interviews with 75 stakeholders from four other arid Department of Energy sites in the western United States. In addition, the demonstration of Membrane Separation had been completed before the VOC-Arid ID stakeholder involvement program began, so its evaluation has the same basis.

This report offers three principal sets of information:

- Principal comments concerning each of the technologies organized according to category of concern; and
- Comments about each of the technologies from stakeholders at the four sites other than Hanford.
- Requirements stakeholders have for the acceptance of any innovative technology;

Appendix A presents a matrix recording Hanford stakeholders' data requirements for the demonstration of each of the technologies.

STAKEHOLDER INVOLVEMENT PROCESS

The Volatile Organic Compounds in Arid Soils Integrated Demonstration (VOC-Arid ID) extensively involved stakeholders in the evaluation of innovative technologies to remediate contamination by VOCs. The stakeholder involvement program identified data requirements and issues at five arid sites. Data requirements are needs for specific information about a technology and its performance. They derive from questions about a technology's demonstration and operation. Issues and concerns are requirements and conditions for the acceptability of a technology; an example is "Technologies should be versatile in application and not transfer contaminants from one environmental medium to another."

A goal of the VOC-Arid ID was to test a technology once and then be able to deploy it broadly by ensuring that test plans for technologies to be demonstrated at one site included the issues, concerns, and data requirements of stakeholders from other sites where the technology was likely to be used. Ultimately, the process was designed to expedite deployment of effective and acceptable remedial technologies by determining what stakeholders required of these technologies.

Stakeholder involvement proceeded in three phases. Throughout, innovative technologies were evaluated in comparison to technologies in current use ("baseline" technologies.) In the first phase, through individual interviews, Hanford site stakeholders contributed to the development of criteria by which technologies would be evaluated. In focus groups, these stakeholders defined data requirements and posed questions to be

addressed in technology demonstrations. An integrated workshop was then held to augment the demonstration plans for six technologies. The workshop included all of the Hanford stakeholders and the scientists and engineers developing and testing the technologies. The six technologies were:

- Passive Soil Vapor Extraction Using Borehole Flux
- Tunable Hybrid Plasma
- ResonantSonic Drilling
- In-Situ Bioremediation
- In-Well Vapor Stripping
- Membrane Separation

In the second phase of the technology evaluation program, 75 stakeholders from four other arid DOE sites accomplished two goals through individual interviews. First, they validated and further refined the data requirements, issues, and concerns identified by Hanford stakeholders. Second, they defined requirements specific to their site and region.

Demonstrations for three of the technologies are now complete. These three are Passive Soil Vapor Extraction, ResonantSonic Drilling, and Tunable Hybrid Plasma. Although the technologies discussed in this report did not go through a post-demonstration final evaluation phase, stakeholder comments are still valuable information for those making decisions about technology deployment.

IN-WELL VAPOR STRIPPING

TECHNOLOGY DESCRIPTION

In-Well Vapor Stripping is a VOC-removal system that volatilizes VOCs in groundwater and draws them up as vapor inside a well to the surface where they can be treated. The system works somewhat like a fish tank filter. It consists of a well within a well, where the inner well extends from the ground surface into the saturated zone and is open in the zone of contamination. The outer well extends through the unsaturated zone and may end above the water table. A gas injection line in the inner well injects bubbles into contaminated water. VOCs in the contaminated groundwater volatilize into the air inside the bubbles. The bubbles and contaminated water rise together. This column of water with bubbles then hits a “packer” causing the bubbles to burst. The water falls down in the space between the inner and outer wells and returns to the water table. The contaminated gas from the bubbles is vacuumed off through a line extending from the ground surface into the space between the inner and outer wells. In this way the system extracts the VOC-laden vapor, and partially cleaned water is returned to the aquifer. The system re-circulates groundwater through air lift pumping. Groundwater becomes cleaner and cleaner with each pass through the system.

In-Well Vapor Stripping removes VOCs from groundwater without bringing contaminated water to the surface. Contaminated water does not need to be handled, stored or disposed of above ground, and injection wells are not needed.

PRINCIPAL STAKEHOLDER COMMENTS CONCERNING IN-WELL VAPOR STRIPPING

Stakeholders see as advantages the technology's ability to:

- treat water without removing it from the aquifer;
- avoid the energy requirements of pumping water to the surface;
- avoid possible exposure to contaminants by leaving water in the ground; and
- avoid the cost of handling, treating and disposing of contaminated water at the surface.

Environmental Impacts. Hanford stakeholders, particularly regulators, see environmental risk associated with the technology's possible spreading of subsurface contamination (moving it beyond the treatment zone). Stakeholders advocate subsurface monitoring and control. They are concerned about groundwater possibly rising into the vadose zone as the result of the technology's operation, and about the possible effects of re-circulation on the aquifer and vadose zone. Stakeholders want to know if the technology causes mounding of groundwater and changes in water chemistry. They are also concerned about clogging and the loss of permeability within the aquifer. Stakeholders ask that the effects of possible pressurized vapor releases in the subsurface be determined.

Public Health and Safety. Stakeholders require the monitoring and capturing of off-gas releases during operation.

Remaining Contamination. Hanford stakeholders raised concerns about evaluating the amount and type of contamination remaining after use of In-Well Vapor Stripping. Stakeholders at other sites raised issues about the technology's ability to completely clean contaminated water, to handle other types and concentrations of VOCs, metals, and radionuclides, and to deal with non-aqueous phase liquids.

Process Waste. Stakeholders require information about:

- whether co-contaminants will remain in process waste; and
- how off-gas and secondary waste will be treated and disposed of.

Track Record and Regulatory Precedence. There is no specific regulatory framework for this class of technologies that move groundwater within the subsurface, and no regulatory or operating track record. Stakeholders point out the need to address whether changing the groundwater level would create regulatory concerns.

Works as Intended. Stakeholders want to know:

- if the technology causes secondary contamination as it moves groundwater from level to level in the subsurface;
- if the technology is effective with a deep unsaturated zone and a fast moving, high yield aquifer such as the Snake River aquifer under INEL;
- if the technology works in heterogeneous soils at varying depths, with non-VOC contaminants and in a pulsing mode because of slow recharge; and
- how operators will be assured that new water is being drawn into circulation.

Practicality. For stakeholders, zone of influence of the vapor stripping wells is a major issue affecting rate of performance and cost.

The technology's effect on co-contaminants, especially tritium and heavy metals, is an important issue to stakeholders.

The table on the following pages records comments concerning In-Well Vapor Stripping from 75 stakeholders at four arid sites other than Hanford.

**COMMENTS CONCERNING IN-WELL VAPOR STRIPPING FROM 75 STAKEHOLDERS
AT FOUR ARID SITES OTHER THAN HANFORD**

ISSUES BY CATEGORY	SITES WHERE ISSUES RAISED	STAKEHOLDER CATEGORIES
<p>Remaining Contamination</p> <ul style="list-style-type: none"> Assess how completely the technology captures contaminants and its effectiveness in capturing different concentrations of carbon tetrachloride. Are all volatiles stripped, or just those with lower or higher molecular weight? Consider the effects of co-contaminants, the potential side effects, and the levels of removal achieved. Assess the cost effectiveness of having separate systems for co-contaminants. Demonstrate the technology's ability to reduce contamination faster than pump and treat. There is concern about spreading contamination in ground water, and vadose-to-ground water contaminant transfer through returning stripped ground water. Consider the use of liquid nitrogen, with its expansion coefficient, to enable greater removal of VOCs. Assess the effectiveness of the technology for NAPLs; will it disperse the non-aqueous phase liquids (NAPLs)? 	<ul style="list-style-type: none"> INEL Rocky Flats INEL Rocky Flats Sandia INEL INEL Sandia Los Alamos Rocky Flats 	<ul style="list-style-type: none"> Interest Group Regulator Interest Group Regulator Interest Group Technology User Interest Group Interest Group Technology User Regulator

ISSUES BY CATEGORY	SITES WHERE ISSUES RAISED	STAKEHOLDER CATEGORIES
<p>Process Waste</p> <ul style="list-style-type: none"> There is a concern about transferring contaminants from one medium to another and the ultimate disposal of the waste. Define the off gas and secondary waste generated by the technology, including metals precipitated from the aeration process. Define the technology's ability to use a destruction system for off gas. Determine waste transportation and disposal needs and costs. Demonstrate that in-well vapor stripping can be used with a contaminant disposal/destruction system other than GAC; reliance on GAC is problematic. 	<ul style="list-style-type: none"> INEL Los Alamos Rocky Flats Sandia Rocky Flats 	<ul style="list-style-type: none"> Interest Group Regulator Regulator Technology User Regulator Regulator
<p>Practicality</p> <ul style="list-style-type: none"> Define the zone of influence around each well, extrapolate to differing soil and formation types, provide extraction volume numbers, and evaluate predictability of flow. Define the number of wells and distances between them required for plumes of different sizes and types. Demonstrate how deep in the subsurface this technology can operate effectively. Evaluate the efficiency of the system, and the ability to draw in water after reinfiltration starts. Assess whether a forced gradient will bring contaminants toward the collection point. 	<ul style="list-style-type: none"> INEL Los Alamos Rocky Flats Sandia Rocky Flats Sandia INEL Sandia 	<ul style="list-style-type: none"> Regulator Technology User Technology User Tribes Interest Group Regulator Technology User Regulator Technology User Regulator Technology User Interest Group Regulator Regulator

ISSUES BY CATEGORY	SITES WHERE ISSUES RAISED	STAKEHOLDER CATEGORIES
<ul style="list-style-type: none"> Confirm the ability to use the technology broadly. This technology's transferability is an advantage. Evaluate differing efficiencies with changes of the well screen and packer relative to the water table; evaluate the cost for modifying the well screen elevations to maintain expected efficiencies. Evaluate the ability of the technology to be coupled with bioremediation. Assess performance with different types of off-gas treatment systems. Evaluate the ability of the technology to retrofit existing water supply and monitoring wells. Define well size ranges and relate to the radii of influence. Evaluate alternative sources for procuring the technology; there appears to be single source. Consider using the technology with surfactants for DNAPLs and sorbed VOCs. Evaluate the pumping rate needed to get appropriate withdrawal without overpumping; expect capture problems. Assess the need to circulate new water into the well to keep from treating the same water over and over. An advantage to this technology is that it addresses all VOCs. Evaluate enhanced degradation at the well due to air circulation. 	<ul style="list-style-type: none"> Rocky Flats Sandia Sandia Sandia Rocky Flats INEL Rocky Flats Sandia Sandia INEL INEL INEL INEL Los Alamos 	<ul style="list-style-type: none"> Technology User Regulator Interest Group Regulator Regulator Technology User Regulator Technology User Regulator Technology User Regulator Regulator Interest Group Technology User

ISSUES BY CATEGORY	SITES WHERE ISSUES RAISED	STAKEHOLDER CATEGORIES
<ul style="list-style-type: none"> • This is just another extraction system like pump and treat, and all extraction systems have inherent flaws. • There is not a lot of application at LANL; the only current ground water contamination issue is tritium. • Define the advantages of in-well vapor stripping over sparging. • Assess whether the technology can be used in pulsing mode (due to slow recharge). • Compare this technology with use of surfactants or with dewatering followed by vapor extraction. • Assess whether the technology experiences precipitation problems (clogging). • To bring new, untreated water into the well, consider reinjecting water upstream to increase circulation and the effective radius of influence. • Define moisture limitations in the above-grade treatment train. 	<ul style="list-style-type: none"> • Los Alamos • Los Alamos • Rocky Flats • Rocky Flats • Rocky Flats • Rocky Flats • INEL 	<ul style="list-style-type: none"> • Technology User • Regulator • Regulator • Technology User • Technology User • Technology User • Technology User
<p>Works as Intended</p> <ul style="list-style-type: none"> • Evaluate the effectiveness of the technology at drawing water into the wells, the flow, rate, and potential mounding effect, and the ability of the technology to operate in dense saturated zone soils and clay soils. • Define how effectiveness will be measured (volume of ground water, contaminant captured) and the levels of cleanup that are achievable. 	<ul style="list-style-type: none"> • INEL • Los Alamos • Rocky Flats • Sandia • Rocky Flats • Sandia 	<ul style="list-style-type: none"> • Technology User • Technology User • Regulator • Technology User • Regulator • Technology User • Regulator • Interest Group

ISSUES BY CATEGORY	SITES WHERE ISSUES RAISED	STAKEHOLDER CATEGORIES
<ul style="list-style-type: none"> Quantify the recirculation characteristics of the technology, the ability to set up circulating cells, the size of the circulation pattern, and the possibility of spreading the plume. Demonstrate how many times contaminated water has to be recirculated through the technology, and at what cost, to reach each cleanup level. Consider other influences, such as water supply wells, on the technology's operation. Consider heating water to enhance VOC transfer. Consider returning cleaned water upgradient of the well, outside the zone of influence, to push contamination toward the stripping well. Define the function and effectiveness of the packer (separator plate). There is concern about packers not staying in place, and creating maintenance problems. Demonstrate what prevents volatiles from bypassing the extraction wells. Determine in-well vapor stripping's applicability by determining how long it will take for contamination at a particular site to migrate. 	<ul style="list-style-type: none"> Los Alamos Rocky Flats Sandia Sandia Los Alamos Sandia INEL Los Alamos Rocky Flats Rocky Flats 	<ul style="list-style-type: none"> Technology User Regulator Technology User Regulator Regulator Technology User Regulator Technology User Regulator Interest Group
Cost <ul style="list-style-type: none"> Assess the numbers of wells needed to implement the technology. 	<ul style="list-style-type: none"> Sandia 	<ul style="list-style-type: none"> Regulator

ISSUES BY CATEGORY	SITES WHERE ISSUES RAISED	STAKEHOLDER CATEGORIES
<ul style="list-style-type: none"> Evaluate the total cost to operate the technology, including startup costs, well installation, costs of pumping into wells, determining how long water must be cycled through the unit, contaminant removal and treatment, and the cost per pound of contaminant removed. Evaluate costs of the technology in terms of process efficiency, and costs compared with pump and treat. 	<ul style="list-style-type: none"> Los Alamos Rocky Flats Sandia Los Alamos Sandia 	<ul style="list-style-type: none"> Public Official Regulator Technology User Interest Group Technology User Technology User Technology User
Time <ul style="list-style-type: none"> Define the length of time needed for the technology to operate as planned, including the time for setup and operations, and the time to reach target volumes and efficiency. 	<ul style="list-style-type: none"> INEL Los Alamos Rocky Flats 	<ul style="list-style-type: none"> Interest Group Technology User Interest Group Technology User
Worker Safety <ul style="list-style-type: none"> Evaluate worker protection needs if soil vapor extraction is used in conjunction with stripping. Assess the potential for explosion, and the possibility of using nitrogen as a carrier gas to avoid explosions. 	<ul style="list-style-type: none"> INEL Los Alamos 	<ul style="list-style-type: none"> Interest Group Technology User
Public Health and Safety <ul style="list-style-type: none"> Evaluate the potential for release of off gas and how it will be controlled. Evaluate the ability of the technology to capture mobilized vadose zone contamination. Assess in-well vapor stripping's ability to clean water to a 5 ppb drinking water standard. Assess the likelihood of the technology to spread contaminants. 	<ul style="list-style-type: none"> Sandia INEL Rocky Flats Rocky Flats 	<ul style="list-style-type: none"> Technology User Interest Group Regulator Technology User

ISSUES BY CATEGORY	SITES WHERE ISSUES RAISED	STAKEHOLDER CATEGORIES
<p>Environmental Impacts</p> <ul style="list-style-type: none"> Assess mounding, water chemistry changes, and mixing characteristics in the aquifer resulting from use of the technology. Evaluate whether packer materials will affect water quality. Determine whether some contaminants are moved beyond the treatment zone. Assess whether the technology increases biomass in the aquifer. This technology offers the advantages of bringing only gas to the surface and leaving contaminated ground water below; of eliminating the need to reinject ground water; and of not pumping, particularly when contaminated water is deep. 	<ul style="list-style-type: none"> Sandia Sandia INEL Rocky Flats INEL Los Alamos Sandia 	<ul style="list-style-type: none"> Regulator Interest Group Technology User Technology User Technology User Tribes Interest Group Interest Group
<p>Public Perception</p> <ul style="list-style-type: none"> Because the in-well vapor stripping system is a modification of air sparging technology already in use, this technology should be acceptable for projects funded with public money. The "low-tech" nature of this technology makes it attractive, and it is familiar to regulators and the public. 	<ul style="list-style-type: none"> Sandia Los Alamos 	<ul style="list-style-type: none"> Technology User Regulator
<p>Socio-Economic Interests</p> <ul style="list-style-type: none"> Evaluate the availability of a work force competent to operate the technology. 	<ul style="list-style-type: none"> Sandia 	<ul style="list-style-type: none"> Technology User

ISSUES BY CATEGORY	SITES WHERE ISSUES RAISED	STAKEHOLDER CATEGORIES
Regulatory Infrastructure and Track Record <ul style="list-style-type: none"> Regulators may not be comfortable with this technology; make them familiar with it early. In-well vapor stripping is not new; regulators are relatively familiar and comfortable with it. 	<ul style="list-style-type: none"> Sandia Rocky Flats 	<ul style="list-style-type: none"> Technology User Regulator
Regulatory Compliance <ul style="list-style-type: none"> There is an advantage to this technology in that no treated water must be disposed of, and therefore no ground-water discharge permit is needed. Evaluate the need for Clean Air Act permitting in New Mexico and elsewhere for this technology. Determine ability to comply with drinking water or irrigation standards or other water requirements after the technology has been used. 	<ul style="list-style-type: none"> Sandia Sandia INEL 	<ul style="list-style-type: none"> Regulator Technology User Interest Group
Other <ul style="list-style-type: none"> Evaluate the availability of business partners for deployment of this technology. 	<ul style="list-style-type: none"> Sandia 	<ul style="list-style-type: none"> Interest Group

IN-SITU BIOREMEDIATION

TECHNOLOGY DESCRIPTION

In-Situ Bioremediation involves stimulating naturally occurring microorganisms in the subsurface so that they degrade and detoxify chemical contaminants. Native microorganisms, stimulated in this case by the addition of acetate and nitrate, degrade and consume carbon tetrachloride. In-Situ Bioremediation technology injects nutrients (as needed after initial nitrates are depleted) through a series of injection wells. The injected nutrients produce a zone of active organisms around the well.

In-Situ Bioremediation can be used as a sole cleanup method or as a “polishing” technology to remove the last vestiges of contamination in an aquifer. The technology destroys contaminants in place, rather than pumping groundwater to the surface for treatment.

PRINCIPAL STAKEHOLDER COMMENTS CONCERNING IN-SITU BIOREMEDIATION

Stakeholders have mixed opinions about the acceptability of In-Situ Bioremediation. Some see bioremediation as a natural process, others as a disturbance of natural processes.

Although there are public concerns about the control of stimulated microorganisms, some stakeholders do not see In-Situ Bioremediation creating an alarmed public reaction because of the advantages the technology offers. These include treating contamination in place and thereby reducing exposure as well as transportation, storage, and disposal of wastes.

Other stakeholders maintain that the public opposes the addition of anything to an ecosystem, so acceptance may depend on showing that the nutrients injected are the minimum needed to bring about cleanup.

Remaining Contamination. Stakeholders’ acceptance of the technology will depend in part on the answers to these questions:

- Can bioremediation remove the levels of contamination needed to clean groundwater to regulatory standards?
- Will the action of the stimulated microorganisms on contaminants produce harmful by-products?
- Will acetate and nitrate combine to produce hazardous by-products?

Stakeholders require information about the following:

Aquifer Clogging and Process Waste. Will injecting nutrients cause aquifer clogging? Will the microbial degradation of contaminants generate chlorides, chlorine gas, vinyl chloride, or other process wastes?

Failure Control, and Monitoring. Proven failure controls must be part of the use of this technology. Stakeholders require monitoring both during and after the technology's operation.

Public Health and Safety. Stakeholders ask that it be made plain how microorganisms work both during and after stimulation to allow immediate detection of any impending effect on human health. It is necessary to know the risk and possible result of ingesting stimulated microorganisms.

Many stakeholders see treating contamination in place as an advantage both in terms of protecting health by reducing exposure, and in terms of eliminating the transportation, treatment, and disposal of wastes.

Environmental Impacts. Stakeholders require that the technology have the ability to stop microbial growth, and to not spread contamination.

It will be necessary to demonstrate that stimulated microbial activity will not, in the case of the Hanford site, harm the biota of the Columbia River.

Potential impacts on the quality of groundwater and sources of drinking water are significant concerns at all the arid sites. For example, stakeholders in the Albuquerque area will likely be concerned about the injection of nitrates because some groundwater in that area is now high in nitrates.

Practicality. Stakeholders will ask:

- Is the technology effective with multiple contaminants and in a range of geologic conditions?
- What is the technology's rate of performance? How long will it require to reach cleanup goals?
- What are the limits of its effectiveness? For example, how well will the technology be able to deliver nutrients and stimulated microorganisms in arid, non-sedimentary soil, fractured basalt, and the Snake River Aquifer's fast moving water? How well will the process work with a wide range of temperatures, microorganisms, soil depths, and contaminants?
- How does the technology's performance compare to that of an established remediation system such as pump and treat?

Works as Intended. In order for the technology to be accepted for use it will be necessary to explain what microorganisms will do following the withdrawal of nutrients.

This technology is seen, especially by technology users, as a good "polishing" method, but good data are needed on the levels of contamination, site conditions, plume size, aquifer characteristics, and permeability ranges with which in-situ bioremediation is effective.

Regulatory Compliance. In Washington state, in relation to the Hanford site, the Department of Ecology critically reviews the injection of anything but oxygen to stimulate microbial growth because of the state's non-degradation standard for groundwater. In order for the technology to be accepted for use, Washington state

regulators must be satisfied with the safety, in terms of mobility and health, of anything added to the subsurface. Similarly, New Mexico strictly regulates the injection of anything into groundwater.

At all arid sites, regulators will carefully examine the technology's ability to comply with drinking water standards

The table on the following pages records comments concerning In-Situ Bioremediation from 75 stakeholders at four arid sites other than Hanford.

**COMMENTS CONCERNING IN-SITU BIOREMEDIATION FROM 75 STAKEHOLDERS AT
FOUR ARID SITES OTHER THAN HANFORD**

ISSUES BY CATEGORY	SITES WHERE ISSUES RAISED	STAKEHOLDER CATEGORIES
<p>Remaining Contamination</p> <ul style="list-style-type: none"> Determine the environmental ramifications of the use of acetate, including the effects on pH, metal mobility and redox potential, and reactions of acetate and nitrate that might make something in the aquifer more hazardous. Assess how biomass affects organic and inorganic co-contaminants and pesticides (range of concentrations), and whether it metabolizes metals or changes their valence state. Assess the efficiency of the technology. Define its ability to handle the total contamination problem, including radionuclides and metals, and define performance levels. Define any restrictions on future ground water use. 	<ul style="list-style-type: none"> INEL Sandia Sandia Sandia Rocky Flats Sandia 	<ul style="list-style-type: none"> Interest Group Regulator Regulator Interest Group Technology User Interest Group Technology User
<p>Process Waste</p> <ul style="list-style-type: none"> Evaluate the possibility that the action of the stimulated microorganisms will produce unwanted by-products. Determine the quantities and types of degradation products, both anticipated and unanticipated, and their potential environmental impacts. Evaluate the secondary waste, including biomass, produced from microbial digestion of carbon tetrachloride. Evaluate approaches to prevent microbial waste products from eventually shutting down the system. 	<ul style="list-style-type: none"> INEL Los Alamos Rocky Flats Sandia Los Alamos Rocky Flats Sandia Sandia 	<ul style="list-style-type: none"> Interest Group Technology User Regulator Technology User Interest Group Regulator Interest Group Technology User

ISSUES BY CATEGORY	SITES WHERE ISSUES RAISED	STAKEHOLDER CATEGORIES
<p>Practicality</p> <ul style="list-style-type: none"> In-situ techniques are preferable to bringing contamination to a well or withdrawal system. The benefit of this technology is its ability to handle contaminants that pump and treat cannot fully address. Evaluate the usefulness and applicability of this technology for a broad range of applications and conditions including: a range of constituents; co-contaminants; various soil types and geologies; the ability to function in the vadose zone, in different weather conditions, and in plutonium-contaminated zones. Address the technology's ability to work in changing aquifer characteristics and transmissivity characteristics, and to address subsurface aquifer discontinuities. Evaluate and document failure scenarios. Evaluate the potential for entrainment of metals and particulates (including radioactively contaminated particulates) and the ability to concentrate dispersed plutonium. Evaluate needed nutrient balances in different conditions. Evaluate the ability to supply nutrients when microbes sorb onto soil particles and the ability to deliver nutrients in arid climates, non-sedimentary materials, and fast-moving subsurface ground water. 	<ul style="list-style-type: none"> INEL Los Alamos INEL Los Alamos Rocky Flats Sandia Sandia INEL Rocky Flats INEL 	<ul style="list-style-type: none"> Interest Group Technology User Technology User Interest Group Technology User Interest Group Regulator Technology User Regulator Technology User Regulator Technology User

ISSUES BY CATEGORY	SITES WHERE ISSUES RAISED	STAKEHOLDER CATEGORIES
<ul style="list-style-type: none"> Determine the requirements for nutrients, oxygen, and temperature, and assess the likelihood of getting microbes to live in field conditions. Evaluate the ability to couple aerobic with anaerobic bioremediation to address all contaminants. 	<ul style="list-style-type: none"> Los Alamos Sandia 	<ul style="list-style-type: none"> Technology User Interest Group
<ul style="list-style-type: none"> Define the genus and class of native microorganisms that will be stimulated and the expected effects of stimulation. Evaluate the broad applicability of the technology to sites with different climates and populations of microorganisms. Culture soils and/or ground-water samples in advance to ascertain that the microbes needed for the chemicals of concern are present. 	<ul style="list-style-type: none"> INEL Los Alamos Rocky Flats 	<ul style="list-style-type: none"> Technology User Regulator Technology User Interest Group Regulator
<ul style="list-style-type: none"> Consider using bioengineered specialized microbes, rather than native microorganisms. 	<ul style="list-style-type: none"> INEL Los Alamos Rocky Flats 	<ul style="list-style-type: none"> Technology User Technology User Regulator
<ul style="list-style-type: none"> Evaluate monitoring techniques to verify coverage and effectiveness of the technology in an heterogeneous subsurface. 	<ul style="list-style-type: none"> INEL 	<ul style="list-style-type: none"> Technology User
<ul style="list-style-type: none"> Assess whether the technology reduces soil permeability. 	<ul style="list-style-type: none"> Rocky Flats 	<ul style="list-style-type: none"> Technology User
<ul style="list-style-type: none"> Assess the ability to control the growth and spread of microorganisms. 	<ul style="list-style-type: none"> Rocky Flats 	<ul style="list-style-type: none"> Technology User
<ul style="list-style-type: none"> Consider using horizontal wells rather than vertically-oriented wells. 	<ul style="list-style-type: none"> Los Alamos 	<ul style="list-style-type: none"> Technology User
<ul style="list-style-type: none"> Define the number of holes required to get enough nutrients down to ground water. Determine how to prevent surface contamination from washing down holes. 	<ul style="list-style-type: none"> Los Alamos 	<ul style="list-style-type: none"> Tribes

ISSUES BY CATEGORY	SITES WHERE ISSUES RAISED	STAKEHOLDER CATEGORIES
<ul style="list-style-type: none"> Evaluate the ability to operate in a pulsed fashion and in a quasi-closed loop system, with inputs (bio-stimulants) equaling output, so that ground-water mounding does not occur. 	<ul style="list-style-type: none"> Sandia Los Alamos 	<ul style="list-style-type: none"> Regulator Technology User
<ul style="list-style-type: none"> Evaluate the usefulness of the technology for near-surface ground-water cleanup. 	<ul style="list-style-type: none"> Sandia 	<ul style="list-style-type: none"> Regulator
<ul style="list-style-type: none"> Does the potential effect of biomass slowing ground-water flow and stabilizing contamination preclude other treatments later? 	<ul style="list-style-type: none"> Sandia 	<ul style="list-style-type: none"> Regulator
<ul style="list-style-type: none"> Consider opening up the subsurface geology to allow the movement of stimulated microorganisms. 	<ul style="list-style-type: none"> Rocky Flats 	<ul style="list-style-type: none"> Interest Group
<ul style="list-style-type: none"> Benzene is a primary concern at Rocky Mountain Arsenal. Define whether there is a need to add both nitrates for in-situ bioremediation to function effectively. 	<ul style="list-style-type: none"> Rocky Flats 	<ul style="list-style-type: none"> Regulator
<ul style="list-style-type: none"> Assess bringing waste to the surface and using the technology where it could be observed and controlled. 	<ul style="list-style-type: none"> Rocky Flats 	<ul style="list-style-type: none"> Technology User
<ul style="list-style-type: none"> Injection and withdrawal wells may be needed at Rocky Flats to create a predictable flow pattern in clay soils. 	<ul style="list-style-type: none"> Rocky Flats 	<ul style="list-style-type: none"> Technology User
<ul style="list-style-type: none"> Assess whether this technology creates a reduction zone at the edge of plumes, making metals more soluble. Selenium is a problem at Rocky Flats. 	<ul style="list-style-type: none"> Rocky Flats 	<ul style="list-style-type: none"> Technology User
<ul style="list-style-type: none"> Can the technology be used with other technologies (e.g., air stripper, pump and treat)? 	<ul style="list-style-type: none"> Rocky Flats 	<ul style="list-style-type: none"> Technology User

ISSUES BY CATEGORY	SITES WHERE ISSUES RAISED	STAKEHOLDER CATEGORIES
<ul style="list-style-type: none"> Define skill levels and assess the level of specialized training needed to operate the technology. Evaluate the effectiveness of using in-situ bioremediation first, and then using other technologies as polishing approaches. This technology is not useful at Sandia due to the depth of ground water and the fact the most contamination is now in the vadose zone. 	<ul style="list-style-type: none"> Rocky Flats Sandia Sandia Sandia 	<ul style="list-style-type: none"> Technology User Interest Group Technology User Technology User
<p>Works as Intended</p> <ul style="list-style-type: none"> Assess the effects of solvent toxicity on microbes. Consider the need for a site-specific system design to accommodate differing strata and the nature of contamination. It is unclear how microbes would stay in fractured basalt at depth at INEL. This appears to be a good polishing technology. Evaluate the upper limits of concentrations the technology can handle (potential application to tank sludge to remove RCRA regulated organics and leave radionuclides only). Identify the lower limits of effectiveness. Evaluate characterization needs and levels, including the effects of encountering unexpected contaminants or concentrations on effectiveness. Evaluate the effects of geology in order to know if organisms will spread to targeted areas. Evaluate the zone of influence and the maximum area possible for treatment with this technology. Evaluate the usefulness of the technology for large plumes versus limited areas of contamination. 	<ul style="list-style-type: none"> INEL INEL INEL INEL Rocky Flats INEL Rocky Flats INEL Los Alamos Sandia 	<ul style="list-style-type: none"> Regulator Regulator Regulator Technology User Technology User Technology User Interest Group Public Official Tribes Technology User Public Official Regulator Technology User Tribes

ISSUES BY CATEGORY	SITES WHERE ISSUES RAISED	STAKEHOLDER CATEGORIES
<ul style="list-style-type: none"> Evaluate aquifer flow restrictions, particularly as the technology may affect spring flows. Determine aquifer permeability ranges for effective nutrient delivery, and the potential for preferential direction of the distribution of the biomass by aquifer characteristics. Assess the technology's ability to treat heterogeneous contamination. Assess the ability of the technology to operate effectively and provide detailed input/output analysis. Determine the methods for delivering nutrients at different distances from the wells. Quantify how air bubbles move in the aquifer in order to appropriately design the technology. In-situ bioremediation's effectiveness has not been proven with lower-carbon-chain contaminants. Assess the ability to control the vertical distribution of microbes. Assess the potential for ground water mounding at the treated area. Develop consistent coefficients and theories of action for the technology. Ensure that there are enough wells to avoid dead spots and small anaerobic areas, which will compromise the effectiveness of the technology. 	<ul style="list-style-type: none"> INEL Los Alamos Sandia Los Alamos Sandia Rocky Flats Los Alamos Rocky Flats Sandia Sandia Sandia Sandia 	<ul style="list-style-type: none"> Technology User Regulator Interest Group Interest Group Technology User Interest Group Regulator Regulator Regulator Technology User Technology User Technology User

ISSUES BY CATEGORY	SITES WHERE ISSUES RAISED	STAKEHOLDER CATEGORIES
<p>Cost</p> <ul style="list-style-type: none"> Evaluate system costs before full-scale testing, including startup costs and operating costs for the timeframe required for the process to work. Evaluate in-situ bioremediation's cost competitiveness with technologies performing similar functions, including pump and treat. Define costs per unit of contaminant treated or destroyed. These costs appear to be low, thus making the technology's use appropriate for small businesses. The system costs seem expensive. Startup costs appear to be minimal. 	<ul style="list-style-type: none"> INEL Sandia Los Alamos Sandia Sandia Sandia Sandia 	<ul style="list-style-type: none"> Interest Group Interest Group Public Official Regulator Interest Group Interest Group Technology User Public Official Technology User
<p>Time</p> <ul style="list-style-type: none"> Define the timeframe to complete cleanup of ground water to usable levels. Can the water be used during treatment? Evaluate the duration of the microbe bloom and die-back phases. 	<ul style="list-style-type: none"> Los Alamos Sandia Sandia 	<ul style="list-style-type: none"> Public Official Interest Group Technology User Technology User
<p>Worker Safety</p> <ul style="list-style-type: none"> Define needs for operator training to adequately monitor the system. 	<ul style="list-style-type: none"> Sandia 	<ul style="list-style-type: none"> Technology User

ISSUES BY CATEGORY	SITES WHERE ISSUES RAISED	STAKEHOLDER CATEGORIES
<p>Public Health and Safety</p> <ul style="list-style-type: none"> • Define controls for excess microbial growth and controls to ensure that the appropriate organisms are stimulated. • Evaluate the ability to monitor the technology, and to demonstrate that contaminants are not spreading and escaping from the treatment area. • Define the microbes more clearly, and assess the potential impacts on humans if the microbes are ingested. • Subsurface or in-situ treatment is an advantage due to reduced potential exposures, elimination of transportation, and reduced treatment and disposal costs. 	<ul style="list-style-type: none"> • Rocky Flats • Rocky Flats • Sandia • Sandia 	<ul style="list-style-type: none"> • Interest Group • Technology User • Public Official • Technology User

ISSUES BY CATEGORY	SITES WHERE ISSUES RAISED	STAKEHOLDER CATEGORIES
<p>Environmental Impacts</p> <ul style="list-style-type: none"> Define the environmental impacts of the technology's use, including the impacts of creating abnormal conditions and potentially spreading contamination. Assess whether that affected section of the ecosystem will impact other sections. Assess the ability to stimulate specific microbes and to control the growth of microorganisms. Consider above-ground, controlled use in 100% containment. Evaluate whether radionuclides could affect microbial growth and cause escapes. Define the effects of acetate on ground water. Evaluate the effects of the technology, including long-term effects, on permeability and flow conditions of an aquifer and on water quality. Will side effects on the ground water interrupt natural processes? Evaluate microbial growth in ground water and the area of effectiveness. Could water treated by this method be used for irrigation or drinking? What would the requirements be for filtration or processing water treated by bioremediation? The technology is likely to spread contamination in INEL conditions. Evaluate the buildup of nitrates in ground water, and possible mechanisms to monitor and control the buildup. There is concern about creating another cleanup problem by adding nitrates. Use of native microbes is an advantage; don't import "exotic" species. 	<ul style="list-style-type: none"> Rocky Flats INEL Rocky Flats Rocky Flats INEL Sandia Los Alamos Sandia INEL INEL Los Alamos Los Alamos 	<ul style="list-style-type: none"> Interest Group Technology User Interest Group Interest Group Public Official Interest Group Regulator Technology User Interest Group Public Official Regulator Tribes Interest Group Public Official Regulator Tribes Interest Group

ISSUES BY CATEGORY	SITES WHERE ISSUES RAISED	STAKEHOLDER CATEGORIES
<ul style="list-style-type: none"> Evaluate the relationship of selected microbes to other microbes in the area. Evaluate whether the microbes stop growing when nutrient addition ends. Evaluate how microbes behave with indigenous food sources. Evaluate the effects of the technology at the discharge point and the possible creation of an imbalanced ecosystem. Define the size and footprint of necessary equipment at the surface. Assess the tendency of the technology to create a reducing environment (wherein electrons are being added to ions), and the likelihood of increased inorganic contaminant mobility. Evaluate dissolution and precipitation of metals and biofouling of the well and aquifer in the vicinity of the well screen. Define monitoring requirements for growth and spread of microorganisms. How will degradation of contaminants be measured? Evaluate creation of by-products. Assess differences over time (e.g., increased biomass) with microbial growth in saturated soil. Evaluate the likelihood of releasing product into free phase and causing it to move into ground water as free product. 	<ul style="list-style-type: none"> Sandia Sandia Los Alamos Sandia Sandia Rocky Flats Rocky Flats Sandia Sandia 	<ul style="list-style-type: none"> Regulator Regulator Technology User Interest Group Regulator Regulator Interest Group Technology User Interest Group Regulator
Public Perception <ul style="list-style-type: none"> Potential clogging of the aquifer with biomass and slowing ground water flow will be the public perception problems at INEL. Evaluate the potential impacts on aquifer quality and quantity. 	<ul style="list-style-type: none"> INEL 	<ul style="list-style-type: none"> Interest Group

ISSUES BY CATEGORY	SITES WHERE ISSUES RAISED	STAKEHOLDER CATEGORIES
<ul style="list-style-type: none"> Information is generally available about this technology. This provides a context and makes people somewhat more comfortable with it. This technology is not really natural; there is experience with the public not wanting anything added to the natural ecosystem. Demonstrate that the additives are only at necessary levels. Because it is a natural process, public perception may be positive. Consider use of the technology as a preventive technique. Deployment would require a local education program using local resources. Consider verifiability and independent review of the demonstration. 	<ul style="list-style-type: none"> INEL INEL Sandia Sandia Sandia 	<ul style="list-style-type: none"> Interest Group Regulator Interest Group Regulator Interest Group
Tribal Rights and Future Land Uses <ul style="list-style-type: none"> There is a perceived advantage on the reservation to this technology as being a natural process, which is protective of the natural environment. 	<ul style="list-style-type: none"> INEL 	<ul style="list-style-type: none"> Tribes
Regulatory Compliance <ul style="list-style-type: none"> Regulatory permitting and reporting requirements include NESHAPS and risk-based reporting, especially of radioactive co-contaminants. Evaluate the ability to meet regulatory standards, ranges of effectiveness, and interim versus final results. Include the off-gas from process intermediates (using human health-based risk limits). Assess optimum nitrate concentrations in ground water and compliance with the 10 ppm drinking water standard. Levels of nutrient injection below drinking water standards must be maintained to inspire confidence in ground water regulators. 	<ul style="list-style-type: none"> Los Alamos Sandia Sandia 	<ul style="list-style-type: none"> Technology User Interest Group Regulator Technology User Regulator

ISSUES BY CATEGORY	SITES WHERE ISSUES RAISED	STAKEHOLDER CATEGORIES
<ul style="list-style-type: none"> New Mexico will not permit the subsurface injection of anything into ground water or within 50 feet of ground water. 	<ul style="list-style-type: none"> Sandia 	<ul style="list-style-type: none"> Technology User
<p>Other</p> <ul style="list-style-type: none"> This is an attractive technology. A treatability study of the use of bioremediation in soils is being conducted at Rocky Flats. Compare bioremediation to other technologies. Comparison to pump and treat may be biased; a more comparable baseline technology may be in-well vapor stripping. The statement in the profile that EPA's strong endorsement adds credibility to bioremediation may not be accurate; the public is skeptical of EPA. The highest comfort level is with above-ground technologies. Reduction of soil permeability is not necessarily of added value in plutonium-contaminated soils if the plutonium is bound to the soil and non-mobile. 	<ul style="list-style-type: none"> INEL Rocky Flats Rocky Flats Rocky Flats Rocky Flats Rocky Flats 	<ul style="list-style-type: none"> Technology User Regulator Regulator Regulator Technology User Public Official

MEMBRANE SEPARATION

TECHNOLOGY DESCRIPTION

Although a six-month demonstration of Membrane Separation was completed before the VOC-Arid ID stakeholder involvement program began, stakeholders' comments remain relevant to evaluating this and other above-ground technologies considered for deployment at Department of Energy sites. Because the demonstration occurred several years before the final evaluation, the stakeholder involvement team did not include membrane separation in the last round of interviews with Hanford stakeholders. Comments and data requirements summarized here derive from initial interviews, focus group discussion and a workshop with Hanford stakeholders, and interviews with 75 stakeholders at four other arid sites in the western United States.

Using high pressure and operating at the surface, membrane separation removes VOCs, specifically carbon tetrachloride, from contaminated air streams. A stream of contaminant-laden air, drawn from the ground by vacuum extraction, is compressed and sent through a condenser where carbon tetrachloride is recovered. The condenser stream then goes to a membrane module for further concentration. The membrane module is made up of thin-film membrane wound around a collection pipe. These membranes further concentrate the air stream as it passes through them twice. The system removes approximately 95 percent of VOC vapors before the remaining five percent is captured on granular activated carbon (GAC).

PRINCIPAL STAKEHOLDER COMMENTS CONCERNING MEMBRANE SEPARATION

Process Waste. The principal concern with membrane separation is the creation of what some stakeholders see as three waste streams requiring off-site disposal or treatment. These three secondary waste streams are the concentrated VOC from the technology's condenser, the used membranes themselves, and the GAC canisters capturing the remaining contaminant. Stakeholders prefer complete destruction of contaminant on-site to storage or off-site disposal.

Citing the fact that carbon tetrachloride is a listed hazardous waste, some stakeholders felt that the chance of finding a market for reclaimed solvent was slim, particularly in competition with virgin solvent.

Stakeholders at the other arid sites more frequently cited membrane separation's creation of secondary waste as a significant disadvantage than did Hanford stakeholders.

Hanford stakeholders indicated that if a use and market can be found for reclaimed carbon tetrachloride, the risks associated with transporting GAC and its limited disposal options make the use of membrane separation preferable to the use of GAC alone.

The possibility of tritium and radon being contained in the condensed liquid is an issue for stakeholders.

Practicality. Stakeholders are concerned about membrane separation's applicability to VOCs other than carbon tetrachloride, and whether the technology's process is affected by co-contaminants such as tritium, plutonium, and semi-volatiles.

Stakeholders ask if the technology is able to operate with a wide range of contaminant concentrations in extreme temperatures without constant direct human supervision.

They want to know if the technology is better suited to the saturated or the vadose zone and whether it is effective with high concentrations of contaminants.

The issue of membrane fouling and regeneration was raised at all five sites. Stakeholders are interested in the length of the membrane's useful life.

Cost. Hanford stakeholders requested data on total cost per pound to remove contaminant, including the cost of subsequent treatment of liquid waste and GAC. Stakeholders at other sites urged cost comparisons with other commercially available treatment methods such as PURUS and catalytic oxidation.

Worker Safety. At the New Mexico sites, stakeholders raised the concern that characteristically high background radon concentrations may create radon buildup during the technology's operations.

Environmental Impacts. New Mexico stakeholders raised the issue of air quality permitting requirements. If new, purer power were needed to operate a membrane separation unit, such generation would require Clean Air Act permits, which are hard to obtain in New Mexico.

Public Perception. Hanford stakeholders indicated that since this is an above-ground technology, it is easier to monitor and evaluate than if operated in the subsurface. They saw liquid waste as preferable to GAC.

Track Record and Regulatory Precedence. Hanford regulators indicated that there is no regulatory framework to address membrane separation, although regulatory decision documents may specify the use of GAC. They point out that analysis of regulatory requirements should include management of the technology's process waste.

Regulatory Compliance. Hanford stakeholders saw the condensed liquid the technology produces as a regulatory concern. This was echoed at INEL, where liquid waste VOCs are considered a RCRA-listed hazardous waste. In New Mexico, as with other technologies, membrane separation's need to meet state air standards for stack gas is a major regulatory compliance issue. A Rocky Flats regulator noted that the CERCLA preference for permanent remedies might work against membrane separation, which is essentially a media transfer technology.

The table on the following pages records comments concerning Membrane Separation from 75 stakeholders at arid sites other than Hanford.

**COMMENTS CONCERNING MEMBRANE SEPARATIONS FROM 75 STAKEHOLDERS
AT FOUR ARID SITES OTHER THAN HANFORD**

ISSUES BY CATEGORY	SITES WHERE ISSUES RAISED	STAKEHOLDER CATEGORIES
<p>Remaining Contamination</p> <ul style="list-style-type: none"> Evaluate the technology's ability to remediate down to 5 ppb in ground water with low (15 ppb) levels of contamination and high volumes of water. Assess the technology's ability to address TCE and PCE, which are found at INEL. Define the technology's ability to remove radionuclides or particulates before passing vapor through the membrane, and the needs for management of those materials. 	<ul style="list-style-type: none"> Sandia INEL Rocky Flats 	<ul style="list-style-type: none"> Regulator Interest Group Technology User
<p>Process Waste</p> <ul style="list-style-type: none"> Evaluate the quantity and characteristics of secondary waste produced, including requirements for storage, treatment, off-site transportation, disposal, and waste minimization. The disposal of GAC associated with this or other technologies is a problem for INEL. Evaluate other technologies that compete but don't generate secondary waste (membrane, GAC, liquid waste). Complete destruction and one-step technologies are preferable. Regenerating GAC onsite is preferable to transporting it. Compare the economics of recycling secondary waste versus destruction on site. 	<ul style="list-style-type: none"> INEL Los Alamos Sandia INEL INEL Rocky Flats Sandia Sandia INEL 	<ul style="list-style-type: none"> Interest Group Technology User Tribes Public Official Interest Group Technology User Technology User Regulator Interest Group Technology User Interest Group Interest Group

ISSUES BY CATEGORY	SITES WHERE ISSUES RAISED	STAKEHOLDER CATEGORIES
<ul style="list-style-type: none"> Determine the processing steps and costs necessary to get carbon tetrachloride pure enough to be sold/recycled. Determine how pure the technology's carbon tetrachloride condensate is, and whether it can be sold competitively with solvents from other sources. Define any needed further processing, and the costs of that processing. Investigate the ability to reuse/recycle TCE after condensation. Consider combining membrane separation with tunable hybrid plasma so there is less residual contamination in the resulting stack gas. Off-gas treatment systems are hard to maintain, expensive, and complex; the benefit of membrane separation is that it produces a liquid waste rather than off gas requiring treatment. 	<ul style="list-style-type: none"> INEL Rocky Flats Sandia INEL Rocky Flats 	<ul style="list-style-type: none"> Interest Group Technology User Regulator Technology User Interest Group Technology User
<p>Practicality</p> <ul style="list-style-type: none"> Assess membrane reliability and specifications (standard or custom), including monitoring needs, evaluation of membrane fouling and required response to membrane fouling (the ability to clean, flush, reuse, or regenerate the membrane), the maximum flow and range of flow achievable with membranes, and the potential for leakage and failure and the management of the resulting liquid. 	<ul style="list-style-type: none"> INEL Rocky Flats Sandia 	<ul style="list-style-type: none"> Interest Group Technology User Regulator Technology User Interest Group Regulator Technology User

ISSUES BY CATEGORY	SITES WHERE ISSUES RAISED	STAKEHOLDER CATEGORIES
<ul style="list-style-type: none"> Assess the range of the technology's application, including the method and efficiency of vapor recovery, the ability to capture all VOCs and to handle multiple waste streams, the ability to deal with TCE and mixed organics, the ability to handle pulsed flows, the ability to treat air stripping tower off gas, the ability to work in conjunction with PSVE, system sizing for different uses, and effectiveness for the final stages of site remediation. 	<ul style="list-style-type: none"> INEL Los Alamos Rocky Flats Sandia 	<ul style="list-style-type: none"> Technology User Technology User Interest Group Regulator Technology User Regulator Technology User
<ul style="list-style-type: none"> Define cleanup rates and ranges of concentrations at which membrane separation is effective. Assess the ability to handle low concentrations. 	<ul style="list-style-type: none"> INEL Rocky Flats Sandia 	<ul style="list-style-type: none"> Technology User Regulator Technology User Regulator
<ul style="list-style-type: none"> Evaluate the availability from multiple vendors; there appears to be a single source. 	<ul style="list-style-type: none"> Sandia 	<ul style="list-style-type: none"> Technology User
<ul style="list-style-type: none"> Evaluate security arrangements that will be needed; this technology may be subject to being vandalized. 	<ul style="list-style-type: none"> Sandia 	<ul style="list-style-type: none"> Technology User
<ul style="list-style-type: none"> The technology is not practical for a majority of circumstances; it is too sophisticated for most uses. 	<ul style="list-style-type: none"> Sandia 	<ul style="list-style-type: none"> Technology User
<ul style="list-style-type: none"> Evaluate power needs, sources, and costs. The technology power source would need to be solar or propane at remote INEL locations. 	<ul style="list-style-type: none"> INEL 	<ul style="list-style-type: none"> Interest Group Technology User
<ul style="list-style-type: none"> This technology duplicates the function of PURUS, which is available off-the-shelf and adaptable. 	<ul style="list-style-type: none"> INEL 	<ul style="list-style-type: none"> Technology User
<ul style="list-style-type: none"> Destroying of carbon tetrachloride on site is important. 	<ul style="list-style-type: none"> INEL 	<ul style="list-style-type: none"> Regulator
<ul style="list-style-type: none"> Determine the recyclability of the carbon tetrachloride generated by membrane separation. 	<ul style="list-style-type: none"> INEL 	<ul style="list-style-type: none"> Interest Group

ISSUES BY CATEGORY	SITES WHERE ISSUES RAISED	STAKEHOLDER CATEGORIES
<ul style="list-style-type: none"> Assess the ability to use bleed-off or clean air dilution valves so that variable carbon tetrachloride concentrations can be equalized. Define the effect of ambient winter temperatures on the technology, the ranges of operation, and the ability to operate under extremes of temperature. Evaluate the ability of the technology to operate automatically with only periodic checking. Consider a lengthier, lower-temperature condensation step, thus leaving less for the membrane to act on; use a heat exchange unit to recover energy. Assess methods for minimizing water entrainment at the well head, which may cause freezing and icing on the condenser. 	<ul style="list-style-type: none"> Rocky Flats INEL Rocky Flats INEL Los Alamos Rocky Flats 	<ul style="list-style-type: none"> Technology User Interest Group Technology User Interest Group Technology User Technology User
<p>Works as Intended</p> <ul style="list-style-type: none"> An attractive aspect of membrane separation is condensation of vapor into liquid. Define the range of concentrations on which membrane separation technology is effective; the threshold of 300 ppm seems too high for Sandia. Evaluate membrane separation against technologies currently in use, including catalytic or thermal oxidation. Assess the fouling of the membrane by other constituents of the waste stream. Evaluate the membrane's ability to work with possibly unidentified mixed contaminants. 	<ul style="list-style-type: none"> Sandia Rocky Flats Sandia Sandia Rocky Flats INEL Rocky Flats INEL 	<ul style="list-style-type: none"> Interest Group Technology User Interest Group Technology User Technology User Technology User Interest Group Technology User Interest Group

ISSUES BY CATEGORY	SITES WHERE ISSUES RAISED	STAKEHOLDER CATEGORIES
<ul style="list-style-type: none"> Evaluate the ability of the technology to work with a condenser alone, i.e., with no membrane. 	<ul style="list-style-type: none"> Rocky Flats 	<ul style="list-style-type: none"> Technology User
<p>Cost</p> <ul style="list-style-type: none"> Evaluate the total system life-cycle costs, including realistic cost of membranes and membrane replacement, the machine, GAC management, process waste management and disposal, and patent or licensing costs. The technology appears to be expensive, including startup costs and maintenance costs. Define the range of concentrations at which the technology is cost effective; it does not appear to be cost effective for low concentrations. Evaluate the cost of the unit compared to proven commercially available technologies, including competing technologies (PURUS, catalytic oxidization, thermal oxidation, GAC) at lower concentrations (300 to 2000 ppm) Evaluate costs of the technology versus tunable hybrid plasma, which appears more cost-effective. Evaluate the reasons for the membrane expense, including consistent materials, function, and the effects of high pressure. Assess the ability to recycle or regenerate the membranes, and the cost savings that would result. Evaluate power costs and include in the treatment-per-unit costs. 	<ul style="list-style-type: none"> INEL Los Alamos Rocky Flats Sandia INEL Sandia Los Alamos Sandia Rocky Flats INEL Rocky Flats Rocky Flats Sandia Sandia 	<ul style="list-style-type: none"> Technology User Regulator Technology User Regulator Technology User Interest Group Regulator Technology User Technology User Technology User Regulator Interest Group Regulator Regulator Technology User

ISSUES BY CATEGORY	SITES WHERE ISSUES RAISED	STAKEHOLDER CATEGORIES
<ul style="list-style-type: none"> Define the assumptions for the cost estimates per unit of VOCs removed. The cost of membrane replacement needs to be included in the cost per pound. There are added "transaction costs" associated with managing two waste streams rather than one; this will affect cost and efficiency. 	<ul style="list-style-type: none"> INEL Los Alamos Sandia Rocky Flats 	<ul style="list-style-type: none"> Interest Group Regulator Interest Group Regulator
Time <ul style="list-style-type: none"> Define the duration of treatment needed. 	<ul style="list-style-type: none"> Sandia 	<ul style="list-style-type: none"> Interest Group
Worker Safety <ul style="list-style-type: none"> Assess worker protection needs and their effectiveness. Define radon buildup during operations. 	<ul style="list-style-type: none"> INEL Sandia 	<ul style="list-style-type: none"> Interest Group Regulator
Public Health and Safety <ul style="list-style-type: none"> Evaluate off-gas releases, including frequency, volume, and accidental releases. 	<ul style="list-style-type: none"> INEL 	<ul style="list-style-type: none"> Interest Group
Environmental Impacts <ul style="list-style-type: none"> Define noise and aesthetic impacts of the technology. Evaluate power needs and the ability of the technology to run on standard electrical systems, or the need for special, expensive electrical installations. Evaluate the purity of the power needed; power generators will need Clean Air Act permits, which are difficult to obtain in New Mexico. 	<ul style="list-style-type: none"> Sandia INEL Sandia Sandia 	<ul style="list-style-type: none"> Interest Group Interest Group Technology User Technology User

ISSUES BY CATEGORY	SITES WHERE ISSUES RAISED	STAKEHOLDER CATEGORIES
<ul style="list-style-type: none"> Assess the size of the unit, including GAC portion. Define the technology's ability to be removed when remediation is complete. 	<ul style="list-style-type: none"> Sandia Sandia 	<ul style="list-style-type: none"> Interest Group Interest Group
Public Perception <ul style="list-style-type: none"> The simplicity of membrane separation technology is an advantage. An above-ground operation is an advantage because it can be observed, but it increases the risk of spills or releases. Membrane separation technology is not an innovative approach, but just another way to concentrate vapor into liquid. The diagram in the technology profile is misleading because it does not reflect the elimination of VOCs from the waste stream. 	<ul style="list-style-type: none"> Sandia Los Alamos INEL Rocky Flats 	<ul style="list-style-type: none"> Regulator Interest Group Regulator Interest Group
Regulatory Infrastructure and Track Record <ul style="list-style-type: none"> Evaluate state and federal regulators' level of familiarity with this technology. Regulatory unfamiliarity may make it difficult or impossible to conduct projects funded with public money. 	<ul style="list-style-type: none"> Sandia 	<ul style="list-style-type: none"> Technology User
Regulatory Compliance <ul style="list-style-type: none"> Releases of off gas may require permitting under the Clean Air Act and/or meeting state air standards; these requirements should be investigated. 	<ul style="list-style-type: none"> Los Alamos Sandia 	<ul style="list-style-type: none"> Technology User Technology User

ISSUES BY CATEGORY	SITES WHERE ISSUES RAISED	STAKEHOLDER CATEGORIES
<ul style="list-style-type: none"> This is not an attractive technology for INEL because INEL must avoid liquid VOC waste; the non-contained gas is not a RCRA listed hazardous waste, but the liquid is. 	<ul style="list-style-type: none"> INEL 	<ul style="list-style-type: none"> Regulator
<p>Other</p> <ul style="list-style-type: none"> The benefits of membrane separation include no need to scrub off gas, with associated high costs. There is not necessarily a market for recycled carbon tetrachloride. 	<ul style="list-style-type: none"> Rocky Flats INEL Rocky Flats 	<ul style="list-style-type: none"> Technology User Regulator Technology User

APPENDIX A

HANFORD STAKEHOLDERS' DATA REQUIREMENTS AND PROPOSED MODIFICATIONS TO TECHNOLOGY TEST PLANS

IN-WELL VAPOR STRIPPING

IN-WELL VAPOR STRIPPING

FOCUS GROUP DATA REQUIREMENTS	WORKSHOP COMMENTS	TEST PLAN ELEMENTS TO ADDRESS DATA REQUIREMENTS	DEMONSTRATION RESULTS
<p>1. Define methods to measure changes in groundwater levels caused by use of the technology. Determine if contamination in the vadose zone is being introduced into the groundwater.</p>	<p>1. Changes in groundwater level are of substantial concern to some stakeholders. Technology developers noted that a simulation model of groundwater elevation changes will be run prior to the use of the technology. During the demonstration, two monitoring wells in the vicinity of the stripping well will monitor changes in groundwater elevation. The technology may cause mounding effects in the water table and increase slightly organic compound vapor levels in subsurface soils. Three methods will be used to assess mounding effects: cross-well seismic tomography, water level monitoring in the wells, and geophysical logging. Stakeholders noted that two monitoring wells to determine the technology's effects on groundwater elevation did not seem sufficient. It was suggested that additional funds be sought to provide for more monitoring wells. It was also suggested that proven and existing geophysical methods be employed in making determinations in this area (e.g. neutron logging and electrical resistance tomography.)</p>	<p>1. PNL has begun a cooperative planning effort for the demonstration of the in-well vapor stripping technology with DoD at Edwards Air Force Base in California. Depending on characterization information, suitability determinations, and funding, this demonstration may replace the test originally planned for Hanford. It is also possible that two separate demonstrations of in-well vapor stripping may be performed. Information on both demonstrations is presented here.</p> <p>HANFORD: There will be three monitoring wells in place in the vicinity of the vapor stripping well. One well is screened in the area of the aquifer which will be treated. Two new monitoring wells with flow sensors (three or four sensors per well) will be installed for the demonstration. One of the new wells will be completed in three zones of the aquifer and the other in four zones. Two of the monitoring wells will be placed down-gradient from the stripping well at distances of 50 feet and 100 feet. One well will be placed cross-gradient from the stripping well at a distance of 20 feet. Cross-hole seismic tomography probably will not be used but pressure head monitoring will be done in all three wells.</p>	

IN-WELL VAPOR STRIPPING			
FOCUS GROUP DATA REQUIREMENTS	WORKSHOP COMMENTS	TEST PLAN ELEMENTS TO ADDRESS DATA REQUIREMENTS	DEMONSTRATION RESULTS
		<p>EDWARDS AFB: There will be a total of eight monitoring wells in the vicinity of the vapor stripping well. Two of these wells are existing and six will be installed for the demonstration.</p> <p>All of these wells are, or will be, completed in two to three zones of the affected aquifer. The monitoring wells will be placed at various distances (approximately 25 to 80 feet) from the stripping well, in up-gradient, cross-gradient, and down-gradient locations.</p> <p>In both demonstrations, multiple subsurface thermal flow sensors and neutron logging will be used, and soil moisture profile information will be collected on at least one open borehole per test site.</p>	
2. Test for the consequences of losing power to the demonstration. Determine immediate and long-term effects.	2. Technology developers reported that an "on paper" simulation will be conducted to determine potential effects of power loss prior to the demonstration of the technology. The demonstration will also test for the consequences of the loss of power. PIs noted that a loss of power should only cause the system to stop circulating air and drawing a vacuum. They do not expect that the cessation of these operations would have any consequences other than the halting of contaminant withdrawal. In any case, contamination does not become worse if the system shuts down.	2. A simulated power failure has been incorporated into the test plan and will be tested during the demonstration. Data will be gathered as to effects of the power loss.	

IN-WELL VAPOR STRIPPING

FOCUS GROUP DATA REQUIREMENTS	WORKSHOP COMMENTS	TEST PLAN ELEMENTS TO ADDRESS DATA REQUIREMENTS	DEMONSTRATION RESULTS
<p>3. Determine if there are releases of contaminants from sampling ports or at other above ground locations. Determine if there are pressurized vapor releases into the vadose zone due to some failure. Simulate this condition prior to demonstration and design a failure control method to stop and/or collect such releases.</p>	<p>3. An analysis will be conducted prior to the system's use. During the demonstration, the system will be shut down if air releases are discovered. The system will be monitored for pressure drops and volatile organic vapors at critical joints in the system using photoionizing detectors. Stakeholders pointed out the necessity of engineered controls above ground and the importance of informing the public about carbon tetrachloride including its hazardous qualities, the volume planned for extraction, and its potential to vaporize.</p> <p>If the demonstration does not collect data on releases of contaminants then it must be communicated to the public why this is not being done. It would be preferable to have an independent third party evaluate and communicate this information to lend credibility. (High school Science teachers were suggested.)</p>	<p>3. The test plans specify the use of Photo Ionization Detectors (PIDs) at various locations around the demonstration site and specifically in work zones. These instruments detect organic contaminants in air. Data will be kept on the readings from these instruments and worker personnel protection equipment requirements will be determined based on levels detected.</p> <p>In addition to PIDs, system operating pressures and pressure changes, particularly those associated with the well, will be monitored and recorded. Any deviations from expected operating pressures will be investigated, adjustments made if necessary, and records kept.</p>	
<p>4. Define applicable regulations and regulatory precedents for this or similar technologies. Specifically address whether changing the groundwater level creates a regulatory concern.</p>	<p>4. ID technical staff said that the demonstration will be conducted under CERCLA regulations. Potentially changing groundwater levels will be addressed with CERCLA regulators. They said that there are no known NEPA constraints, and that OSHA applies.</p>	<p>4. No regulatory precedents or roadblocks have been identified. Discussions are being held with Washington and California regulators to determine what, if any, regulatory issues need to be addressed during the demonstration. Regulators have expressed concern about introducing water into the contaminated vadose zone. No official regulatory interpretations have been made yet.</p>	

IN-WELL VAPOR STRIPPING

FOCUS GROUP DATA REQUIREMENTS	WORKSHOP COMMENTS	TEST PLAN ELEMENTS TO ADDRESS DATA REQUIREMENTS	DEMONSTRATION RESULTS
<p>5. Demonstrate the effects of operating this technology on co-contaminants. Define the sampling methods and requirements to collect this information.</p>	<p>5. Participants pointed out the need to know if co-contaminants are present. The ID representatives stated the demonstration will take place only if non-VOC co-contaminants are not present. Technical staff noted that other VOCs as co-contaminants are not considered a problem for the system's operation, but that the demonstration cannot go ahead if plutonium is present. Measurements will be made for all co-contaminants, and soil types and properties will be characterized where possible.</p>	<p>5. The test plans specify sampling and analyzing the vadose and saturated zones for metals (ICP-method), ions, alkalinity, radioactivity (gross alpha, beta, and gamma), semi-volatile compounds, volatile compounds, PCBs, pesticides, and physical parameters during drilling of the vapor stripping wells. Results of initial sampling and analysis will determine appropriate parameters for sampling and analysis during the demonstration. In other words, co-contaminants will be sampled for if they are encountered during the installation of the vapor stripping wells.</p>	
<p>6. Define the air release concentration and mass limits for this technology. Measure performance against these limits. Define the methods of measurement.</p>	<p>6. Technical staff noted that the test plan will include monitoring for leaks during the demonstration. The system will be monitored for pressure drops and volatile organic vapors at critical joints using photoionizing detectors.</p>	<p>6. The test plans specify that vapors collected from the stripping wells will be treated using the "PURUS" system which is a vermiculite-based sorption technology. In addition, treated off gas will be recirculated through the compressor, and reinjected down-well. The test plan also specifies that any off gases released will be monitored for VOCs. Off-gas VOC concentrations will be measured and calculations will be made to determine mass release.</p>	

IN-WELL VAPOR STRIPPING			
FOCUS GROUP DATA REQUIREMENTS	WORKSHOP COMMENTS	TEST PLAN ELEMENTS TO ADDRESS DATA REQUIREMENTS	DEMONSTRATION RESULTS
7. Define the limits of applicability of demonstration results to other geologic settings.	7. Technical staff reported that models will be used following the demonstration to help describe and predict the applicability of in-well vapor stripping to other sites with different geological conditions and contaminants.	7. If both demonstrations go forward (Hanford and Edwards AFB), then data from two different geological environments will be used to create and verify a design model that will address a broad spectrum of geological settings. If only one of the demonstrations goes forward, then the broad-spectrum design model will use a single set of geological verification data.	
8. Define the confidence limits of models based on demonstration results. Demonstrate how many wells are needed to cover a specified area of groundwater contamination and compare this to the number of wells required for a pump and treat remediation approach.	8. Critical data will be collected during the demonstration to provide as much input to the models as possible to calculate how many wells are needed and how this technology compares to pump and treat. The following data, suggested by stakeholders, will be collected during the demonstration. <ul style="list-style-type: none"> • Costs for wells and equipment for the area affected. • Labor hours needed compared to the size of the area affected. The drilling cost comparisons used in the evaluation should be specific to Hanford because the "Hanford System" is having a significant effect on costs. Therefore, only a Hanford-to-Hanford cost comparison of technologies is valid. Cost data should be itemized so they are readily transferable to other sites based on components used (i.e. casing type used, diameter of well, depth of well, etc.). This information enables judgements about the applicability of demonstration results to other sites. Technical staff said that information will be put into a format that can be incorporated into CERCLA feasibility studies (FS). Participants noted that information needs to be widely distributed so that it can be incorporated into other sites' FSs.	8. The confidence limits of the design model will be examined after the demonstrations are complete and data can be compared to model predictions. At this time, models cannot be further developed without results from the field demonstration. PIs do not expect that this technology will deliver more water than traditional withdrawal-type pump and treat remediation. In certain geological formations, air lift pumping cannot deliver water at the same rate as traditional withdrawal pumping. Details of performance (hydraulic effectiveness) will be examined during the demonstration.	

IN-WELL VAPOR STRIPPING			
FOCUS GROUP DATA REQUIREMENTS	WORKSHOP COMMENTS	TEST PLAN ELEMENTS TO ADDRESS DATA REQUIREMENTS	DEMONSTRATION RESULTS
9. Design the demonstration to be able to add wells later to increase removal efficiency.	9. Technical staff said the demonstration procedure includes conducting a baseline with three wells and then conducting the test. If there is a 60% reduction in contamination in the aquifer the technology will be considered successful. PIs noted that there is a huge cost associated with additional wells so it is uncertain if they will be funded. The zone of influence will be determined by modeling during and after the demonstration so that additional wells can be added if needed.	9. The test plan and well installation design incorporate this requirement. The vapor treatment system can accommodate two additional wells should they be added.	
10. Define the level of contamination that remains in place after the technology is used.	10. PIs reported that contamination levels will be monitored during the test and modeled after the demonstration. Please see comments in #9 above.	10. The test plan includes measuring residual contamination in the subsurface during the demonstration and after the demonstration is complete.	
11. Test to measure the effectiveness of the technology's circulation of water within the aquifer.	11. PIs reported that tracers will be used to measure the effectiveness of the technology's circulation of water within the aquifer.	11. The test plans include provisions to measure aquifer circulation effectiveness. (See Requirement #1 for details about monitoring wells and measurement devices.)	
12. Design the demonstration such that the speed at which the technology performs and the rate at which the technology makes progress toward meeting determined cleanup goals are measured.	12. A stakeholder asked if cycling or pulsing was going to occur. PIs responded that this will not be done initially in the demonstration because 90 days is too short a time to see the results of pulsing. However, shutting the test off after 90 days to allow for evaluation of data will serve as a pulse.	12. The test plan includes provisions to operate the system on pulsed, cycled, and sustained bases over six months and relate each of these methods to contaminant removal rate. PIs will then relate this information to overall cleanup projections using this technology.	
13. Define the parameters of successful technology performance and describe the basis for selection of those parameters.	13. PIs noted that 60% or greater reduction of VOCs at the monitoring wells will be considered success. This measure is based on comparison to the baseline pump and treat technology which is generally credited with achieving approximately 50% reduction in contamination.	13. PIs still define success as 60% or greater reduction of the contaminant concentration at the down-gradient monitoring well. Current laboratory work and modeling indicate that the technology is likely to achieve this goal in the field.	

IN-WELL VAPOR STRIPPING			
FOCUS GROUP DATA REQUIREMENTS	WORKSHOP COMMENTS	TEST PLAN ELEMENTS TO ADDRESS DATA REQUIREMENTS	DEMONSTRATION RESULTS
14. Define all costs associated with in-well vapor stripping. Include capital, installation, operation, maintenance, licensing, and other costs.	14. Participants pointed out that the demonstration needs to collect data concerning removal of carbon tetrachloride on a dollars per cubic yard basis. PIs reported that after the demonstration, models will provide a comparison to the costs of pump and treat.	14. The test plan includes provisions to collect and present cost data as requested.	
15. Define the "breakpoint" depth of groundwater where pump and treat costs the same as in-well vapor stripping.	15. Technical staff noted that modeling will determine this after the demonstration is complete, and that results will be included in the report.	15. Current PI understanding of cost elements indicates that "breakpoint" cost is probably associated more with management of contaminants at the surface (contaminated water versus contaminated vapor) than with depth to groundwater. Contaminated air is cheaper to manage and treat than contaminated water. An analysis of these comparative costs will be included in the demonstration report.	
16. Define and quantify other possible and probable applications for this technology.	16. PIs noted that the system could be used as a soil vapor extraction (SVE) system. A list of applications of this technology to other areas (i.e. with different co-contaminants and different geology) will be developed. At this time there are no plans within DOE to expand the system or use it with any other application; however, many general applications appear promising. There appears to be a very large need in the remediation of contamination caused by leaking underground storage tanks at gas stations for which this technology is applicable.	16. Other applications for this technology will be examined during the demonstration. Special emphasis will be placed on usefulness of soil cleansing in the re-infiltration zone above the water table.	
17. Worker safety issues	17. Stakeholders pointed out the need to communicate clearly and completely any risks associated with the use of the technology both to workers and the public. Technology developers agreed to present this information as clearly as possible.	17. The system operates under no extreme pressures or temperatures. There are few mechanical parts. Workers are unlikely to be exposed to hazardous vapors. However, all worker accidents and/or exposure incidents will be recorded during the demonstrations and compared with the occupational health and safety records of comparable pump and treat technologies.	

IN-WELL VAPOR STRIPPING			
FOCUS GROUP DATA REQUIREMENTS	WORKSHOP COMMENTS	TEST PLAN ELEMENTS TO ADDRESS DATA REQUIREMENTS	DEMONSTRATION RESULTS
18. There needs to be a "Plan B" if there is no response from one of the monitoring wells.	18. Pls reported that the ID will assess results at the end of the demonstration and determine what further action is appropriate. Perhaps the technology demonstration will be run for a longer period of time if desired results are not achieved in the currently planned period, or the demonstration will be run at a faster rate.	18. Should there be no response from one of the monitoring wells, the situation will be analyzed. Specifically, reinfiltration of water will be checked. If indicated, another monitoring well could be requested and installed at a new location.	

IN-SITU BIOREMEDIATION

IN-SITU BIOREMEDIATION			
FOCUS GROUP DATA REQUIREMENTS	WORKSHOP COMMENTS	TEST PLAN ELEMENTS TO ADDRESS DATA REQUIREMENTS	DEMONSTRATION RESULTS
1. Define how the aquifer characteristics will be measured prior to the use of the technology. Characteristics must include chemical, radiological, geotechnical, and water quality parameters.	1. There was extensive stakeholder discussion on this subject. Stakeholders strongly recommended moving ahead with cleanup action. The characterization of the subsurface environment is perceived to have gone on too long and is perceived to be never ending if everything must be known. Data needs must be determined, uncertainties defined, and the risks presented to the public. Public interest group representatives said, in essence, don't use the perceived need for more characterization as an excuse for inaction. A PI noted that in the demonstration programs as now structured there is an emphasis on getting into the field and conducting and concluding the demonstration. What is needed is more support from all stakeholders, including management, to allow more of an observational approach. If PIs set data objectives, collect data, and then realize that assumptions were wrong going into the characterization, they should have the support to add more characterization, to go back in and get what is needed. The problem is setting objectives up-front that limit characterization to just what is needed, while not being dependent on goals that don't change when more is learned about the site's characteristics. Participants agreed that too much characterization is bad, and too little is bad and that defining how much is enough is critical, yet difficult. Participants agreed that a third party review would be beneficial in determining the level of characterization that is enough. An independent, third party review would help confirm that the level of characterization was enough and that the data collected are valid.	1. The test plan includes three phases: characterization, observation of changes due to nutrient addition, and process optimization based on observations. Phase I will last 3 months and involve groundwater circulation and measurement only. No nutrients will be added during this phase. Water quality, hydraulic, biological, and chemical parameters will be characterized and baseline data established during this phase. (Radiological characterization is not planned because there is no known radiological contamination at the demonstration location.) Phase II will begin after Phase I is complete and last 3 months. It will involve injection of nutrients at levels presumed to be appropriate based on Phase I information and bench tests. Phase III will begin after Phase II is complete and will last 3 months. It will involve adjusting nutrient (acetate and nitrate) quantities and ratios and circulation rates and patterns based on observations made during Phase II. The objective will be to maximize contaminant removal (destruction) and to support the design simulation model.	

IN-SITU BIOREMEDIATION			
FOCUS GROUP DATA REQUIREMENTS	WORKSHOP COMMENTS	TEST PLAN ELEMENTS TO ADDRESS DATA REQUIREMENTS	DEMONSTRATION RESULTS
2. Define how bioremediation's effect on the permeability of the aquifer will be measured.	2. Stakeholders advised consideration of chemical and biological fouling and dual source injection. Based on stakeholder issues and concerns raised, the ID test plan will include the following: 1) chemical fouling - analyze groundwater chemistry and reactions at the site 2) biological fouling - this has been a major thrust of the ID's work and will be addressed in the test plan. 3) biomass distribution, and 4) dual source injection - The ID is considering dual source injection as well as "skewed" pulses of nutrients. Preliminary analysis of groundwater indicates that chemical fouling will not be a problem. With respect to determining biomass distribution, soil column experiments have been conducted and a computer simulated tool has been developed to model possible fouling effects of injecting nutrients.	2. Aquifer permeability will be measured before the growth of the biomass (during Phase I) and after the biomass has been supplied with nutrients (during Phases II and III). Permeability will be measured by observing pressure and flow in the circulation system, in injection and extraction wells as well as in monitoring wells. The test plan also includes periodic tracer tests using bromide and nutrients. The rate at which nutrients are metabolized and/or transferred through the aquifer will indicate groundwater flow and microbial activity.	
3. Demonstrate how the possible clogging of the aquifer near where nutrients are injected will be monitored and corrected.	3. Stakeholders suggested that clogging needs to be prevented, and the data requirement should be restated to reflect that the need is to demonstrate how it will be prevented. In response, ID technical staff said that possible clogging will be monitored and prevented by: tracer tests, constant gathering of flow and pressure data which indicate fouling, and comparison of field data to results of computer simulation.	3. See Requirement #2.	

IN-SITU BIOREMEDIATION			
FOCUS GROUP DATA REQUIREMENTS	WORKSHOP COMMENTS	TEST PLAN ELEMENTS TO ADDRESS DATA REQUIREMENTS	DEMONSTRATION RESULTS
4. Show how hydrologic conductivity will be addressed in the demonstration.	4. Stakeholders asked if two points of injection were planned for injecting nutrients in order to retard clogging. Technical staff said yes; the plan is also to pulse the injection to avoid a build up or clogging.	4. Baseline aquifer pump tests have been conducted in the demonstration area to determine baseline hydraulic conductivity. Tracer and pump tests, as noted in Phases II and III of the demonstration, will be done across vertical and horizontal profiles and the results compared to baseline.	
5. Define the methods, frequency, and rationale for monitoring during and after the technology's demonstration. Define how far away from the demonstration site monitoring will occur. Will monitoring occur in surface water connected to groundwater (i.e. the Columbia River)?	5. No specific concerns were raised about this data requirement at the workshop. Subsequently, PIs said that weekly monitoring will be conducted for: VOCs, anions, cations, ph, redox, and microbial samples. During injection of nutrients, sampling will be conducted every half-hour, looking for changes in ion concentrations and using nutrients as tracers. No microorganisms will be injected. Monitoring will continue for months after the demonstration is completed. Monitoring will occur right at the demonstration site as well as several hundred feet down gradient. The site is ten miles from the Columbia and this distance makes it unlikely that the demonstration will impact the river.	5. All demonstration monitoring is planned to occur within the bio-growth area (an elliptically shaped area, measuring 50 to 60 feet along the long axis). PIs presume that monitoring in this area will yield the most useful data, as an 80% recirculation rate (water volume) is expected. Biomass is not expected to migrate outside the test area due to the tendency for the microbes to adhere to soil particles in the nourished area. The existing site-wide groundwater monitoring network will determine any effects on groundwater quality outside the nourished area. No monitoring of the Columbia River or other surface water is planned for the reasons noted above, and because the river is 10 miles from the test site.	

IN-SITU BIOREMEDIATION			
FOCUS GROUP DATA REQUIREMENTS	WORKSHOP COMMENTS	TEST PLAN ELEMENTS TO ADDRESS DATA REQUIREMENTS	DEMONSTRATION RESULTS
6. Define failure scenarios for this technology. Describe how failure would be detected. Define the circumstances under which the demonstration would be halted. Define the control measures, if any, that would be used in these cases.	6. Stakeholders stressed the need to define failure scenarios. Failure as it might present risks to public health and safety is the major concern. The test should push for failure as a positive learning exercise but this method of test must be balanced with possibly negative perceptions associated with "failure." Technical staff noted that catastrophic failure was unlikely and that for this technology failure means plugging a well with biomass or producing chloroform rather than completely degrading carbon tetrachloride. Technical staff said that the computer simulation tool will allow problems in the field demonstration to be anticipated and identified early. In other words, PIs have anticipated potential failures, will try to avoid them and will probably shut the demonstration down if they occur. PIs said that they don't want the system to fail because failure would be too costly, but that they do have a clear picture of what the major failure scenarios are and what to monitor and control to prevent them. Staff said the demonstration would be halted if wells became plugged and no more nutrients could be added. Control of microbial activity is important and will be achieved by monitoring a wide range of parameters while simultaneously comparing field results to results of the computer simulation and previous lab tests.	6. The primary anticipated failure is plugging of the nutrient addition wells with biomass. Monitoring of pressure change in the well's flow will detect plugging. Failure will be dealt with by ceasing nutrient feed and allowing natural microbial die back or by using standard well purging techniques such as bleach addition. As noted in Item #5, movement of biomass outside the nourished area is not anticipated due to the high solid surface adhesion demonstrated by microbes.	

IN-SITU BIOREMEDIATION			
FOCUS GROUP DATA REQUIREMENTS	WORKSHOP COMMENTS	TEST PLAN ELEMENTS TO ADDRESS DATA REQUIREMENTS	DEMONSTRATION RESULTS
7. Define the method of determining and measuring the effectiveness (destruction efficiency) of the technology.	7. Stakeholders pointed out that it is critical to compare expected destruction efficiency with the measured efficiency. Compare the cost, in dollars per pound of contaminant removed, with the baseline pump and treat technology. Technology developers noted that comparisons of costs for pump and treat vs. costs for bioremediation are difficult to make because of the very different physical operations, but acknowledged that comparisons must be made to the degree possible. Technology developers said that the technology's effectiveness would be measured by analyzing data on the following: concentrations of carbon tetrachloride at the site, nutrient consumption, the microbiological activity of indigenous microorganisms, and the results of DNA and RNA probes to identify the exact organisms that degrade carbon tetrachloride. PIs will perform a detailed cost analysis and engineering evaluation of various implementation scenarios for full scale operation. These analyses are designed to provide the data requested by stakeholders.	7. The test plan includes measurement of carbon tetrachloride concentrations across the treatment zone. Readings will be taken at the injection point, at several intermediate points, and at the withdrawal point of the recirculation system. These data will then be used to develop cost effectiveness measures, which will be provided in the demonstration report.	
8. Demonstrate the rate of action and the area limits of the technology. Compare this technology's rate of action and area limits to those of pump and treat.	8. ID technical staff noted that the results of the demonstration will be used, if appropriate, to scale up the technology for use at other sites. The demonstration will identify key parameters such as radius of influence. The product of the demonstration will be a recommendation about how to implement this technology at the Hanford Site as a starting point for its deployment. Extrapolations will be made to enable other sites to draw conclusions and determine the applicability of the technology to their sites.	8. The test plan includes measurement of destruction efficiencies and hydraulic effects in the treatment zone on a three-dimensional basis (up to 300 feet deep). Tracer tests will be used to establish the radius of influence. The resulting data will be used in a three-dimensional simulation model to apply lessons learned from this demonstration to other sites and contaminant situations.	

IN-SITU BIOREMEDIATION			
FOCUS GROUP DATA REQUIREMENTS	WORKSHOP COMMENTS	TEST PLAN ELEMENTS TO ADDRESS DATA REQUIREMENTS	DEMONSTRATION RESULTS
9. Determine what percentage of VOC contamination at Hanford this technology can address.	9. Hanford stakeholders pointed out that this issue is critical to evaluate all remediation scenarios and with integrated remediation approaches (i.e. as a stand-alone technology and as a polishing technology). NO ₃ is important. Technology developers agreed that NO ₃ is important and said that remediation scenarios will be ultimately evaluated as they are fully deployed, not just against the demonstration criteria. Technical staff said that in the lab the technology has handled VOC contamination with concentrations up to 25 ppm. Two to three ppm are found at the bioremediation test site. Eight ppm is the highest concentration found in 200 West Area groundwater to date. The demonstration, and more specifically, follow-on simulation and engineering design, will show at which sites this technology is likely to be most appropriately used as a source treatment or as a plume interception process. Demonstration will also show which treatments to use with this technology.	9. Bench-scale testing has sustained the belief that 25 ppm is the upper concentration limit in groundwater where this technology is expected to be effective. Field demonstration results, including consideration of lithology, will be used to verify or alter this finding. Calculations regarding applicability at Hanford and elsewhere will then be made.	
10. Define how it will be known when data requirements necessitate the addition of a well or wells.	10. Demonstration data on hydrologic conductivity and reaction kinetics will be used to review the number and location of wells. Information from the ID's simulation tool will also be used.	10. The demonstration will provide more information on hydrologic conductivity under nutrient addition conditions.	
11. Define how the demonstration will determine if the technology would be effective in working from the outside of a contaminant plume toward the source. Conversely, define if the technology would be effective at contaminant source reduction or elimination.	11. Performance data from the demonstration will indicate under which conditions the technology is best used as a source treatment and under which conditions it is best used as an interception treatment. Computer simulations will be used to evaluate alternative approaches to full scale implementation based on results from the field demonstration that helped to calibrate the simulation tool.	11. The effectiveness of this technology for different applications will be evaluated using the design model after the demonstration has been conducted.	

IN-SITU BIOREMEDIATION			
FOCUS GROUP DATA REQUIREMENTS	WORKSHOP COMMENTS	TEST PLAN ELEMENTS TO ADDRESS DATA REQUIREMENTS	DEMONSTRATION RESULTS
12. Define what bench-scale demonstrations using microbes and soil from the demonstration zone will be conducted to better understand performance factors for the field demonstration.	12. Subsequent to the workshop, PIs noted that the following bench-scale demonstrations will be conducted: soil column tests, batch kinetics, and liquid culture in the lab for a nutrient addition strategy and confirming kinetics in the soil.	12. Laboratory scale studies on the kinetics of byproduct formation, biofilm dynamics, and biomass disruption will continue through the field demonstration phase in order to optimize nutrient feed schemes and to maximize degradation. Continued soil column testing will also be conducted to help avoid plugging problems. Results of soil column tests will be compared to model simulations.	
13. Define how bioremediation's ability to perform effectively in a variety of geologic conditions will be demonstrated and/or modeled. Identify the hydrogeologic areas where bioremediation will and won't work. Determine the extrapolations that will be made from the data collected to define acceptable conditions for use of this technology.	13. ID technical staff said that the simulation tool will allow testing of varying geologic conditions such as permeability and the technology's performance. The field demonstration will calibrate the simulation's findings, that is make sure that the simulation's models will reasonably predict the types of performance that occur in the field test. The field demonstration will also provide additional information about hydrogeologic areas and conditions appropriate for the technology's use.	13. Bioremediation's ability to perform effectively in a variety of geologic conditions will be assessed by using field data from the demonstration in the simulation tool and then varying lithological conditions. The design tool will model a variety of conditions.	

IN-SITU BIOREMEDIATION			
FOCUS GROUP DATA REQUIREMENTS	WORKSHOP COMMENTS	TEST PLAN ELEMENTS TO ADDRESS DATA REQUIREMENTS	DEMONSTRATION RESULTS
14. Describe how the possible human health effects and mobility of the acetate and nitrate injected to stimulate the growth of microorganisms will be measured. Demonstrate that the materials injected to stimulate microorganisms and the stimulated microorganisms themselves will have no ill effects on the Columbia River and its biota. Define the short and long-term effects on microorganisms from this technology. Describe how it will be demonstrated that microorganisms will not use the injected material to become harmful to the ecosystem or to grow uncontrollably. Describe how such growth would be controlled, if it occurred.	14. Stakeholders pointed out the need to balance and control (measure and demonstrate) the fate of NO ₃ . Technical staff noted that when it is injected, nitrate will be above MCLs but it will be quickly diluted. Chemical reactions and microbial growth will be monitored, as will the possible presence of coliform. Microbes will be stimulated in a small area (20' radius). The microbes' tendency to adsorb to the soil column will limit their mobility. The short-term result of injection will be to increase the number of natural denitrifiers. Microorganisms ("bugs") will autodigest; bugs are expected to eat other bugs until they return to background or at least low levels. The ID will monitor the site after the demonstration to learn how the population of microorganisms changes with time. The ID will determine exactly which types and numbers of microorganisms are stimulated and will modify the nutrients injected accordingly. Stopping the injection of nutrients will stop the growth of microorganisms.	14. As noted earlier, the biomass is not expected to migrate from the demonstration area. Similarly, the added nutrients are expected to be diluted and quickly metabolized in the demonstration zone. Once nutrients are withdrawn, microorganisms are expected to die back to background levels. Health and safety issues for the handling of the nutrients above ground before they are injected has been accounted for by system design that includes secondary containment and operator training. Bioinjection equipment and chemicals are contained in a trailer with safety controls.	
15. Define the circumstances under which microorganisms are no longer expected to respond to nutrients.	15. Without all three elements -- nitrate, acetate, and bacteria -- there will be no response or growth by microorganisms. Therefore, if either of the nutrients is withdrawn, microorganisms will no longer respond.	15. Bench-scale tests have indicated that when nutrients are no longer supplied to the biota in the groundwater they will cease growing and begin die off.	

IN-SITU BIOREMEDIATION			
FOCUS GROUP DATA REQUIREMENTS	WORKSHOP COMMENTS	TEST PLAN ELEMENTS TO ADDRESS DATA REQUIREMENTS	DEMONSTRATION RESULTS
16. Demonstrate and measure the effects of the technology on co-contaminants.	<p>16. Stakeholders called for the demonstration to measure for the mobilization or demobilization of contaminants.</p> <p>The applicability of this technology to mixed waste sites must be made based on mobility (or immobility) of contaminants. Technical staff responded that there is no indication that mobility will be increased. Lab studies have been ongoing to look at decreased mobility of metals and radionuclides in the presence of microorganisms. Additional studies are needed to address the potential mobilization of contaminants. All evidence to date indicates that mobilization won't occur, but lab studies should be done to confirm this. Staff said that there are no radionuclide co-contaminants at the demonstration site.</p>	16. There are no radioactive co-contaminants at the VOC-Arid ID demonstration site. Laboratory tests indicate, however, that the biological process that will be employed creates a reductive biochemical environment. Under this condition the mobility of radionuclides is reduced. It is not known if this effect is permanent or temporary. Future research may examine this issue further.	
17. Demonstrate and measure the effects of radionuclides now in soils at Hanford on microorganisms stimulated by the bioremediation demonstration.	17. Technical staff said that there are no radionuclides at the site for the technology's demonstration. However, the full carbon tetrachloride plume does contain co-contaminants that are important to the technologies' usefulness. A combination of lab studies and engineering analysis will be done to evaluate the impacts of radionuclides.	17. As discussed earlier, the test plan does not include addressing this issue in the VOC-Arid ID.	
18. Define the costs of bioremediation in light of the possible continued use of pump and treat technology to bring contaminated groundwater to the surface. Define cases in which it might be cheaper to undertake remediation above ground.	18. The demonstration will provide data on operating costs. The computer simulation will be used to make cost comparisons and determine how to integrate bioremediation with other treatment methods. The field test will enable evaluation of the simulation's results. The use of the simulation will allow the evaluation of cost scenarios, treatment scenarios, and the technology's applicability to other sites.	18. The analysis documents and reports prepared after the completion of the demonstration will provide comparative cost information and cost/benefit analyses.	

IN-SITU BIOREMEDIATION			
FOCUS GROUP DATA REQUIREMENTS	WORKSHOP COMMENTS	TEST PLAN ELEMENTS TO ADDRESS DATA REQUIREMENTS	DEMONSTRATION RESULTS
19. Show how the demonstration has taken into account insurance requirements.	19. The demonstration has not had to take insurance requirements into account because of DOE indemnification. At this time the demonstration is not acquiring data on insurance requirements.	19. The test plan does not address these issues directly. Performance of the technology will serve to answer some insurer questions, but the VOC-Arid ID has not identified a separate set of information needs for insurance purposes.	
20. Identify regulatory constraints on the demonstration of in-situ bioremediation, for example the injection of material into groundwater.	20. Technical staff said that the ID is at this time working through constraints and requirements with regulators. The purge water exemption clause built into NEPA planning allows for extraction and reinjection.	20. The demonstration documentation will record the actual levels of acetate and nitrate that are injected during the demonstration and their digestion and dilution profiles in the aquifer. These concentrations and quantities can then be compared with specific state and federal water quality requirements. The demonstration is operating within the purge water agreement under the Hanford Tri-Party Agreement.	
21. Define how data from the demonstration will satisfy CERCLA treatability study requirements.	21. Integrated test plans for the demonstration will be modeled after CERCLA treatability studies and will be at least as comprehensive, if not more so.	21. The test plan for the demonstration has been developed in the CERCLA treatability study format with data quality objectives (DQOs) identified.	

IN-SITU BIOREMEDIATION			
FOCUS GROUP DATA REQUIREMENTS	WORKSHOP COMMENTS	TEST PLAN ELEMENTS TO ADDRESS DATA REQUIREMENTS	DEMONSTRATION RESULTS
22. Define how bioremediation's ability to meet regulatory milestones will be measured.	22. Specific evaluation criteria in the test plan will determine the technology's effectiveness in the field. (The demonstration itself has no regulatory milestones it is required to meet.) The simulation tool will be used to project the technology's capabilities on a larger scale, and show its ability to meet regulatory guidance and milestones. The simulation tool will be used to answer questions about how fast the technology will work and what levels of contaminant reduction it is finally able to achieve.	22. Following the demonstration, performance will be measured and modeled against regulatory requirements and existing Hanford milestones. Data from the demonstration showing the rate and effectiveness of contaminant reduction may be used to manage compliance with future milestones.	
23. Define which independent party, if any, will review the results of the demonstration.	23. Stakeholders suggested an independent review of the demonstration's results such as by an Underwriter's Laboratory, a consumer group, or other separately funded organization. A stakeholder noted that DOE contractors are not trusted nor is DOE itself. The more review the better. Technical staff said that a characterization and monitoring Technical Support Group drawn from industry and science will review the demonstration's results, and also noted DOE's demonstration operations review procedure that stakeholders have been involved in formulating. Stakeholders have contributed directly to developing evaluation criteria for the technology -- criteria reflected in the plans with which the technology will be tested. The Integrated Demonstration will continue to work with DOE headquarters to develop more independent review processes for the technology program.	23. Currently the demonstration team is using the services of the Technical Support Group (TSG) to review work and will use the services of the VOC-Arid ID operations group to do an economic evaluation. No further outside review is planned.	

MEMBRANE SEPARATIONS

MEMBRANE SEPARATION		
FOCUS GROUP DATA REQUIREMENTS	WORKSHOP COMMENTS	DEMONSTRATION RESULTS AND CLARIFICATIONS (Demonstration Completed)
1. Demonstrate potential failures of the unit (e.g., power failure, membrane failure, loss of containment, overheating, and explosion). Demonstrate failure control and response methods and results.	1. Participants agreed that this is an important element for demonstration. PIs stated that the Hanford demonstration was run for six months with no signs of membrane failure. Technical staff noted that explosion is not a risk for carbon tetrachloride, but may be for other VOCs, so analysis of this risk should be included in future demonstrations when appropriate.	1. The demonstration included testing of all safety and automated shut-down systems. The unit was operated in extremes of ambient temperature (0° to 115° F) and during dust and wind storms, without negative effect. The input vapor stream was artificially heated and cooled to check system temperature limits and the automatic shut-down system worked when temperatures exceeded design limits. The membrane did not fail during the test, but the test was only designed to run six months, and membrane life is typically three years in other applications of the technology. No degradation of the membrane was observed after the six-month test.
2. Compare full system costs of membrane separation (cost per pound of VOC removed) including cost of all secondary waste management (e.g., ultraviolet light oxidation) to the costs of baseline technology. Design the demonstration to measure the decrease in GAC used based on pounds of VOC removed.	2. Participants agreed that this is an important element for demonstration. There was consensus that total dollars per pound of VOC removed is an appropriate measure of cost for comparison to baseline technologies.	2. Demonstration results indicate that for contaminated vapor feed streams at concentrations below 500 ppm, GAC is cheaper to use than membrane separation. For contaminated vapor feed streams at concentrations between 500 and 2000 ppm, GAC and membrane separation are about equal in cost. For contaminated vapor feed streams at concentrations of 10,000 ppm, the membrane separation technology was half the cost of GAC treatment.
3. Demonstrate that this technology is viable for application at other sites and to other waste streams. Determine availability and cost of membranes for technology use that can treat multiple contaminants.	3. Participants agreed that assessing the flexibility of a technology to address conditions at other sites, other waste streams, and multiple contaminants in a waste stream should be demonstrated in future work. PIs noted that this was beyond the scope of the previously completed demonstration but agreed that tests at other sites or in the lab could gauge this and other technologies' effectiveness with multiple contaminants.	3. The membrane technology will work on other VOCs including 1,1,1 Trichloroethane, Acetone, Octane, Methyl Chloride, CFC 11, Tetrahydrofuran, and some others. Units are available for rent or for purchase and many units are operating in industrial applications.
4. Design the demonstration to measure useful life of membranes.	4. Measurement of the useful life of membranes is important in a demonstration of this technology. PIs noted that this requires extrapolation from short-term tests, the approach taken in the VOC-Arid ID demonstration.	4. Manufacturers are confident of a three-year useful life for the membrane. No element of the VOC-Arid ID refuted this claim.

MEMBRANE SEPARATION		
FOCUS GROUP DATA REQUIREMENTS	WORKSHOP COMMENTS	DEMONSTRATION RESULTS AND CLARIFICATIONS (Demonstration Completed)
5. Demonstrate how the carbon tetrachloride condensed out by this technology will be treated and residuals managed.	5. Participants agreed that the treatment of carbon tetrachloride and the management of its residuals were important parts of the demonstration. Several stakeholders noted the need to incorporate into the technology's evaluation the costs and risks of a number of methods for disposing of residuals. Participants were specifically concerned about transportation risk and the effect on cost of decreasing land disposal capacity. In light of these concerns, participants endorsed the use of this technology rather than sole reliance on GAC because the use of GAC alone generates a higher-volume waste stream requiring treatment and disposal.	5. The condensed carbon tetrachloride from the demonstration was sent to a permitted hazardous/dangerous waste Treatment Storage and Disposal Facility (TSDF) at a cost of \$300 per 55-gallon drum. This cost included transportation, management, and disposal. No buyers were identified to purchase the condensed carbon tetrachloride during the course of the demonstration. PIs noted that the chemical is banned from use in the United States but is not banned in other countries. Six months of intermittent operation of the technology generated four 55-gallon drums of carbon tetrachloride.
6. Determine the regulatory requirements for the technology's operation and management of the secondary waste it produces.	6. Participants confirmed the need to determine applicable regulatory requirements and to structure the demonstration to show how well the technology satisfies these requirements. The VOC-Arid ID membrane separation demonstration provided this information in its report.	6. The demonstration was subjected to the NEPA checklist process and a determination of non-significance (DNS) was made. The test plan for the demonstration was formulated in the CERCLA treatability study format with DQOs noted. The demonstration itself was included in the Expedited Response Action (ERA) documentation and the condensed carbon tetrachloride was classified and managed as a regulated dangerous/hazardous waste under WAC173-303 and RCRA.
7. Define how the demonstration of this technology will deal with the possibility that tritium may be contained in the condensed liquid, on the membranes, or in the GAC.	7. Participants agreed that the ability to deal with tritium should be assessed by future demonstrations. The membrane separation demonstration site at Hanford seemed to have limited tritium in the vapor stream because vapors were being drawn from the vadose zone. Participants noted that the presence of tritium could limit the alternatives for the disposal of residuals considered under data requirement #5.	7. After the demonstration, tritium levels were measured. Tritium levels were below background levels on the membrane separation equipment and in the condensed carbon tetrachloride liquid.
8. Design the demonstration to determine whether radon will be contained in the liquid produced by this technology. Determine regulatory and DOE limitations if radon is present.	8. Participants agreed that a determination of the presence and impacts of radon should be included in a demonstration of this type of technology. PIs noted that radon did not pose a problem for the demonstration because the membrane separation technology does not collect radon. The radon goes through the system and is captured in the GAC. They agreed, however, that radon could be a concern at other sites and with other technologies, and therefore it should be considered in future test plans.	8. Radon did not collect on the membrane separation equipment or in the condensed carbon tetrachloride during the demonstration.

MEMBRANE SEPARATION		
FOCUS GROUP DATA REQUIREMENTS	WORKSHOP COMMENTS	DEMONSTRATION RESULTS AND CLARIFICATIONS (Demonstration Completed)
9. Determine air release concentration and mass permit limits for the technology. Measure actual performance compared to these limits.	9. Participants agreed that actual air release performance should be measured against permit limits in technology tests. Pls noted that this was done for the demonstration with results provided in the demonstration report.	9. The air release concentration limit for the technology during demonstration was 25 ppm. Actual releases were monitored and did not exceed 15 ppm. (The lower detection limit for air release monitoring was 2 ppm.)
10. Determine the percentage of the total VOC contamination problems at Hanford that can be effectively treated with this technology.	10. Participants recommended that this data requirement be deleted because it is covered adequately by #11 and #12.	10. Refer to Item numbers 11 and 12.
11. Define what level of contaminant concentration makes the operation of the technology economical.	11. Participants recommended that this data requirement be combined with #12 because they both address the concentrations of VOC for which the operation of technology is economical.	11. Refer to information provided in response to Item #2.
12. Define how the use of this technology will be linked to those areas of sufficiently high concentrations (assumed to be >600 ppm) of VOC's to make operation of the technology economical.	12. Participants agreed that it is important to identify the range of contaminant concentrations, and, hence, the range of contaminated areas for which a technology is economical and effective. Pls reported that the demonstration tested for the range of contaminants it could effectively treat. Participants recommended combining this data requirement with #10 and #11.	12. There are two or three soil vapor extraction wells at Hanford that deliver concentrations at or above 10,000 ppm carbon tetrachloride. For these wells, membrane separation could be economically viable. For example, at 10,000 ppm and 300 cfm, the membrane separation technology could extract approximately 130 gallons of carbon tetrachloride in a day, a rate which would fill a GAC canister to capacity in an hour.
13. Demonstrate the robustness of the technology (i.e., maintenance costs, response to varying conditions, etc.).	13. Participants agreed that the technology should be tested for its maintenance requirements and flexibility in operating reliably under varying conditions of temperature, humidity, etc. Pls said that the completed demonstration addressed maintenance requirements, and that no mechanical failures of any kind occurred during the demonstration.	13. The technology operated without interruption through dust storms, ambient temperatures ranging from 0° to 115° F, and various tests of the Program Logic Control System. In all circumstances, performance was at or above expectations.

MEMBRANE SEPARATION

FOCUS GROUP DATA REQUIREMENTS	WORKSHOP COMMENTS	DEMONSTRATION RESULTS AND CLARIFICATIONS (Demonstration Completed)
14. Demonstrate the applicability and effectiveness of the technology for groundwater as well as soil.	14. Participants recommended that future demonstrations examine the effectiveness of technologies for groundwater. The completed demonstration addressed soil vapor contamination only. Participants noted, however, that many technologies may also be applicable to contaminated groundwater, for example in combination with a technology such as in-well vapor stripping. PIs pointed out that although this information may be appropriate to evaluate for other technologies, current data indicate that the membrane separation technology becomes inefficient in such circumstances due to higher humidity. Higher humidity necessitates increased use of energy and generates additional secondary waste.	14. PIs do not expect this technology to be applicable to contaminated groundwater remediation. Groundwater contaminant levels are often too low to make the use of this technology economically viable.
15. Determine the ease and simplicity of operating the technology.	15. Participants recommended that data requirements in future test plans include ease and simplicity of operation. This would give indication of the type of labor force needed, the robustness of the technology, and the ability to transfer the technology to other DOE sites as well as the commercial sector. PIs noted that the report on the demonstration provides some of this information. Additional information on these issues can be obtained by examining data from the completed demonstration.	15. PIs indicated that this technology was extremely easy to operate and maintain, based on the demonstration.

APPENDIX B

STAKEHOLDER COMMENTS APPLICABLE TO ANY INNOVATIVE ENVIRONMENTAL TECHNOLOGY

An analysis of the stakeholders comments collected during the focus group meetings and individual interviews revealed concerns and data requirements that apply to all of the technologies evaluated. Those making decisions about the use of any environmental technology should take these perspectives into account. Comments are sorted into the following categories: performance, cost, environmental health and safety, regulatory issues, and socio-political issues.

PERFORMANCE

Potential to increase contaminant mobility. Stakeholders require that a technology not increase the mobility of contaminants it is designed to remediate.

Subsurface injection. Some technologies involve the injection of substances ranging from water to microorganisms. This injection raises stakeholders' concerns related to regulation (e.g. Washington State's non-degradation standard for groundwater), effects on groundwater levels, effects on indigenous microorganisms, or the ability to monitor and control the consequences of subsurface injection.

Transfer of contaminants from one environmental medium to another. Stakeholders oppose removing contamination from one area or environmental medium only to transfer it to another, for example from the subsurface to the atmosphere. Technologies that do not immobilize or destroy contaminants on-site will raise these concerns.

Ability to deal with co-contaminants. Stakeholders clearly express concern about a technology's ability to remediate all the contaminants it is likely to encounter. They are concerned about technologies that do not take care of the entire problem, leaving or mobilizing other contaminants. This is a particular concern with mixed radioactive and hazardous contaminants and important for in-situ technologies facing the challenge of residual co-contaminants.

Versatility. In a related issue, stakeholders prefer technologies that deal with a range of contaminants and that are effective in varying conditions of soil, temperature, climate, and other site conditions. Stakeholders will challenge the wisdom of investing in a technology with narrow application.

Process/Secondary waste. Although almost all remediation methods produce some type and quantity of process waste, there is significant stakeholder concern about how that waste will be treated, stored, transported, disposed of, or otherwise managed. Therefore, stakeholders will likely be critical of any innovative technology that generates secondary waste that concentrates toxicity or is more difficult to dispose of or recycle than secondary waste generated by a baseline technology.

Complexity. A technology's complexity of design and operation raises questions for stakeholders. There is a common belief that the more complex a technology, the more expensive it is, the more likely it is to fail, and the more costly and difficult it is to repair.

Maintenance and operation. Red flags go up for stakeholders if they sense that a technology will require complicated, expensive, off-site maintenance. Many prefer technologies that local labor can operate and maintain.

Auxiliary technologies. Stakeholders evaluate a technology within the context of the entire system within which it operates. In order to assess one component of the system, stakeholders point out that it is necessary to evaluate the benefits and drawbacks of the entire system. Technologies that require auxiliary components raise issues if the supporting technologies are not completely described, understood, or reliable.

Off-site treatment/transport. Off-site transport, treatment, or disposal of contaminants concern stakeholders. These considerations include the complexities of dealing with varying jurisdictional authorities, possible environmental and health exposure, and accidents, as well as the impact of treatment and disposal facilities.

Timeliness. A technology may have significant benefits in terms of effectiveness, cost or other attributes, but may operate more slowly than a baseline technology. In evaluating technologies, stakeholders take into account rate of performance and time required to complete the job. Many believe that time is of the essence in remediation, particularly in relation to blocking the migration of contaminated plumes.

COST

In evaluating technology, cost is important to stakeholders without taking precedence over certain other considerations, especially health and safety. Stakeholders are concerned about the following aspects of cost:

Cost greater than baseline. Stakeholders will be interested to know if the cost to develop, operate, or decommission a new technology is greater than for the baseline technology. A particular point of concern to stakeholders is life-cycle cost, including startup, operations, maintenance, and decommissioning. Stakeholders will ask to see a complete accounting of life-cycle costs.

Reduced budgets. Stakeholders point out that many decisions about technology development and deployment now have to be made in light of reduced budgets.

ENVIRONMENTAL HEALTH AND SAFETY

Stakeholders are interested in the effect any new technology may have on the health and safety of workers and the public. Specifically they will be concerned about the following:

Failure. You can expect this to be a critical issue with stakeholders. Effects on the environment, the public, or on workers from the failure of a technology - which may range from release of contaminants to mechanical failure and injury - must be carefully considered. Stakeholders require that the ability to control and mitigate failure be built into any technology.

Emissions or releases. Stakeholders are very concerned about any uncontrolled emissions or releases of contaminants or other hazardous materials resulting from installation, operation, or removal of a technology. Stakeholders require detailed

information about the possible impact of releases on people, wildlife, vegetation, air, water, and soil.

Energy demand. The use of large amounts of energy, for example electric power, to construct, operate, remove, and decommission a technology will matter to stakeholders. A projected energy demand greater than for baseline will raise concern as will the possibility that using the technology and supplying it with energy will place an inordinate demand on or damage natural resources.

REGULATORY ISSUES

Track record/Regulatory precedence. A technology with no history of approval within the federal, state or local regulatory system will raise stakeholders' concerns. Regulatory precedence refers to the regulations and regulatory guidance needed to evaluate a technology's compliance. Obviously, regulators' familiarity with a technology reduces regulatory uncertainty. Stakeholders will also have concerns about a technology that requires many complex regulatory approvals.

SOCIO-POLITICAL ISSUES

Future options. Stakeholders evaluate unfavorably technologies they see as foreclosing future options for remediation or land use. They will likely prefer methods that promote unrestricted future use of currently contaminated sites, including spiritual, traditional, and practical uses. Stakeholders are critical of technologies that change the physical nature of the land itself, or that preclude future waste processing or other remediation.

Potential to impact natural or cultural resources. Any potential impact from a technology on resources valued by a particular community or region will raise significant concern among stakeholders. These resources include clear air and scenic vistas, drinking water/groundwater supplies, important habitats, open space, and tribal resources and traditional land uses.

Hanford stakeholders identified the following data requirements as applicable to all technologies:

DATA REQUIREMENTS - ALL TECHNOLOGIES	
1.	Demonstrate the technology considering differing geological conditions and with a broad range of contaminants and contaminant mixtures to measure its versatility.
2.	Define the demonstration assumptions and expectations about the production, storage, treatment, and disposal of secondary waste from the technology.
3.	Define the specific elements of risk and the risk management strategy to be used in the demonstration and in subsequent deployment of the technology.
4.	Define the elements of and process for assessing operational readiness for the demonstration of the technology.
5.	Define the liability implications and insurance requirements for the deployment of the technology.
6.	Define the control mechanisms and methods for response for all potential technology failures.
7.	Define the methods and equipment necessary to monitor the effectiveness of the technology both as an operating unit and with respect to effects on the environment.
8.	Demonstrate that further cleanup action is not foreclosed by the technology's use.