

# Tank Waste Remediation System Vadose Zone Program Plan

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### Acknowledgments

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Confederated Tribes of the Umatilla Indian Reservation  
Nez Perce Tribe, Department of Restoration and Waste Management  
Oregon Office of Energy  
U.S. Department of Energy  
Washington Department of Ecology  
Yakama Indian Nation

Team members unanimously support moving forward aggressively with vadose zone characterization, at increased funding levels such as are proposed in this document. This version of the plan has therefore been issued to support development of the budget for characterization of the vadose zone in the single shell tank farms. However, team members still have disagreements with the document, principally in the following areas:

- regulatory authority and process for decisions on storage/disposal of immobilized low activity waste (ILAW)
- balance between characterizing for broad scientific understanding and characterizing to support TWRS decisions
- lack of emphasis on the magnitude of the existing problems resulting from past leaks, spills, and intentional discharge of high level tank waste to the soil
- regulatory drivers
- selection and prioritization of past leak locations (plumes) to characterize in an initial vadose zone characterization campaign.

This plan will be re-issued following additional work by the TWRS Vadose Zone Interagency Team to resolve these issues, and review by an external panel of scientists.

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## INTRODUCTION

A substantial inventory of high-level waste (and hazardous chemicals) is contained in 177 underground storage tanks managed by the Tank Waste Remediation System (TWRS). Waste from these tanks must be removed and treated as part of Hanford site cleanup. The immobilized low activity fraction of this waste will be disposed of onsite. Tank farms from which waste has been removed must be closed in accordance with applicable state and federal regulations.

Although much of the liquid waste originally contained in single-shell tanks (SSTs) has been pumped to double-shell tanks (DSTs), a substantial inventory (~36 million gallons, ~110 million curies) remains in SSTs in the form of liquid, saltcake, and sludge. 67 of the 149 SSTs are designated "assumed leakers." More may have leaked. Reported leakage from these tanks is 0.6 to 0.9 million gallons. Quantitative estimates of volumes leaked and associated curies released to the environment are highly uncertain.

The 149 SSTs are grouped in twelve tank farms. These twelve tank farms are grouped in seven Waste Management Areas (WMAs). These WMAs are monitored by upgradient and downgradient wells that are sampled periodically for groundwater contamination. Tank leaks are strongly suspected of having contributed to groundwater contamination in at least three (possibly four) of these WMAs.

Limited evidence to date indicates that contaminants from tank leaks have been largely contained in the soils below the tanks--and above the groundwater table. It is believed that the persistent mobile contaminants (for example  $^{99}\text{Tc}$ ,  $^{14}\text{C}$ ,  $^{129}\text{I}$ ,  $^{79}\text{Se}$ , uranium, nitrate) pose the greatest long-term risk to human health and the environment through the groundwater pathway. (Other normally non-mobile constituents may also contribute to risk if complexants are present.) Substantial data exist for  $^{137}\text{Cs}$  distribution in the vadose zone in tank farms, but not much for other contaminants. Based on measurements from groundwater monitoring wells, up to 10 curies of  $^{99}\text{Tc}$  from tank leaks is estimated to have already reached groundwater.

It is estimated that 350 billion gallons of contaminated liquids have been discharged to cribs, ponds, ditches, trenches, and reverse wells in the 200 Area of the Hanford Site. This has resulted in an estimated 160,000 curies of radioactivity, principally tritium ( $^3\text{H}$ --decayed to June, 1998), in groundwater. These past liquid discharges are believed to be the largest source of groundwater contamination at the Hanford Site.

Present evidence indicates groundwater contamination from tank leaks is far less than groundwater contamination from intentional discharges of contaminated liquids. However, unless appropriately controlled, tank waste constituents pose major *future* health and environmental risk from contamination of groundwater and the Columbia River.

Making sound management decisions concerning tank farm cleanup and future Hanford Site use therefore requires a thorough understanding of the implications of contaminants released

to the environment. This includes past tank leaks, retrieval leaks, releases from residual waste remaining in tank systems at closure, releases from onsite disposal facilities, and releases from other Hanford sources.

To ensure that TWRS cleanup decisions adequately consider site-wide cumulative effects, and to assure consistency with other Hanford Site cleanup activities, the TWRS vadose zone program must be closely coupled with other Hanford Site cleanup activities. The Hanford Site Groundwater/Vadose Zone/Columbia River Integration Project was created for this purpose.

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## LIST OF TERMS

AEA	<i>Atomic Energy Act of 1954</i>
AEC	U.S. Atomic Energy Commission
CERCLA	<i>Comprehensive Environmental Response, Compensation and Liability Act of 1980</i>
CFR	Code of Federal Regulations
CRCIA	Columbia River Comprehensive Impact Assessment
D&D	decontamination/decommissioning
DNFSB	Defense Nuclear Facilities Safety Board
DOE	U.S. Department of Energy
DQO	Data Quality Objective
DST	double-shell tank
Ecology	Washington State Department of Ecology
EIS	Environmental Impact Statement
EMWD	Environmental Measurement While Drilling
ERDF	Environmental Restoration Disposal Facility
FY	fiscal year
GTCC	Greater-than-Class C
GW/VZ/CR	Hanford Site Groundwater/Vadose Zone/Columbia River Integration (Project)
HF	Hanford Facility
HLW	high-level waste
HSWA	Hazardous and Solid Waste Amendments (to RCRA)
HTI	Hanford Tanks Initiative
ILAW	immobilized low activity waste
IMUST	inactive miscellaneous underground storage tank
ITRD	Innovative Treatment Remedial Demonstration (Program)
LDMM	Leak Detection, Monitoring and Mitigation
LDR	land disposal restriction
LLW	low-level waste
NRC	Nuclear Regulatory Commission
NEPA	<i>National Environmental Policy Act of 1969</i>
OU	operable unit
RFI/CMS	RCRA facility investigation/corrective measures study
RCRA	<i>Resource Conservation and Recovery Act of 1976</i>
RD&D	Research, development, and demonstration
RL	U.S. Department of Energy, Richland Operations Office
SNF	spent nuclear fuel
SST	single-shell tank
STCG	Site Technology Coordinating Group
SWMU	Solid Waste Management Unit
Tri-Party Agreement	<i>Hanford Federal Facility Agreement and Consent Order</i>
TSD	treatment, storage, and disposal
TWRS	Tank Waste Remediation System
WMA	waste management area

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## TANK WASTE REMEDIATION SYSTEM VADOSE ZONE PROGRAM PLAN

### 1.0 WHY THE VADOSE ZONE?

This Tank Waste Remediation System (TWRS) Vadose Zone Program Plan was developed by the TWRS Vadose Zone Interagency Team to support the TWRS mission. The intention of the document is to guide the collection of data to understand the extent, mobility, and behavior of tank wastes in the vadose zone. The TWRS Program is responsible for:

- waste storage
- retrieval of waste from single-shell (SST) and double-shell tanks (DSTs)
- closure and decontamination/decommissioning (D&D) of the SST and DST farms and related facilities such as piping and pipeline transfer systems, inactive miscellaneous underground storage tanks (IMUSTs), past liquid discharge sites belonging to TWRS (cribs, ditches, trenches, etc.) and contaminated tank farm soils
- onsite disposal of immobilized low activity tank waste
- interim storage of immobilized high level waste that eventually will be shipped offsite for disposal.

Figure 1 illustrates the time frame for carrying out these elements of the TWRS mission. Some of the *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) milestones for TWRS include the following:

- initiating a demonstration of sluicing retrieval of Tank C-106 by October, 1997 (a milestone that was not met)
- completing construction and related testing of the initial SST retrieval system for an entire tank farm or equivalent number of tanks by November, 2003
- closing the first SST farm by March, 2014
- closing the remaining SST farms by September, 2024.

To do this, TWRS needs to understand the health and environmental consequences of tank wastes released to the environment, and associated uncertainties. This must consider past leaks, spills, and intentional liquid discharges impacting tank farm soils, potential leaks during retrieval, releases from residual waste after tank farm closure, and releases from immobilized

Figure 1. Tank Waste Remediation System Mission Objectives and Time Frame.



low-activity waste disposal facilities. In addition, future site use, as well as cumulative effects from other Hanford Site cleanup activities must be considered. As understanding develops of the consequences and associated uncertainties of tank waste releases to the environment, TWRS waste retrieval, tank farm closure, and other activities can be planned and conducted consistent with Hanford Site cleanup objectives to best protect health, safety, and the environment, and to protect groundwater in coordination with other Hanford cleanup actions. Better characterization data about the geology and geochemistry of the vadose zone, better definition of what has already leaked, and better knowledge about how tank wastes have moved and will move through the vadose zone is important for developing the required understanding of past and future releases. Final tank farm cleanup decisions will require estimating the nature and extent of existing contamination. This will be based on characterization of tank farm soils contaminated by past leaks. The assumption that the vadose zone will act as a permanent barrier to migration of contaminants is inaccurate, and there is a high degree of uncertainty about the inventory and distribution of contaminants currently in the vadose zone. The U.S. Department of Energy (DOE) must have more accurate information in order to demonstrate whether or not the residual contamination in the tanks and in the soil will combine to present unacceptable future risks to human health and the environment through contamination of the groundwater and the Columbia River.

Vadose zone issues for TWRS must be integrated with other Hanford Site activities. However, some information is unique to TWRS due to the chemistry of tank wastes and its geochemical interaction with vadose zone soils which may cause it to move through the vadose zone differently than other types of waste. The geotechnical information about the zone underneath the tank farms is not unique to TWRS, and the TWRS program may draw on data gathered for other activities such as the Composite Analysis, the Sitewide Groundwater Program, the TWRS Immobilized Waste Program, and the solid waste performance assessment. However, due to the time schedule on which TWRS decisions must be made, some of this information needs to be developed before the results of other activities may be available. This Program Plan, developed with regulatory agency and Tribal Nation participation, will become an important element that will be incorporated into the Hanford Site Vadose Zone and Groundwater Project as that effort evolves.

The Vadose Zone Partnering Team was formed in August 1997, by agreement of DOE and the Washington State Department of Ecology (Ecology), to identify issues and provide solutions to the TWRS Program related to the vadose zone and to address data needed about the TWRS vadose zone for other Hanford initiatives. The Team's charter is to capture this in a TWRS vadose zone strategy and program plan. The plan is to be responsive to TWRS decisions and to other data users within TWRS and across the Hanford Site and to do so cost-effectively. It is also intended that this program plan address recommendations of the SX Farm Expert Panel (DOE 1997b) and findings of the General Accounting Office (GAO 1998).

## **1.1 SCOPE**

An understanding of the migration of tank waste through the vadose zone and into the saturated zone underneath the tanks is critical for retrieval, for some ongoing operations, and for disposal and closure decisions. It is also needed for integration with all other site vadose zone

and groundwater impacts in order to be able to close Hanford sites under the *Resource Conservation and Recovery Act of 1976* (RCRA) and *Comprehensive Environmental Response, Compensation and Liability Act of 1980* (CERCLA). While a general understanding of subsurface conditions and processes at Hanford is relevant to all Site cleanup activities, understanding transport processes associated with tank leak transients poses some unique challenges for TWRS.

Technical problem statement: General understanding is needed of the movement of past, present, and future leaks and spills from the tanks and transfer lines, intentional liquid discharges, and retrieval operations. Understanding of what factors control movement of contaminants from leaks, spills, and liquid discharges may also have relevance to movement of contaminants released from low-activity waste disposal facilities. Geotechnical understanding at Hanford is incomplete, and improving this knowledge is important to all Hanford projects. Tank waste, however, is unique to TWRS, and its migration must be addressed first within the TWRS program before being generalized and integrated into other vadose zone-groundwater-Columbia River activities.

## 1.2 OBJECTIVES

The objective of the vadose zone characterization under this program is to develop a better conceptual geohydrologic model of identified tank farms which will be characterized so that threats to human health and the environment from past leaks and spills, intentional liquid discharges, potential future leaks during retrieval, and from residual contaminants that may remain in tank farms at closure can be explicitly addressed in decision processes. This model will include geologic, hydrologic, and hydrochemical parameters as defined by the requirements of each of the TWRS programs identified in the sections below. The intent of this TWRS Vadose Zone Program Plan is to provide justification and an implementation plan for the following activities:

- Develop a sufficient understanding of subsurface conditions and transport processes to support decisions on management, cleanup, and containment of past leaks, spills, and intentional liquid discharges
- Develop a sufficient understanding of transport processes to support decisions on controlling potential retrieval leaks
- Develop a sufficient understanding of transport processes to support decisions on tank farm closure, including allowable residual waste that may remain at closure
- Provide new information on geotechnical properties in the 200 Area to supplement data used for design and performance assessment for immobilized low-activity waste disposal facilities.

## 1.3 HISTORY AND GENERAL APPROACH

### 1.3.1 History of the Partnering Team, Participants, Review Process

In August, 1997 Ecology and the DOE, TWRS Interagency Management Team formed the TWRS Vadose Zone Interagency Team. The function of this Team is to identify and provide input to the resolution of vadose zone issues in TWRS, and to address data needed about the TWRS vadose zone for other Hanford initiatives. In addition, the Yakama Indian Nation, the Confederated Tribes of the Umatilla Indian Reservation, and the Nez Perce Tribe requested membership as sovereign governments with treaty rights to Hanford and because of their concern how the condition of the vadose zone affects the cumulative impacts of and future use of the Hanford Site. The State of Oregon has been represented as well primarily because of concerns that the vadose zone of the SST farms is inadequately characterized and concern over potential present and future impacts to the Columbia River. As mentioned in the acknowledgements of this document, members of Ecology, the Tribal Nations, and the State of Oregon went beyond providing "input," but were active participants in identifying decisions requiring vadose zone information and approaches to acquire and analyze the data; developing the outline for the plan, and writing sections of it as well. Although the official role of the Interagency team is being rolled into the Hanford Site-wide Vadose Zone and Groundwater Integration Project, the members of this team will continue to serve as important points of contacts for their respective agencies and governments as vadose zone activities in TWRS are implemented.

### 1.3.2 General Approach

Developing the basis for TWRS decisions on management of past leaks, spills, and intentional liquid discharges to the soil, control of retrieval leaks, and closure of tank farms requires understanding the science of subsurface conditions and processes. Knowing where to focus resources on development of science related to subsurface conditions and processes is dependent on the decisions to be made. The TWRS approach is to:

- define the conceptual models that will be used in analysis supporting decisions
- gather the data needed to test hypotheses supporting those conceptual models
- revise hypotheses and conceptual models based on analysis of new data
- gather data necessary to validate the conceptual models, and then validate the models
- make and implement decisions when uncertainty from all sources, including conceptual model uncertainty, is reduced to the point that additional data would not be expected to change the decision(s) reached.

The TWRS vadose zone program approach also recognizes that characterization data have both scientific and economic value. Scientific value comes from our ability to use the data

to solve critical unknowns such as mobility of tank waste with different chemistries and to generalize to a broader understanding of contaminant migration so that other projects can take advantage of the data generated under this plan. Economic value is gained from estimating the most cost-effective approach to resolve the issue or to provide decision stability.

Concepts for developing adequate information about risks and uncertainties for decision-making include the following steps (PNNL 1997), consistent with the approach recommended in the Columbia River Comprehensive Impact Assessment (CRCIA) (DOE 1997c), and the strategy outlined in this Plan:

- identify key decisions and general scientific goals
- identify specific data users and drivers
- compile a common (or comprehensive) set of data requirements
- determine whether adequate data already exists (if yes, make decision; if no, proceed to next step)
- identify key (dominant) parameters through a sensitivity analysis
- evaluate the uncertainties tolerated by the specific decision
- identify the consequences to decision stability of not gathering adequate data, of not having any data, or of gathering data that is either too imprecise or more precise than necessary
- provide clear process links to other related plans and activities (is the information available from another program within TWRS or outside of TWRS; will another program be using the data as well, and if so, what data can be used by multiple projects?)
- collect data (experimental, historical, and/or sampling)
- validate data and verify uncertainty
- use data to make decision or take action
- evaluate decision quality.

Important attributes of the recommended characterization strategy are that it:

- maintains focus by matching problem solving methods and activities to problem resolution needs
- improves the general understanding of the vadose zone and how contaminants migrate through it

- is flexible enough to feed into various types of groundwater models (2D, 3D, etc.) and into various risk or impact or performance assessments
- recognizes uncertainty in knowledge of complex waste-vadose interactive systems and balances the degree of effort to the level of uncertainty and importance of the parameter
- uses only data of known quality to support decision making
- is iterative in nature, with continual data improvements as additional tanks are retrieved or monitoring results are obtained, etc.

#### 1.4 KEY DECISIONS THAT DEPEND ON TWRS VADOSE ZONE CHARACTERIZATION DATA

Three general types of TWRS decisions have been identified:

- short-term operations and retrieval decisions
- longer-term retrieval, disposal and closure decisions
- decisions on acceptable models to use in contaminant transport analysis and risk assessment for a particular waste type and geologic type.

These first two types of decisions are different in the timing, geographic scale, and data precision of required information. TWRS vadose zone information may have to satisfy either or both types of decisions, so it is important to clearly state the decision and to identify the information needed to make the decision. Table 1 lists the major and interim Tri-Party Agreement milestones that are impacted by the need to understand vadose zone conditions and processes as a basis for making the first two types of decisions. Also listed in Table 1 are the key TWRS decisions, discussed in more detail in Section 2.0 of this TWRS Vadose Zone Program Plan, that support each of these Tri-Party Agreement milestones. Section 5.0 of this plan addresses the approach and schedule for gathering vadose zone data supporting these key decisions.

The third type of decision, acceptability of models to use in contaminant transport and risk assessment, requires more general information that may be somewhat different (such as more extensive geologic stratigraphy, chemical interaction of wastes and soils, changes in soil parameters resulting from waste movement) than information keyed to a single specific decision.

Table 1. Tri-Party Agreement Milestones and Related Key Tank Waste Remediation System Decisions Impacted by Need to Understand Vadose Zone Conditions and Processes.

TPA Milestone Number	TPA Milestone Description	TPA Milestone Date	Related Key TWRS Decisions Impacted by Need to Understand Vadose Zone Conditions and Processes
<b>I. Short-term Operations and Retrieval Decisions:</b>			
M-41-00	Complete SST Interim Stabilization	September 30, 2000	Determine need for interim surface barriers and drainage controls to limit infiltration
M-45-08	Establish Full Scale Capability for Mitigation of Waste Tank Leakage During Retrieval Sluicing Operations	June 30, 2003	Determine requirements for controlling leakage during retrieval to minimize long-term human health and environmental impacts
M-45-02	Submit Annual Updates to SST Retrieval Sequence Document	September 30, annually	Determine sequence of SST waste retrieval that incorporates risk reduction objectives
<b>II. Longer-term Disposal and Closure Decisions:</b>			
M-45-06	Complete Closure of All SST Tank Farms	September 30, 2024	Specify retrieval system performance requirements for Phase II treatment and immobilization  Determine cleanup levels and methods, and closure requirements for tank farms
M-90-08	Initiate Hot Operations of ILAW Disposal Facility	December 31, 2005	Determine acceptability of siting and design of ILAW disposal facility relative to long term performance

ILAW = immobilized low activity waste.

SST = single-shell tank.

TPA = Tri-Party Agreement.

TWRS = Tank Waste Remediation System

## 2.0 OVERVIEW OF THE TWRS VADOSE ZONE PROGRAM

The mission of TWRS is to store and remediate tank waste in a manner that protects human health and the environment. Some activities required to carry out this mission (such as tank waste storage, tank waste retrieval, tank farm closure, and immobilized low activity waste [ILAW] disposal) potentially affect contamination of the vadose zone. Migration of contaminants in the vadose zone may have already contaminated Hanford Site groundwater. Contaminants in groundwater could potentially impact the Columbia River.

Understanding the role of the vadose zone as a buffer moderating movement of contaminants from tank leaks requires understanding processes during the leak transient, as well as understanding long term processes driven by infiltration, chemical reactions, diffusion, dispersion, and other factors. Understanding these conditions and processes is necessary to assess implications for human health and the environment. This will provide the basis for decisions on management of existing vadose zone contamination, retrieval of tank waste, closure of tank farms, and disposal of immobilized low-activity waste.

Waste chemistry, geology, hydrology (including infiltration rate), and geochemistry affect contaminant migration and distribution in the subsurface. Distribution and concentration of contaminants in the subsurface environment are also affected by tank waste chemistry and volume of leaked liquids. Decisions involving the vadose zone will be based on conceptual models of how these factors affect contaminant movement, including interaction of contaminants and the soil, and on resulting numerical models that make predictions of contaminant movement over time. The objective of vadose zone characterization is to gather enough data to reduce the inherent uncertainties in conceptual and numerical models so that sound decisions can be made.

Figure 2 depicts the relationship of TWRS decisions to contaminants that eventually impact the environment. Figure 3 illustrates the relationship of TWRS vadose zone program activities to other elements of the TWRS program.

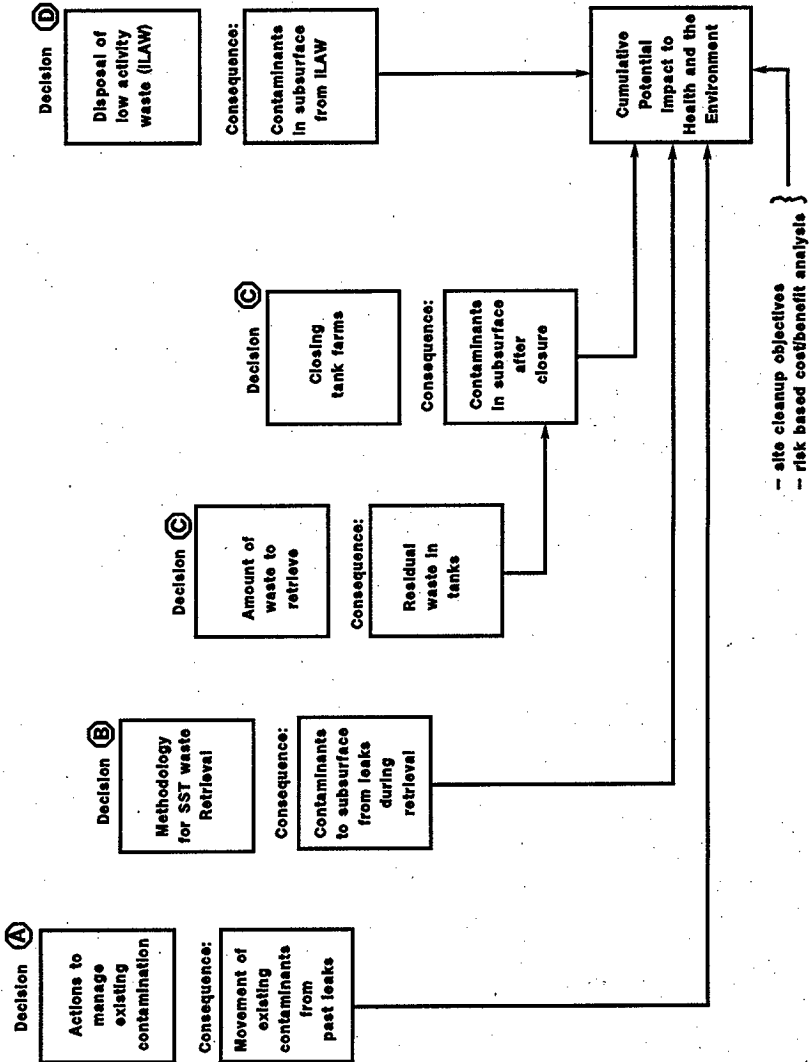
### 2.1 TWRS MISSION, PROGRAM DRIVERS, AND KEY DECISIONS

There are several TWRS program areas where key decisions will be made that potentially impact vadose zone contamination in tank farms, or are potentially impacted by vadose zone contamination conditions and understanding. Making sound decisions in these areas requires an understanding of consequences of tank wastes released to the environment, and associated uncertainties.

#### 2.1.1 Management of Existing Vadose Zone Contamination

Nearly a million gallons of liquid waste is reported to have leaked from SSTs. Some estimates place this number higher. Estimates of radioactivity currently in the environment from tank leaks are highly uncertain, but range from several hundred thousand to over 1 million

Figure 2. Impacts of Tank Waste Remediation System Decisions on the Environment.





(primarily <sup>137</sup>Cs). Only a very small amount of the radioactivity from tank leaks (less than 10 curies—primarily <sup>99</sup>Tc) is believed, based on evidence to date, to have reached groundwater. Water infiltration can potentially cause deeper migration of these existing contaminants.

Key Decision—Determine needs for interim surface barriers and surface drainage controls to limit infiltration: A variety of corrective and preventive measures have been suggested to limit infiltration. Some measures are relatively inexpensive and should be implemented as “good housekeeping” practices such as eliminating leaking water lines, capping boreholes, sealing abandoned wells. Other measures such as tank farm drainage control and interim surface barriers can be quite costly and/or impact ongoing tank farm operations. Sound decisions regarding implementation of measures that are relatively expensive or that may adversely impact tank farm operations require assessment of costs, risks, adverse impacts, and benefits. Assessment of benefits and design of such infiltration control measures require understanding of existing conditions and mechanisms that control further contaminant transport.

### 2.1.2 SST Waste Retrieval

The inventory of contaminants currently in the environment from SST leaks (on the order of several hundred thousand to over a million curies) is far less than what still remains in SSTs (~110 million curies). Removing remaining waste from tanks for treatment and immobilization is essential for long-term risk reduction. Current and planned SST retrieval technologies involve adding liquids for dissolution, dislodging, and mobilization of waste. Addition of liquids to potentially leaking SSTs entails added risk of leakage of contaminants to the subsurface.

Key Decision—Determine sequence of SST waste retrieval that incorporates risk reduction objectives: Risk of retrieval leakage can be partially mitigated by initially retrieving waste from assumed sound tanks until operating experience, improved technologies, and better understanding of leak impacts can be applied to more problematic tanks. The TWRS SST Program is developing a waste retrieval strategy that incorporates risk reduction objectives in sequencing SST retrieval operations. The SST Program is also responsible for developing technologies and operating procedures to limit the risk of potential retrieval leaks. The sequence and timing of waste retrieval from SSTs is driven by the need to provide feed to private contractors in accordance with established quantity, composition, and schedule requirements, and by Tri-Party Agreement milestones. Constraints on retrieval sequence are imposed by availability of DST storage space. Retrieval sequence and timing may be optimized within such constraints, to achieve, for example, early risk reduction. Consultation with regulators, Tribal Nations, and stakeholders will be important for defining parameters or objectives by which waste retrieval sequence can be optimized. Understanding implications of potential retrieval leaks will be necessary for establishing a sound basis for optimizing retrieval sequence (and for selecting appropriate retrieval technology—see next key decision). Tri-Party Agreement milestone M-45-02 requires annual updating of the tank waste retrieval sequence.

Key Decision—Determine requirements for controlling leakage during retrieval to minimize long term human health and environmental impacts: Understanding impacts of leaks during SST waste retrieval is relevant to defining the required retrieval technologies and operational procedures. The TWRS vadose zone program will characterize tank farm soils

contaminated by past leaks as a basis for developing the necessary understanding to support decisions on potential retrieval leakage. Technologies and operating procedures for controlling retrieval leaks are being developed under the Leak Detection, Monitoring and Mitigation (LDMM) program (see Appendix D). In addition, decisions on choice of leak detection and leak mitigation technology, and appropriate retrieval technologies, will incorporate results of the Hanford Tanks Initiative (HTI) studies on leak impacts. To further minimize risk of leaks, SST waste retrieval will initially be limited to assumed sound tanks. Initial SST retrieval (after C-106) will nonetheless require that impacts of potential leaks be assessed. This will necessarily precede final decisions on how tank farms will be closed (including decisions on remediation of contaminated soil). However, for supporting initial SST retrieval, characterization of tank farm soils contaminated by past leaks will be important to understanding processes for retrieval leaks.

### 2.1.3 Tank Farm Closure

Eventually, following completion of waste retrieval operations, tank farms will be closed in accordance with applicable state and federal regulations. Additional information is needed before closure alternatives can be evaluated, and a closure decision reached. Tank waste characterization data, vadose zone characterization data, retrieval performance data, and closure technology development data are identified in the Record of Decision (DOE 1997a) for the TWRS Environmental Impact Statement (EIS) (DOE 1996) as necessary input to a subsequent *National Environmental Policy Act of 1969* (NEPA) process for closure. The closure NEPA process will provide the basis for finalizing requirements on residual waste that may remain in tanks, ancillary equipment, and tank farm soils at closure.

Key Decision--Determine method of closing tank farms: The NEPA process will evaluate closure alternatives, and alternatives or ranges for retrieval system performance necessary for tank farm closure. Assessment of environmental impacts of closure alternatives will require understanding of nature and extent of contamination remaining in tank farms at closure, and capability to model contaminant transport through the environment. All of this requires acquiring a thorough understanding of vadose zone conditions and transport processes to provide confidence in the tools that are needed (numerical analysis models) for reliable and defensible assessment of alternatives. Uncertainties associated with the magnitude, character, location, and interaction of the waste with soils are key to decisions regarding tank farm closure.

Key Decision--Specify retrieval system performance requirements for Phase II treatment and immobilization: Until the interim Tri-Party Agreement goal for residual waste is modified based on final closure decisions or for other reasons, it will serve as a requirement for waste retrieval. Final decisions on tank farm closure will provide the basis for converting the interim Tri-Party Agreement goal into a final waste retrieval goal for SSTs. Since understanding of vadose zone conditions and transport processes is essential for evaluating closure options and reaching final decisions on tank farm closure, establishing performance requirements for Phase II retrieval is also dependent on vadose zone characterization. In addition to vadose zone characterization, establishing performance requirements for retrieval during Phase II depends on results of demonstration of retrieval system capability under the 106-C sluicing project (W-320),

106-C heel cleanout (HTI), subsequent SST retrieval to meet feed delivery requirements during Phase I treatment and immobilization, and any future demonstrations of retrieval techniques, including demonstrations at other DOE sites.

#### **2.1.4 Immobilized Low Activity Waste Disposal**

Under the ILAW program ILAW produced by private contractors will be disposed of onsite in disposal facilities. ILAW facilities are slated to be constructed in currently uncontaminated areas of the 200 East Area. Data and understanding of conditions and processes in tank farms may also be useful in reducing geotechnical uncertainties in ILAW performance assessments.

Key Decision--What are design, operation, and closure requirements for ILAW disposal facilities, relative to their long term performance: Previously constructed grout vault facilities will be modified for receipt of waste product from the private vendor starting 12/31/02, under Tri-Party Agreement milestone M-90-06. Construction is scheduled to begin for the initial ILAW disposal facility 4/1/03, under Tri-Party Agreement milestone M-90-08, with hot operations scheduled to begin 12/31/05, under Tri-Party Agreement milestone M-90-10. Tri-Party Agreement milestone M-90-05-T01 requires submittal of the final ILAW facility performance assessment to Ecology for review, by 12/31/01. This will contain results of contaminant transport modeling and risk assessment supporting decisions on siting and design of the ILAW facilities. The ILAW program has separately funded a site characterization effort to serve its unique needs, including drilling of 3 boreholes during fiscal year (FY)98-FY00. Appendix C summarizes current and planned vadose zone characterization activities directly supporting the ILAW program. Results of TWRS vadose zone characterization in tank farms to understand factors affecting contaminant movement may potentially provide new data that must be factored into the ILAW performance assessment and/or peer reviews. Decisions supporting construction and plant operations may therefore be impacted by TWRS vadose zone characterization in tank farms.

The Nuclear Regulatory Commission (NRC) has provisionally concurred with DOE having regulatory authority for ILAW disposal, once the NRC is satisfied its "incidental waste" guidelines (NRC 1997) are satisfied. Previously, the states of Oregon and Washington and the Yakama Indian Nation had petitioned the NRC to retain regulatory authority over disposal of low-activity tank waste at Hanford. While that petition was denied, input from representatives of the TWRS Vadose Zone Interagency Team indicate that issues pertaining to transfer of regulatory authority for disposal of radioactive constituents in tank waste may still need to be addressed as factors in this key decision.

#### **2.2 SITEWIDE INTERFACES**

For consistency and cost effectiveness, decisions on TWRS vadose zone characterization activities and remediation actions, as described above, must be integrated with other vadose zone and groundwater activities onsite. Those activities include the CRCIA, the Composite Analysis,

and the Hanford Site Groundwater/Vadose Zone/Columbia River Integration (GW/VZ/CR) Project.

### 2.2.1 Columbia River Comprehensive Impact Assessment

The Columbia River Comprehensive Impact Assessment--CRCIA (DOE 1997c), Part II, defines a framework of factors or analysis modules comprising a comprehensive assessment of impacts to the Columbia River, and discusses important principles that are recommended to guide that assessment. Three of the nine analysis modules, "Hanford materials and contaminants (sources and inventories)," "containment failure and contaminant release," and "transport mechanisms and pathways to the Columbia River" will be considered in this vadose zone characterization plan. The key principles identified in CRCIA that are directly applicable to this plan and are basic to carrying out an effective Data Quality Objective (DQO) process are:

- dominance -- a small number of factors dominate the outcome; whatever assessment is performed, it should not leave out any factors which dominate the result
- uncertainty -- quantify the uncertainty in results and determine the level of uncertainty that will be tolerated; manage uncertainty by understanding the balance between spending more to reduce uncertainty and making decisions based on existing uncertainty levels
- fidelity of assessment results -- this involves how clear things need to be, how accurate the result must be, the resolution of information in time, location, and statistical significance; distinguish in decision-making among the various cleanup and disposal alternatives
- integration with other site efforts -- vadose zone efforts must be integrated with groundwater risk assessments and groundwater cleanup strategies, other related activities such as EISs, conceptual design contract awards, planning bases for budget submittals, and remedial strategic planning
- use of other study results -- where the results of other studies meet the requirements stated, there is no need to duplicate those efforts; where the results do not measure up, do not use them without convincing justification.

These principles from CRCIA will be integrated into the technical planning of the vadose zone characterization program. The CRCIA template linking principles and requirements will be used to assure that the vadose zone problems and data needs to make waste retrieval decisions are understood and addressed. Results of TWRS vadose zone characterization and performance assessments will be incorporated into sitewide risk assessments and decision processes, as recommended in CRCIA.

### 2.2.2 Composite Analysis

The Hanford Site Composite Analysis (PNNL 1998a), prepared in response to the Defense Nuclear Facilities Safety Board (DNFSB) Recommendation 94-2, provides an estimate of the cumulative radiological impacts to site users resulting from active and planned low-level waste (LLW) disposal actions and other events (e.g., tank leaks). This includes:

- solid waste burial grounds
- Environmental Restoration Disposal Facility (ERDF)
- TWRS ILAW facility
- past leaks from tanks
- retrieval leaks
- pre-1988 solid waste burial grounds
- liquid waste discharges to cribs, ditches, trenches, ponds, reverse wells, and French drains
- U.S. Ecology radioactive waste disposal site.

Estimating cumulative impacts will provide the basis for making programmatic disposal and/or cleanup decisions within the context of consequences and uncertainties for the entire site. This can also be a tool for evaluating sensitivity and, to a limited degree, dominance consistent with guidance in CRCIA, and for integrated consideration of sitewide contribution to a comprehensive assessment of impacts to the Columbia River, also consistent with CRCIA.

The Composite Analysis will be periodically revised and reissued. The second iteration of the Composite Analysis is planned to incorporate the following enhancements:

- a fully consistent Hanford Site-wide inventory
- an accepted suite of conceptual models of liquid and dry disposals
- a tested linkage of inventory, release, and vadose zone models sufficient to explain existing plumes.

### 2.3 SITEWIDE INTEGRATION OF GROUNDWATER AND VADOSE ZONE ACTIVITIES

The DOE Richland Operations Office (RL) has implemented a new project, the GW/VZ/CR Project (DOE 1998). This project's initial task is to prepare an integrated site-wide plan and to lead a consolidated project to characterize the Hanford Site vadose zone and

groundwater, and to assess all relevant site programs and plans, with the primary objective of protecting the Columbia River. The TWRS Vadose Zone Program Plan will become a sub-set of the Integration Project documentation and the identified vadose zone needs will become part of the integrated technical baseline of the site.

Integration of site-wide vadose zone and groundwater activities is essential for TWRS decision-making, and beneficial to all of the program elements being integrated, for the following reasons:

- Cleanup objectives for individual programs must be consistent with final site use decisions. These cannot be established unilaterally, but must be derived from an overall site perspective. The GW/VZ/CR Project will define these sitewide requirements, and will pass them on to individual programs such as TWRS.
- Cleanup decisions made within individual programs, such as TWRS, are dependent on analysis of contaminant transport to and through the Hanford site groundwater system and on cumulative effects of all contamination sources onsite. For consistency and technical defensibility TWRS will rely on validated groundwater and contaminant transport models and assessment of cumulative impacts and uncertainties developed by the GW/VZ/CR Project.
- Independent scientific and technical peer review is important to the credibility and success of the cleanup decision-making process within individual programs, such as TWRS. The GW/VZ/CR Project will provide that function for the benefit of all site programs, thus assuring consistency and greater technical defensibility of cleanup decisions made within each program.
- Integration through the GW/VZ/CR project provides opportunities for information-sharing, resource-sharing and greater cost-effectiveness in such areas as model development, technology development, and data acquisition.

In kicking-off this new integration project, RL committed to the following objectives:

- Establish a single integrated groundwater/vadose zone management process for the Hanford Site.
- Identify steps needed to:
  - Establish requirements for all Hanford Site activities to contain contamination and assure protection of groundwater resources and the Columbia River.
  - Establish a broad and thorough approach to understanding transport mechanisms and pathways to the Columbia River.

- Integrate science, research, and technology development, focused on the vadose zone and groundwater remediation, as major components of the Hanford Site's mission.
- Establish a strong and effective independent technical review process, to include participation by a panel of experts from applicable fields of science and technology, by national laboratories, and by the National Academy of Sciences.
- Involve Hanford Site regulators, Tribal Nations, and stakeholders in the development and implementation of the plan.

The primary goal is to establish and maintain a site-wide management function that is responsible for identifying, correlating, and coordinating those plans and activities that pose a real or potential impact to the Hanford Site's subsurface soil, groundwater, and the Columbia River.

### **3.0 REGULATORY FRAMEWORK**

Following is a brief summary of the principal regulatory and legal requirements that pertain to TWRS decisions and activities that potentially affect human health and the environment, and therefore that affect vadose zone characterization strategy and plans:

#### **3.1 TREATY RIGHTS**

The most significant written law relating to environmental quality for the Yakama, Umatilla, and Nez Perce Nations are the Treaties of 1855. These treaties between the federal government and the tribal governments ceded hundreds of square miles to the United States, while retaining the core reservation lands and reserving perpetual rights to be exercised in common with the citizens of the territory on the "open and unclaimed" lands within and beyond the boundaries of the ceded area "for as long as the grass shall grow." The Treaties also confirmed that the United States government has a fiduciary trust responsibility to assure that land uses in the ceded areas be maintained in a manner consistent with the treaties. Hanford lies entirely within this ceded territory. The treaties are still active, valid, and upheld by courts and the Constitution of the United States, and may not be amended.

These treaty-reserved rights were not granted by the U.S. government to the tribes, but were retained by the original owners of the land (the tribal nations) and recognized by the U.S. government when recorded in the treaties. The treaties protect (or reserve) rights that support the continuity and well-being of the tribal people, and their age-old cultural traditions handed down by their ancestors and established through millennia of interaction with the environment. This traditional culture is resilient and robust, and ensures survival through drought and flood, feast and famine, health and sickness. It is being modified as modern aspects are incorporated into every day life, but the underlying core values and practices are carefully

maintained. Specific treaty-reserved rights that may be exercised in the ceded areas include hunting, gathering, pasturing, fishing, access to and care of sacred sites, and many other unlisted activities necessary to support the traditional way of life, including religious, social, cultural, and subsistence practices. Impacts to the ability to safely practice these activities on Hanford lands, to the continuity of access and safe use, and to the integrity of the environment form the focus of tribal risk assessment, cleanup, and restoration.

Recent environmental laws such as CERCLA and RCRA did not have treaties in mind when they were promulgated. This does not necessarily mean that they are inadequate, but rather that traditional lifestyles, with their higher environmental contact rates, were not recognized at the time. Additionally, the authors of CERCLA and RCRA did not envision that sites as complex as Hanford and with contamination so widespread and long-lived would need to be addressed. Thus, the holistic and long-term perspectives of treaties and trusteeship are not really reflected in RCRA and CERCLA closure guidance. Implementing RCRA and CERCLA with respect to treaty rights and trusteeship simply means that resources must be protected on behalf of tribes (and other people) and that cleanup must occur so that their rights can be safely exercised.

### **3.2 FEDERAL FACILITY AGREEMENT AND CONSENT ORDER REQUIREMENTS (TRI-PARTY AGREEMENT)**

The *Federal Facility Agreement and Consent Order* (Tri-Party Agreement) was signed by DOE, Ecology and the U.S. Environmental Protection Agency (EPA) on May 14, 1989. The agreement is a legal document that governs the cleanup of the Hanford Site over the next 30 years and binds the DOE to comply with RCRA, CERCLA, and the State of Washington Hazardous Waste Management Act.

The Tri-Party Agreement establishes an action plan for cleanup of the Hanford Site, addresses priorities and provides a framework for cleanup, assigns lead agency responsibilities, methods for resolving disputes, and establishes a schedule for cleanup actions. The general purposes of the agreement are to:

- ensure that the environmental impacts associated with past and present activities at the Hanford Site are thoroughly investigated and that appropriate response actions are taken as necessary to protect health, welfare, and the environment
- provide a framework for permitting Treatment, Storage, and Disposal (TSD) units and to promote an orderly, effective investigation and cleanup of contamination at the Hanford Site
- ensure compliance with RCRA and the Washington Hazardous Waste management Act for TSD units including requirements covering permitting, interim status, land disposal restrictions (LDRs), closure, and post-closure care

- establish a procedural framework for development, prioritizing, implementing, and monitoring appropriate response actions at the Hanford Site in accordance with CERCLA, the National Contingency Plan, Superfund guidance policy, and RCRA guidance and policy
- facilitate cooperation, exchange of information, and the coordinated participation of the parties in such actions
- minimize the duplication of analysis and documentation.

The Tri-Party Agreement includes an "Action Plan" that is updated annually. A work schedule is included in this plan. This work plan includes milestones and deliverables for the various cleanup activities. A list of the milestones that relate to the vadose zone program plan are listed in Table 1-1.

The Tri-Party Agreement assigns the "lead agency responsibility" for both SSTs and DSTs to Ecology. Both SSTs and DSTs are classified as RCRA TSDs operating under interim status. As presently planned, a Final Status Part B permit application will be prepared and submitted to Ecology to support the continued use of DSTs. SSTs will continue to store waste under interim status and will be closed in accordance with the provisions outlined in Tri-Party Agreement Milestone M-45-00. Generally speaking, although SSTs continue to store waste, all SSTs were taken out of service by 1980 and their function was replaced by DSTs.

### **3.3 REQUIREMENTS PERTAINING TO RADIOACTIVE WASTE CLEANUP AND DISPOSAL**

The SSTs and DSTs contain both hazardous and radioactive waste (mixed waste). The radioactive component is interpreted by DOE to be regulated under the *Atomic Energy Act of 1954* (AEA). It is the position of DOE that any procedures, methods, data, or information that relate solely to the radioactive component of the tank waste are outside the scope of RCRA. It is Ecology's position that the radioactive component influences safe management of the waste and therefore information about this component is necessary to ensure compliance with the Dangerous Waste Regulations and the Hanford Facility RCRA Permit (HF RCRA Permit).

#### **3.3.1 Atomic Energy Act**

The AEA authorized the U.S. Atomic Energy Commission (AEC) to develop and implement regulations governing nuclear defense. Through the AEA, Congress assigned control of the production and use of fissile materials to the AEC. The *Energy Reorganization Act of 1974* redirected federal energy agency activities. The AEC was abolished and replaced with the Energy Research and Development Agency that was later replaced with the DOE. The Energy Reorganization Act gave the NRC the authority to regulate high-level waste (HLW) that included the licensing authority for facilities that receive, store and dispose of this waste. The DOE has

authority for conducting nuclear defense, waste management, environmental restoration and remediation, and RD&D activities on the Hanford Site. DOE implements this authority through various DOE Orders some of which have been codified.

### **3.3.2 Nuclear Regulatory Commission Rules and Regulations Pertaining to High-Level Radioactive Waste Disposal**

HLW is the waste that results from the processing of spent nuclear fuel (SNF) to recover unfissioned uranium and plutonium. As such, HLW is defined by origin and not constituents and therefore this definition is not based on specific concentration of various constituents. The *Nuclear Waste Policy Act of 1982* established the national program for the disposal of SNF and HLW. This act assigned three agencies responsibility for disposing of HLW: EPA to set the standards, DOE to develop and operate the facility (mined geologic repository), and NRC to license the facility. The Nuclear Waste Policy Act defines a disposal program which includes vitrification of HLW and placement of the vitrified product in a mined geologic repository.

Because HLW is defined by origin and not content, Hanford tank waste continues to be managed as HLW. It is believed that once the waste is retrieved from the SSTs and DSTs, the residual waste that exists in the tanks may be classified as incidental waste. Incidental waste is not a true class of waste but is defined by both origin and characteristics. Although the NRC has defined some general criteria to support this waste designation, each situation is addressed on a case-by-case basis.

On three separate occasions, the NRC has exercised the incidental waste ruling for Hanford tank waste that has undergone various treatments. On each of these occasions the NRC has provisionally agreed that the waste could be managed as low-activity waste and not HLW. (See NRC 1997 for the most recent provisional determination on disposal of ILAW at Hanford.) The NRC has defined the following set of criteria or tests to determine if a low-activity waste stream is incidental waste:

- The HLW has been processed (or will be processed) to remove key radionuclides to the maximum extent that is technically and economically practical
- The incidental waste will be incorporated in a solid physical for at a concentration that does not exceed the applicable concentration limits for Class C LLW defined in 10 CFR Part 61
- The incidental waste are to be managed, pursuant to the AEA, so that safety requirements comparable to the performance objectives set forth in 10 CFR Part 61 are satisfied.

Classification of residual waste is also an issue for contamination in tank farm soils, resulting from tank leaks. Past leaks typically occurred at or below the ground surface from underground pipes, pits, or the tanks. In some locations, surface spills have also contributed to contamination of tank farm soils. The subsurface tank leaks and surface spills have resulted in general contamination spread throughout the near surface region of the tank farm. Limited data

exist on the nature and extent of near surface and subsurface contamination at all of the SST tank farms, and therefore the concentrations of specific contaminants in soils are not well understood. However, at some SSTs (such as SX and BX tank farms) radiological contamination is known to extend deep into the vadose zone (from 41 to 64 m [135 to 210 ft] beneath the surface) and may have impacted groundwater at some tank farms. Additional leaks may occur from planned waste retrieval operations, causing further contamination of tank farm soils, and spread of contamination through the vadose zone and groundwater.

The regulatory options available to DOE for remediation and/or disposal of contaminated soils are similar to the options available for residual tank waste. These include the following.

- Seek a determination from the NRC that based on the incidental waste criteria contaminated soils are incidental waste and/or LLW and, hence, may be disposed of in place near the surface under the DOE rules on radioactive waste management.
- If DOE is unable to support an incidental or LLW determination, seek a determination from NRC that the waste is Greater-than-Class C (GTCC) and can be disposed of near surface in a manner that is protective of inadvertent intruders and members of the public.
- If DOE is unable to support an incidental, LLW or GTCC determination, consider alternative regulatory frameworks for radioactive waste disposal including remediation and disposal under CERCLA or disposal as HLW under EPA's 40 CFR 191 or 40 CFR 197 (yet to be written); or DOE Order 5820.2A, Chapter I (or its draft replacement, DOE 435.1); and NRC's 10 CFR 60, or its equivalent.

Input from representatives of the TWRS Vadose Zone Interagency Team indicate that issues may still remain pertaining to regulatory authority for disposal of radioactive constituents in tank waste and closure of tank farms containing residual radioactivity. How those issues are resolved may affect which of the regulatory options listed above are viable.

### **3.4 U.S. DEPARTMENT OF ENERGY RULES AND ORDERS PERTAINING TO CLEANUP AND DISPOSAL OF RADIOACTIVE AND MIXED WASTE, AND OPERATION OF NUCLEAR FACILITIES**

Through the authority of the AEA, DOE is responsible for establishing comprehensive programs at its facilities to protect health, safety, and the environment. Formerly, DOE carried out this responsibility by directing the activities of its employees and contractors with a series of DOE Orders. Since August 1994, DOE has begun shifting to a system of regulations and directives, in a standards-based management approach. DOE regulations are generally found in Title 10 of the Code of Federal Regulations (CFR).

DOE Order 5820.2A addresses management of radioactive and mixed waste. Chapter 1 of DOE Order 5820.2A addresses HLW. DOE's historic planning strategy has been to dispose

of the majority of its HLW in a national repository. For purposes of disposal, DOE Order 5820.2A differentiates between new and readily retrievable existing HLW, and waste that is not readily retrievable--“new and readily retrievable waste shall be processed and the HLW fraction disposed of in a geologic repository according to the requirements of the Nuclear Waste Policy Act.” For HLW that is not readily retrievable, the order provides for evaluation of such methods as in-place stabilization as well as possible retrieval and processing as required for new and readily retrievable HLW. Chapter III of DOE Order 5820.2A addresses LLW. DOE’s planning strategy for LLW has been to manage and dispose of LLW “on the site at which it is generated, if practicable.” LLW that contains hazardous waste constituents must be managed and disposed of in conformance with DOE Order 5820.2A and RCRA regulations. DOE Order 5820.2A is intended to be superseded by DOE 435.1, which presently exists in draft form. Tank farm closure is explicitly addressed in draft DOE 435.1, but not in existing DOE Order 5820.2A.

### **3.5 REQUIREMENTS PERTAINING TO TREATMENT, STORAGE, AND DISPOSAL OF DANGEROUS/HAZARDOUS WASTE**

RCRA establishes requirements for generators and transporters of hazardous waste and also establishes a specific permit program for TSD of hazardous waste. The EPA regulations implementing RCRA are found in 40 CFR Parts 260 through 280. RCRA creates cradle to grave regulations for the generation, identification, transportation, treatment, storage and disposal of hazardous waste.

In 1984, Congress added the Hazardous and Solid Waste Amendments (HSWA) to RCRA. These amendments required that new, replaced, or expanded landfills and surface impoundments meet certain minimum technological requirements including double liners, a leachate collection system and groundwater monitoring. Included in the HSWA were restrictions on the land disposal of specific waste that collectively have become known as the LDRs. The implementation of RCRA and the HSWA are specifically addressed in the Tri-Party Agreement. Since the State of Washington has received authorization from EPA to administer and enforce the hazardous waste management program within the State of Washington. This program is administered through Ecology’s Dangerous Waste Regulations. The state has also received authority to implement portions of the HSWA. The remaining portions of HSWA not implemented through the Dangerous Waste Regulations are implemented by EPA through the HSWA Permit.

SSTs continue to operate under RCRA Interim Status. As incorporated into the Tri-Party Agreement (Change Number M-45-93-01, January 25, 1994), “For the purpose of this agreement all units located within the boundary of each tank farm will be closed in accordance with WAC 173-303-610. This includes contaminated soil and ancillary equipment that were previously designated as RCRA past practice units. Adapting this approach will ensure effective use of funding and will reduce potential for duplication of effort via application of different regulatory requirements: WAC 173-303-610 for closure of the TSD units and RCRA 3004(u) for remediation of RCRA past practice units. ...In evaluating closure options for single-shell tanks, contaminated soil, and ancillary equipment, Ecology and EPA will consider cost, technical practicability, and potential exposure to radiation. Closure of all units within the boundary of a

given tank farm will be addressed in a closure plan for the single-shell tanks." The intent of the Tri-Party Agreement as stated in the change request is to close the SSTs under Interim Status and incorporate these units into Part V of the HF RCRA Permit.

As part of the Tri-Party Agreement, groundwater monitoring was required during the interim operation of the SSTs. The reason for including this provision in the Tri-Party Agreement was that the SSTs did not have secondary containment and that a number of SSTs had leaked. It has been estimated that the SSTs have leaked as much as a million gallons of waste into the soil column.

### **3.5.1 Dangerous Waste RCRA Permit**

The Hanford Site is permitted as a single RCRA facility and has been issued a single RCRA dangerous waste permit. This permit is called the HF RCRA Permit. The Permit consists of 6 Parts to facilitate the permitting process. Part I lists the general standard conditions (Standard Conditions) that this part is similar to conditions that appear in all dangerous waste permits. Part II consists of General Facility Permit Conditions that address specific issues associated with the Hanford Site or in this case, the Hanford Facility. Part III is reserved for Unit-Specific Conditions for those units operating under final status. As operating TSDs are incorporated into the permit through issuance of the Part B permit application, the unit-specific conditions that relate to each unit are incorporated into Part III in the form of chapters. The corrective action process and requirements will be incorporated into Part IV of the HF RCRA Permit. Part V is reserved for TSDs or units that will be closed. Similar to Part III, as closure plans are prepared and approved for the various units, specific closure conditions are defined for the unit and included as a chapter in Part V. Part VI of the permit addresses units that require post-closure care and maintenance. The function and process for including information in Part VI is similar to Parts III and V. Chapters III, V, and VI contain specific chapters for each unit, i.e., unit-specific conditions for either operation, closure, or post-closure. It is assumed that chapter IV when included in the HF RCRA Permit will be organized in a similar manner.

As indicated, although the Permit as written includes the flexibility to incorporate both corrective action, and groundwater and vadose zone monitoring, the Permit assumes that the information will be included in either Part III, Part V, or Part VI. At the present time, it is assumed that as future information is incorporated into the permit it will remain compartmentalized. Therefore, it is possible and perhaps likely that during remediation and or closure of an SST unit, the various actions will be incorporated into one or more Parts of the Permit.

As stated previously, the SSTs are planned to be closed in accordance with WAC 173-303-610. As specified in the M-45-00 Milestone, a closure plan will be prepared for each of the six operable units (OUs). Each OU contains one or more tank farms as provided in Appendix C of the Tri-Party Agreement. As such, a closure plan will be written and will address the remediation of both the engineered component including ancillary equipment and media (contaminated soil) for each OU. It is possible that a separate or stand alone plan could be prepared.

In these closure plans, the media (soil), would be separated from the structures (tanks and ancillary equipment). The closure plan would specify what the remedial decisions will be for media and structures. If clean closure can not be achieved, then a post-closure plan would be written and included in Part VI of the HF Permit.

If RCRA corrective action is conducted for the groundwater and vadose zone, the RCRA Past Practice process outlined in the Tri-Party Agreement will be followed. The RCRA facility investigation/corrective measures study (RFI/CMS) documentation will be included in Part IV of the Permit. The final corrective measures for groundwater remediation would be coordinated with the final closure decision for the SST media and structures in the closure plan and any resulting post closure care will be coordinated with the post-closure plan provided in Part VI.

### **3.5.2 RCRA Past Practice Corrective Action**

The HSWA Permit issued by EPA to DOE requires that the permittee (DOE) investigate any release or potential for release of hazardous waste or hazardous constituents from any Solid Waste Management Unit (SWMU) at the facility regardless of the time at which the waste was placed in the unit. In addition, the permittee is required to take corrective action for any such release on-site and/or off-site where necessary to protect human health and the environment.

All identified SWMUs have been assigned to OUs within the Tri-Party Agreement along with other waste management units. Newly identified SWMUs will be assigned to the appropriate OU via the Tri-Party Agreement change control process outlined in Chapter 12.0 of the Action Plan. Either CERCLA response action authority or RCRA corrective action authority will be assigned to the lead agency responsible for the investigation and cleanup process for each OU. The schedules of compliance for those assigned RCRA corrective action authority are considered as part of the HF RCRA Permit via reference to the Tri-Party Agreement. The Tri-Party Agreement change control process will be used to modify the schedules of compliance as necessary, meeting the intent of 40 CFR 270.34 (proposed). Remedy selections, either as a corrective measure or as an interim measure, will be incorporated into modifications of the HF RCRA Permit.

Schedules to implement any corrective actions will be developed and maintained within the Tri-Party Agreement. The SST Closure Work Plan as it is updated will identify schedules for preparation of RFI/CMS documents.

### **3.5.3 Post-Closure Monitoring**

The Hanford RCRA Facility Permit allows three methods of closing tank farms: (a) clean closure, (b) modified closure, and (c) landfill closure. Clean closure and landfill closure are addressed in Chapter 173-303 of the Washington State Department of Ecology Dangerous Waste Regulation. Under the clean closure alternative, post-closure monitoring would not be required (WAC 173-303-610 (1)(b)). Under the landfill closure alternative, post-closure monitoring would be required for at least thirty years after completion of closure operations (WAC 173-303-610 (7)(a)). Under the modified closure alternative, tank farms would be

cleaned up to a level specified under Method C of Chapter 173-340 of the Washington Administrative Code (per Section II.K.3 of the Hanford Site RCRA Permit, WA7890008967), and would require post-closure monitoring for at least five years following completion of closure operations. Post-closure monitoring requirements for modified closure and landfill closure would be established in the Closure Plan (WAC 173-303-610 (3)). It is assumed that post-closure monitoring will involve some combination of vadose zone monitoring and groundwater monitoring.

If the closed tank farms fail to contain the radioactive or hazardous materials during or following the post-closure monitoring period, additional cleanup may be required under RCRA or CERCLA regulations. It is essential that closure decisions and designs adequately prevent the migration of wastes to preclude the need for major corrective actions.

#### **4.0 TWRS VADOSE ZONE PROGRAM OBJECTIVES**

To be successful the TWRS Vadose Zone Program must meet a series of technical goals. The program will be successful by following a series of well-established principles. This chapter describes those goals and principles as well as the program priorities.

##### **4.1 TECHNICAL GOALS OF THE TWRS VADOSE ZONE PROGRAM**

The TWRS Vadose Zone Program supplies information and understanding to other parts of TWRS. The program, in general, does not implement actions; the actions are the responsibility of those other parts of TWRS. Thus the major technical goals of the TWRS Vadose Zone Program are:

- provide vadose zone information and impacts to TWRS decision makers
- determine the nature and extent of vadose zone contamination in the tank farms
- validate models used in providing information used in decision-making
- develop the database needed for development and validation of tank farm models and additional data collection
- perform interim corrective actions for existing tank leak contaminants.

It should be noted that the second through fourth bullets are important inputs to the first bullet.

#### **4.1.1 Provide Vadose Zone Information and Impacts to TWRS**

##### **Decision-makers**

Many decisions that the TWRS functions must make (see Section 2.1) involve information pertaining to the vadose zone underlying TWRS facilities. Such information covers a wide range. At one extreme are surveillance data (for example, the movement of contaminants) that could trigger an operational action on a particular tank. At the other extreme are detailed and complex risk analyses that impact the choice of program directions (for example, how much waste should remain in each tank after retrieval).

The type and amount of environmental information will be determined by each of the TWRS functions. The priority of obtaining such information is discussed in section 4.3. However, based on TWRS function needs and the current understanding (see Appendix F), certain technical goals can be defined. These are discussed in the next three sections (4.1.2 through 4.1.4).

#### **4.1.2 Determine the Nature and Extent of Vadose Zone Contamination in the Tank Farms**

Presently contamination exists in tank farm soils from past leaks and spills, intentional liquid discharges, and other sources. Contamination presently in the tank farm vadose zone is believed to be predominantly from tank leaks. Contamination of soils outside tank farms, in sites under jurisdiction of the Environmental Restoration Program, is predominantly from past intentional liquid discharge to cribs, ditches, trenches, and reverse wells. An estimated 0.6 to 0.9 million gallons containing radioactive and hazardous constituents is estimated to have leaked from tanks (Table H-1, "Single-Shell Tank Leak Volume Estimates," LMHC 1998). Four Waste Management Areas (WMAs) containing eight of the twelve SST farms are currently under RCRA Assessment to determine whether contamination observed in downgradient RCRA groundwater monitoring wells is attributable to tank leaks, and if so, the source of such contamination. Phase I RCRA Assessments have concluded that groundwater contamination can be attributed to tank leaks in at least three of the four WMAs (PNL 1998b, PNL 1998c, and PNL 1998d).

The nature and extent of existing contamination will need to be determined for a variety of purposes:

- Focusing activities on most impacted locations (tank areas with significant reported or estimated leak volumes)
- Deferring consideration of retrieval from tanks over contaminated areas during the initial stage of easy, safe retrieval from sound tanks to eliminate the potential for driving this waste through the soil to groundwater
- Providing data on source terms and associated uncertainties for risk calculations

Because of the need to quickly identify near term actions that may be required to moderate long term effects, initial activities must focus on the "most impacted" locations. Vadose zone sampling and analysis to support decisions on what, if any, near term mitigation actions may be required, will initially focus on what are believed to be the most impacted locations, based on potential risk to human health and the environment. Leak volume, inventory of contaminants of concern in the leaked waste, evidence of groundwater contamination from tank leaks, evidence of movement of gamma-emitting radionuclides over time since the initial tank leak event, and groundwater travel time to the Columbia River will be factors in identifying such most impacted locations. Selection of locations to sample will also be designed to test hypotheses on what factors may be most important to movement of contaminants during tank leak events, and/or that can be used for estimating concentration and distribution of contaminants of concern at locations not initially characterized. This will allow extrapolation of findings from the most impacted high priority locations to provide a basis for timely decisions on near term mitigation actions at other locations, in lieu of or in advance of site-specific characterization.

The emphasis of the very initial retrieval operations will focus on retrieval of waste from tanks that are considered sound and which are not over contaminated soil. To support the decision on which tanks are part of the initial retrieval sequence, the nature and extent of the existing contamination is necessary.

Any risk assessment concerning tank farms must consider the nature and extent of existing contamination. Such information will be one of the important components of the source term for the assessment. Whereas the first two applications of existing contamination information mainly rely on existing knowledge of contamination, this application needs more detailed information on spatial extent and radioisotope and hazardous material inventory.

#### **4.1.3 Validate Models Used in Providing Information**

In order for the results from these analyses to be believed, the simulation models must be compared to measured field data (that is, they must be validated). As models are composed of submodels, these submodels must also be validated. Validation requires input data for development of the model, and measured data not used or assessed during model creation against which to test the model.

Factors that have been postulated to have greatest influence on contaminant movement from tank farm actions include leak characteristics (including volume, area, and rate), waste chemistry, and hydraulic and geochemical properties associated with tank farm geology/stratigraphy. Other factors may be able to be used based on correlations established in sampling and analysis of "most impacted" locations, include groundwater chemistry changes between upgradient and downgradient RCRA monitoring wells, historical gross gamma logging data, and spectral gamma logging data.

#### **4.1.4 Develop the Database Needed for Tank Farm Models and Data Collection**

Besides data for locations used in the validation studies, data will be needed for the models used for other locations. Much of this data may be able to be inferred from previous activities but new data will have to be gathered.

#### **4.1.5 Perform Interim Corrective Actions for Existing Tank Leak Contaminants**

Infiltration through the tank farm surfaces and subsurface occurs through one of two general mechanisms; subsurface loss of conveyed water, or surface infiltration resulting from precipitation in the form of rain or snow, with or without ponding that could potentially occur from surface runoff. Potential man made sources of surface water infiltration (e.g., fire hydrant flushing) in or adjacent to SST farms are controlled by operating procedures, and are not believed to be a credible source of contaminant migration in tank farms. Mitigation of infiltration can be accomplished by removing the source of water, limiting the access of water to the tank farm land surface, eliminating direct access of surface water to preferential subsurface pathways, or constructing some level of infiltration barrier to prevent water from entering the impacted vadose zone.

### **4.2 PRINCIPLES TO BE USED IN THE TWRS VADOSE ZONE PROGRAM**

The above section provided the technical goals of the TWRS Vadose Zone Program. To accomplish these goals, the program has adopted a series of principles that will guide the program:

- Information generated will be driven by needs of other TWRS programs
- Scientific methods and principles will be used in gathering and interpreting data that results in information used in TWRS decision-making
- Information from other programs will be used in the program where applicable
- Before new data or tools are generated, current information will be reviewed for use
- External peer review is important for program success
- Input from the public is important for program success.

#### **4.2.1 Information Generated Will Be Determined by Needs of Other TWRS Programs**

Large amounts of data are needed to be able to generate the environmental information needed by the various TWRS programs. To ensure that the data needed are the data that are gathered, first the type of needed data must be determined (taking into consideration fidelity of existing data, and data gaps) and then the amount of data needed must be determined. The TWRS Vadose Zone Program will use screening processes to determine the type of data needed, and through development of detailed characterization plans, as described below, will define how that data will be obtained and the amount of data.

##### Screening Assessments and Value of Information

Gathering data in the Hanford Site vadose zone is very expensive. It is even more expensive when the data are from contaminated areas, as precautions against the hazardous and radioactive wastes must be taken. It is still more expensive to gather data in the tank farms as the gathering of the data must not hinder the safe storage of the tank waste. The CRCIA principles will be used to ensure that the data gathered is both necessary and sufficient.

As recommended in CRCIA guidance (DOE 1997b), screening assessment, such as was done in support of retrieval performance evaluation criteria assessment for the HTI project (JEG 1998a, JEG 1998b) can be a useful tool in identifying dominant factors, and dominant uncertainties that can be reduced through characterization. What additional data are needed beyond the initial sampling campaign (as described in 5.3) depends on risk assessment results relative to the established level of protection, using that initial data. If, upon accounting for uncertainty and variability, the decision is clear cut and additional data would not be expected to change the decision, then no additional data needs to be gathered to support decision-making. If the decision is not clear cut, then additional characterization may be required to reduce uncertainties that preclude decision-making.

##### Detailed Characterization Plans

A detailed vadose zone characterization plan (or plans) will be needed to define the specific approaches that will be employed for explaining contaminant migration, and specifying data collection efforts required to support decision-making. This will define drilling locations, drilling methods, sampling locations, sampling methods, and field/laboratory analyses to be conducted and reported.

In a particular location to be characterized, it is anticipated that a combination of drilling and sampling techniques using multiple boreholes may be required to adequately assess inventory and distribution of contaminants at that location. Collecting high quality samples is a necessary part of meeting the objectives of the TWRS vadose zone program, but also is one of the most expensive. Conducting necessary activities in a cost-effective manner is important to program success. The following steps are anticipated in development and implementation of the required detailed characterization plans:

- Apply value engineering in developing detailed characterization plans.

- In developing detailed characterization plans, evaluate alternative drilling and sampling techniques.
- Map out characterization “campaigns” where the same drilling and sampling crew is used in succession at several sites, reducing mobilization and demobilization costs.
- Use dedicated support personnel, e.g., health physics technicians.
- After a field activity is complete, conduct lessons-learned meetings to identify how future activities can be carried out more efficiently.
- In selecting drilling and sampling techniques at particular locations to be characterized, consider benefits of using directional and slant drilling techniques with drill pads located outside the tank farm boundaries.

The process used in developing detailed characterization plans is intended to ensure that the data to be gathered are both necessary and sufficient to support the decisions that need to be made. This requires identifying (a) the decision to be made, (b) the criteria that will be used in making the decision, and (c) identifying data needed to apply the criteria. As vadose zone data are gathered, the need for additional data to further improve understanding and/or reduce uncertainty, as a basis for retrieval decision-making, must be assessed. As data are gathered and analyzed, detailed characterization plans for subsequent characterization activities will be refined.

The process used here to evaluate existing data and to identify data gaps that must be satisfied by acquiring additional data will follow the guidance in CRCIA Part II, Appendix C, Section 4.0, Data Quality. CRCIA Part II guidance on dealing with dominance (including screening analysis), uncertainty, integration with other site efforts, and use of other study results will be applied in defining specific characterization activities and data needs.

Members of the TWRS Vadose Zone Interagency Team will be provided an opportunity to participate in review and/or development of approaches for defining specific data needs and methods to assure the objectives of vadose zone characterization activities as described in this program plan will be satisfied.

#### **4.2.2 Scientific Methods And Principles Will Be Used**

Unsaturated soils (that is, the vadose) have been studied much less than saturated systems (such as groundwater). In addition, very dry unsaturated soils (such as the natural soils at the Hanford Site) have been studied much less than moist soils (such as those used in agriculture).

For example, the thermal conductivity of copper alloys as a function of composition and environmental conditions is well understood because of its economic importance. However, the

conductivity of water through dry soils is extremely dependent on sediment type, moisture content, and a variety of other data. Even the functional representation of conductivity as a function of moisture content has a number of forms.

In addition, because the processes are so complicated (for example, moisture conductivity can vary by four orders of magnitude ( $10^4$ ) going from typical Hanford Site vadose zone conditions to groundwater conditions), they are not yet understood from elementary principles. Therefore, it is necessary to retain a critical and questioning approach to ensure that important processes are not overlooked.

#### **4.2.3 Information from Other Programs Will Be Used in the Program as Appropriate**

The TWRS Vadose Zone Program will use information from and provide information in support of a number of programs and projects. Some of these are within TWRS:

- TWRS Hanford Tanks Initiative
- TWRS Immobilized Waste Program
- TWRS Single-Shell Tank Retrieval Program
- TWRS Tank Closure Program.

In addition, the TWRS Vadose Zone Program relies on information from and/or provides information to other Hanford Site programs, e.g., the Environmental Restoration Program, specifically in relation to the groundwater monitoring and the Composite Analysis. The TWRS Vadose Zone Program also is a component of the GW/VZ/CR Project (See Section 2.3), created in February 1998. In addition, the TWRS Vadose Zone Program seeks information from technology development programs administered by DOE's Office of Science and Technology (EM-50). Other elements of TWRS that are linked with the TWRS Vadose Zone Program are described below. In addition, science and technology needs areas with particular relevance to the TWRS Vadose Zone Program are described.

#### **TWRS HTI**

The goal of the HTI project is to provide near-term technologies to support TWRS programs. This includes retrieval technologies and characterization technologies (in-tank and ex-tank). The HTI project is also conducting engineering studies to provide data for evaluating retrieval and closure alternatives for a representative SST farm (AX farm). This includes evaluating leak impacts, supporting the SST Program's responsibilities in the area of LDMM. In addition, the project is developing retrieval and closure performance measures, determining uncertainties in long term risk performance, and identifying data required to reduce uncertainties. This analysis is using uncertainty and sensitivity studies of an entire tank farm system (i.e., source term, contaminant transport through the vadose zone and groundwater, and receptor exposure) to provide a system-wide basis for data collection and analysis. Results of HTI's studies on retrieval and closure alternatives will be used in developing closure strategy, and will be provided as input to evaluation of closure alternatives through a NEPA process.

### TWRS Immobilized Waste Program

The goal of the TWRS Immobilized Waste Program is to store the immobilized high-activity waste product until it is shipped to a federal repository and to dispose of the ILAW product at the Hanford Site. In order to support planned disposal of low-activity waste, much geotechnical information is being generated for the natural Hanford system. More information is given in Appendix C.

### TWRS Waste Storage, Retrieval, and Closure Programs

The goal of these programs are safe storage of tank waste until retrieval, retrieval of tank waste for treatment and immobilization, and closure of tank farms. These programs establish the requirements for the information that the TWRS Vadose Zone Program provides.

TWRS Waste Storage provides data on the tank contents, tank farm configuration, and tank integrity, and establishes the rules under which TWRS Vadose Zone Program activities (such as borehole drilling and remediation actions) are conducted to ensure safety.

LDMM is an element of SST Retrieval. The LDMM activity is an ongoing effort to identify technologies and establish the strategy to detect, monitor and mitigate leakage during the retrieval of the Hanford SSTs. The objective of this program is to identify and develop technologies and procedures that assure retrieval operations are conducted in a manner that protects human health and the environment from potential leakage. Additional details regarding the LDMM program are provided in Appendix D.

The purpose of waste retrieval is to place tank farms in an environmentally safe end state. Through a NEPA process, decisions will be reached on how tank farms will be closed, based on evaluation of environmental, safety, and health impacts of closure alternatives. This will also provide the basis for defining retrieval requirements for closure.

### Science and Technology Needs

TWRS has submitted a number of science and technology needs to Hanford's Site Technology Coordinating Group (STCG). The needs of most relevance to this program are:

1. Long-Term Testing of Surface Barrier (RL-WT017)
2. Testing of Sand-Gravel Capillary Barriers (RL-WT018)
3. Getter Materials (RL-WT-019)
4. Data and Tools for Performance Assessments (RL-WT029)
5. Contaminant Mobility Beneath Tank Farms (RL-WT030)

Items 1, 2, and 4 deal with estimating how moisture flows through the Hanford's vadose zone. Items 3, 4, and 5 deal with estimating how the contaminants move in relationship to moisture.

Appendix E provides more information on science and technology needs being addressed through the STCG.

Not only are the projects at the Hanford Site noting these science and technology needs, but these projects have a long history in funding these areas. For example, the ILAW Disposal Project is funding research in many of these areas. The Hanford Tank Initiative has funded much instrument development. The TWRS programs will actively seek to incorporate better data, methods, and tools in the execution of its projects.

#### **4.2.4 Before New Data Or Tools Are Generated, Current Information Will Be Reviewed For Use**

Much vadose zone data has been generated for the Hanford Site. Models have been created and tested. Some of this information can be applied to the TWRS Vadose Zone Program. Other parts will lead the program astray if blindly accepted. The TWRS Vadose Zone Program is committed to get the data and information it needs. All data used will be carefully checked for quality and relevance.

#### **4.2.5 External Peer Review Is Important for Program Success**

The data supplied by this program will be used in important decisions. These decisions are important because they involve large financial commitments and, most importantly, because they could involve large potential impacts to the environment and to public safety. Therefore the data and models used by the TWRS Vadose Zone Program must be of very high quality and the regulators and the public must be able to trust their accuracy. A major step in such acceptance is that external peer groups review the data, the models, and the program to provide independent judgment of their quality.

Such a panel was set up to review the characterization work in the SX Tank Farm. Their report (DOE 1997b) contained 22 recommendations. The status of actions taken in response to those recommendations is given in Appendix A.

#### **4.2.6 Input from the Public is Important for Program Success**

The public could be impacted by TWRS decisions. Therefore it has shown a strong interest in being involved in TWRS activities. The TWRS Vadose Zone Program believes that public involvement is essential for program success.

The plan of the TWRS Vadose Zone Program to involve the public, stakeholders, and Tribal Nations is provided in Appendix B.

### **4.3 TWRS VADOSE ZONE PROGRAM PRIORITIZATION**

The first and foremost priority for the TWRS vadose zone program is to determine what actions are necessary and/or prudent to minimize long term health and safety risks that may

result from further migration of existing contamination sources in tank farms. Existing contamination sources in tank farms are primarily from leaks and spills from tanks and tank farm operations. Further movement of these contaminants is driven by infiltration from natural and man-made sources. Four WMAs containing eight SST farms are presently under RCRA Assessment due to evidence that past tank leaks have already contaminated groundwater.

The second priority for TWRS vadose zone characterization is to understand implications of leaks so that waste retrieval efforts are consistent with site cleanup goals (e.g., how to retrieve waste from SSTs so as to minimize potential leak impacts). Risk of leakage during retrieval can be reduced by (a) tank selection, (b) choice of retrieval technology, (c) development and deployment of leak detection capability, and (d) development of retrieval operating procedures that define appropriate response actions to detection of leakage. Each of these factors is being addressed in the TWRS SST retrieval program. Evaluation of consequences of potential retrieval leakage is also needed as input to retrieval decisions.

The third priority for TWRS vadose zone characterization is tank farm closure. This includes (a) determining the amount of waste that must be retrieved for closure, as well as (b) how to close tank farms. Information gained on nature and extent of vadose zone contamination from past leaks, coupled with improved understanding of factors that affect rate of migration of contaminants during leak events, will allow estimation of nature and extent of contaminated tank farm soils at completion of retrieval. When such data and understanding are sufficient for evaluation of tank farm closure alternatives, including alternatives for soil remediation, the closure decision process can begin.

Other categories of TWRS vadose zone program activities that are not prioritized include those that support, in general, each of the above priorities (e.g., technology development, external review, and Tribal Nation/stakeholder involvement), or that support ongoing tank farm operations through completion of retrieval (e.g., spectral gamma logging surveillance). Site characterization for decisions on disposal of ILAW is being conducted independently of vadose zone characterization in SST farms, and thus is not affected by the prioritization approach described above.

## **5.0 VADOSE ZONE PROGRAM ACTIVITIES, SCHEDULE, AND FUNDING REQUIREMENTS**

A substantial inventory of high level waste (and hazardous chemicals) is contained in underground storage tanks managed by TWRS. Waste is reported to have leaked from 67 SSTs, and there is evidence that contaminants from these leaks have already reached groundwater in some locations. In addition, surface spills, transfer line leaks, tank overflows, and intentional liquid discharges to cribs, ditches, etc., have contributed to soil contamination in SST farms. TWRS is responsible for conducting the necessary activities to clean up tank farms and dispose of low-activity tank waste in a manner that adequately protects human health and the environment. Sound actions on tank farm cleanup and waste disposal require understanding the consequences of tank wastes released to the environment, and associated uncertainties. Vadose

zone information is essential to developing the required understanding. This section describes the vadose zone program activities needed for:

- managing existing vadose zone contamination in tank farms (i.e., taking actions to prevent or slow their movement towards groundwater)
- characterization activities to develop understanding of subsurface conditions and processes,
- modeling simulations and analysis to provide information on the repercussions of the waste inventory in the vadose zone for TWRS mitigation and remediation activities
- general support activities including technology development, external reviews, and Tribal Nation/stakeholder involvement.

In addition, this section discusses schedule, and funding requirements for those activities.

## **5.1 INTERIM CORRECTIVE MEASURES FOR MANAGEMENT OF EXISTING VADOSE ZONE CONTAMINATION**

Infiltration through the tank farm surfaces and subsurface occurs through two general mechanisms: subsurface loss of conveyed water, or surface infiltration. Surface infiltration results from precipitation in the form of rain or snow, with or without ponding caused by surface runoff. Potential man made sources of surface water infiltration (e.g., fire hydrant flushing) in or adjacent to SST farms are controlled by operating procedures, and are not believed to be a credible source of contaminant migration in tank farms. Tank leaks into previously contaminated zones are also potential hydraulic drivers that could contribute to movement of existing contamination, but are not considered "infiltration" sources in the context of this discussion. Mitigation of infiltration can be accomplished by removing the source of water, limiting the access of water to the tank farm land surface, eliminating direct access of surface water to preferential subsurface pathways, or constructing some level of infiltration barrier to prevent water from entering the impacted vadose zone.

Some prudent actions that do not require vadose zone characterization entail elimination of man-made sources (e.g., leaking water lines in or adjacent to SST farms), elimination of preferential pathways (e.g., unsealed abandoned wells, poorly capped boreholes), and drainage control (i.e., grading to eliminate ponding over tank farms from surface runoff). Other more expensive actions may require vadose zone characterization and improved understanding of transport processes as input to cost/benefit analysis (e.g., removal of gravel covers, placement of interim surface barriers to reduce infiltration, and/or remediation of contaminated soils).

### 5.1.1 Removing Water Sources

Leakage from charged waterlines in the vicinity of SSTs presents a potential means of transporting contaminants deeper into the vadose zone. Most waterlines, potable, and raw are not routinely used under present day operating scenarios and therefore are generally unnecessary.

The ages of the existing water service lines are sufficiently great that the threat of failure is increasing steadily. Documented decommissioning of these water lines is the goal of this effort.

An investigation of the status of waterline decommissioning in the S and SX Tank Farms revealed that due to incomplete documentation, the status of the sanitary and fire protection water supply lines could not be verified without excavation of those sites where cutting and plugging of the lines was planned to be done. In addition, even if the lines had been decommissioned, not all downstream storage sites had been emptied, making back flow a possibility.

A detailed work plan will be prepared describing the process and documentation requirements for removing from service all unnecessary charged waterlines and water storage units from the vicinity of the SST Farms. Implementation of activities in accordance with the work plan will eliminate this infiltration source.

### 5.1.2 Eliminating Direct Access of Surface Water to Preferential Subsurface Pathways

Dry wells in the tank farms have historically been fitted with caps to protect them against infusion of surface water. Over the years, many of these caps have been altered, damaged and/or lost. Replacement of the caps with units that can be sealed to preclude ready entry of water is planned. This activity will serve two purposes: 1) prevent direct infiltration of surface water and potential contamination of the inside of the casings; and 2) provide a time and cost saving associated with periodic removal of water before logging operations can proceed. This is a low-cost activity that does not require vadose zone characterization data.

Several monitoring wells constructed prior to acceptance of RCRA well construction guidelines exist within the tank farm boundaries. These wells are not generally used in the RCRA or operational monitoring efforts; although there are exceptions. The wells provide a potential for short-circuiting of contaminants directly to the groundwater. Under this effort, the improperly constructed and unused wells will be identified, individual decommissioning plans prepared, and the wells decommissioned according to those plans. In areas where the casing cannot be pulled, these casings will require perforating by jet or mechanical methods and pressure grouting to assure that all annular spaces are sealed and the well eliminated as a direct pathway to groundwater. This activity is also relatively low-cost, and does not require vadose zone characterization data.

Similarly, some boreholes are deteriorated or perforated and no longer suitable for spectral gamma logging. These could be abandoned and sealed. Spectral gamma logging reports prepared by DOE's Grand Junction, Colorado Office contain information on what wells and boreholes should be considered for decommissioning.

### 5.1.3 Limiting Access of Water to the Tank Farm Land Surface (Drainage Control)

Many of the tank farm surfaces act as collection points for runoff during heavy precipitation or rapid snow-melt events. Historically, tank farm surfaces have been altered to provide shielding from radionuclide emissions. In some instances this has resulted in a "dish-shaped" configuration with the center of the dish corresponding to the center of the tank dome. Water ponds in the dish and infiltrates the subsurface. Freezing is most often associated with periods of rapid snow melt when the ground surface is frozen and restricts infiltration. Recontouring of tank farm surfaces and adjacent upgradient areas to control and redirect runoff away from the farm surfaces will limit infiltration to a portion of that water which falls directly on the farms.

An engineering study is needed to assess existing conditions, make recommendations, and develop requirements for tank farm surface drainage controls. Initially, this would not involve assessment of long term risk implications or quantification of risk reduction benefits. If construction costs and/or impacts to tank farm operations are significant, then assessment of risk reduction benefit would be needed. Decisions on implementation would then be dependent on vadose zone data and improved understanding of factors that control movement of contaminants from tank leaks.

### 5.1.4 Infiltration Barriers

Barriers to infiltration generally consist of engineered covers designed to either deflect moisture away from the protected surface (i.e., asphalt cover) or a cover that holds moisture in a shallow zone for subsequent evapotranspiration processes to return the water to the atmosphere. A variety of barriers have been designed to protect Hanford waste facilities from infiltrating meteoric water. Ultimately, the tank farms may be provided with such covers during tank farm closure, but such a barrier would not be practicable before and during retrieval.

Hanford has been selected for funding an effort to evaluate and develop options for placing interim surface barriers for tank farms, under the Innovative Treatment Remedial Demonstration (ITRD) Program. Supplementing a previous study on interim covers for tank farms (WHC 1992), this effort would evaluate geosynthetic clay liner systems, composite soil or asphalt layer systems, and other concepts to minimize water percolation through tank farm soils. The study may include demonstrations using lysimeter facilities near the tank farms. The study would also evaluate approaches for documenting percolation rates with and without cover systems in place. Impacts on tank farm operations, including worker exposure, environmental monitoring, and safety will be addressed. These studies will provide information on performance and technical feasibility, and requirements for materials, design, and placement methods. Studies will also consider compatibility with tank farm closure alternatives. Planned studies will include participation from TWRS tank farm operations personnel, Ecology, Tribal Nations, and Pacific Northwest National Laboratories.

Decisions on placement of interim surface barriers will depend on whether such barriers are shown to be technically feasible and beneficial to long-term risk reduction. Assessing benefits of interim surface barriers in terms of implications to human health and the environment depends on vadose zone characterization and understanding of factors that control movement of contaminants.

## 5.2 CONDUCT INITIAL VADOSE ZONE CHARACTERIZATION CAMPAIGN

An initial vadose zone characterization campaign is needed to develop the basic data that are necessary to develop, refine, and validate the understanding to support each of the three priorities described in 4.3. Clearly, developing an understanding of consequences of past leaks is essential to taking sound actions to protect human health and the environment. Taking sound action starts with actions to limit migration of existing vadose zone contaminants. Since past leaks can be considered analogs for potential retrieval leaks, results can also be applied in analysis of impacts of potential retrieval leaks. Understanding mechanisms that control migration of contaminants during leak transients allows estimation of nature and extent of contamination that is likely to be present in tank farm soils at completion of waste retrieval. This allows evaluation of tank farm closure alternatives under a closure NEPA process. New information on geotechnical properties of the 200 Area vadose zone may also contribute to refining performance assessments supporting decisions on ILAW disposal facilities.

The initial vadose zone characterization campaign provides a starting point for gathering data that will be important to TWRS mitigation and remediation actions. In addition to supporting that objective, results of this initial effort will also provide the basis for determining whether/what additional data may be needed.

A detailed characterization work plan will be prepared identifying specific locations to characterize, sequence of characterization, drilling and sampling methods, sampling frequency, field and laboratory tests to be conducted, geophysical logging, and other aspects of vadose zone characterization to be employed. As a large amount of data is needed to develop, refine, and validate the understanding of subsurface processes, planning will incorporate measures to improve productivity, as described in 4.2.1. This includes such measures as assigning a dedicated drilling rig, drilling crew, field geologist, and TWRS support personnel full time for the period necessary to conduct the pre-planned field activities. Assigning dedicated equipment and personnel will improve productivity of data collection by minimizing mobilization/demobilization costs, developing reliable, trained, experienced staff, identifying and overcoming obstacles to efficient operation, and achieving economies of scale. Modern drilling techniques will be employed that will minimize drilling and sampling time. In selecting drilling and sampling methods, this effort will consider results of demonstrations of alternate technologies for vadose zone characterization, planned to be conducted in FY98 or early FY99 (e.g., directional drilling and Environmental Measurement While Drilling [EMWD], cone penetrometer-deployed sensors and sampling probes), as well as more conventional technologies that have been used or proposed at Hanford (e.g., vertical drilling, slant drilling). Development of a detailed characterization work plan will also incorporate results of data gaps analysis and

science and technology roadmapping activities conducted as part of the Hanford Site VZ/GW/CR Project, as it becomes available to TWRS.

Characterization to support decisions on what, if any, near term mitigative actions may be required will initially focus on worst case locations, based on potential risk to human health and the environment. WMAs currently under RCRA assessment (due to evidence of groundwater contamination from past leaks) are a major consideration in selecting such "worst case" locations for sampling. Selection of sampling locations will also be designed to test hypotheses on factors that control contaminant transport during tank leak events, and/or that can be used for estimating concentration and distribution of contaminants of concern at locations not initially characterized. Factors that are believed to control waste migration in the subsurface are gravity, geology/stratigraphy (due to physical and hydraulic properties that affect flow), waste chemistry (due to postulated effects on hydraulic properties of soil, and/or geochemical interactions between contaminants and the soil,) and leak volume (due to effects on hydraulic driving force, and spatial extent of waste chemistry effects.) As vadose zone contaminant plumes in the 200 East Area are closer to the Columbia River and overlie more permeable sediments than plumes in the 200 West Area, contamination in the 200 East Area poses the most immediate threat to human health and the environment. This will be a factor in establishing the order in which past leak events are characterized.

Waste chemistry factors tentatively believed to be among the most important discriminating factors affecting movement of contaminants during leak events are (a) aluminum concentrations in leaked waste, and (b) presence of organic complexants. Ionic strength and pH may also affect contaminant mobility, but tend not to be discriminating factors since liquids in SSTs are predominantly of high ionic strength and high pH. Aluminum ions can react with silicates in the soil to form aluminum silicate (clay) which may locally reduce hydraulic conductivity (PNNL 1998b). For purposes of testing this hypothesis, leak events where concentration of aluminum ions in leaked waste was in excess of 0.1 mole/liter will be characterized and compared with leak events where concentration of aluminum ions was less than 0.1 moles per liter. It is expected that if the interaction of aluminum ions in the waste with soil minerals has formed clay-like soils, then the leaked waste may be more likely to spread laterally, which may complicate definition and modeling of contaminant movement. Presence of organic complexants, which can preclude normal adsorption/desorption processes, may also affect contaminant transport. For purposes of testing this hypothesis, leak events where organic complexants are believed to have been present will be characterized and compared with leak events where organic complexants are not believed to have been present.

An important geologic discriminator among SST farms is the Plio-Pleistocene formation (present in the 200 West Area, absent in 200 East Area). The Ringold formation (present above the water table in the B, BX, and C tank farms of 200 East Area) may also be important. Initially, plumes in both 200 East Area and 200 West Area will be characterized to compare differences in distribution of contaminants that possible can be attributed to presence or absence of the Plio-Pleistocene formation.

Estimated leak volumes for the 67 assumed leakers range from 300 gallons to 115,000 gallons<sup>1</sup> (LMHC 1998). The estimated leak detection threshold using currently available leak detection technology is around 8,000 gallons. Since one of the objectives of characterizing past leaks is to examine “most impacted” locations first (see 4.1.2) past leaks reported below 8,000 gallons will be excluded from the initial characterization campaign. The only exception will be if a sufficient number of “large” leaks is not available for hypothesis testing, as described above. 18 of the 67 SSTs known or assumed to have leaked in the past have reported leak volumes exceeding 8,000 gallons.

Nine past leak events have been tentatively selected for an initial characterization campaign. These nine locations will be reassessed, and possibly revised in development of the detailed characterization plan, as discussed in 4.2.1. Approaches to improve cost-effectiveness of drilling, sampling, and analysis are also discussed in 4.2.1.

Sampling in these nine locations will provide at least three data points to test the hypotheses described above, as indicated in Table 2. Seven of these nine locations are in WMAs currently under RCRA assessment (PNNL 1998c, PNNL 1998d, PNNL 1998e). Collectively, these seven locations include all four of the WMAs under RCRA Assessment. In two of the nine locations, A-105 and SX-115, the initial tank leak was followed by leakage of larger volumes of water, or at least more dilute waste. Distribution of contamination in these locations may therefore also provide indication of effects of retrieval leaks on movement of pre-existing contamination. These locations (A-105 and SX-115) may also serve as a proxy for the effects of infiltration (simulated by the added water) on leaked contaminants, if differences between infiltration rates under acute and chronic conditions are properly considered.

Results of initial sampling and analysis will probably lead to modifications to these initial hypotheses, and therefore modifications to the targeted characterization locations identified in Table 2, or to the targeted locations defined in the detailed characterization plan. As indicated in Section 5.6, these nine locations are targeted for characterization in FY99-FY00. Three of the four largest leaks (T-106, 115K gallons; BX-102, 70K gallons, and SX-115, 50K gallons) are targeted for characterization the first year. If additional characterization in the other nine “large leak” locations, or in these initial nine locations, is required for decision-making, those locations would be characterized in FY01 and later, as indicated in Section 5.6. Criteria for determining whether additional characterization would be required cannot be quantitatively established, per the approach described in Section 4.2.1, prior to further development of tools for applying CRCIA principles on dominance, uncertainty, and value of information. Development of such tools is also included in the activities and schedule provided in Section 5.6. Development of the detailed characterization plan (Section 4.2.1) will address quantitative approaches for defining characterization needs.

Following completion of this initial TWRS vadose zone campaign, improved understanding of subsurface conditions and processes associated with tank leaks may allow grouping of past tank leak events. The purpose of creating such groupings is to allow

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<sup>1</sup> The highest reported volume of leaked tank waste is 115,000 gallons, from 241-T-106, in 1973. However, a higher volume of liquid is estimated to have leaked from 241-A-105. Following its rupture in 1963, an estimated 610,000 gallons of water may have been added to the tank to aid evaporative cooling, and up to 277,000 gallons of liquids (primarily the added cooling water) may have actually leaked from this tank.

extrapolation of results and conclusions to other situations. This includes extrapolation to leak locations not initially characterized, and/or to potential future retrieval leaks. Ability to extrapolate results and conclusions to other situations depends on identifying factors that strongly influence contaminant migration, and/or that can indicate presence and concentration of contaminants. Such factors include spectral gamma logging, trends in historical gamma logging, tank waste chemistry parameters, tank leak history, and evidence of groundwater contamination.

Table 2. Sampling Locations for Initial Tank Waste Remediation System Vadose Zone Characterization Campaign.

Tank Leak Event	Under RCRA Assessment		Geology		Aluminum		Organic Complexants		Leak Volume	
	Yes	No	200E	200W	Less Than 0.1 moles/l	Greater Than 0.1 moles/l	Not Present	Present	8K to 40K gallons	Greater Than 40K gallons
A-105		x	x		x		x			x
B-110	x		x			x		x	x	
BX-102	x		x			x	x			x
C-101		x	x		x		x		x	
SX-109 <sup>1</sup>	x			x		x	x		x	
SX-110	x			x		x		x		
SX-115	x			x		x	x			x
T-106	x			x		x		x		x
TY-105	x			x	x		x		x	

Note 1: Supplementing characterization activities associated with extension of borehole 41-09-39 to groundwater, in FY98, characterizing the "hot zone" (above 130 foot depth) in this borehole will be accomplished by conducting sidewall sampling as the borehole casing is removed. Additional drilling and sampling in the vicinity of SX-108, SX-109, SX-111, and SX-112 may also be conducted pursuant to SX Expert Panel recommendations following its June 1998 program review.

For example, if it is found that <sup>137</sup>Cs migration and <sup>99</sup>Tc migration can be correlated through laboratory analysis of samples in vadose zone plumes, then borehole spectral gamma logging data may help in estimating distribution of <sup>99</sup>Tc in past leak locations where the chemistry of leaked waste can be estimated. Development of any such correlations will be subjected to external peer review, and may need to be validated by further sampling.

Extrapolation of consequences of past leaks to potential retrieval leaks requires establishing correlations between observed distribution of contaminants in vadose zone plumes, and parameters that are believed to have affected such distribution (e.g., geology/stratigraphy, waste chemistry, leak volume). Characterization of past leak locations will test hypotheses on

what factors are believed to most strongly affect movement of contaminants during leak events, and will therefore directly support retrieval actions as well as waste storage actions.

Tentative designation of groupings of past leak events (existing plumes), based on the assumption that the geology and waste chemistry factors described above will prove to be principal discriminators in migration of contaminants during tank leaks, is provided in Table 3.

Table 3. Tentative Grouping of Past Single-Shell Tank Leak Events by Geology and Waste Chemistry.

Group	Geology	Waste Chemistry	Representative Assumed Leaking Single-Shell Tanks(1)
1	Hanford Formation only	Low Aluminum, Organic Complexants Not Present	<b>A-105*</b> , <b>C-101*</b>
2	Hanford Formation only	Low Aluminum, Organic Complexants Present	B-201, B-203, B-204, C-203
3	Hanford Formation only	High Aluminum, Organic Complexants Not Present	BX-101
4	Hanford Formation only	High Aluminum, Organic Complexants Present	<b>BX-102*</b> , <b>BX-108</b> , <b>B-110*</b>
5	Hanford and Plio-Pleistocene Formations	Low Aluminum, Organic Complexants Not Present	TY-103, <b>TY-105*</b> , <b>TY-106</b>
6	Hanford and Plio-Pleistocene Formations	Low Aluminum, Organic Complexants Present	T-111
7	Hanford and Plio-Pleistocene Formations	High Aluminum, Organic Complexants Not Present	<b>S-104</b> , <b>SX-107</b> , <b>SX-108</b> , <b>SX-109*</b> , <b>SX-111</b> , <b>SX-112</b> , <b>SX-113</b> , <b>SX-114</b> , <b>SX-115*</b> , <b>TY-101</b> , <b>U-101</b> , <b>U-104</b> , <b>U-110</b> , <b>U-112</b>
8	Hanford and Plio-Pleistocene Formations	High Aluminum, Organic Complexants Present	<b>SX-110*</b> , <b>T-106*</b> , T-108, TY-104

Note (1): Past leak events in excess of 8,000 gallons are in bold. Asterisks denote past leak events targeted for characterization in the initial TWRS vadose zone characterization campaign (see Table 2).

This Table lists 32 past leak events where composition of past tank leaks can be estimated based on process knowledge and/or in-tank characterization (if commingling of waste has not occurred between the time of the leak and the time of in-tank sampling for characterization). For the other 35 past leak events, chemical composition of leaked waste is indeterminate at this time. Data obtained in the characterization process will either validate the grouping approach, or provide the basis for (a) further refinement of groupings or (b) modification of this vadose zone characterization strategy.

### 5.3 PROVIDE VADOSE ZONE INFORMATION FOR TWRS ACTIONS

Vadose zone data are needed to provide understanding of implications of tank wastes released to the environment. This understanding is necessary for sound decisions on (a) how to control the dispersion of existing subsurface contamination from tank leaks, (b) how to control potential leaks during retrieval, and (c) how to close tank farms, including how much waste must be retrieved from tanks for closure. The approach for applying improved understanding of vadose zone conditions and processes in TWRS decisions is described in the following sections.

#### 5.3.1 Vadose Zone Data and Analyses Needed for Control of Existing Contamination

The first priority for the TWRS vadose zone program is to control existing vadose zone contamination from past leaks. Relatively inexpensive "good housekeeping" measures (see 5.1.1 and 5.1.2) do not require vadose zone data and/or improved understanding of subsurface conditions and processes. Decisions on measures such as interim infiltration barriers, surface drainage controls, soil remediation, or other preventive or corrective measures do require a better understanding of existing subsurface conditions and mechanisms that control subsequent movement of contaminants. Better understanding of subsurface conditions and processes is necessary to assess long term risk implications of existing soil contamination, and the degree of risk reduction that would result from such preventive/corrective measures.

Traditional approaches to risk assessment require quantifying source terms and release rates, modeling contaminant transport through the environment, and assessing consequences at a designated compliance boundary relative to established levels of protection, as well as associated uncertainties. Actions that are based on such risk assessment always involve selection of an alternative. To the extent that consequences, uncertainties, and other factors differ for alternatives, these must be evaluated for each alternative under consideration. All such assessments have associated uncertainty. Probabilistic approaches may be used that explicitly address uncertainty and parameter variability.

To determine how to control further dispersion of existing subsurface contamination from past leaks, vadose zone characterization will gather data on the distribution of contaminants in selected contaminant plumes. Initially this characterization will be in locations described in 5.2, and will determine inventory and distribution of contaminants in those locations to validate or refine conceptual models. Additional characterization beyond the initial characterization campaign described in 5.2 may be necessary to validate or refine conceptual models (hypotheses). Improved understanding of mechanisms that control contaminant transport during tank leak transients will allow estimation of source terms for tank leak events that are not characterized (predominantly smaller tank leaks). This process applies to tank leaks and other sources of contamination in the tank farm vadose zone (e.g., contaminants from spills, transfer line leaks, and liquid discharges to nearby cribs, ditches, and/or trenches).

Modeling subsequent contaminant transport through the vadose zone and groundwater is based on conventional hydrologic processes driven by infiltration and dispersion, and

conventional geochemical processes which retard movement of some contaminants. This results in predictions of contaminant concentrations at the designated compliance boundary. Consequences and associated uncertainties are estimated based on exposure scenarios corresponding to the established level of protection (e.g., dose to the maximally exposed individual). Regulatory levels of protection are irrespective of the source of contamination. Consequently, as discussed in 2.2.2, cumulative effects from all potential contamination sources must be considered. Contamination from liquid discharges to cribs, ponds, ditches, trenches, and reverse wells are likely to be major additional contamination sources that must be considered in decisions on mitigation/remedial actions for past leaks (PNNL 1998a). For purposes of this modeling, "established levels of protection" will be reduced by the portion of the regulatory level of protection allocated for such past liquid discharges. Also, other impacts from the combined release of contaminants at Hanford may be identified through the Hanford Site GW/VZ/CR Project, which may necessitate further reducing the "established levels of protection."

Actions that result from such assessment depend on the predicted consequences relative to established levels of protection, and their associated uncertainties. For example if predicted consequences are well below established levels of protection without mitigation/remedial actions, then such mitigation/remedial actions would not be required. If predicted consequences exceed established levels of protection, then mitigation/remedial actions will likely be required. Selection of the optimal mitigation/remedial action would require assessment of adverse impacts and benefits (improvements relative to established levels of protection) of alternative mitigation/remedial actions. If the level of uncertainty is too high to support an action, then addition vadose zone characterization or additional study may be necessary to reduce the uncertainty.

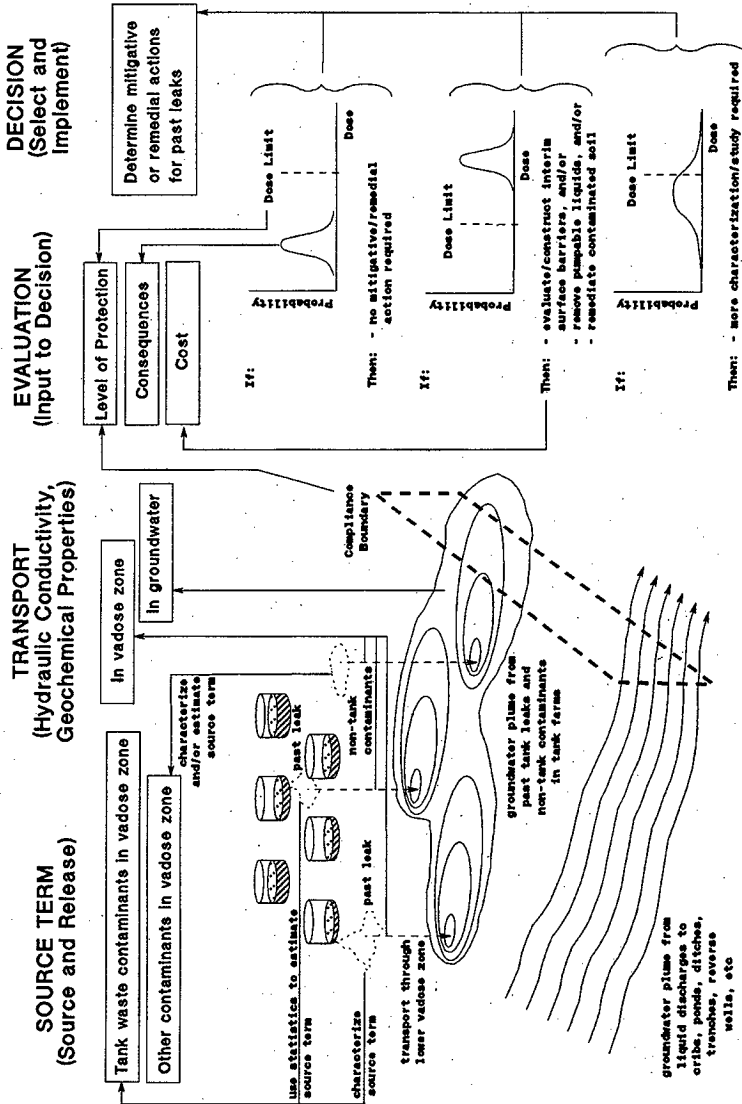
The process described above is illustrated in Figure 4.

### **5.3.2 Vadose Zone Data and Analyses Needed for Actions to Control Potential Retrieval Leaks**

The second priority for the TWRS vadose zone program is to support actions to control potential retrieval leaks. Retrieval strategy, retrieval technology, and LDMM technology and procedures to control leakage are being developed under the SST Program. For initial retrieval of SST wastes (after C-106), risks associated with potential leaks will be minimized by retrieving from assumed sound tanks. Even so, implications of potential retrieval leaks will need to be assessed. The process for such assessment, and input to decisions on how to retrieve waste from potentially leaking tanks, is as described in 5.3.1.

Understanding factors that controlled movement of contaminants during past tank leak transients, as described in 5.3.1, can be applied for estimating source terms that would result from leaks during retrieval. Modeling subsequent contaminant transport in the vadose zone and in groundwater utilizes the same approach as described in 5.3.1. Arrival of contaminants from potential retrieval leaks at the established compliance boundary will be assumed to coincide with arrival of contaminants from past leaks. In this case, the cumulative impact of retrieval leaks and past leaks must be considered in assessing consequences relative to established levels of protection.

Figure 4. Approach for Vadose Zone Input to Decisions on Mitigative/Remedial Actions for Past Leaks.



Mitigation/remedial actions for past leaks and actions to control retrieval leaks depend on the predicted consequences and uncertainties relative to established levels of protection, and also on cost differences between alternatives, including alternatives that involve soil cleanup. For example if the combined effect of past leaks and potential retrieval leaks from the baseline retrieval technology (hydraulic retrieval) is well below the established level of protection, then waste retrieval using the baseline technology, with baseline LDMM technology and procedures, may be acceptable. If consequences of past leaks alone exceed the established level of protection, then preventive or remedial actions may be required even without additional contamination from retrieval leaks. Under those conditions, baseline retrieval technology and LDMM approaches may also be acceptable, since consequences of retrieval leakage would be mitigated by actions to be taken anyway for past leaks. If, using baseline retrieval technology and baseline LDMM approaches, the additional consequences of potential retrieval leaks exceed the established levels of protection, alternative retrieval technologies, and/or alternative LDMM technologies or procedures may be required.

As for decisions on mitigative/remedial actions for past leaks, if uncertainty is too high to make a clearcut decision then additional vadose zone characterization or additional study may be required.

The process described above is illustrated in Figure 5.

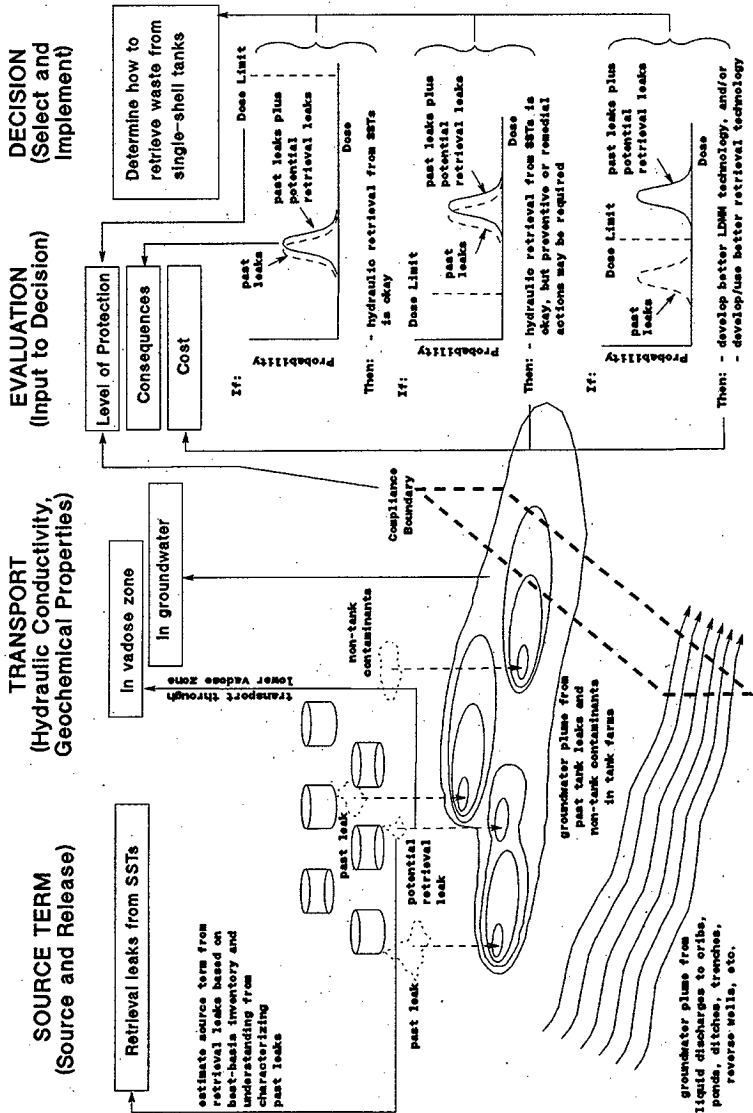
### **5.3.3 Vadose Zone Data and Analyses Needed for Decisions on How to Close Tank Farms**

The third priority for the TWRS vadose zone program is to support decisions on tank farm closure. Decisions on degree of waste removal required for closure, and approach to tank farm closure, will be made through a closure NEPA process, and subsequent permitting activities including RCRA closure. Evaluation of alternatives will involve the same process described in 5.3.1 and 5.3.2.

In this case the source term is the residual waste left in tanks and ancillary tank farm equipment at closure, and the release characteristics are affected by the method of closing tank farms. Contaminant transport through the vadose zone and groundwater is as described in 5.3.1 and 5.3.2. Understanding of subsurface conditions and transport processes that supports decisions on mitigation/remedial actions for past leaks, and decisions on controlling retrieval leaks, can also be applied to assessment of closure alternatives. It is unlikely that arrival of contaminants from residual waste in tanks or ancillary tank farm equipment at the designated compliance boundary will coincide with arrival of contaminants from past leaks and retrieval leaks. However, this must be assessed and verified as part of a comprehensive site assessment.

Decisions on tank farm closure also depend on the predicted consequences and uncertainties relative to established levels of protection, and on adverse impacts and cost differences between alternatives. For example, if consequences of residual waste left in tanks using baseline retrieval technology and landfill closure methods are well below the established level of protection, then waste might be retrieved and tank farms closed safely and economically using those approaches. However if the converse is true, then alternative retrieval or closure

Figure 5. Approach for Vadose Zone Input to Decisions on Minimizing Impacts of Potential Leaks During Waste Retrieval.



approaches will be required. The objective of the TWRS vadose zone program is to develop an understanding of vadose zone conditions and processes sufficient to support evaluation of closure alternatives in a NEPA process. Validation, using subsurface data, of models used in contaminant transport analysis and risk assessment under the NEPA process will be essential to a technically defensible decision.

The process described above is illustrated in Figure 6.

#### **5.4 SURVEILLANCE AND MAINTENANCE**

The baseline spectral gamma logging effort in SST farms will be completed in FY 1998, with completion of documentation expected in mid FY 1999. This establishes a baseline record that can be used during ongoing tank farm surveillance to assess changes over time. It is expected that future surveillance would be conducted, as a minimum, prior to and following waste retrieval operations in tank farms. Frequency and procedures for conducting additional logging efforts would be established as part of tank farm operations ongoing surveillance and maintenance activities.

As groundwater levels drop and groundwater flow patterns change due to curtailment of past liquid effluent practices on the Hanford Site, modifications to the RCRA monitoring well network around tank farms will be required for continued surveillance of groundwater contamination. Expenses for such modifications are shared between Environmental Restoration and TWRS.

#### **5.5 PROCESS IMPROVEMENTS**

As noted in 4.3 some vadose zone program activities are more or less continuous, and support, in general, all or at least several areas of TWRS. Technology development, enhanced productivity initiatives, external review, and Tribal Nation/stakeholder involvement are such activities. Technology development may be needed to improve techniques for borehole surveillance, or for improved methods of subsurface sampling and analysis. As long as vadose zone surveillance and sampling/analysis activities continue, opportunities for identifying and developing technology improvements and increasing productivity will be explored. As noted in 4.2.5 and 4.2.6, external review and public/stakeholder/Tribal Nation involvement will be important elements of the TWRS vadose zone program strategy. These functions may be absorbed within the Hanford Site GW/VZ/CR Integration Project, as noted in 2.3, but are identified in the TWRS Vadose Zone Program, as reflected 5.6.

#### **5.6 SCHEDULE FOR VADOSE ZONE CHARACTERIZATION**

Figure 7 provides a tentative schedule and rough order of magnitude cost estimates for planned vadose zone characterization activities supporting key TWRS decisions and actions discussed in 2.1. This schedule is dependent on availability of funding to support the required activities. Table 4 describes each activity, funding requirements, and rough order of magnitude cost estimate basis.

Figure 6. Approach for Vadose Zone Input to Decisions on How Much Waste Must be Retrieved for Closure, and How to Close Tank Farms.

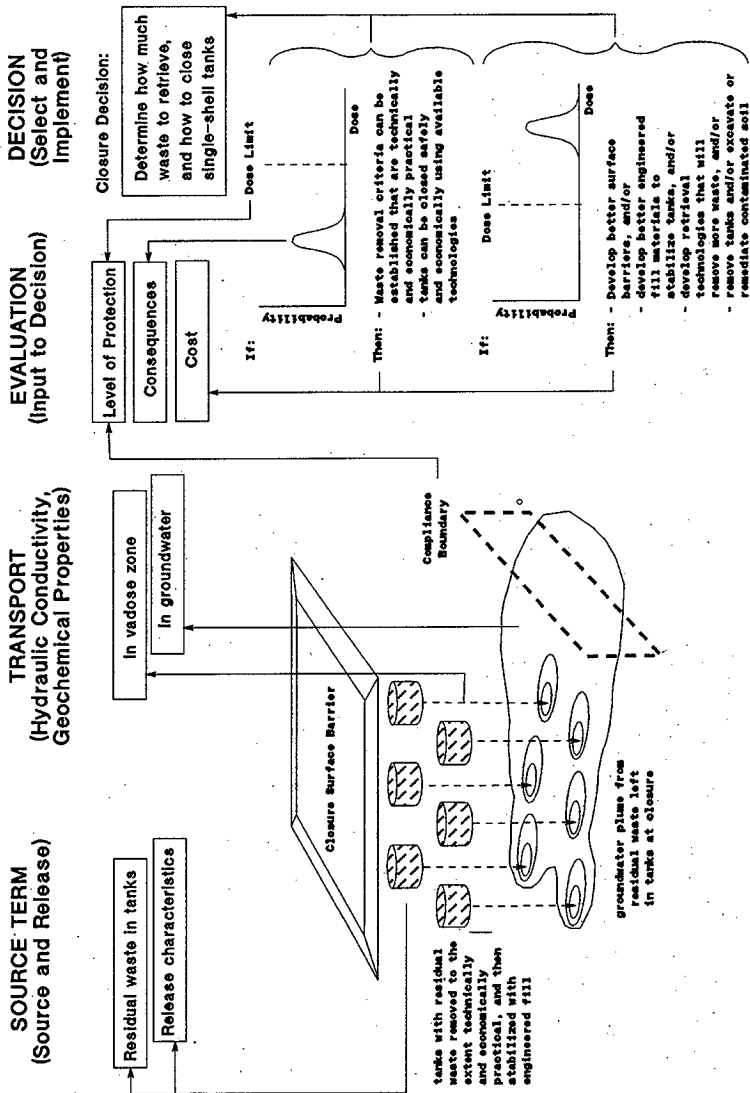


Figure 7. Schedule and Funding Requirements for Tank Waste Remediation System Vadose Zone Program Activities. (Sheet 1 of 2)

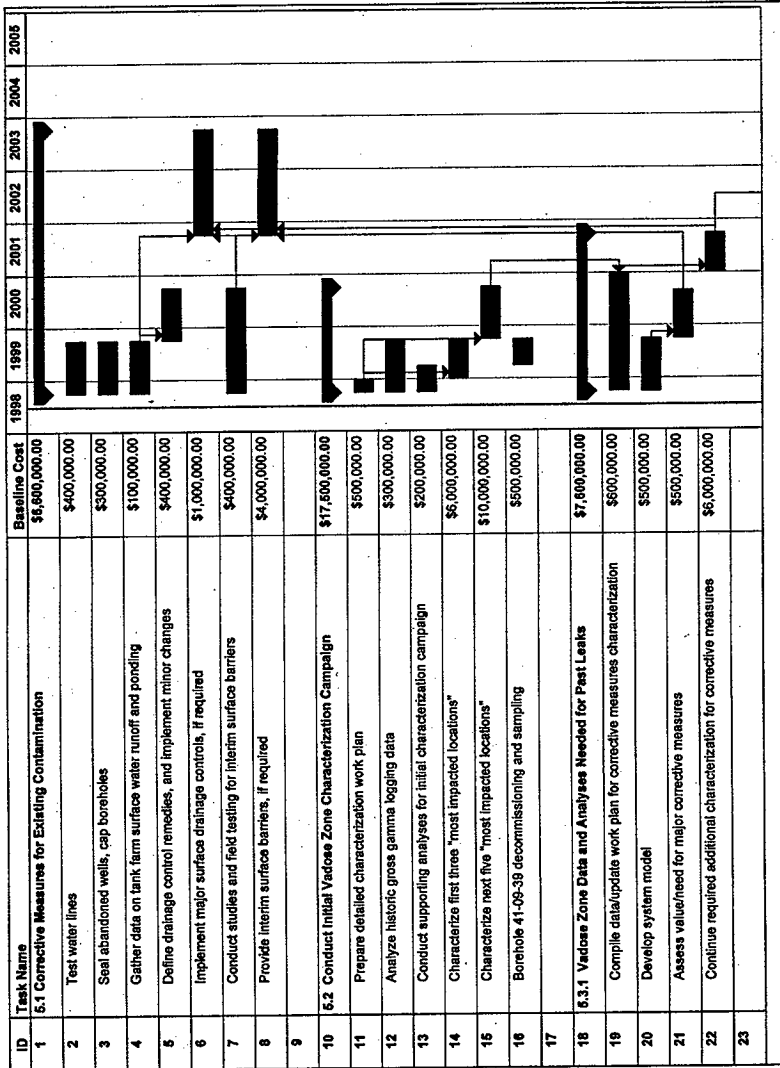


Figure 7. Schedule and Funding Requirements for Tank Waste Remediation System Vadose Zone Program Activities. (Sheet 2 of 2)

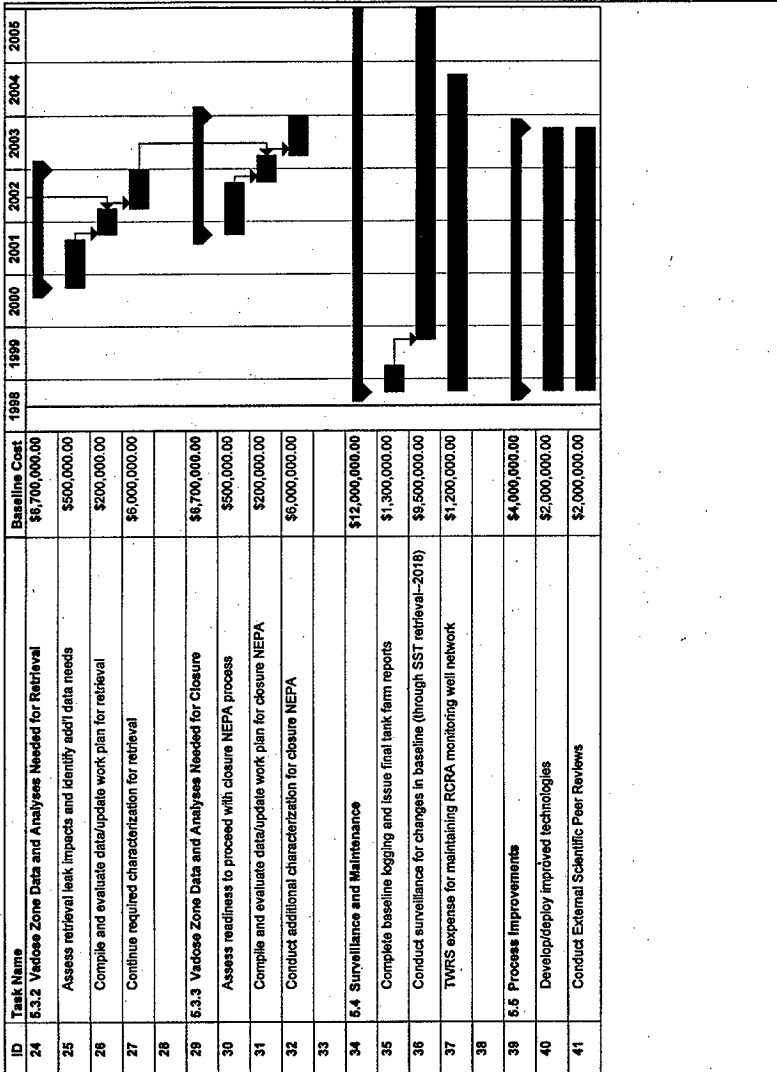


Table 4. Summary of Planned Tank Waste Remediation System Vadose Zone Characterization and Mitigation Activities.

Activity Title	Estimated Funding Requirement and Period	Basis of Estimate	Scope Description	Rationale & Objectives
<b>5.1 Evaluate and Implement Corrective Measures for Management of Existing Vadose Zone Contamination:</b>				
Test water lines	\$400,000 (FY99)	Estimate pending cost proposal from DynCorp	Review site drawings and test records in all SST farms, determine configuration of valving, identify active water lines in vicinity of tank farms, test water lines, shut off inactive but charged water lines where practical. Summarize findings, corrective actions taken, and recommendations for more extensive corrective actions in final report. (See Section 5.1.1 for more information.)	Leakage from charged waterlines presents a potential means of transporting contaminants deeper into the vadose zone. The ages of existing water service lines are sufficiently great that the threat of failure is increasing steadily.
Seal abandoned wells, cap boreholes	\$300,000 (FY99)	Estimate by Waste Management Northwest (WMNW), assumes 10 wells at \$25K/abandonment and \$50K for purchase and installation of well caps.	Procure/install leak-tight caps for SST boreholes, to replace existing caps. Identify wells and dry wells to abandon in tank farms based on DOE-GJPO tank farm reports, their configuration, and depth. Develop activity plan, and seal per Ecology requirements. (See Section 5.1.2 for more information.)	Historically, dry wells have been fitted with caps to prevent infusion of surface water. Many of these caps have been altered, damaged and/or lost. Replacement with units that can be tightly sealed will eliminate these wells as a source of recharge and minimize maintenance before they can be used for geophysical logging.  Several monitoring wells constructed before acceptance of RCRA well construction guidelines exist. These wells are generally unused. The wells provide a potential for short-circuiting of contaminants directly into the groundwater. Abandonment of these structures will eliminate that direct pathway.

Table 4. Summary of Planned Tank Waste Remediation System Vadose Zone Characterization and Mitigation Activities.

Activity Title	Estimated Funding Requirement and Period	Basis of Estimate	Scope Description	Rationale & Objectives
Gather data on tank farm surface water runoff and ponding	\$100,000 (FY99)	Best estimate pending estimate by PHMC Alliance Contractor	Conduct study on historical records associated with surface water runoff, drainage, and ponding in tank farms. Organize and compile data in summary report that will be provided as input to design and/or implementation of surface water drainage control measures. (See Section 5.1.3 for more information)	Many tank farm surfaces act as collection points for runoff during heavy precipitation or rapid snowmelt events. Identification of these tank farms and the conditions under which they served as collection points will be used as input to the design of alternative drainage controls.
Define drainage control remedies, and implement minor changes	\$400,000 (FY00)	Best estimate, pending estimate from PHMC Alliance Contractor	Review historical records compiled and summarized in FY99 activity. Conduct field surveys. Consult with tank farms engineering and operations on recommendations for rework. Implement simple and relatively inexpensive surface drainage control measures. Develop engineering drawings and specifications for implementation of complex and/or expensive surface drainage control measures, utilizing input from parallel modeling and risk assessment described in 5.3.1. (See Section 5.1.3 for more information)	Modifications to configuration of tank farm facilities must be conducted in accordance with established engineering, configuration management, and work control processes. Where modifying existing surface drainage features potentially result in high design and construction costs, or significant impacts to ongoing operations, justification of the benefit of the proposed changes, i.e., quantification of the expected resulting risk reduction must be provided.
Implement major surface drainage controls, if required	\$1,000,000 (FY02-FY03)	Best estimate pending results of FY00 engineering study and design	Implement complex and/or expensive surface drainage control measures, per design drawings and specifications developed in FY00 activity. (See Section 5.1.3 for more information.)	Drainage control activities that will require more significant reengineering of tank farm surfaces will be conducted to control accumulation of water. Activities under this task would be the subject of risk assessments noted above.

Table 4. Summary of Planned Tank Waste Remediation System Vadose Zone Characterization and Mitigation Activities.

Activity Title	Estimated Funding Requirement and Period	Basis of Estimate	Scope Description	Rationale & Objectives
Conduct studies and field testing for interim surface barriers	\$400,000 (FY99-FY00)	Estimate pending completion of EM-50 funded study in FY98	Develop and field test concepts for interim surface barriers for tank farms to limit infiltration prior to closure, as input to decision on installation of interim surface barriers. Utilize input from parallel modeling and risk assessment described in 5.3.1. Provide recommendations and technical bases in summary engineering study. Consult with tank farms engineering and operations on evaluations and recommendations. (See Section 5.1.4 for more information)	Barriers to infiltration may be provided over the tank farms during closure, these barriers are generally not practicable before and during retrieval. Hanford has been selected for funding of an effort to evaluate an develop options for interim surface barriers for the farms under the Innovative Remedial Demonstration Program. This effort supplements that funding  Decisions on placing interim surface barriers will depend on whether such barriers are shown to be technically feasible, beneficial and cost effective.
Begin providing interim surface barriers, if required	\$4,000,000 (FY02-FY03)	Estimate pending completion of EM-50 funded studies in FY99-FY200. \$25M to surface 17 tank farms (WHC-SD-WM-ES-165, 1992). Assume that interim barriers would be required for only 1 or 2 farms.	Prepare engineering drawings and specifications consistent with recommendations in FY99-FY00 studies, and install interim surface barriers, including sub-barrier moisture sensors. (See Section 5.1.4 for more information)	Based on the findings above, interim barriers to control infiltration will be installed where necessary and appropriate.

Table 4. Summary of Planned Tank Waste Remediation System Vadose Zone Characterization and Mitigation Activities.

Activity Title	Estimated Funding Requirement and Period	Basis of Estimate	Scope Description	Rationale & Objectives
<b>5.2 Conduct Initial Vadose Zone Characterization Campaign:</b>				
Prepare detailed characterization work plan	\$500,000 (FY99)	Best estimate based on 1996 planning (per Ecology)	Using input from site technical experts in working sessions, and based on objectives in this program plan, develop characterization plan and sampling and analysis plans for the initial characterization campaign. These plans shall detail the process for evaluating existing data, identifying data gaps, identifying and prioritizing locations for sampling, identifying characterization methodologies, and estimating costs, including value engineering to identify areas where costs may be reduced. (For subsequent characterization campaigns, the detailed characterization plan and/or sampling and analysis plans will be updated.)	Prepare the project plan describing the information to be collected, the use of the data, the quality of that data, the quantity of data and the locations from which the data are to be collected. The objective is to clearly define the characterization campaign so that work may be accomplished in the most cost-effective manner possible. Value engineering will be applied to assess those high cost elements where significant savings may be realized.
Analyze historic gross gamma logging data	\$300,000 (FY99)	\$40,000 per farm for 8 farms not completed in FY98 (based on cost for SX, B, BX, BY farms in FY98)	Compile and process historic gamma logging data. Develop plots of activity over time, by borehole. Develop grade thickness products, and compare against radionuclide decay curves. Summarize data analysis and interpretation in report for each farm. Support external reviews.	Dry well monitoring within the tank farms has resulted in a vast data base of gross gamma data. These data were originally collected for the sole purpose of leak detection and have not been assessed for their wealth of environmental information. The data provide the only information on the movement of tank waste constituents through the vadose zone during the period of active tank use, and since the boreholes were constructed and logged.

Table 4. Summary of Planned Tank Waste Remediation System Vadose Zone Characterization and Mitigation Activities.

Activity Title	Estimated Funding Requirement and Period	Basis of Estimate	Scope Description	Rationale & Objectives
Conduct supporting analyses for initial characterization campaign	\$200,000 (FY99)	LANL estimate for chemistry of past leaks (\$50K) and estimating leak volumes for all of SX farm (\$30K). Six man-months labor for compiling information on TWRs cribs and trenches.	Estimate contaminant inventory in past leaks for "most impacted" locations (plumes), estimate leak volumes based on evaluation of process history for "most impacted" locations, and evaluate process history and estimated liquid and contaminant discharge for TWRs cribs and trenches.	Tank waste chemistry and leak volume are believed to be important factors in movement of contaminants from tank leaks. Waste transfer records provide a portion of the information leading to calculation of tank leak chemistry and volume. Analysis of these data using appropriate computer codes will provide a "best basis" inventory of leaks. In addition to leaks from tanks, discharge of contaminated liquids to ponds, cribs, ditches and trenches currently the responsibility of TWRs must be assessed in the TWRs vadose zone program.
Characterize first three "most impacted" locations (plumes)	\$6,000,000 (FY99)	\$2,000,000 per "most impacted" location. This estimate is pending issuance of detailed plan for initial characterization campaign. (Based on past costs with improvements including dedicated crew and continual operations.)	Drill and sample in each "most impacted location" using combination of vertical drilling, cone-penetrometer, "Environmental Measurement While Drilling" and/or slant drilling, or as otherwise specified in detailed characterization plan. Conduct field and laboratory analysis, provide field support, seal lower portion of borehole(s) to groundwater after sampling. Work includes safety authorization process, QA, project management, materials and equipment, summary report preparation, and support to external reviews.	The initial vadose zone characterization campaign provides the basic data for refining current hypotheses on distribution of contaminants from tank leaks, and on what principal factors have controlled their movement. Specific locations to be characterized in the first year of the campaign, data to be obtained, and drilling and sampling methods to be employed will be defined in the detailed characterization work plan.

Table 4. Summary of Planned Tank Waste Remediation System Vadose Zone Characterization and Mitigation Activities.

Activity Title	Estimated Funding Requirement and Period	Basis of Estimate	Scope Description	Rationale & Objectives
Characterize next five "most impacted" locations (plumes)	\$10,000,000 (FY00)	Same as "Characterize first three most impacted locations"	Same as "Characterize first three most impacted locations"	Same as "Characterize first three most impacted locations" except this will be carried out in year 2 of the initial campaign.
Borehole 41-09-39 decommissioning and sampling and sampling	\$500,000 (FY99)	Estimate from WMN/W (decommissioning and sampling) and PNNL (analysis)	Decommission borehole 41-09-39 in accordance with approved decommissioning plan. In "hot zone" below tank bottom, conduct sidewall sampling as casing is removed.	Decommissioning of the borehole is required by state law. Sampling of the sidewall during the decommissioning provides the best opportunity to ascertain the vadose zone conditions in an area of high contamination. This is a high priority sampling and analysis effort.
5.3.1 Vadose Zone Data and Analyses Needed for Decisions on Mitigation of Existing Contamination:				
Compile and evaluate data/update work plan for corrective measures characterization	\$600,000 (FY99-FY00)	\$300,000 per year based on FY98 costs	Data analysis and compilation, updates to conceptual model descriptions and data gaps reports, creation and maintenance of graphical data bases. Update detailed characterization plan for continuation of required characterization for corrective measures decisions.	Maintain detailed project plan to assure that data collection and characterization activities are commensurate with the level of information needed to support programmatic decision making. Intended to use "lessons learned" to guide field efforts.

Table 4. Summary of Planned Tank Waste Remediation System Vadose Zone Characterization and Mitigation Activities.

Activity Title	Estimated Funding Requirement and Period	Basis of Estimate	Scope Description	Rationale & Objectives
Develop system model	\$500,000 (FY99)	Best estimate pending input on costs of similar efforts for DOE facilities	Obtain computer simulation tools necessary to estimate the environmental impact of TWRS tank actions (storage, retrieval, and closure) for TWRS decisions, and to guide data collection based on value of information concepts and "dominance" principles addressed in CRCIA. Such tools shall conform to Hanford Site standards, including the need for documentation. For each tool, code specifications shall be developed, a code obtained and /or developed meeting those specifications, and the code tested against TWRS field data.	Numerical analysis tools will be needed to assess implications of contaminants in the environment, relative to established risk and regulatory criteria. Implications are affected by preventive or remedial actions that may be taken. The usefulness of numerical analysis tools to guide decisions on preventive or remedial actions is affected by the degree of uncertainty in conceptual models and parameter values. Hence, numerical analysis tools can also be used to identify dominant factors or dominant uncertainties. Such tools therefore also provide the basis for guiding data collection to reduce uncertainties, and for assessing "value of information."
Assess value/need for major corrective measures	\$500,000 (FY00)	Assumed same level of effort as initial development of system model	Determine the need for/preferred alternative for drainage control measures (see Section 5.1.3), interim surface barriers (See Section 5.1.4), and/or additional data needed to support these decisions (per figure 4).	Application of the system model will be needed to assess the risk reduction benefit of proposed preventive or mitigating measures that may have high cost or significant impact to ongoing tank farm operations.
Continue required additional characterization for corrective measures	\$6,000,000 (FY01)	Same as "Characterize first 3 most impacted locations" (Assume 3 add'l tank leak locations)—eventually cost estimate will be based on detailed characterization plan.	Continue vadose zone data collection based on results of FY00 modeling and risk assessment activity ("assess value/need for major corrective measures") to complete necessary understanding of the subsurface under tank farms for decisions on major corrective measures.	Additional characterization beyond the 2 year initial characterization campaign may be required to provide sufficient justification for decisions on preventive or mitigating actions needed for existing contaminants in tank farm soils.

Table 4. Summary of Planned Tank Waste Remediation System Vadose Zone Characterization and Mitigation Activities.

Activity Title	Estimated Funding Requirement and Period	Basis of Estimate	Scope Description	Rationale & Objectives
<b>S.3.2 Vadose Zone Data and Analyses Needed for Decisions on Controlling Potential Retrieval Leaks:</b>				
Assess retrieval leak impacts and identify additional data needs	\$500,000 (FY01)	Assumed same level of effort as initial development of system model	Incorporate refinements in system model based on results of initial vadose zone characterization campaign. Conduct contaminant transport analysis and risk assessment to quantify impacts of potential retrieval leaks, to support decisions on leak loss controls during retrieval, (per figure 5)	Numerical analysis tools will be needed to assess implications of retrieval leakage, as input to selection and development of leak detection/leak mitigation technologies and retrieval technologies and procedures. Behavior of retrieval leaks can be expected to be similar to behavior of past leaks. Therefore refinements in understanding of mechanisms that have controlled distribution of contaminants from past leaks can be applied to prediction of consequences of retrieval leaks. Results will support LDMM activities carried out under the SST Waste Retrieval Program.
Compile and evaluate data/update work plan for retrieval	\$200,000 (FY02)	Six man-months exempt labor, six man-months consultant support	Evaluate new data resulting from characterization to support decisions on major corrective measures, new data relative to leak detection technology and operational controls, and results of FY01 activity to assess retrieval leak impacts. Update detailed characterization plan for continued characterization for retrieval decisions.	New data from vadose zone characterization and groundwater monitoring must be assessed and factored into the detailed characterization plan for additional characterization, if any, needed to support retrieval decisions. Also, based on lessons learned in characterization to support decisions on preventive or mitigating measures, refinements in drilling and sampling approaches, or analytical approaches, may be warranted to improve cost effectiveness.

Table 4. Summary of Planned Tank Waste Remediation System Vadose Zone Characterization and Mitigation Activities.

Activity Title	Estimated Funding Requirement and Period	Basis of Estimate	Scope Description	Rationale & Objectives
Continue required characterization for retrieval	\$6,000,000 (FY02)	Same as "Characterize first 3 most impacted locations." Assume 3 additional tank leak locations—eventually cost estimate will be based on detailed characterization plan.	Continue vadose zone data collection in accordance with updated detailed characterization work plan to complete necessary understanding of the subsurface under tank farms for decisions on controlling potential retrieval leaks.	Additional data collection focused on specific retrieval leak impact questions may be required. This activity provides that additional data collection and analysis.
<b>5.3.3 Vadose Zone Data and Analyses Needed for Decisions on How to Close Tank Farms:</b>				
Assess readiness to proceed with closure NEPA process.	\$500,000 (FY02)	Assumed same level of effort as "Develop system screening model"	Incorporate refinements in system model based on results of vadose zone characterization supporting decisions on controlling potential retrieval leaks. Conduct contaminant transport analysis and risk assessment to quantify impacts of residual waste in tanks and tank farms at closure (per figure 6), and associated uncertainties. Determine whether data from vadose zone characterization for waste storage, and waste retrieval is sufficient for evaluating closure alternatives, or whether additional data is needed.	The Record of Decision for the TWRS EIS stated that additional vadose zone characterization was needed as a basis for proceeding with a NEPA process for decisions on how tank farms should be closed. The system model developed for evaluating implications of contaminants in the environment, decisions on preventive/remedial actions and controlling retrieval leaks, and for identifying dominant factors and dominant uncertainties, may also be used for determining when subsurface information is sufficient for proceeding with a NEPA process for decisions on tank farm closure.

Table 4. Summary of Planned Tank Waste Remediation System Vadose Zone Characterization and Mitigation Activities.

Activity Title	Estimated Funding Requirement and Period	Basis of Estimate	Scope Description	Rationale & Objectives
Compile and evaluate data/update work plan for closure NEPA	\$200,000 (FY03)	Six man-months exempt labor, six man-months consultant support	Evaluate new data resulting from characterization to support decisions on controlling retrieval leaks, and results of assessing readiness to proceed with closure NEPA process. Update detailed characterization plan for continued characterization for closure NEPA. Use input from external experts (see 5.5).	New data from vadose zone characterization and groundwater monitoring must be assessed and factored into the detailed characterization plan for additional characterization, if any, needed for decisions on tank farm closure. Also, based on lessons learned in characterization to support decisions on controlling retrieval leaks, refinements in drilling and sampling approaches, or analytical approaches may be warranted to improve cost effectiveness.
Conduct additional vadose zone characterization for closure NEPA	\$6,000,000 (FY03)	Same as "Characterize first 3 most impacted locations." Assume 3 additional tank leak locations—eventually cost estimate will be based on detailed characterization plan.	Continue vadose zone data collection in accordance with the updated detailed characterization work plan to complete necessary understanding of conditions under tank farms for initiating the NEPA process for closure.	Additional data collection focused on providing information needed for decisions on closure may be required. This activity provides that additional data collection, in accordance with the updated detailed characterization plan.
<b>5.4 Surveillance and Maintenance:</b>				
Complete baseline logging and issue final tank farm reports	\$1,300,000 (FY99)	Grand Junction Project Office cost estimate for completing current scope and shape factor analysis for all tank farms, by mid FY99	Complete spectral gamma logging, apply shape factor analysis to all tank farms, prepare tank summary reports and tank farm reports, support external reviews.	Provide the baseline information and analysis of the distribution of gamma emitting radionuclides beneath the tank farms. Provides the basis for assessing impacts of safe storage, retrieval and closure.

Table 4. Summary of Planned Tank Waste Remediation System Vadose Zone Characterization and Mitigation Activities.

Activity Title	Estimated Funding Requirement and Period	Basis of Estimate	Scope Description	Rationale & Objectives
Conduct surveillance for changes in baseline	\$9,500,000 (FY00-FY18)	25% of FY 1998 baseline logging annual costs, per year	Conduct periodic surveillance of changes in spectral gamma activity in boreholes around SSTs, relative to baseline spectral-gamma logging. As a minimum, log prior to retrieval, and following retrieval, but not less frequent than every 10 years prior to retrieval. Evaluate surveillance data and assess implications for waste storage.	Periodic surveillance to monitor changes in the baseline may be required during tank farm operations to assess tank integrity, effectiveness of preventive/corrective measures to control infiltration, or to supplement retrieval leak detection activities.
TWRS expense for maintaining RCRA monitoring well network	\$1,200,000 (FY99-FY04)	\$150,000 per year for six years for maintaining the RCRA well network, based on PNNL cost estimates, plus \$50,000 per year for six years for obtaining and analyzing new samples.	Provide expense funding to maintain RCRA compliant monitoring well network around SST farms (which will involve drilling new wells), and to obtain and analyze samples as required from drilling of new RCRA wells.	Fulfills TWRS obligation to support RCRA monitoring system for Tank Farm Waste Management Areas. Assures that appropriate geologic, hydrologic and/or geochemical analyses are performed as monitoring wells are replaced.

Table 4. Summary of Planned Tank Waste Remediation System Vadose Zone Characterization and Mitigation Activities.

Activity Title	Estimated Funding Requirement and Period	Basis of Estimate	Scope Description	Rationale & Objectives
<b>5.5 Process Improvements:</b>				
Develop/deploy improved technologies	\$2,000,000 (FY99-FY03)	20% of annual baseline logging costs, for 5 years (i.e., to completion of vadose zone characterization for decision on initiating closure NEPA process)	Develop and deploy new technologies that provide improved accuracy or cost-effectiveness, or new data needs not satisfied by existing technologies. Examples: temperature logging and analytical basis, moisture logging, high rate logging, Environmental Measurement While Drilling, instrumentation for cone-penetrometer deployment, electrical or electromagnetic methods for vadose zone monitoring.	Assure appropriate new technologies are either developed or deployed within the TWRS Program.
Conduct external scientific peer reviews	\$2,000,000 (FY99-FY03)	\$400,000 per year for five years, based on projected SX Farm Expert Panel costs in FY98, and knowledge that the expert panel will be expanded	Conduct scientific peer review of vadose zone characterization results and analyses, using outside experts, and within the framework of external scientific review developed by the Hanford GW/VZ/CR Integration Project. Costs cited in this plan are for tank farm-specific external review—not for the core external review panel.	Provide outside technical review of vadose zone activities to help assure that work being performed is appropriate and correct.

CRCIA	Columbia River Comprehensive Impact Assessment	PNNL	Pacific Northwest National Laboratory
DOE-GIPO	U.S. Department of Energy Grand Junction Projects Office	QA	quality assurance
EIS	Environmental Impact Statement	RCRA	<i>Resource Conservation and Recovery Act of 1976</i>
EM-50	U.S. Department of Energy Office of Science and Technology	SST	single-shell tank
FY	fiscal year	TWRS	Tank Waste Remediation System
LDMM	Leak Detection Monitoring and Mitigation	GW/VZ/CR	Groundwater/Vadose Zone/Columbia River Integration
NEPA	<i>National Environmental Policy Act of 1969</i>	WMNW	Waste Management Northwest
PHMC	Project Hanford Management Contract		

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**APPENDIX A**  
**ACTIONS IN RESPONSE TO EXTERNAL REVIEWS**

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**LIST OF TERMS**

ALARA	as low as reasonably achievable
DOE	U.S. Department of Energy
DOE-RL	U.S. Department of Energy, Richland Operations Office
DQO	Data Quality Objective
EM	Environmental Management
ER	Environmental Restoration
FY	fiscal year
GAO	Government Accounting Office
GJO	Grand Junction Office
GJPO	Grand Junction Projects Office
HTI	Hanford Tanks Initiative
ILAW	Immobilized Low Activity Waste
IR	infrared
NEPA	<i>National Environmental Policy Act of 1969</i>
RCRA	<i>Resource Conservation and Recovery Act of 1976</i>
RFP	request for proposals
RPECA	Retrieval Performance Evaluation Criteria Assessment
SGLS	Spectral gamma logging system
SST	single-shell tank
TAP	Tank Advisory Panel
TWRS	Tank Waste Remediation System
XRF	X-Ray fluorescence

## APPENDIX A

## ACTIONS IN RESPONSE TO EXTERNAL REVIEWS

A.1 STATUS OF ACTIONS TAKEN IN RESPONSE TO  
EXPERT PANEL RECOMMENDATIONS

(Ref. *TWRS Vadose Zone Contamination Issue Expert Panel Status Report*, prepared by John G. Conaway, Robert J. Luxmore, John M. Matuszek, and Ralph O. Patt, DOE/RL-97-49, Rev. 0, April 1997)

**Expert Panel Recommendation 1:** It is imperative that a comprehensive characterization of the vadose zone be undertaken to give clear focus and definition for computer simulations.

**Status:** Vadose zone characterization data are necessary to support several Site programs including Environmental Restoration (ER), the Retrieval Performance Evaluation Criteria Assessment (RPECA), and the Immobilized Low Activity Waste (ILAW) Performance Assessment. A Tank Waste Remediation System (TWRS) Vadose Zone Program Plan has been developed through the TWRS Vadose Zone Interagency Team to efficiently collect data to support TWRS program decisions in waste retrieval, tank farm closure, and interim tank waste storage operations. Data obtained will also potentially benefit the TWRS ILAW program. The TWRS vadose zone program is focused on acquiring the data needed to support decision making. The important schedule drivers in TWRS for providing sufficient vadose zone information for decision-making are 1) initiation of single-shell tank (SST) retrieval during Phase I privatization to demonstrate retrieval technology as well as provide waste to contractors for demonstration of high-level waste vitrification; 2) developing a request for proposals (RFP) for Phase II privatization of tank waste retrieval and remediation; and 3) initiation of a *National Environmental Policy Act of 1969* (NEPA) process for reaching decisions on how tank farms will be closed.

As part of the planning process, information on all SST Farms is being collated. These data include geology, hydrology, gross and spectral gamma logging, sediment sampling, tank contents, history of waste transfers, and leak history, including any vadose zone studies performed in response to a reported leak. As shown in the March 1998, meeting of the Panel, these data are being electronically stored to provide ready access and independent assessment. In addition, these data are being combined in several ways to help in determining those investigations to be performed by the vadose zone program and the order in which those investigations should be conducted. The physical parameters of the tanks and tank farms will be combined with the current order of planned waste retrieval to further define where and when vadose zone investigations should be performed. The data compilation defines the quantity and quality of available data and points the direction toward those data which must yet be collected.

An effort to integrate sitewide groundwater and vadose zone programs is being led by Bechtel Hanford, Incorporated, and the ER Program. Elements of the Hanford Vadose Zone/Groundwater/Columbia River Integration Restoration include: Projects Division of ER

(200 Area Cleanup Strategy and Groundwater Program), Waste Management Division (Low-Level Burial Grounds), and TWRS (Vadose Zone Project, Hanford Tanks Initiative [HTI], Immobilized Low-Activity Waste, and Closure).

**Expert Panel Recommendation 2:** Extend boreholes 41-09-39 and 41-09-04 to groundwater with logging, sampling and analysis of contaminants and transport properties.

**Status:** Activities were initiated to extend 41-09-39 during fiscal year (FY)-1997, with completion early in FY-1998. Near-continuous core was collected from the bottom of the existing bore to the water table. Screening level analyses were run on all core segments; these analyses included gamma spectroscopy and moisture content. A series of groundwater samples were collected once the bore reached the aquifer. Selected sediment samples from seven zones have been analyzed for a suite of chemical, radiological, and geological parameters; the initial evaluation of these samples was presented at the March 1998 Panel meeting; a final report is due out in June 1998.

As part of the Data Quality Objective (DQO) process associated with extension of 41-09-39, extension of 41-09-04 was considered at length. The conclusion reached was that the age of the 41-09-04 and its internal degradation made it an undesirable alternative with high risk of failure. There is some doubt that the structure could hold up to the forces of drilling through it, because the casing is perforated, and thus could not be safely driven deeper. By leaving the bore as it is, it remains as a baseline for any future logging activity.

Major findings included a rapid reduction in cesium concentration from an initial 2E06 pCi/g to less than detectable over a distance of 25 ft. Carry down of contamination was a problem, but samples were selected to avoid those areas of cross contamination. (Cross contamination was generally from material smeared on the inside of the casing dropping down into the uppermost sample sleeve.) Technetium-99 was generally coincident with the cesium-137 above the Plio-Pleistocene carbonate rich zone and less than detectable below that geologic horizon. Groundwater samples collected and analyzed by the *Resource Conservation and Recovery Act of 1976* (RCRA) program showed no cesium contamination and 25 pCi/l <sup>99</sup>Tc. In general the groundwater chemistry indicated that contaminants probably originated from a source upgradient from SX tank farm. Geochemical analyses are incomplete at this time.

The decommissioning of the bore will be done by pulling back the drill casing and grouting the bore to the original depth of 130 ft. with sand (below the water table), bentonite (within the Ringold formation), and cement (through the Plio-Pleistocene unit). The borehole was logged regularly with both gross gamma and spectral gamma tools and contaminant drag down assessed. Upon reaching total depth a full suite of geophysical logs, including moisture content was run. Additional logs may be run prior to decommissioning.

**Expert Panel Recommendation 3:** Steps should be taken to minimize and monitor drag down during drilling.

**Status:** This is a most important consideration and was part of the planning process. A smooth drive shoe was used initially on the drill casing in the extension of 41-09-39. It was found that this casing could not be advanced due to excessive side-wall friction, and an under-

reaming drive shoe was needed. In both cases, care has been taken to minimize drag down of contaminated material. Some drag down occurred, requiring special consideration in the selection of samples for comprehensive analysis. Shape factor analysis was applied to the final geophysical logs to help evaluate the impact of drag-down. The use of in-hole tracers is being considered to monitor and quantify drag down in future drilling endeavors.

**Expert Panel Recommendation 4:** Drilling through known contamination zones should be avoided by slant drilling, unless deliberate sampling and analysis of the zones is to be undertaken.

**Status:** These concerns about drilling through contaminated zones are foremost in both environmental protection and as low as reasonably achievable (ALARA) thought processes and data and information for the deepening, sampling, and completion of borehole 41-09-39. The feasibility of slant and or directional drilling has been evaluated and is being pursued. Discussions are ongoing with Bechtel Hanford Inc. to prepare a performance specification RFP, similar to the contracting strategy for the HTI, to acquire slant/directional drilling services for Hanford.

A meeting, held November 12, 1997, specifically discussed the application of slant drilling to the SX Tank Farm. The consensus of that meeting was that slant drilling was feasible and could be readily applied for tank farm investigations. A combination of percussion advanced hole and more conventional air-rotary methods was identified as the most likely approach to successful sampling of the subsurface through slant drilling.

A demonstration of directional drilling application in the Hanford environment is being planned for late FY-1998. This demonstration will be done to assess the application of low-angle drilling, logging while drilling, and sampling to the tank farm environment. The test will be conducted in two non-tank farm locations to: 1) answer concerns about controlling bit location so as not to compromise tank integrity; and 2) to test the ability of on board logging systems to detect gamma contamination as an aid to selective sampling.

**Expert Panel Recommendation 5:** Hanford should acquire or develop a high-flux spectral gamma-ray measurement capability.

**Status:** A cost estimate for this work has been prepared by the U.S. Department of Energy (DOE) Grand Junction Office (GJO). The existing work has pointed out that the overwhelming majority of gamma flux is due to cesium-137, making a gated tool potentially applicable to this effort. The majority of mobile constituents are beta emitters, for which DOE has considerably less information because they cannot be detected by geophysical logging techniques. Uranium is an exception to this generalization. However, high flux spectral gamma is the highest priority for development of enhanced logging techniques.

**Expert Panel Recommendation 6:** Methods, such as shape-factor and spatial-response analysis should be developed to distinguish between borehole and formation contamination.

**Status:** Initial development and application of Shape-Factor Analysis has been reported by GJO at the March, 1998 meeting. As noted by the Panel at that meeting, limitations on the method restrict its unrestricted application. Work to address the Panel's concerns continues.

Results presented to date indicate that some borehole effects can be identified and eliminated, and that the distribution of gamma emitting radionuclides may not be as widespread as initially represented. When and if proven as an appropriate methodology, shape factor analysis will be incorporated into GJO reports. In addition, Shape Factor Analysis may be applied to previously reported Tank Farms.

**Expert Panel Recommendation 7:** Hanford should obtain a capability for accurate logging of formation temperature

**Status:** The availability of applicable temperature logging equipment has been pursued through a search of potential vendors. Tools that would meet Hanford needs appear to be available from major suppliers (borehole logging firms). Options and costs are being evaluated. Down-hole temperature measurements are being pursued at a proof-of-principle level, associated with the reported high heat zone at 132 feet in borehole 41-09-39, where no strontium-90 was found in the analyzed sediments. Non-contact thermal infrared (IR) system components have been acquired and are being configured for down hole use.

**Expert Panel Recommendation 8:** Heat transport calculations should be performed to establish the relationship between formation temperature and casing temperature under various conditions.

**Status:** As part of the data compilation process that is underway, several documents have been identified on the relationship between formation temperature and level of soil contamination. These reports date back to the early 1970's and deal with the thermal effects of tanks and tank leaks. These reports will be evaluated first to determine if they provide the necessary information on formation temperature and casing temperature.

**Expert Panel Recommendation 9:** Preferential flow must be part of the conceptual model and be included in simulation models of the vadose zone.

**Status:** New transport calculations have been performed under the HTI that include preferential flow paths. Both preferential flow paths and chemically enhanced mobility concepts are included in the simulations of past leaks from the SX Tank Farm where substantial leaks have occurred and additional subsurface investigations have been completed. The findings and lines of evidence from these simulations are being applied to the conceptualization and mathematical models of the AX Tank Farm (under HTI). Also, probabilistic analyses, using a systems approach, that include the uncertainty of preferential flow paths was performed for the AX and SX Tank Farms to determine the relative importance of potential preferential flow paths with respect to the overall system performance. The performance assessments for the solid waste burial grounds in the 200 East and 200 West Areas considered clastic dikes (one example of a preferential flow feature) in their sensitivity simulations. In addition, a proposal has been submitted to the EM Science Program to look at wetting front instability that could occur from high concentration sodium solutions that might leak from a tank.

**Expert Panel Recommendation 10:** Vadose zone characterization at Hanford must provide data sufficient to make use of predictive models which include small-scale (preferential) flow.

**Status:** The discontinuous nature of clastic dikes seen in outcrops makes characterization of the dikes beneath any tank farm a tenuous effort at best. Therefore, no effort is planned to specifically look for clastic dikes beneath the tank farms. Pre-construction aerial photography that may provide evidence of clastic dikes at tank farm locations is being sought. The possibility of chemically enhanced flow as noted in the panel report, and by the Chemical Reactions Sub-Tank Advisory Panel (TAP) in its review of the Agnew SX leak model, will be addressed as additional data are acquired. If such features are noted during any characterization effort, they will be described and included in the conceptual and numerical models. Shape-factor analysis, while limited in application to zones with less than 1000 pCi/g <sup>137</sup>Cs, is being pursued as a means of determining whether or not the boreholes have acted as conduits for contaminants that are present deeper than expected in the vadose zone. See also item 6.

The Groundwater Project in the Restoration Projects Division is currently collating all known information on clastic dikes. A report on this effort is due out in FY-1998. This report is anticipated to outline those measurements that could be made to map these structures and measure their properties. The ILAW Glass Performance Assessment has prepared a test plan and will conduct hydraulic properties measurements on clastic dikes as part of its FY-1998 activities.

**Expert Panel Recommendation 11:** Relevant concepts from petroleum, geothermal, and other suitable sources should be incorporated into transport models for simulation of near-field tank farm phenomena.

**Status:** As new models are considered for application, relevant existing models from industrial and government sources are being considered. PORFLOW is one of the models currently being used and it incorporates many state-of-the-art modeling approaches and concepts. Additional consultations with Sandia National Laboratories, including its Geothermal Group, and Los Alamos National Laboratories are being made to determine what improvements may be available.

**Expert Panel Recommendation 12:** The Vadose Zone Characterization Program should extend its efforts through the unsaturated zone to groundwater.

**Status:** The 41-09-39 extension included groundwater sampling. Those groundwater samples were collected under the ER Program. The ILAW Performance Assessment has drilled the first of three characterization boreholes in FY-1998. It was completed as a RCRA groundwater monitoring well. Some funding is being held for vadose zone samples to be collected in the vicinity of tank farms where the ER Program will drill new RCRA monitoring wells to replace some wells that may not be serviceable because of the falling water table. Finally, the needs of the RCRA groundwater assessments are being considered.

**Expert Panel Recommendation 13:** Evaluation of gross-gamma logs should be extended to other boreholes including laterals for indications of contaminant movement.

**Status:** Analysis of the historical gross-gamma logs for the vertical boreholes has been initiated. This effort is in addition to the nominal research reported through the baseline logging program. A detailed look at these data, similar to the analysis presented to the panel by RK Price in 1997, has been conducted for all available historical drywell logs in the SX Farm. This analysis was presented to the Panel during the March 1998 meeting. The data derived from the laterals has been located, and will be incorporated into the analyses. The status of the caissons and laterals has also been researched, and we have determined that their use for future logging is highly suspect, as they have been in disrepair since they were last logged in the mid-1980s.

**Expert Panel Recommendation 14:** Periodic gamma-ray logging of existing boreholes should be reinstated using calibrated equipment.

**Status:** Upon completion of the baseline spectral gamma logging, the current plans call for Tank-Farm Operations to conduct periodic relogging. Interpretation of those logs will be by professional staff. At a minimum, rebaselining is planned for immediately prior to and following retrieval activities at all farms. Decisions will be made concerning which wells should be monitored and the frequency of logging. The groundwater project has called for logging of boreholes around the B/BX cribs under the RCRA Assessment efforts; these bores are being logged with both a high-flux tool (uncalibrated) and a spectral gamma tool in an attempt to differentiate tank and crib contaminants. Other plans include logging of bores around the Plutonium Finishing Plant cribs using both tools.

In addition, when in-tank monitoring indicates an anomalous condition, dry well logging will be an additional tool to help ascertain if a new leak has occurred. Such monitoring against the baseline was conducted in January, 1998 because of a suspected leak from tank SX-102.

**Expert Panel Recommendation 15:** Records of contaminant movement developed from gross-gamma logs should be considered when developing and performing transport simulations.

**Status:** The gross and spectral gamma logs are key elements in the available data base on contaminant movement. Data derived to date from the historical SX logging efforts show great promise for use in assessing contaminant movement. Work is currently underway to evaluate the historical gamma logging data for the B-BX-BY Tank Farms. Early records are not readily available; and the history of the leaking tanks during the time of active leaking is sparse at best. The logs will be used to corroborate/validate the movement of gamma emitting radionuclides as predicted by the numerical simulations. Evaluation of the conceptual model is underway. Reassessment of the numerical code and its validation will be conducted following those activities.

**Expert Panel Recommendation 16:** When the data bases from vadose zone characterization reach a sufficient level to support renewed predictive simulation modeling, the modeling effort should be put to an RFP.

**Status:** This is a contractual element that will be considered when appropriate. At a minimum, use of independent, outside reviewers will continue.

**Expert Panel Recommendation 17:** Field and laboratory characterization efforts should be coordinated to provide the types of data bases which will support comprehensive simulation modeling.

**Status:** These elements were a part of the planning for extension of the 41-09-39 bore and will continue to be used throughout the vadose zone program. Integration of sitewide vadose zone and groundwater activities, including simulation modeling, will further contribute to this objective in the future.

**Expert Panel Recommendation 18:** A slant borehole passing beside borehole 41-09-39 should be installed, including logging and sampling during installation, from the west side of the SX tank farm to avoid contaminant drag down from the high-contamination zone.

**Status:** Slant boreholes are being closely considered for future drilling in the tank farms. The close working spaces surrounding the tank farms make slant drilling within the farms difficult, but slant drilling may allow work to proceed from outside the farm fences. Working from outside the fences provides an opportunity for increased efficiency of operation. Modern techniques, ranging from percussion drilling (pile driving) through the suite of rotary techniques will be considered in slant drilling; as cable-tool percussion drilling is incapable of drilling in that mode. In slant or directional drilling, friction on the non-vertical drill pipe may exceed that experienced in vertical drilling, potentially making advance of a borehole more difficult. As noted during the initial drilling of 41-09-39, the 7-inch, extra heavy casing was deflected from vertical near the base of the tanks. Such a deflection in close proximity to the tanks could result in violation of tank integrity. In addition, drag down (or across) will not be entirely eliminated by slant or directional drilling, thus requiring telescoped casing sizes.

The placement or use of a slant drilled hole will be determined after the results from extending 41-09-39 have been fully assessed and the DQOs for the next borehole developed. See also 4 and 13.

**Expert Panel Recommendation 19:** Other non-nuclear borehole logging techniques should be evaluated and used where appropriate for future monitoring; included are temperature, soil-water and density logs.

**Status:** Non-nuclear logging techniques are being evaluated for future use, along with other technology enhancements. The ongoing effort to integrate sitewide groundwater and vadose zone activities includes provisions for infusion of science and technology to aid in developing the necessary understanding of subsurface conditions and processes. High flux logging is being considered for FY-99 to help assess inventory of  $^{137}\text{Cs}$  by being able to measure contaminant zones that saturate the current SGLS equipment.

**Expert Panel Recommendation 20:** The SGLS gamma logging should be continued, adding technical enhancements such as shape factor and spatial response analyses, as appropriate.

**Status:** Baseline SGLS logging is scheduled for completion in FY 1999; field work on the remaining two tank farms (B and T) will be completed in FY-1998. When developed to the point where its use is defensible shape factor analysis will be incorporated. In addition, shape

factor analysis will be applied retroactively to logs run prior to the technique being available. Refer also to the status of the Expert Panel's recommendation No. 6.

Moisture content is recognized as one of the most important parameters controlling the movement of tank waste constituents through the vadose zone. In addition to spectral gamma logging, specific wells have been logged using a moisture gage. The Grand Junction Projects Office (GJPO) team has borrowed this tool from Waste Management Northwest when its use was requested, or when the team felt its use was appropriate. This tool is not calibrated, but does provide an indication of relative moisture. Analysis of the results from this logging is hampered by interferences and variabilities due to changing formation density.

**Expert Panel Recommendation 21:** Percussion drilling should be considered for investigative boreholes in lieu of drilling techniques more commonly used at Hanford.

**Status:** Percussion drilling will be considered. The technique applied at 41-09-39 does not allow for collection of samples as requested in recommendations 1, 2, 10, and 17. Where appropriate, in those areas where direct sampling is not necessary, the method will be considered further. If alteration of the casing tip can be accommodated so that it can be removed for sampling, this technique would present a major benefit. As noted at the March 1998 Panel meeting, the percussion drilling technique, as applied for bores 41-12-01 and 41-09-39, did not preclude dragdown. All drilling methods will be considered and that method most closely filling the needs of the individual drilling effort will be specified.

**Expert Panel Recommendation 22:** Drilling resistance measurements should be made when the percussion drilling method is used.

**Status:** If percussion drilling (pile driving) is used to advance additional boreholes, resistance to casing advancement will be monitored. If cone penetrometer technology proves useful for tank farm investigations, a resistance sleeve, placed on the penetrometer tip, is an already proven method of obtaining this information.

Further use of cone penetrometers for tank farm characterization is being pursued by the Leak Detection Monitoring and Mitigation activity of the HTI. That effort has focused on three tools to be tested in the AX Tank Farm. Those tools include a sodium iodide spectral gamma tool, an X-Ray fluorescence (XRF) tool, and a moisture probe. Other standard configurations include an inclinometer and a metal detector along with various industry-wide soil measurements. Cold tests of this equipment have already been conducted in the 200 Area. Hot tests to help characterize vadose zone contamination in the AX Farm are scheduled for November, 1998.

## A.2 STATUS OF RESPONSES TO GOVERNMENT ACCOUNTING OFFICE (GAO) RECOMMENDATIONS

(Ref: *Understanding of Waste Migration at Hanford is Inadequate for Key Decisions*, Report to Congressional Requesters, U.S. General Accounting Office, GAO/RCED-98-80, March 1998)

**GAO Recommendation:** Develop a comprehensive vadose zone strategy for the Hanford Site that addresses cleaning up the high-level waste tank farms and the cribs, ponds, trenches, and other waste sites.

**Status:** The U.S. Department of Energy, Richland Operations Office (DOE-RL) has formed an integrated Vadose Zone, Groundwater, Columbia River action team with ER Division contractor Bechtel Hanford Inc. as the lead. All Hanford contractor elements are involved in this effort. A comprehensive, integrated program plan is being developed through this effort. An independent panel of experts is being identified to provide continuing review of the integrated effort. A list of nationally, and internationally, known experts has been compiled; that list has been provided to an independent committee made up of the University of Washington and University of Oregon representatives who will make the final membership selections.

As part of the integration directive, DOE-RL has convened, on the recommendation of the Under Secretary of Energy, a consortium of National Laboratory representatives to review the status of Hanford vadose zone and groundwater information, studies and remediation activities. This consortium of technical experts is to provide insight into ongoing activities at other DOE sites and also recommendations on the applicability of those activities to the Hanford environment.

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**APPENDIX B**  
**PUBLIC INVOLVEMENT PLAN FOR THE TWRS VADOSE ZONE PROGRAM**

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**LIST OF TERMS**

BHI	Bechtel Hanford, Inc.
DOE	U.S. Department of Energy
DOE-RL	U.S. Department of Energy, Richland Operations Office
DQO	Data Quality Objective
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
FY	fiscal year
HAB	Hanford Advisory Board
LMHC	Lockheed Martin Hanford Corporation
OEA	Office of External Affairs
TWRS	Tank Waste Remediation System

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**APPENDIX B****PUBLIC INVOLVEMENT PLAN FOR THE TANK WASTE REMEDIATION SYSTEM  
VADOSE ZONE PROGRAM****B.0 OVERVIEW**

One of the main concerns regarding Hanford Site activities is the potential for contaminants to reach the Columbia River. In recent years, reevaluation of contaminants in the vadose zone have increased regulator, tribal and stakeholder scrutiny of the vadose zone program. Additionally, various Tank Waste Remediation System (TWRS) program decisions regarding tank waste retrieval, leak loss, and the need for interim corrective measures will be made in the near future for which vadose zone data will be needed. It is imperative that an effective stakeholder involvement plan is in place to ensure that pertinent information is coordinated and distributed; that opportunities for receiving input and comment are provided; and that the views of regulators, tribal governments, stakeholders and the general public are identified and considered in the decision making progress.

As an important element in the planning process, this involvement strategy attempts to build upon the values and principles identified by the Hanford Tank Waste Task Force in 1993, and the TWRS Vadose Zone Partnering Team whose work is nearing completion. In addition, this strategy will be modified as public involvement activities are identified and initiated for the Hanford Site-Wide Vadose Zone and Groundwater Integration Project. It is intended that the Integration Project become the primary vehicle for public participation in vadose zone and groundwater activities on the Hanford Site. Consequently, this plan for TWRS specific vadose zone activities will be modified when a plan for the Integration effort is completed.

The goal of involvement in TWRS is to build off of the Integration activities and create an environment of information exchange that contributes to the further development, understanding, support and success of the TWRS Vadose Zone Program. Expectations and results of this plan include:

- consensus on the development and refinement of conceptual and numerical models used to predict contaminant movement in the subsurface to support tank waste retrieval, tank closure, and interim corrective measures
- active participation in developing Data Quality Objectives (DQOs) and reviewing activity plans to support drilling and other sampling activities
- integrated review of key project plans and deliverables by highly interested parties
- integration of stakeholder and tribal values into program planning and execution.

Specific TWRS Vadose Zone program elements requiring stakeholder involvement are outlined below, and proposed interactions with interested audiences are provided for review.

## **B.1 CONCEPTUAL MODEL(S)**

Data relating to the vadose zone already exist in a large number of documents contained in various locations at the Hanford Site. This information is being compiled into a singular database. The data is being used to refine conceptual models and to identify data gaps. Data gaps which are determined to represent significant uncertainty will be identified, thereby providing information which will be used in a DQO process to develop characterization activities to fill those gaps and reduce the uncertainties.

The baseline conceptual models for contaminant movement beneath the tanks and tank farms must be consistent with similar models developed for vadose zone transport outside the tank farms. Integration with other program transport models for liquid waste sites and burial grounds will be included in the process for refining the tank farm conceptual models. Coordination of vadose zone model development is one of the major technical objectives of the Hanford Site Vadose Zone/Groundwater/Columbia River Integration Project.

## **B.2 DQOs AND WORK PLANS**

DQOs will be developed in order to fill in the data gaps. Key audiences will be involved in the DQO process and development of associated work plans and sampling/analysis plans. Final products will be shared with interested and identified parties.

## **B.3 OUTREACH AND STAKEHOLDER INVOLVEMENT PLANNING**

### Audiences

The activities outlined are designed to accommodate a variety of highly interested and concerned audiences. These audiences include: Regulators (Washington State Department of Ecology [Ecology] and U.S. Environmental Protection Agency [EPA]), Tribal Nations, the Hanford Advisory Board (HAB), Oregon Department of Energy and Oregon Hanford Waste Board, Natural Resources Trustee Council, elected local, state and federal officials; community leaders, employees, and other interested parties.

### Objectives of the Plan

Key objectives of this plan are to assist in the successful completion of the goals and schedule of the Vadose Zone Program, as well as supporting role in many Hanford projects. To ensure this happens, there are four objectives for regulatory, tribal and stakeholder involvement:

- Provide timely and accurate information regarding the vadose zone characterization activities.
- Encourage participation in project activities and decision making processes when such participation is required, desired, or determined appropriate.
- Provide opportunities for interaction to gain input, identify issues and concerns, and determine appropriate levels of public involvement and the need for access to relevant project information.
- Implement methods to provide feedback to stakeholders on their involvement in the process so that public participation activities can be periodically modified to make them as effective as possible.

This outreach and public involvement plan provides a strategy for presenting pertinent information to interested audiences and suggests opportunities for dialogue and comment-responses as each of the program activities progress during the remainder of fiscal year (FY)1998 and beyond. Key opportunities for interaction are outlined, but flexibility is provided to accommodate changes in activity elements.

### Methods of Interaction

There are different methods that can be used to provide opportunities for interaction and dialogue, depending on the given audience. Most of these methods are coordinated through the Office of External Affairs (OEA) and can include, but are not limited to:

- Tribal Interactions - Consultations with Tribal Nations can be conducted either individually, with other Tribes, or with other governmental audiences. These consultations are conducted with assistance from Kevin Clark/ U.S. Department of Energy, Richland Operations Office (DOE-RL)/OEA when formal input is sought. Interaction will also occur through the participation of the Tribal Nations in the Interagency TWRS Vadose Zone Team until the team's work is complete.
- HAB Meetings - Presentations can be provided to the relevant Committees or during Full-Board meetings.
- One-on-Ones - Individual discussions can be arranged with regulators (Ecology and U.S. EPA) Tribal representatives, HAB Board Members, interest and environmental groups, elected local, state and federal officials, selected stakeholders, etc.

- Media Relations - Communicating specific information to general audiences through the media can be accomplished through the use of press releases, interviews/editorial boards, fact sheets, and other mechanisms for large-scale distribution.
- Internet - This vehicle of communication provides rapid access to pertinent documents and data. Web page entries will enhance information availability to entities not located in the immediate area. A TWRS web page has been established which includes an entry for vadose zone information. In addition, the Hanford Site-Wide Vadose Zone and Groundwater Integration effort will also be making use of the Internet to share information.
- Meetings/Workshops - Working meetings with selected groups are an effective way discuss current information, issues, ideas and alternative thoughts, develop lasting relationships, and receive comments, concerns and observations from participants. Groups already identified as playing a key role in the success of this stakeholder involvement strategy are:
  - Hanford Vadose Zone and Groundwater Integration Project
  - Contractor Information Exchange and Program Reviews
  - Independent Technical Review Panels including the SX Panel and peer review panels that are being formed as part of the site-wide integration effort.

The TWRS Interagency Partnering Team has been a key activity for sharing information and gaining input on vadose zone activities in TWRS during FY 1998, particularly with respect to the single shell tanks. This group will be formally disbanded with completion of a multiyear program plan for TWRS vadose zone activities. Nevertheless, it is hoped that the participants in this team will continue to be principle points of contact for public participation activities related to TWRS vadose zone and related activities in the future because of their familiarity with program issues and because of their effort in formulating a program plan.

A calendar of upcoming public participation activities will be kept by TWRS for the upcoming four fiscal quarters, although emphasis will be on identifying activities during the next fiscal quarter. One month prior to the beginning of a new fiscal quarter, the calendar will be updated. A calendar of events for activities across Hanford related to the vadose zone, groundwater, and the Columbia River is maintained by the Integration Project and TWRS-specific activities and included in it.

#### **B.4 RESPONSIBILITIES**

DOE Office of External Affairs TWRS Contact:  
Guy Schein

**Overall TWRS Public Involvement:**

Carolyn Haass

**TWRS Vadose Zone specific Project Leads are listed below:**

David Shafer, DOE-RL

Ed Fredenburg, LMHC

**Hanford Site Vadose Zone/Groundwater/Columbia River Integration Project Public Involvement**

Dru Butler, BHI

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**APPENDIX C**  
**IMMOBILIZED LOW ACTIVITY WASTE VADOSE ZONE**  
**CHARACTERIZATION ACTIVITIES**

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**LIST OF TERMS**

DOE	U.S. Department of Energy
FY	fiscal year
ILAW	immobilized low activity waste
PUREX	Plutonium Uranium Extraction (facility)

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## APPENDIX C

**IMMOBILIZED LOW ACTIVITY WASTE VADOSE ZONE  
CHARACTERIZATION ACTIVITIES**

The immobilized low activity waste (ILAW) Performance Assessment Activity has a vigorous vadose zone characterization program underway. The main study areas are geology, recharge, near-field hydraulics, far-field hydraulics, and geochemistry. The philosophy and tasks of this activity are described in a document revised each June (the latest version being Mann 1997). The emphasis is on completeness and technical defensibility.

The geology study area includes not only determining the geologic layers at the two disposal sites, but other areas as well. The task supervises the drilling of the on-site boreholes used to obtain site-specific samples for the other study areas to use. The first borehole (located southwest of the Plutonium Uranium Extraction [PUREX] facility in the 200 East Area) was successfully completed in fiscal year (FY)98 and yielded much new scientific information forcing a reinterpretation of some Hanford Site geologic and groundwater flow information. Two more boreholes will be drilled in FY99/00. This study area also provides information on the expected distribution of special geologic features on the two sites, such as clastic dikes and possible faults). It also supports other areas in determining where natural analogues can be found on the Hanford Site or in the Pacific Northwest.

The recharge study area will use three different techniques to determine the expected natural recharge rate at the two sites as a function of time. Firstly, long-term (already over a decade in length) experiments using lysimeters will be continued with some of the tubes being modified to reflect new surface conditions of interest. Such lysimeter experiments allow a fundamental understanding of the major natural and vegetative drivers in determining recharge. Secondly, a set of tracer measurements (from borehole, auger, and backhoe samples) will allow the experimental determination of recharge over the past 10,000 years. Measurements using Cl and <sup>36</sup>Cl have already started. Finally, computer simulation is being used to predict the effect of man-made and natural changes.

The near-field hydraulics study area is determining the parameters necessary to predict moisture flow in the human-affected parts of the disposal system. An important part of this effort is to determine how these parameters change as the materials age and hence change. This area is working closely with the facility design engineers to optimize the selection of materials and their combination.

The far-field hydraulics study area is determining the parameters necessary to predict moisture flow in the natural vadose system. Samples are being analyzed not only from the disposal sites (through the use of borehole samples) but also from analogous sites. Parameters for both normal soils and special features (such as clastic dikes) are being determined. In addition, analytic studies are being performed to determine how to upscale these laboratory measurements to field conditions and how to determine those parameters which are not amenable to laboratory measurements (such as dispersion).

The geochemical study area is determining the additional parameters needed to predict the contaminant transport. Geochemical retardation (how much chemical reactions slow the movement of contaminants) is being determined as a function of various properties of the fluid stream on both borehole samples and on analogous samples. An important area of study is how the breakdown of the waste form and facility structure will affect contaminant movement after the contaminants are released from the waste form. Colloidal transport has already been investigated and found not to be important.

Thus the ILAW Performance Assessment Activity has a robust program to understand moisture flow and contaminant movement in the undisturbed vadose zone underlying the two disposal sites. The program has been reviewed and additional reviews are expected as part of the review of the 1998 ILAW Performance Assessment (Mann et al. 1998) by the U.S. Department of Energy (DOE), the Nuclear Regulatory Commission, the Defense Nuclear Facilities Safety Board, and the National Academy Sciences panel on DOE Tanks.

### References

- Mann, F. M., 1997, *Statements of Work for FY1998 to 2003 for the Hanford Low-Level Tank Waste Performance Assessment Activity*, HNF-SD-WM-PAP-062, Rev. 2, Lockheed Martin Hanford Corporation, Richland, Washington, June 1997.
- Mann, F. M., R. J. Puigh II, P. D. Rittmann, N. W. Kline, J. A. Voogd, Y. Chen, C. R. Eiholzer, C. T. Kincaid, B. P. McGrail, A. H. Lu, G. F. Williamson, N. R. Brown, P. E. LaMont, 1998, *Hanford Immobilized Low-Activity Tank Waste Performance Assessment*, DOE/RL-97-69, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

**APPENDIX D**  
**LEAK DETECTION, MITIGATION, AND MONITORING (LDMM)**  
**FOR WASTE RETRIEVAL**

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**LIST OF TERMS**

DOE	U.S. Department of Energy
DST	double-shell tank
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
ERT	Electrical Resistance Tomography
LDMM	Leak Detection, Monitoring and Mitigation
SST	single-shell tank
Tri-Party Agreement	<i>Hanford Federal Facility Agreement and Consent Order</i>

**APPENDIX D****LEAK DETECTION, MITIGATION, AND MONITORING (LDMM)  
FOR WASTE RETRIEVAL**

It is estimated that as much as ~1 million gallons of liquid waste has leaked from 67 single-shell tanks (SSTs). To reduce the risk of leakage from SSTs, much of the liquid waste originally contained in SSTs has been pumped to double-shell tanks (DSTs). This effort continues under the SST Stabilization Program. *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) Milestone M-41-00 requires completion of SST stabilization by September 30, 2000. Retrieval of waste from SSTs by addition of liquids may cause additional leakage. The Leak Detection, Monitoring and Mitigation (LDMM) activity is an element of the SST Retrieval Program designed to assure that SST retrieval operations are conducted in a manner that adequately protects human health and the environment from potential leakage.

**D.1 PROGRAMMATIC COMMITMENTS FOR LDMM**

The following Tri-Party Agreement milestones form the basis for the LDMM program:

M-45-08: Establish full scale capability for mitigation of waste tank leakage during retrieval sluicing operations.

M-45-08-T02: Establish the criteria through stakeholder participation and Washington State Department of Ecology (Ecology) approval for: (1) determining allowable leakage volumes, and (2) acceptable leak monitoring/detection and mitigation measures necessary to permit sluicing operations. Consistent with authorities granted by U.S. Environmental Protection Agency (EPA) to the State under its delegated hazardous waste management program, Ecology will have final authority in determining acceptable criteria for this target activity.

M-45-08A: Complete system design and operation strategy for tank leak monitoring and mitigation for systems to be used in conjunction with initial retrieval systems for SSTs.

M-45-08B: Complete demonstration and installation of leak monitoring and mitigation systems for initial SST retrieval.

M-45-09A-H: Submit annual progress reports on the development of waste tank leak monitoring/detection and mitigation activities in support of M-45-08. Reports will provide a description of work accomplished under M-45-08, technologies, applications, cost, schedule, and technical data. Reports will also evaluate demonstrations performed by U.S. Department of Energy (DOE) and private industry for applicability to SST retrieval and provide recommendations for further testing for use in retrieval operations.

## D.2 TECHNICAL BASIS FOR LDMM

The strategy for LDMM, and the criteria for determining "allowable leakage volumes" (see M-45-08-T02 above) have been developed through a four-year ongoing effort involving engineering studies and reports (PNL 1994, PNL 1995b, FWEC 1995, WHC 1996a, WHC 1996b, WHC 1996c, WHC 1996d, WHC 1996e).

The following significant findings, regarding the use of LDMM to support SST sluicing campaigns, were derived from these engineering studies:

- Technology surveys could not identify any available or deployable, externally applied technical devices, or methods, that can detect waste leakage from an SST, (1) during the duration of planned SST sluicing operations, and (2) under SST and tank farm physical and operations conditions. Technologies reviewed do not provide an improved detection capability over existing internal technologies.
- Retrieval operations must be capable of responding to detected leakage for even the most ideal, available, and deployable leak detection or monitoring tool to be valuable.
- Deployment of a leakage detection or monitoring device presents an equally difficult, if not greater, challenge than finding and developing a technique to work under actual SST tank farm conditions.
- No new (i.e., other than the current baseline approach) internally applied technical devices, or methods, have been identified that can detect waste leakage from an SST during the duration of planned SST sluicing operations.
- The candidate, pre- and post-sluicing monitoring technology, ERT, could potentially reduce the uncertainty or risk incurred due to leakage by confirming and assessing leakage as small as 1,000 gallons or less. Existing (baseline) in-tank leak determination methods currently claim a minimum detection level of 8,000 gallons. If proven, external leakage monitoring could provide significant data to support post-sluicing assessments for multi-tank campaigns and provide assurance that actual leakage volumes did not exceed, projected and accepted, accumulated risk.
- These baseline will continue to be continue to be enhanced and refined as the LDMM effort evolves. Technology surveys will continue to ensure that all new or emerging LDMM technologies are reviewed an incorporated into the existing baseline as appropriate.

The present baseline technology for the retrieval of the Hanford SSTs continues to be past practice sluicing. In support of this sluicing technology, the following LDMM measures remain the only currently available suite of tools to support sluicing operations:

- In-tank, liquid/waste level measurement devices and methods for leak detection (i.e., mass balance techniques).
- Neutron/gamma probe "monitoring" devices, and flow modeling data, to provide pre- and post-sluicing leakage plume assessment and concurrence.
- Operational, procedural, and administrative methods, and retrieval equipment design and availability, to mitigate leakage prior to, and during, sluicing. Engineered systems are not available for deployment as barriers beneath tanks for leak mitigation.

Continued evaluation of candidate LDMM technologies, enhancement of existing technologies, and testing of these tools under actual field conditions is necessary to support the retrieval of the Hanford SST wastes.

### D.3 REFERENCES

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Rev. 0, DE&S Hanford, Richland, Washington.

**APPENDIX E**  
**SCIENCE AND TECHNOLOGY NEEDS RELATED TO VADOSE ZONE ISSUES**

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**LIST OF TERMS**

DOE	U.S. Department of Energy
ILAW	immobilized low activity waste
TFA	Tank Focus Area
TWRS	Tank Waste Remediation System

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## APPENDIX E

## SCIENCE AND TECHNOLOGY NEEDS RELATED TO VADOSE ZONE ISSUES

The Tank Waste Remediation System (TWRS) has submitted a number of science and technology needs to Hanford's Site Technology Coordinating Group. Because of the high site priority, these have been forwarded to the U.S. Department of Energy's (DOE) Tank Focus Area (TFA) group for its funding recommendations (see the TFA's home page at <http://www.pnl.gov/tfa/needs> and Table A1 linked to that page). The needs of most relevance to this program are:

- 1 Long-Term Testing of Surface Barrier (RL-WT017)
- 2 Testing of Sand-Gravel Capillary Barriers (RL-WT018)
- 3 Getter Materials (RL-WT-019)
- 4 Data and Tools for Performance Assessments (RL-WT029)
- 5 Contaminant Mobility Beneath Tank Farms (RL-WT030).

Items 1, 2, and 4 deal with estimating how moisture flows through the Hanford's vadose zone. Items 3, 4, and 5 deal with estimating how the contaminants move in relationship to moisture.

Items 1 and 2: Although the initial driving force of leak-related plumes are leak volumes, the long-term driving force for leak-related plumes as well as for plumes from tank closure and from immobilized low activity waste (ILAW) disposal is recharge from the surface. Determination of natural recharge rates is being done at Hanford through the use of long-term (multi-decay) experiments which vary the surface condition and measure water drainage and other parameters, of measurements of tracers (primarily chlorine) in the soil which allow the determination of recharge rate since the last ice age, and of computer simulations. However, the interaction of physical, chemical, and biological systems make such studies complex. Moreover, how man-made structures (particularly surface barriers) will affect the recharge rate over the lifetime of the structures must also be included. Although significant effort has already been performed at the Hanford Site, much work is needed to determine the long-term driving force for contaminant movement.

Item 3: The interaction of radioactive isotopes with Hanford Site soils greatly slows down the movement of most of the contaminants. Thus, for example, once the transient of a large tank leak has been exhausted, many measurements show that Cs does not significantly move downward in the vadose zone. However, for a few materials (most importantly, technetium, selenium, and nitrates), there is no such retardation in the Hanford soils. Research at various national laboratories has demonstrated that alternate materials can be added to disposal facilities or other facilities to be closed that can greatly slow the movement of contaminants. A well-known example is Portland cement which greatly retards the movement of uranium. Research and development are needed to identify cost effective materials that can have similar behavior with important mobile contaminants.

Item 4: Because of the low expected natural recharge rates and the use of barriers, the vadose zone under the Hanford Site is normally very dry. Conceptual models and many hydraulic relations are based on conditions where there are significant amounts of moisture in the soil. Additional work is needed to understand moisture flow in soils where the moisture content is just a few percent above the residual value. Under such conditions, fingering and other preferential flow is expected to be of more significance. In addition, the relationship between hydraulic conductivity and moisture content and moisture matric potential and water content need to be better known.

Item 4: To estimate moisture flow, hydraulic properties must be used. Normally these are determined for small samples (usually much less than a centimeter in size). However, the properties are to describe flow covering many meters. In such field conditions, many processes may occur which modify the parameters measured in the laboratory. Thus it is important to know how to modify laboratory-derived values so that they can be used to estimate field size environments.

Items 4 and 5: The estimation of retardation of contaminant transport in relation to moisture flow is performed by using the linear isotherm model that relates retardation to soil density, soil moisture, and a chemical dependent parameter (known as  $K_d$ ). Research at Hanford has shown that, contrary to accepted models, the  $K_d$  value for uranium in Hanford soils does depend on the moisture of those zones and that this dependence is different for various soils. Not only must we understand this dependence for uranium (often the most important retarded element), but for other elements as well.

Not only are the projects at the Hanford Site noting these science and technology needs, but these projects have a long history in funding these areas. For example, the ILAW Disposal Project is funding research in many of these areas. The Hanford Tank Initiative has funded much instrument development. The TWRS programs will actively seek to incorporate better data, methods, and tools in the execution of its projects.

**APPENDIX F**  
**CURRENT KNOWLEDGE**

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**LIST OF TERMS**

EM-30	Environmental Management-Waste Management
EM-40	Environmental Management-Environmental Restoration
ER	Environmental Restoration
ILAW	immobilized low activity waste
RCRA	<i>Resource Conservation and Recovery Act of 1976</i>
SST	single-shell tank
TWRS	Tank Waste Remediation System
WMA	Waste Management Unit

**APPENDIX F****CURRENT KNOWLEDGE**

Our current knowledge basis includes the way we approach assessments, our conceptual understanding of the key parts of those assessments, and the data used in the assessments. The following sections describe each of these.

**F.1 CURRENT APPROACHES TO PERFORMANCE/RISK ASSESSMENTS AND MODELING**

Performance and risk assessments are often complex as they rely on a number of disciplines each of which can be complex. Figure F-1 displays the components used in generating the risk assessment and then in making the related decision. Traditionally, risk analyses can be broken up into a number of sub-analyses:

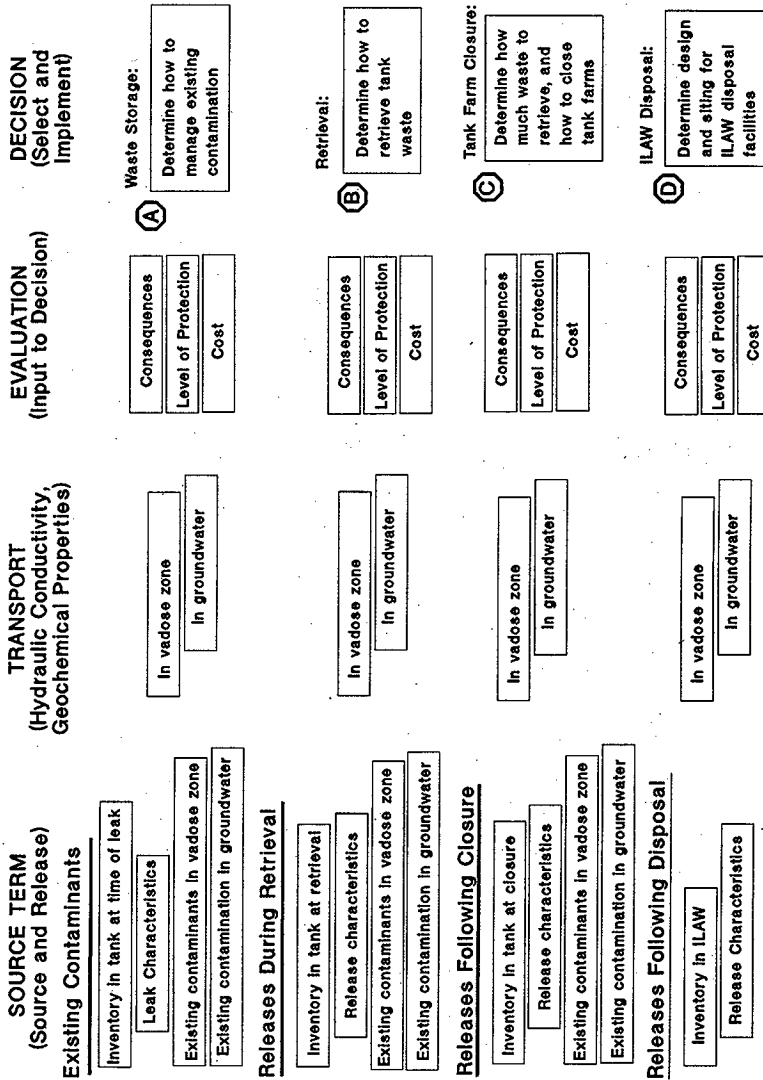
- Inventory in source
- Release rate from source
- Contaminant transport (both in vadose zone and groundwater)
- Environmental and safety impact

The sub-analyses are connected by an overlying scenario, which describes the environment and exposure mechanism. For example, for leaks during single-shell tank (SST) retrieval, the scenario will need to consider subsurface contamination associated with past leaks (estimated or determined by field characterization), leak volumes and inventories of contaminants in postulated retrieval leaks, hydrologic conditions as affected by mitigation actions (e.g., interim surface barriers and/or closure barriers), other postulated remedial actions (e.g., in-situ soil treatment), point of compliance, and exposure assumptions.

For modeling retrieval leaks, the determination of inventory can be complex, as there have been a series of transfers among the tanks during the last 50 years. Best-basis estimates of current tank waste inventories are being developed in the Tank Waste Remediation System (TWRS) waste characterization program. In addition, the physical form (supernate, saltcake, sludge, or hard heel), the physical properties (density and temperature), and the chemical properties (pH and ionic strength) can have a significant effect on release mechanisms. Moreover, when modeling under tanks that have already leaked, information concerning the inventory in the soil also becomes important, causing similar information needs. Estimates of inventories in past leaks, gamma logging data, and characterization of past leaks will provide information important to estimating inventories of contaminants presently in the soil column.

Models for release rates range from very simple ones (solubility of the particular element in a water-based solution) to very complex (glass release rates as a changing function of pH and chemical composition of the surrounding water).

Figure F-1. Technical Basis for Tank Waste Remediation System Decisions Impacting the Environment.



Contaminant transport involves non-linear hydraulic and geochemical processes. Even when the wastes do not disturb the moisture flow and contaminant transport parameters, the calculations can be complex. When the effects of exotic wastes on the parameters are included in the analysis, the predictions become very difficult. Section F.2 describes current conceptual models of contaminant transport in more detail.

Inventory, release rate, and contaminant transport calculations provide the basis for estimates of groundwater contamination levels. These must be converted into environmental and safety impacts (though the use of dosimetry tools) and then the impacts can be compared to acceptable standards. Such dosimetry tools follow the intake of radioactive and hazard materials through various pathways (water ingestion, food ingestion, air inhalation, and direct exposure) and provide a common unit (dose) for comparison to standards. The dosimetry tools used at the Hanford Site are reviewed and approved by the Hanford Environmental Dose Oversight Panel. Previously analyses have usually shown that Federal drinking water standards are usually the most restrictive standards.

In order to translate the contaminant transport hypotheses described in Section F.2 into analyses necessary for input into decision making, several steps are necessary. The necessary steps are:

- 1) Select the model(s),
- 2) Implement of each detailed model into a numerical model,
- 3) Collect data to test each numerical model and for the parameters of each numerical model,
- 4) Run the model so that comparisons against data can be obtained,
- 5) Gather additional data for the analysis, and
- 6) Conduct the analysis.

It should be noted that after the comparison is made (the validation step), the hypotheses may have to be changed, a more accurate numerical model may be needed, more accurate data may need to be collected, or the numerical model may have to be run with different criteria.

As might be expected, this translation is much easier for those contaminant transport cases involving the conventional processes described in F.2.1. Two examples are taken from the Immobilized Low Activity Waste (ILAW) Program: the general modeling of contaminant transport and the adequacy of the linear isotherm ( $K_d$ ) model. Step 1 (the selection of the detailed model) is the acceptance of the classic model for dilute contaminant transport. There are several computer implementations of this classic model (so a variety of computer codes) have been tested. Data collection consisted of performing a moisture injection experiment (with radioactive tracers) in the 200 East Area (RHO 1984) and collecting the basic data needed for modeling. The instruments were recalibrated recently and new measurements made to extend the baseline (PNL 1995). Using the basic site-specific data, two different computer codes were compared against the measured results with good agreement. Site-specific data are now being gathered for application to the disposal of vendor-supplied immobilized low-activity waste. For the second example, step 1 is the decision to test the  $K_d$  model. The numerical model is simple because the  $K_d$  model involves only one simple equation. Data collection involves gathering data for the various expected moisture streams (containing various chemical compositions, pH values,

moisture contents, etc.) and then determining how well the  $K_d$  model predicts the experimental results. Although for most of the conditions, the  $K_d$  model works well, we have already found that for some important contaminants (uranium) that the simple model must be expanded. In addition, we are seeking the point at which the waste streams will overcome the assumptions of the model. The entire database can then be used in the analyses.

The translation for tank leaks is a major focus of this problem. The difficulty of this effort can be seen from two validation efforts. Excellent agreement with numerical models from the large leak from Tank T-106 have been obtained (measurements - RHO 1979, modeling - WHC 1989), while the agreement with the leak from SX-109 is much poorer. Part of this discrepancy may be from the very different wastes in the two tanks; it may be from the quality of the data, or the assumptions made during the running of the code. Future work will focus on obtaining data for a large variety of tank leak conditions and ensuring that all can be modeled.

## **F.2 CURRENT UNDERSTANDING OF CONTAMINANT TRANSPORT MECHANISMS**

One of the most important components of risk assessments that involve tank waste is the movement of contaminants through the vadose zone. The following sections describe current understanding (hypotheses) relating to contaminant transport mechanisms under conventional processes (i.e., where involving infiltrating meteoric water is the hydraulic driving force, and geochemical interactions between contaminants and the soil medium, have not been altered by previous liquid discharges or leaks and spills of tank waste), and under conditions associated with tank leaks, where conventional models may not be applicable.

The estimation of moisture flow and contaminant transport in the vadose zone is inherently difficult as it involves non-linear hydraulic and geochemical processes. Those many parameters must be determined and results validated. In addition, particularly for certain tank leaks, the processes and parameters are poorly known. However, in many cases, the moisture and contaminants do not significantly affect the natural system and well-developed principles can be applied.

### **F.2.1 Contaminant Transport under Conventional Processes**

In the simple case where the wastes do not affect vadose zone properties (e.g., at ILAW disposal sites), the estimation of moisture flow follows the application of Darcy's law which relates the flow to the hydraulic conductivity (which itself depends on moisture content) and the moisture pressure head) while contaminant transport builds on the moisture flow calculation corrected for retardation using the simple  $K_d$  model. The most important parameters are:

- the infiltration rate of water (often taken to be the same as the recharge rate or when tank leaks are involved taken from leak volumes)
- the source release term (which may depend on the infiltration rate, waste form properties, and facility design parameters)

- the hydraulic conductivity of the medium (which depends on the geologic layer) and can vary by many orders of magnitude
- the moisture retention curve of the medium which describes how tightly the material holds onto moisture
- the  $K_d$  parameters which describe the amount of retardation
- the dispersion parameters which describe the diffusion of the contaminants through the moving water.

The ILAW Performance Assessment activity has many activities to determine the natural recharge rate and the properties on which this rate depends.

Much work has been performed on vadose zone parameters (hydraulic conductivity, moisture retention,  $K_d$ , and dispersion parameters), especially in the ILAW Performance Assessment activity for the movement of dilute materials. These data were compiled for the 1998 ILAW Performance Assessment and a new compilation is due in 2000. With the establishment of the Integrated Hanford Site Vadose Zone/Groundwater Project, additional data and compilations are to be expected.

## **F.2.2 Contaminant Transport from Tank Leaks**

The above paragraphs describe the situation where the contaminants do not significantly affect the properties of the vadose zone. However, because of the large leaks of exotic materials that have already occurred (for example, the leaks in the SX tank farms, where the tanks held wastes of 180 °C, high densities, and high chemical ionic content), such simple models are inadequate.

Four factors associated with tank leaks are thought to be important in influencing the movement of waste materials through the vadose zone. These are: stratigraphy, leak volume, leak rate, and waste composition. The leak volume will provide the initial hydraulic driving force for waste movement. The leak rate could influence the initial waste-soil interactions and the waste chemistry would dictate the type of waste-soil reactions that could take place. Once tank waste has reached the soil column then the site-specific geology and hydrologic properties are expected to impact, or perhaps control, movement of wastes in the vadose zone.

For the following discussion, the near field is defined as the wetted plume volume in the vadose zone adjacent to tanks during the initial leak transient. To support waste storage and retrieval decisions, the following three situations may need to be addressed:

- Waste solution and sediment interactions from leaks resulting in an initial contaminant plume
- Subsequent changes due to natural processes

- Possible changes due to retrieval/slicing operations.

Initially it is assumed that leaked liquid volumes saturate pores of sediments adjacent to the leak source and liquid moves a limited distance under saturated flow conditions until the driving force dissipates. Then unsaturated flow properties control liquid travel. The plume expands until retarded by low conductivity regions or by equilibrating with background soil moisture levels controlled by matric potential and gravimetric forces.

It is assumed that both radionuclides and chemicals will be separated to various degrees within the contaminant zone due to differential sorption and precipitation/alteration reactions. Mobile components will be concentrated closer to the wetted front with more reactive constituents held closer to the leak source. The wetted front may be approximated by observations of discontinuities in specific or gross gamma activity, moisture content, or salt content. In the event of salt precipitation near the front, osmotic forces may result in a decrease in moisture content in the soil zone immediately adjacent to the contaminant zone front.

At the initial saturated region of the leak volume near the source, the mineral-waste chemical system is dominated by waste liquid chemistry. The pore volume is completely filled with waste fluids that can react with the fine sand/clay fraction. The fine fraction is predominated by clays and fine, silt-size feldspars and quartz that will likely be the first soil components to react with caustic waste liquids because of their large surface area to mass ratio. If sufficient hydroxide is available, dissolution of fines may increase porosity and hydraulic conductivity in the dissolved volume, but precipitation may occur immediately downstream due to the pH reduction. This may lead to an outer zone of salts in the contaminant volume that can potentially be remobilized during subsequent natural recharge or other liquid infiltration. Presumably the more mobile radionuclides such as Tc-99, I, U carbonate complexes etc. will accumulate in this outer zone.  $K_d$  properties in this outer zone may be expected to be more like those measured in dilute, intermediate pH systems such as those where most Hanford measurements have been made. Also in this outer zone, the natural mineral assemblage would be expected to buffer the solution pH and possible control some cation ratios through hydrolysis reactions such as those between feldspars, clays, and liquids. In summary, the contamination volume may be considered as three zones with an inner zone close to the leak source exhibiting coarse sediments with dissolved or partially dissolved fines, a second intermediate zone with precipitates and mineral alteration phases, and an outer zone with controlled by mineral-water buffer systems, ion-exchange type reactions, and deposits of mobile salts.

It is assumed that liquids moving by advection through partially saturated porous media will be the primary mechanism for continuing contaminant dispersion, although some migration could occur by chemical diffusion through surface films or by water sorbed osmotically by precipitated salts. Advecting liquids can be considered as two types: either additional tank supernates from subsequent leaks from the same tank or adjacent tanks, or more dilute solutions represented by infiltrating recharge water (from precipitation) or condensates and supply line leaks from headers or other tank infrastructure. It is expected that in most cases, additional supernate leaks and condensate discharges would have occurred earlier in the tank leak history and would have a finite volume, while natural infiltration is continuous and seasonal.

Additional tank supernate leakage will add essentially the same type of chemical constituents to the contaminant zone. The total vadose zone volume infiltrated by supernate may be expected to increase and possibly increase the rate of contaminant migration toward the unconfined aquifer if the added liquid volume is high. However, the zonal distribution of contaminants should be similar in sequence to the original chemical distribution even though the size of the zones may increase. Commingling of contaminants from supernate leakage from adjacent tanks may introduce secondary contaminants depending on the waste type leaked.

Natural processes that are expected to spread contaminant zones would primarily consist of natural recharge and the "umbrella" effect from tank domes (discharge of runoff from tank domes into soils adjacent to tank walls). Larger infiltration pulses may occur on an intermittent basis with seasonal snowmelts or occasional flooding. The effects of natural infiltration would be to continue the processes described above for spreading contamination. The recharge water would be rather dilute compared to supernate liquids and "chemically conditioned" through reaction with backfill soils. Infiltration of this water could result in continued separation of contaminants. pH values in zones where hydroxide phases previously were precipitated would increase temporarily until these phases dissolved or were diluted. Dissolution of solubility controlled contaminants, previously incorporated in secondary mineral phases, would likely reduce the contamination concentration in zones of precipitation and allow for sorption downstream leading to spreading of the contaminant volume. The larger contaminant volume would have lower specific unit concentrations. Probably the main long term future potential would be discharge of mobile constituents such as Tc-99 into the unconfined aquifer at lower concentrations while leaving reduced concentrations of less mobile contaminants such as Cs, Sr, and some transuranics spread over a larger volume.

Fluids that potentially leak during retrieval operations would be expected to be caustic, sodium-rich fluids, but possible not as concentrated in salts as supernate, depending on the constraints and criteria developed by retrieval operations for waste transfer. Leakage during retrieval would be expected to have a finite duration and limited volume. The impacts of retrieval leaks on previous contaminant volumes are expected to be primarily enhanced migration rates and separation of contaminants similar to those described above for initial supernate leak events.

### **F.3 CURRENT SITE CONDITIONS**

Information has been collected during numerous activities in and around the SST farms. This information bears directly and indirectly on the movement of water and contaminants through the vadose zone toward the groundwater.

#### **F.3.1 Geology**

An extensive suite of geologic knowledge has been accumulated over Hanford's history. The general geologic relationships of the strata underlying the SST farms has been established through surface geologic investigations, geophysical investigations, and the placement of numerous boreholes and wells. There are nuances and subtleties associated with these strata that

are site specific and therefore less well known. It is these nuances and subtleties that may play significant roles in the absolute movement of contaminants through the geologic system. The geologic framework differs between the 200 West Area and the 200 East Area.

In the 200 West Area the stratigraphic column of the vadose zone consists of the Hanford formation, a fine-grained soil horizon commonly called the Plio-Pleistocene unit, and the Ringold Formation. The Hanford formation is comprised of glacial-fluvial sands and gravels deposited in a relatively high energy environment. Generally, the unit is subdivided into three secondary units, an upper gravel dominated unit, an intermediate unit consisting primarily of sand, and a lower unit consisting primarily of gravel. Where the intermediate unit is absent, the upper and lower units are indistinguishable. Underlying the Hanford formation is the Plio-Pleistocene unit. This unit consists of sand and silt, and is commonly rich in carbonate. This carbonate forms a discontinuous layer often referred to as the caliche layer. Underlying the Plio-Pleistocene unit are the sands and gravels of the Ringold Formation. The Ringold Formation sediments range from fine to coarse and have a range in induration.

In the 200 East Area the vadose zone stratigraphic column is dominated by the Hanford formation. The fine-grained sediments of the Plio-Pleistocene unit are absent, and where the Ringold formation is present, it consists of discontinuous remnants of a fine grained sub-unit called the lower mud. In some places basalt of the Columbia River Basalt Group rise above the water table and form the lowermost part of the vadose zone.

### F.3.2 Hydrology

There is little direct knowledge of the hydrologic aspects of the vadose zone underlying the SST farms. Most information on the unsaturated hydrologic characteristics of the vadose zone has been developed outside the realm of the farms. This information has been extrapolated to assess the movement of moisture beneath the farms. Studies have shown that the manner in which the tank farm surfaces are maintained to reduce the radiological dose to workers has a propensity to increase the amount of infiltration through the surface. The increase in available infiltration is due to the presence of vegetation-free gravel surfaces and in some instances the topography of the individual tank farm. The vegetation-free gravel permits water to readily reach the subsurface without being subjected to evapotranspiration, while the topography of the surface can cause the accumulation of water during rapid snowmelt events. The tanks themselves impact the hydrologic environment by creating large umbrellas that tend to concentrate the infiltrating water along the tank perimeters. The tanks further impact the hydrologic regime due to their high heat load which exerts a drying influence on the surrounding sediments.

Recharge within the tank farms is additionally impacted by anthropomorphic sources such as raw and treated water lines and wastes that have been lost from either tanks or transfer lines. The hydrologic impact of waste reactions with the sediments is an unknown.

Transport of contaminants is thought to be controlled by two hydraulic elements: the driving force exerted by the initial leak; and transport due to infiltrating water. For the less mobile constituents such as  $^{137}\text{Cs}$  the vast majority of movement takes place during the initial leak event. Mobile constituents such as  $^{106}\text{Ru}$  and  $^{99}\text{Tc}$  are initially advanced by the leak event,

followed by transport due to infiltrating water. The impact of the various radionuclides is then due to their rate of transport and longevity, with mobile, long-lived radionuclides contributing the majority of calculated dose.

### **F.3.3 Distribution of Tank Wastes in Vadose Zone**

Knowledge on the distribution of tank wastes within the vadose zone has come primarily from geophysical evidence collected from monitoring over 750 monitoring wells and dry wells that have been installed around the tanks and tank farms. The majority of these monitoring structures were drilled in the mid-1970s. Some tank farms also have had lateral monitoring bores installed beneath tanks. Vadose zone monitoring of these wells, bores and laterals has been done using gamma-ray logging techniques. Early logging campaigns were performed as part of the tank leak detection program and were limited to gross, or total gamma, analysis. The information collected during these regular monitoring efforts were compared against a leak detection criterion, and if that criterion was not exceeded, the data were archived without further examination. If the criterion was exceeded, actions were taken with the tank.

Currently, a program to baseline the distribution of specific gamma emitting radionuclides using spectral gamma logging is underway. This effort using gamma energy analysis to identify and quantify the nature of subsurface contamination has been completed for eight SST farms and is scheduled for completion in 1999. The spectral gamma logging program has confirmed the information provided by the historical program in addition to providing details on the nature of the gamma emitting radionuclides. A parallel effort is underway to reassess the vast data base of historical gross gamma logging information. These data are being analyzed to provide previously unaddressed issues such as stability of contaminated zones, original radionuclide make-up and the like. This in-depth review is providing a level of information previously unrecognized.

Due to safety concerns, the laterals are no longer available for investigation.

Only a very limited suite of samples are, or have been, available for analysis of non-gamma emitting radionuclides. Samples were collected during early (1960s) leak investigations (Raymond and Shdo, 1965), these samples were generally subject to gamma energy analysis. Until recently (1993 and 1997), actual samples for analysis of gamma emitting and other radionuclides and chemicals were generally not available. In 1993, samples were collected as part of a more extensive review of the 1973 leak from Tank 241-T-106. Analysis of these samples provided the first look at the distribution of beta emitting radionuclides such as <sup>99</sup>Tc. In 1997, samples were collected during extension of a borehole adjacent to Tank 241-SX-109. The samples represent the deeper portion of the vadose zone from 130 ft to the watertable at 211 ft.

Data from the 241-T-106 investigation indicate that mobile, non-gamma emitting radionuclides have been significantly retained in and immediately beneath the Plio-Pleistocene unit. Based on analysis of geochemically similar radionuclides, it appears that the vast majority of this movement occurred during the initial leak event. Data from the 241-SX-109 borehole extension show that contaminant migration beyond the Plio-Pleistocene unit has not occurred.

Analysis of groundwater contaminant data indicates that tank wastes from both the 241-T and 241-SX Tank Farms have reached groundwater.

### F.3.4 Groundwater Contamination

Groundwater monitoring in the vicinity of the SST farms is being conducted in accordance with the Hanford Facility *Resource Conservation and Recovery Act of 1976* (RCRA) Permit. Four Waste Management Units (WMA) containing eight SST farms are undergoing Assessment because analysis of indicator parameters indicates that tank waste components have reached groundwater. Beyond indicator parameters, the primary tank waste radionuclide present is  $^{99}\text{Tc}$ . While the investigations conducted at 241-T-106 and 241-SX-109 did not find significant concentration of  $^{99}\text{Tc}$  deep in the vadose zone, other routes through the vadose zone may have resulted in the observed contamination of groundwater. Observed groundwater contamination does not account for the inventory of  $^{99}\text{Tc}$  which has been calculated to have been available to leak from the tanks.

### F.3.5 TWRS Liquid Discharge Sites

Responsibility for management and cleanup of most past liquid discharge sites at Hanford belong to the Environmental Restoration (ER) Program, EM-40, and to TWRS, EM-30. Information needed to support TWRS decisions on management of existing vadose zone contamination (See 5.2) will need to address not only contamination from past tank leaks, but also contamination from past liquid discharges at sites owned by TWRS. Table F-1 provides a listing of those sites.

Table F-1. Liquid Discharge Sites Managed by Tank Waste Remediation System.<sup>1</sup>

Operable Unit	Site Code	Site Name(s)	Site Type	Site Status
200-BP-11	216-B-3A	B Pond Lobe A, B Pond First Expansion Lobe	Pond	Inactive
200-BP-11	216-B-3B	B Pond Lobe B, B Pond Second Expansion Lobe	Pond	Inactive
200-BP-11	216-B-3C	B Pond Lobe C, B Pond Third Expansion Lobe	Pond	Active
200-BP-11	216-B-63	B Plant Chemical Sewer, 216-B-63 Trench	Ditch	Inactive
200-BP-11	216-E-28	216-E-25, Retention Basin: 200 East Area Contingency Pond	Pond	Inactive
200-BP-9	216-B-55	216-B-55 Enclosed Trench, 216-B-55 Crib	Crib and Tile Field	Inactive

Table F-1. Liquid Discharge Sites Managed by Tank Waste Remediation System.<sup>1</sup>

Operable Unit	Site Code	Site Name(s)	Site Type	Site Status
200-BP-9	216-B-62	216-B-62 Enclosed Trench, 216-B-62 Crib	Crib and Tile Field	Inactive
200-PO-2	216-A-40	Ditch	Retention Basin	Inactive
200-PO-3	216-A-39	216-A-39 Crib	Crib	Inactive
200-PO-3	244-CR-WS-1	244-CR French Drain	French Drain	Inactive
200-PO-4	216-A-30	216-A-30 Crib	Crib	Inactive
200-PO-4	216-A-37-2	216-A-37-2 Crib	Crib	Inactive
200-PO-5	216-A-8	216-A-8 Crib	Crib	Inactive
200-RO-1	216-S-25	216-S-25 Crib	Crib	Inactive
200-RO-3	216-S-26	216-S-19 Replacement Facility, 216-S-26 Crib	Crib	Inactive
200-RO-4	216-SX-2	216-SX-2 Crib	Crib	Inactive
200-SO-1	200-E-4	Critical Mass Laboratory Dry Well North	French Drain	Active
200-SO-1	209-E-WS-1	209-E French Drain	French Drain	Inactive
200-SO-1	209-E-WS-2	Critical Mass Laboratory French Drain	French Drain	Inactive
200-SO-1	216-C-7	216-C-7 Crib	Crib	Inactive
200-SS-2	216-W-LWC	W-1	Crib	Inactive
200-TP-1	216-T-32	241-T #1 & 2 Cribs, 216-T-6	Crib	Inactive
200-TP-2	216-T-31	French Drain	French Drain	Inactive
200-TP-3	216-T-12	207-T Sludge Grave, 207-T Sludge Pit, 216-T-11	Trench	Inactive
200-TP-3	216-T-4-2	216-T-4-2 Ditch	Ditch	Inactive
200-TP-4	216-T-1	221-T Ditch, 221-T Trench, 216-T-1 Trench	Ditch	Inactive
200-TP-6	200-W-52	200-T-7 Crib, 241-T-3 Crib	Crib	Inactive
200-UP-2	216-U-14	Laundry Ditch, 216-U-14 Ditch	Ditch	Inactive

Table F-1. Liquid Discharge Sites Managed by Tank Waste Remediation System.<sup>1</sup>

Operable Unit	Site Code	Site Name(s)	Site Type	Site Status
200-UP-2	216-U-16	UO3 Crib	Crib	Inactive
200-UP-2	216-U-17	216-U-17 Crib	Crib	Inactive
200-UP-2	216-Z-20	Z-19 Ditch Replacement Tile Field	Crib	Inactive
200-ZP-2	216-Z-21	216-Z-21 Seepage Basin, PFP Cold Waste Pond	Pond	Active

<sup>1</sup>Does not include unplanned release sites

At present, these sites are considered lower priority for characterization than the soils impacted by releases from SSTs. However, the use of these sites based on historic records and personal knowledge needs to be evaluated. Information on discharges to some of these sites is contained in the Composite Analysis (PNNL 1998). Should review of the records indicate any are of imminent risk, they would be made higher priority for characterization. Review of historic data on them may also indicate if any of the conceptual models developed for the 200 Area Past Practice Strategy would be appropriate for them.

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