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Subsurface Barrier Feasibility Evaluation - External Review Meeting Report

S. L. Lindberg
J. K. Rouse
Bovay Northwest, Inc.

Date Published
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Approved by: _____ 12 Dec 94
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Date

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SUBSURFACE BARRIER FEASIBILITY EVALUATION - EXTERNAL REVIEW MEETING REPORT

ABSTRACT

The Westinghouse Hanford Company - Tank Waste Remediation System Division (TWRS) Program is evaluating subsurface barrier technologies for potential use in supporting remediation of the Hanford Tank Farms for the U.S. Department of Energy, Richland Operations Office (DOE-RL). An External Review Team (ERT) was assembled to perform an independent technical review of the work performed to-date supporting the evaluation process. A set of draft documents was forwarded to the ERT for their review, and a meeting was held August 10 through 12, 1994, to facilitate comments and resolutions. This document summarizes the meeting, the comments provided by the ERT, and the ongoing work to resolve the comments and support a pending decision by The U.S. Department of Energy, Richland Operations Office; the Washington State Department of Ecology; and the U.S. Environmental Protection Agency.

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EXECUTIVE SUMMARY

A Hanford Subsurface Barrier (SSB) External Review Team (ERT) was organized to provide technical assistance in achieving two primary objectives: (1) provide an external review of the documents produced as a part of the SSB Feasibility Evaluation (Treat et al. 1994; Cruse and Lowe 1994; Cruse 1994) and (2) use the ERT's extensive and diversified experience in developing a rationale for evaluating various alternatives against decision values established within the Tank Waste Remediation Sysytems (TWRS) Division.

The SSB Feasibility documents were provided to the ERT for review, and a technical meeting was held in Kennewick, Washington, on August 10 through 12, 1994. The meeting proved to be informative and beneficial in achieving the above-mentioned objectives. The collective experience of the five members of the ERT provided an excellent basis for the meeting. The meeting format allowed for extensive interaction among the ERT members and the evaluation team members.

The meeting agenda included a one-day review of the background information and documents related to the SSB evaluation work performed by TWRS to date. The remaining two days included the ERT providing comments and input regarding the documents and related data and discussion of the decision process values and rationale for evaluating alternative retrieval/SSB concepts against those values. The values included public health and safety, worker health and safety, protection of the environment and the Columbia River, cost

effectiveness, and several other areas of concern. The discussion enabled the ERT to become familiar with the SSB alternatives as well as the stakeholder concerns which must be addressed when planning for future activities at the Hanford Site.

The ERT's consensus was that the TWRS evaluation documents were easy to read and presented the information at a level appropriate for their purposes. Some general comments were provided directed at enhancement and improvement of the documents.

The following action items were taken by the feasibility study team in response to the ERT's input and comments:

- While the reduction in public risk is clearly an important consideration in comparing the alternatives, the analyses show that the relative differences between the alternatives are small. A more detailed analysis of worker and accident risks would be useful, since it appears that use of these risk values as measures would afford greater discrimination between alternatives. The worker/accident risk analyses will be performed and the data presented to the U.S. Department of Energy (DOE), Richland

Operations Office (RL); the U.S. Environmental Protection Agency (EPA), and the Washington State Department of Ecology in a timeframe to support Tri-Party Agreement[1] (TPA) milestone M-45-07B decision process.

- Alternatives using subsurface barriers may show value in cases where large leaks would occur due to significant degradation of the tank containment boundaries. Analysis of the affects of large leakage events would be useful in supporting a final determination of the potential benefit of subsurface barrier technologies. The large leakage event analyses will be performed and the data presented to RL, EPA, and Ecology in a timeframe to support the TPA M-45-07B decision process.

[1]Ecology, 1994, *Hanford Federal Facility Agreement and Consent Order*, as amended, Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy, Olympia, Washington.

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ABBREVIATIONS AND ACRONYMS

^{14}C	carbon-14
CAA	Clean Air Act
COC	constituents of concern
CWA	Clean Water Act
DOE-HQ	U.S. Department of Energy - Headquarters
DST	double-shell tank
EDTA	ethylenediamine tetra-acetic acid
EPA	Environmental Protection Agency
ERT	External Review Team
^{129}I	iodine-129
MEI	maximally exposed individual
MEPAS	Multimedia Environmental Pollutant Assessment System
NEPA	National Environmental Policy Act of 1969
NO_3	nitrate
NO_2	nitrite
QA	quality assurance
RCRA	Resource Conservation and Recovery Act of 1976
RL	U.S. Department of Energy, Richland Operations Office
SSB	Subsurface Barrier
SST	single-shell tank
^{99}Tc	technetium-99
TBP	tri-butyl phosphate
TNPW	total net present worth
TPA	Tri-Party Agreement
TWRS	Tank Waste Remediation System
^{238}U	uranium-238
UST	underground storage tank
WHC	Westinghouse Hanford Company

SUBSURFACE BARRIER FEASIBILITY EVALUATION — EXTERNAL REVIEW MEETING REPORT

1.0 INTRODUCTION

A Hanford Subsurface Barrier (SSB) External Review Team (ERT) Meeting was held August 10 through 12, 1994, in Kennewick, Washington. Bovay Northwest, Inc. helped organize the meeting and established subcontracts with the technical experts that served as the ERT.

1.1 PURPOSE

The purpose of the meeting was to achieve two primary objectives: (1) provide an external review of the documents produced as a part of the SSB Feasibility Evaluation (Treat et al. 1994; Cruse and Lowe 1994; Cruse 1994) and (2) use the ERT's extensive and diversified experience in developing a rationale for evaluating various alternatives against decision values established within Tank Waste Remediation Systems (TWRS).

These objectives were established to help fulfill Milestone M-45-07A of the Tri-Party Agreement (TPA) (Ecology et al. 1994). Milestone M-45-07A requires completion of a feasibility evaluation of SSBs by September 1994, as well as support of TPA Milestone M-45-07B. Milestone M-45-07B requires a decision by the U.S. Department of Energy (DOE), Richland Operations Office (RL), Washington State Department of Ecology (Ecology), and Environmental Protection Agency (EPA) in January 1995 regarding further development and demonstration of SSB alternatives.

1.2 EXTERNAL REVIEW TEAM MEMBERS

The ERT consisted of five members: Professor Joseph S. Byrd, the team chair, and Dr. Alfred Schneider, Dr. Walter E. Grube, Mr. Matthew Moeller, and Mr. Russell Levens. The reviewers were chosen to provide expertise in the design, placement, and performance of an SSB system.

Mr. Byrd is a professor of electrical engineering with the University of South Carolina and specializes in the areas of nuclear instrumentation, computers, and robotics. He is a member of the Waste Management External Advisory Committee for Westinghouse Hanford Company (WHC) and recently chaired a review panel on the Single-Shell Tanks Retrieval Program.

Dr. Schneider is a Professor Emeritus of Nuclear Engineering at Georgia Institute of Technology. Since 1991, he has served as a Visiting Professor and Research Affiliate at the Massachusetts Institute of Technology. He has extensive experience in the field of nuclear engineering with expertise in the areas of safety, economics, nuclear chemical engineering, and the management

of radioactive and toxic wastes. He is currently a member of the Waste Management External Advisory Committee and the Tank Waste Remediation Program Systems Engineering Technical Advisory Board for WHC.

Dr. Grube is a visiting professor of civil engineering at Ohio University and brings more than 20 years of experience in developing, implementing, and reporting a broad range of research projects involving environmental applications. Dr. Grube is nationally and internationally recognized in the application of soil technologies to environmental pollution control and prevention.

Mr. Moeller is the vice-president of Dade Moeller & Associates, Inc. and is a Certified Health Physicist. He has provided technical and program management assistance in the areas of radiation protection, industrial hygiene and safety, risk assessment, and emergency preparedness. His individual research and management experience encompasses operational health physics, risk assessment, radiation measurement and characterizations, and occupational health and safety. Mr. Moeller has extensive knowledge of DOE facilities, particularly those at Hanford.

Mr. Levens is currently a staff geologist with the United States Bureau of Mines at the Spokane Research Center. He has 10 years of experience in the fields of geology and hydrogeology with special interest in the remediation of groundwater contaminated by mining activities. Mr. Levens' specific topics of research include the hydrochemical impacts of backfill on groundwater, hydrologic control of acid mine drainage using injected clay grout barriers, and the mechanisms controlling metal release from sulfide tailings.

1.3 MEETING AGENDA

The following table provides the agenda for the meeting which took place at the Ramada/Clover Island Inn, Kennewick, Washington.

Date/Time	Subject	Presenter/Facilitator
Wednesday, August 10, 1994		
8:00 am	Introductions/Objectives	Bazinet/McLaughlin
8:20 am	Background - Hanford Tanks Background/Summary - Engineering Study	Hampsten
8:40 am	Functional Baseline - Regulatory Analysis/Permitting - Mission Analysis - Functions & Requirements	 Smith Cruse Cruse
9:15 am	Test Strategy and Specifications	Treat
9:30 am	Break	

10:00 am	Feasibility Evaluation	
	- Introduction/Summary	Cruse
	- Qualitative Risk Assessment	Treat
	- Concepts Definition	Rouse
	- Performance & Risk Assessment	
	Alternatives/Approach/Assumptions	Treat
	Risk Assessment	Trenkler
	- Cost/Sensitivity/Conclusions	Treat
12:00 pm	Lunch	
1:30 pm	Questions and Technical Issues	ERT
2:30 pm	Feasibility Evaluation (continued)	
	- Decision Analysis Approach	Treat
3:00 pm	Decision Value Structure	John
3:30 pm	Break	
4:00 pm	Close-out First Day	All

Thursday, August 11, 1994

8:00 am	Review Previous Day	Byrd/McLaughlin
8:15 am	Review Strawman Approach	Treat
9:00 am	Alternative Evaluation (Part I)	Byrd/ERT/Treat
10:00 am	Break	
10:30 am	Alternative Evaluation (continued)	Byrd/ERT/Treat
12:00 pm	Lunch	
1:00 pm	Alternative Evaluation (continued)	Byrd/ERT/Treat
2:30 pm	Break	
3:00 pm	Team Review/Develop Findings (ERT Only)	ERT Only

Friday, August 12, 1994

8:00 am	Review Previous Day	Byrd/McLaughlin
8:15 am	Assess Alternatives on Measures (Part II)	ERT/John
10:00 am	Break	
10:30 am	Assess Alternatives (continued)	ERT/John
12:00 pm	Lunch/Executive Session (ERT)	

1:00 pm	Team Review/Develop Findings	ERT Only
2:00 pm	Management Briefing	Byrd/ERT
4:00 pm	End of Meeting	

1.4 MEETING PARTICIPANTS

Participants in the ERT meeting (in addition to the ERT panel itself) are listed in the following table.

Name	Org.	Phone	Affiliation
W.R. (Wendel) Wrzesinski	RL	509/376-6751	DOE/Customer
G.D. (Jerry) Bazinet	WHC	509/376-3059	Manager, DST Retrieval Engr.
J.M. (Jon) Cruse	WHC	509/372-1024	Team Leader
L.A. (Les) Fort	WHC	509/372-0385	Waste Retrieval Program
K.L. (Ken) Hampsten	WHC	509/376-3127	Cognizant Engineer
G.A. (Gary) Meyer	WHC	509/372-3683	Manager, Retrieval Program
E.H. (Ed) Smith	WHC	509/375-4640	Regulatory Assessment
R.L. (Russ) Treat	FW	509/372-5812	Risk Assessment
T.L. (Tina) Trenkler	FW	206/451-4616	Risk Assessment
A.J. (Alan) Brothers	PNL	509/372-4227	Decision Analysis
R. (Richard) John	USC	213/740-4012	Decision Analysis
T.J. (Tom) McLaughlin	AST	509/375-1938	Concepts Definition
S.L. (Sara) Lindberg	Bovay	509/946-6220	Project Support
J.K. (Jim) Rouse	Bovay	509/946-6220	Concepts Definition

2.0 MEETING SUMMARY

The following sections provide a summary of the presentations and discussion that occurred in the three-day meeting. The sequence of the following paragraphs matches the agenda (shown above). Additional details of the meeting can be found in Lindberg and Rouse, 1994; this letter report includes reproductions of the actual presentation viewgraphs used in the meeting.

Wednesday, August 10, 1994

2.1 INTRODUCTIONS AND OBJECTIVES (Jerry Bazinet, WHC & Tom McLaughlin, AST)

The objective of the Subsurface Barrier Feasibility Evaluation are as follows:

- Complete evaluation to satisfy TPA M-45-07A (9/94)
- Support RL, Ecology, and EPA decision regarding further development and/or implementation - TPA M-45-07B (1/95)

The TPA milestones read as follows:

TPA M-45-07A

- Complete Evaluation of Subsurface Barrier Feasibility September 1994

  Complete a feasibility study of barriers to accomplish the following:

  1. Estimate the *potential environmental impact* of waste storage and retrieval activities without the application of barriers.
  2. Establish *functional requirements* of barriers to minimize the impact associated with the waste storage and retrieval activities.
  3. *Evaluate the application* of existing subsurface barrier technologies to meet functional requirements of barriers and the *potential reduction in environmental impacts* from the application of barriers to single-shell tank (SST) waste storage and retrieval activities.

TPA M-45-07B

- Reach Decision on Whether to Proceed with Demonstration (January 1995)

  Based on the results of the subsurface barrier feasibility study, Ecology, EPA, and DOE will make a decision on whether to proceed with a subscale demonstration. If the decision is negative, then interim milestone M-45-07 will be considered complete.

Earlier this year the TWRS program formed a multi-contractor team to perform the evaluations in support of M-45-07A and support the decision per M-45-07B. The SSB evaluation team is shown as Figure 1.

2.2 HANFORD SITE AND UST SUMMARY (Ken Hampsten, WHC)

The Hanford Site is located in the southeastern corner of Washington State. All of the high-level waste underground storage tanks (USTs) are located in the 200 East and 200 West Areas, near the center of the Hanford Site. A diagram of the Hanford Site is shown in Figure 2.

There are currently 177 high-level waste USTs located in the 200 Areas. Of these tanks, 149 tanks are of a SST containment design and 28 tanks have double containment [double-shell tank (DST)]. The SSB feasibility and evaluation addresses only the SSTs; the DSTs are considered out of scope for the purposes of this project.

The SSTs consist of five different design types varying in volumes from approximately 208,000 L to 3,785,000 L (55,000 gal to 1,000,000 gal). They were constructed with a single, carbon-steel liner with a reinforced concrete support. They are situated in 12 tank farms, with approximately 12 tanks per tank farm. The five tank designs are shown in Figure 3.

The SSTs were taken out of service (i.e., in 1981 no longer receiving waste). Cumulatively, the tanks store approximately 2,115,000 L (568,000 gal) of supernatant; 46,110,000 L (12,181,000 gal) of sludge; and 88,370,000 L (23,345,000 gal) of salt cake as of March 1994. The major waste constituents are nitrate and nitrite salts, hydrated metal oxides, phosphate precipitates, transuranics, ^{90}Sr, ^{99}Tc, ^{129}I, and ^{137}Cs.

Sixty-seven tanks are currently classified as either assumed or confirmed leakers with up to 3,407,000 L (900,000 gal) and 1,130,000 Ci of waste estimated to have leaked to the soil. One hundred-six tanks have been interim stabilized, and intrusion prevention has been completed for 98 tanks. Forty-six tanks are currently on a watch list due to potentially hazardous conditions.

The 241-C Tank Farm was presented in order to give typical dimensions of a tank farm. The 241-C Tank Farm is approximately 107 m by 122 m (350 ft by 400 ft) with twelve 23-m- (75-ft-) diameter, 1,900,000 L (500,000-gal) tanks oriented in three rows of four tanks each. There is approximately 8 m (25 ft) of clearance between the tanks. The 241-C Tank Farm also has four 6-m- (20-ft-) diameter, 208,000-L (55,000-gal) tanks along the perimeter of one side of the farm. The physical separation between the tank farms varies from a distance of 150 m (500 ft) to several kilometers.

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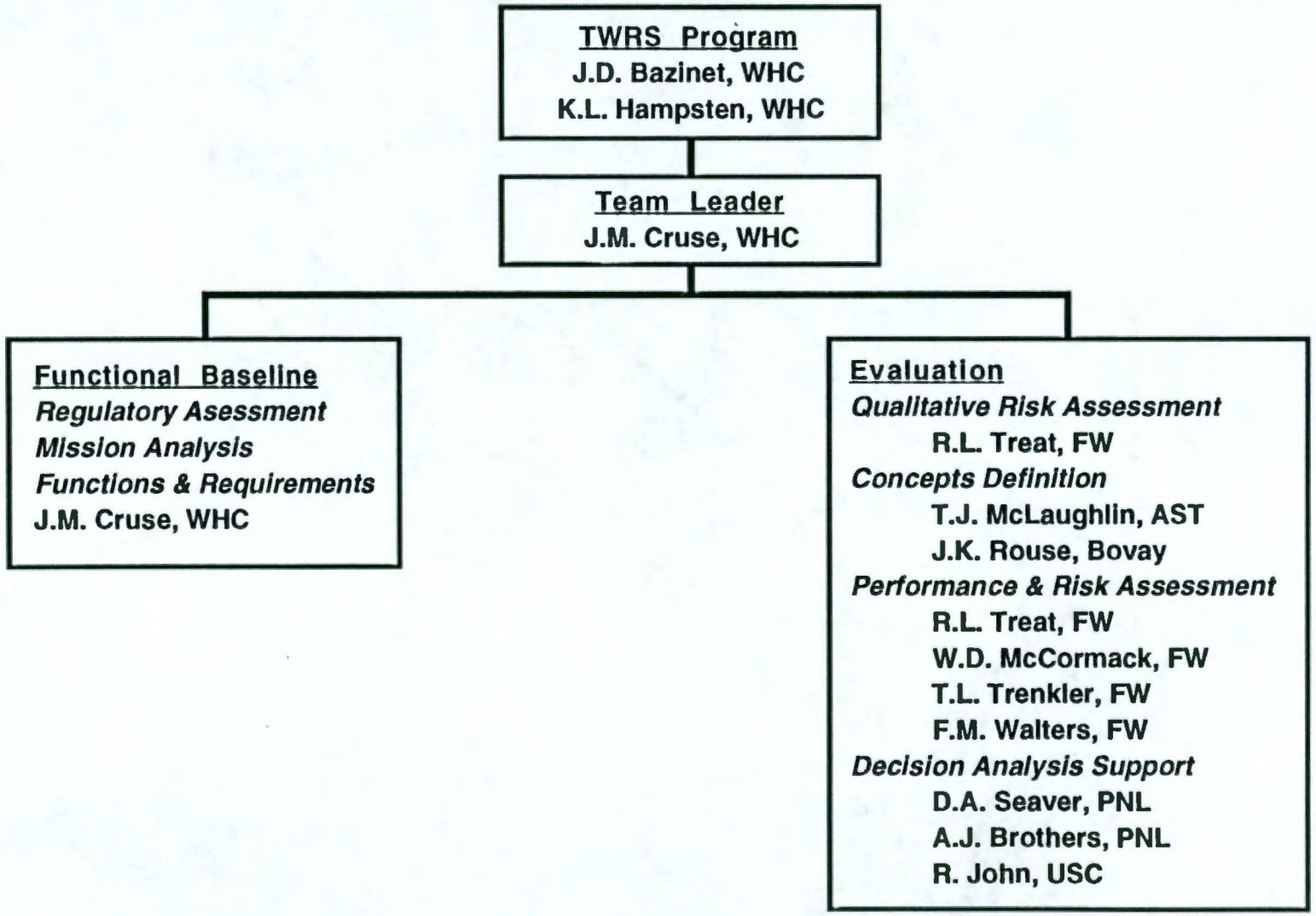

Figure 1. Subsurface Barrier Feasibility Team.

Figure 2. Hanford Site Map

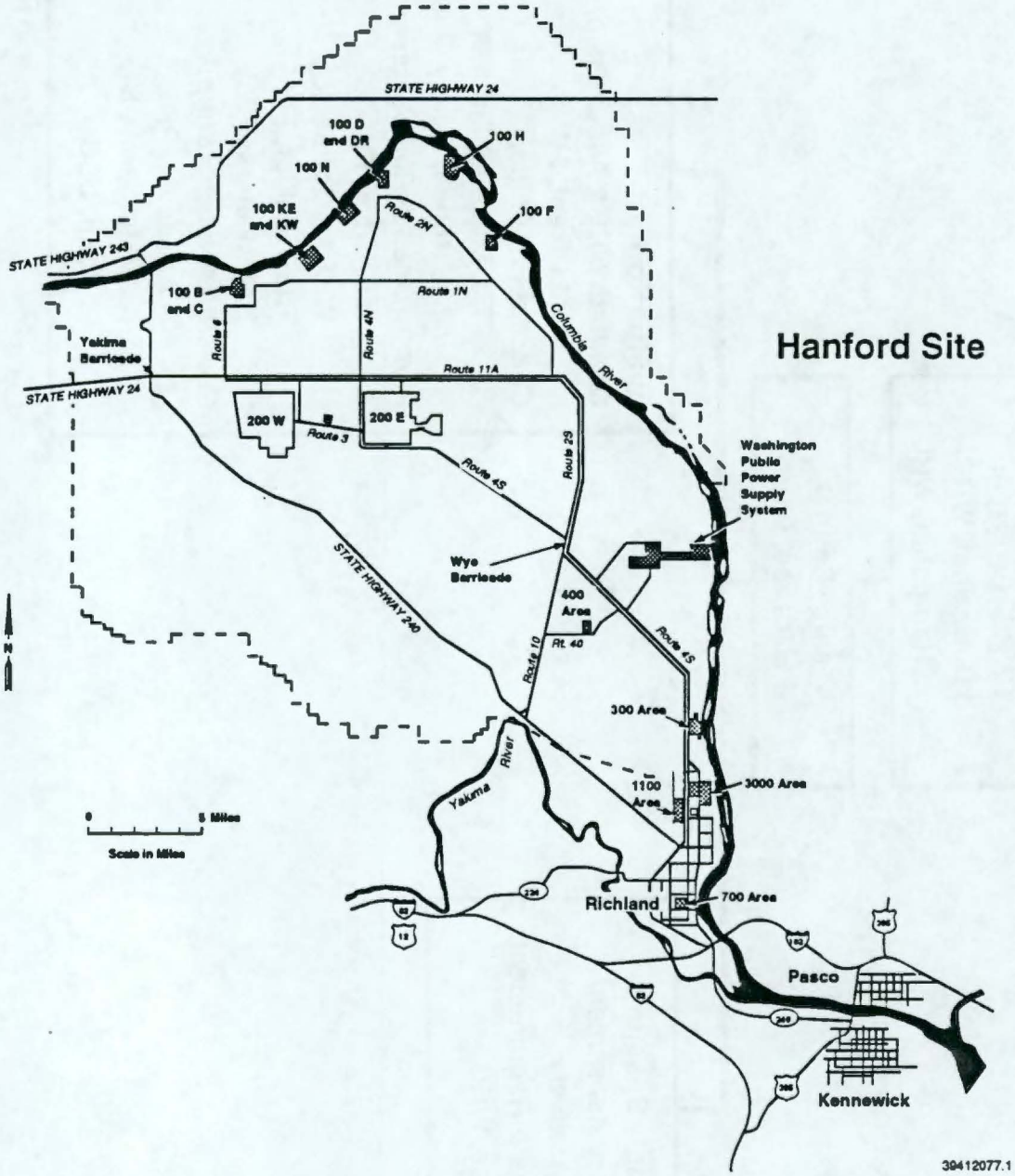

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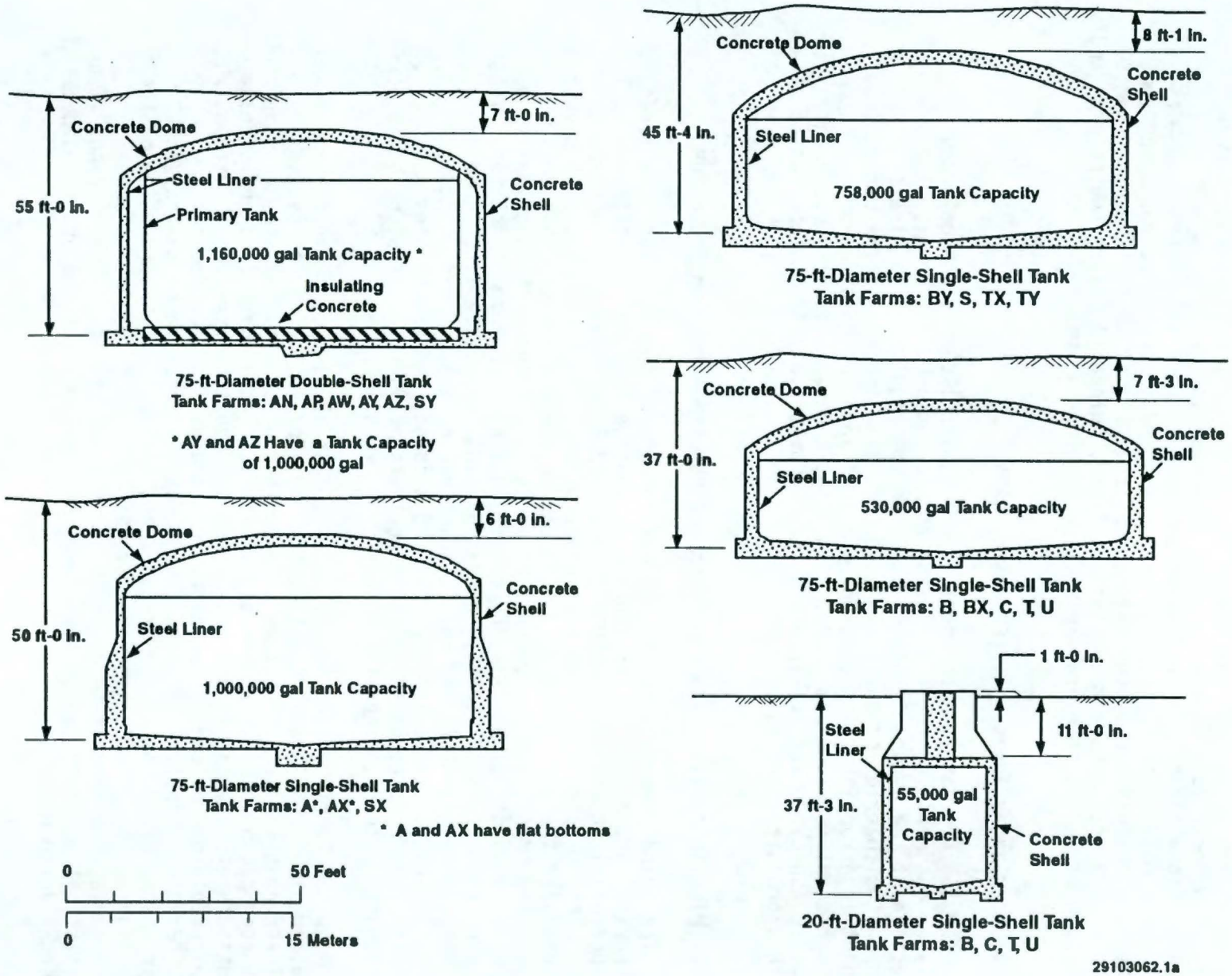
Figure 3. Hanford High-Level Waste Tanks



2.3 FUNCTIONAL BASELINE AND SSB SPECIFICATIONS

Prior to the feasibility evaluation of SSBs, several documents were written in order to establish a functional baseline and preliminary specifications for SSB demonstration at the Hanford Site. These documents included a mission analysis, a functions and requirements document, and the technical strategy and procurement specifications for SSBs. These documents, along with a preliminary regulatory analysis, helped to define the program and assist in providing an overall direction for further work.

2.3.1 Regulatory Assessment (Ed Smith, WHC)

The SSB Regulatory Assessment report (Smith 1994) is a regulatory analysis document for the use of SSBs at the Hanford tank farms. The objective of the document was to determine the regulatory requirements for SSBs so that barrier demonstration and potential implementation can proceed without interruption. The document provides an overview of major environmental requirements (NEPA, RCRA, CAA, and CWA) and includes a matrix of permits, approvals and requirements for the potential SSB implementation at the Hanford Site tank farms.

2.3.2 Mission Analysis and Functions and Requirements (Jon Cruse, WHC)

The primary purpose of the SSB Mission Analysis (Cruse and Lowe 1994) is to provide an analysis of the leakage mitigation mission applicable to past and potential future leakage from the Hanford Site's 149 high-level waste SSTs. This mission is a part of the overall mission of the WHC-TWRS Division to remediate the tank waste in a safe and acceptable manner. Systems engineering principles are being applied to this effort. Mission analysis supports early decision-making by clearly defining program objectives. This document identifies the initial conditions and acceptable final conditions, defines the programmatic and physical interfaces and sources of constraints, estimates the resources to carry out the mission, and establishes measures of success. The results of the mission analysis provide a consistent basis for subsequent systems engineering work.

The SSB Functions and Requirements (Cruse 1994) define the functions and requirements for SST leakage mitigation, by application of the systems engineering process. A function is a definition of what a system or subsystem must accomplish to meet the overall mission; a requirement is a qualitative or quantitative statement of how well a function must be performed. Within TWRS, requirements may be one of two types: constraints and performance requirements. Constraints are imposed upon the function by the external environment. Performance requirements are imposed upon the function by the TWRS program itself and therefore may be traded with respect to other performance requirements to optimize overall performance. The document also identifies the interfaces between functions, and between the program and the external environment.

The encompassing mission objectives for the SSB program are to prevent new leakage, confine the existing contamination from past leakage, remove soil contamination and also monitor and verify that these objectives are met.

2.3.3 SSB Strategy and Specifications (Russ Treat, FW)

The main purpose of the SSB strategy and specifications are to define the approach to be taken in conducting a field demonstration of SSBs and to provide the required supporting information to accompany a request for proposal for conducting an SSB demonstration.

The technical strategy includes three main components: (1) demonstrate three barrier types; (2) demonstrate two barrier configurations; and (3) demonstrate at a reduced scale. The three barrier types identified for demonstration are an injected chemical barrier, a freeze-wall barrier, and a desiccant barrier. The two barrier configurations are a close-coupled design for an individual tank and a stand-off design that would be used for an entire tank farm. While the preliminary field demonstrations are to be implemented at a reduced scale, the technologies should be capable of being expanded to a full-scale implementation.

The specifications are to be used to determine the various vendor and technology qualifications and will be used as a basis for selecting among the proposals received. The 22 specifications are categorized into three types: qualification, predemonstration, and demonstration qualifications.

Qualification specifications will be used to screen proposals at a first level to determine if vendors and/or technologies warrant further consideration. They are not meant to completely rule out any alternatives but will identify any fatal flaws that may exist. These specifications are:

- Proof of readiness
- Estimate of spoils generation
- Estimate of labor and costs
- Identification of materials and quantities
- Identification of operating space requirements
- Estimate of thermal/structural impacts on tanks
- Identification of leak-tightness verification method
- Identification of repair method
- Proof of ability to allow leak remediation
- Proof of 30-year leak-tightness potential.

Vendors and/or technologies that meet these specifications will be screened against predemonstration specifications that will support the decision as to whether or not to proceed with a field demonstration of barrier technologies. The predemonstration specifications include:

- Barrier must provide a basin below and around tanks
- Equipment must be suited to a 3-m- (10-ft-) diameter or larger tank
- Plans must include three or more joints between barrier segments
- Certify no RCRA/Dangerous wastes to be produced
- Plans must include measurement of thermal/structural stresses
- Must be able to meet waste retrieval schedules
- Plan must include pipes for leak monitoring
- Laboratory testing may be done to support design
- Quality assurance (QA) and health and safety plans must be provided
- Detailed demonstration plans/procedures must be provided.

The vendors and/or technologies that adequately address the above specifications will be further evaluated against the field demonstration specifications and will support the decision regarding a full-scale demonstration and application of the barriers. The demonstration specifications are:

- Implement all TWRS-approved plans
- Support leak testing
- Excavate in and around barrier to support barrier inspection
- Properly dispose of excavated barrier materials
- Prepare final report of field demonstration activities and results.

2.4 FEASIBILITY EVALUATION

The documents as discussed above were generated as part of the effort to establish a functional baseline to describe potential use of SSBs at the Hanford Tank Farms. The other major portion of the M-45-07A milestone involved the feasibility evaluation of SSB technologies.

The feasibility evaluation includes a qualitative risk assessment, a discussion of various barrier concepts, a performance and risk assessment, and a cost-sensitivity analysis. The qualitative risk assessment (Treat 1994) was

completed as a predecessor to the more detailed evaluation included in the feasibility study (Treat et al. 1994).

2.4.1 Qualitative Risk Assessment (Russ Treat, FW)

A qualitative risk assessment was performed to determine if SSBs have sufficient potential to reduce risk and thus warrant more detailed analyses and demonstration. Two key assumptions were made for the assessment:

- 99% of the waste is to be retrieved without an SSB in place
- 99.9% of the waste is to be retrieved with an SSB in place using tank acid treatment and/or soil flushing methods.

It was assumed that if an SSB were used in conjunction with waste retrieval, more aggressive waste retrieval methods, such as acid treatments, could be used both in the tanks and within the soil column.

The assessment considered 10 different risk factors. For the purpose of this qualitative approach, they were identified only as factors to be considered equally; therefore, they were not assigned a weighting factor to establish relative importance. The risk factors included:

- Public health risk (via the groundwater pathway)
- Ecological risk (groundwater migration to the river)
- Worker risk
- Technical risk (state of development and technical complexity)
- Compliance and liability risk (present and future regulatory requirements)
- Schedule risk
- Public perception risk
- Cultural resource damage risk (future land use)
- Natural resource over-consumption risk (electricity, manpower)
- Cost risk.

After evaluating the barrier-versus-no-barrier alternatives against each of these risk categories, it was concluded that the no-barrier case is more risky due to the impacts of the higher residual waste levels as was assumed initially. It was also concluded that continued evaluation and consideration of both alternatives appears to be prudent until more detailed analyses show clear-cut advantages of one alternative over the other.

2.4.2 SSB Concepts (Jim Rouse, Bovay)

Thirteen SSB concepts were presented for potential application to SSTs at the Hanford Site. These concepts can be further divided into 11 stand-off concepts (i.e., concepts intended to be installed some distance from several tanks or a tank farm) and two close-coupled concepts (i.e., installed in contact with individual tanks). Of the 13 SSB concepts, 10 are passive injected material barrier concepts. Both of the close-coupled concepts are included within this group. One active cryogenic barrier concept and two types of active desiccant barrier concepts were also presented as stand-off barrier designs. In addition to the 13 primary SSB concepts, 11 less viable concepts were presented in an abbreviated form.

The baseline deployment technologies for these integrated concepts are traditional vertical drilling, directional or slant drilling, and/or horizontal drilling. Other deployment technologies include vertically oriented 5-m- (15-ft-) diameter caissons installed in open areas between tanks or outside tank farms, coffered trenches constructed at the boundary of a tank farm, in situ mechanical mixing, slurry trenching, longwall mining, and various tunneling techniques.

Each SSB technology discussion included a technology description, a graphical depiction, current applications, and potential advantages and disadvantages. This information should be deemed subjective (especially the advantage/disadvantage section), and needs to be proven by field demonstrations if the SSB program proceeds. Most of the information was derived from vendors of the different SSB technologies. In a previous poll of private industry, more than 25 vendors expressed interest in demonstrating SSB concepts at the Hanford Site.

Injected-material SSB concepts include high-pressure jet grouting and low-pressure permeation grouting using portland cement and bentonite clay grouts, montan wax grouts, silica/silicate grouts, polymer grouts, and vertical sheet metal pilings with sealed joints. Current applications include foundation repairs, cofferdams, groundwater control, tunneling, dams, and pavement repairs.

Advantages include:

- The ability to flush the contained soil to remove contamination
- Set times and viscosities can be controlled
- Some of these concepts are extremely durable (i.e., polymer grouts)
- Most have extremely low permeabilities when mixed with Hanford soils.

The primary disadvantage of an injected materials barrier is that its integrity (i.e., lack of gaps or windows) cannot be confirmed without extensive excavation. Other disadvantages include:

- Incompatibility with leaking tank waste (i.e., montan wax and silica/silicate grouts)
- High material costs
- Some are hazardous to workers and/or the environment
- Some technologies produce large amounts of potentially contaminated spoils.

Only one cryogenic SSB concept was presented, although many other potential cryogenic technologies are available in private industry. In a cryogenic or ground freezing concept, the soil temperature is lowered below the freezing point of the soil liquid creating a solid, highly impermeable barrier. To freeze the soil, two primary cooling methods can be used. The first is a closed-loop system were cooling coils are driven into the soil to encompass the soil volume to be contained. A permanent refrigeration plant would be built and a refrigerant (e.g., calcium chloride brine or ammonia) circulated through the installed coils. If the barrier needs to be constructed in a short period of time, a fast freezing or open loop system could be used. In this system liquid nitrogen would be pumped directly into the soil through injection pipes. If soil moisture is too low to permit freezing, water injection may be required. Current applications include tunneling, mine shafts, stabilizing soils during excavation, and ground water control.

Advantages include:

- Extremely low permeabilities
- Barrier integrity can be confirmed through the freezing process and through temperature sensors
- The barrier can be removed
- Leakage can be confirmed through monitoring the refrigeration load after installation.

Disadvantages include:

- Potential damage to the SSTs through soil expansion during the freezing process
- Would require a permanent refrigeration plant to maintain the barrier
- Could require up to a year to construct.

Two desiccant SSB concepts were presented: soil drying and radio frequency soil heating. In soil drying, dry air is forced through the soil using injection and extraction wells, vaporizing the soil moisture in the process. In radio frequency soil heating, electrodes are placed around the area to be contained and using radio frequency energy, the soil is heated up to ~150 °C (300 °F) vaporizing soil moisture, which is removed through extraction wells. In both concepts, an area of dried soil surrounding a potential leak source (e.g., a tank farm) would be created, containing any leakage. Both concepts are based on oil and natural gas extraction technologies but have little or no current applications in private industry or waste management.

Advantages of desiccant barriers include:

- Proven base equipment technologies
- The barrier can be removed
- Leakage can be confirmed by monitoring the air moisture of the extraction wells.

Disadvantages include:

- Unproven waste management containment applications
- May not be able to withstand large releases
- Would not allow for soil flushing
- May take up to a year to construct.

Eleven "other" less viable SSB concepts were also presented to demonstrate that other concepts were investigated but were determined not to be as viable for SST applications at this time. In general, these less viable concepts generated large amounts of spoils and/or were deemed impractical for use around Hanford tanks or tank farms.

2.4.3 Performance and Risk Assessment (Russ Treat, Tina Trenkler, FW)

The objective of this section of the feasibility study is to make a first-approximation of the relative risk and net cost of the SSB and specific alternatives in support of the TPA milestone M-45-07A. The analyses are based upon life-cycle conditions in order to ensure comparable risks and costs among the following alternative concepts:

- Waste retrieval (traditional sluicing, robotic sluicing, mechanical retrieval, confined tank demolition and mining)
- Low-permeability SSBs (chemical, freeze-wall, desiccant)
- Soil flushing (traditional and vacuum techniques)

- Tank stabilization using void grouting
- Surface Barriers
- No SSB.

Using the above technologies and techniques, fourteen alternatives were developed for consideration. These alternatives ranged from no action to clean-closure with a close-coupled chemical barrier. The 14 alternatives are presented in Table 1.

Prior to the performance and risk assessments, the following key assumptions were defined:

- The tank farm consists of twelve 3,785,000-L (1,000,000-gal) tanks.
- Each tank contains an "average" composition of waste.
- K_d (ion-exchange distribution coefficient) = 0
- All constituents of concern (COCs) leach congruently with nitrate
- COCs are: ^{129}I, ^{238}U, ^{14}C, ^{99}Tc, NO_3, NO_2, TBP, and EDTA.

The risk analysis was performed via a two-step process. The first step was to estimate the inventories of COCs from various sources, then estimate the rates and duration of release to the vadose zone. The second step was to model the transport of the COCs through the vadose zone and the aquifer and then to estimate the potential human exposure and risk via the groundwater pathway only. This was completed by using the Multimedia Environmental Pollutant Assessment System (MEPAS) computer code developed by Battelle Pacific Northwest Laboratory. The code generated a relative cancer risk for each alternative using a maximally exposed individual (MEI) scenario. This scenario is illustrated in Figure 4. The risk results for each alternative are listed in Table 2 and shown in Figure 5.

The conclusions from the relative risk assessment were as follows:

- The nonretrieval alternatives (no action and surface barrier only) resulted in significantly (three orders of magnitude) greater cancer risks.
- The clean-closure alternatives resulted in the lowest cancer risks.

Among the various retrieval alternatives:

- Robotic sluicing results in the lowest cancer risk.
- Soil flushing appears to be an effective means of reducing cancer risk.
- Mechanical retrieval results in the highest cancer risks.
- The implementation of an SSB results in a cancer risk reduction of less than a factor of 0.3 compared to having no barrier.

Table 1. Alternatives Description.

Alternative		Subsurface Barrier Alternative	Retrieval Alternative	Flushing	Surface Barrier
1	No Action	None	None	None	None
2	Surface Barrier Only	None	None	None	Yes
3	Traditional Sluicing of Tank Waste	None	<=	No	Yes
4	Robotic Sluicing of Tank Waste	None	<=	No	Yes
5	Mechanical Retrieval of Tank Waste	None	<=	No	Yes
6	Close-Coupled Chemical Barrier	<=	Traditional Sluicing	Yes	Yes
7	Close-Coupled Chemical Barrier without Soil Flushing	<=	Traditional Sluicing	No	Yes
8	Modified Close-Coupled Barrier without Soil Flushing	<=	Traditional Sluicing	No	Yes
9	Box-Shaped Stand-Off Chemical Barrier	<=	Traditional Sluicing	Yes	Yes
10	V-Shaped Chemical Barrier	<=	Traditional Sluicing	Yes	Yes
11	V-Shaped Freeze Wall Barrier	<=	Traditional Sluicing	Yes	Yes
12	Circulating Air Barrier	<=	Traditional Sluicing	Yes	Yes
13	Clean-Closure without a Barrier	None	Traditional Sluicing & Mining	No	No
14	Clean-Closure with a Barrier	Close-Coupled Chemical	Traditional Sluicing & Mining	No	No

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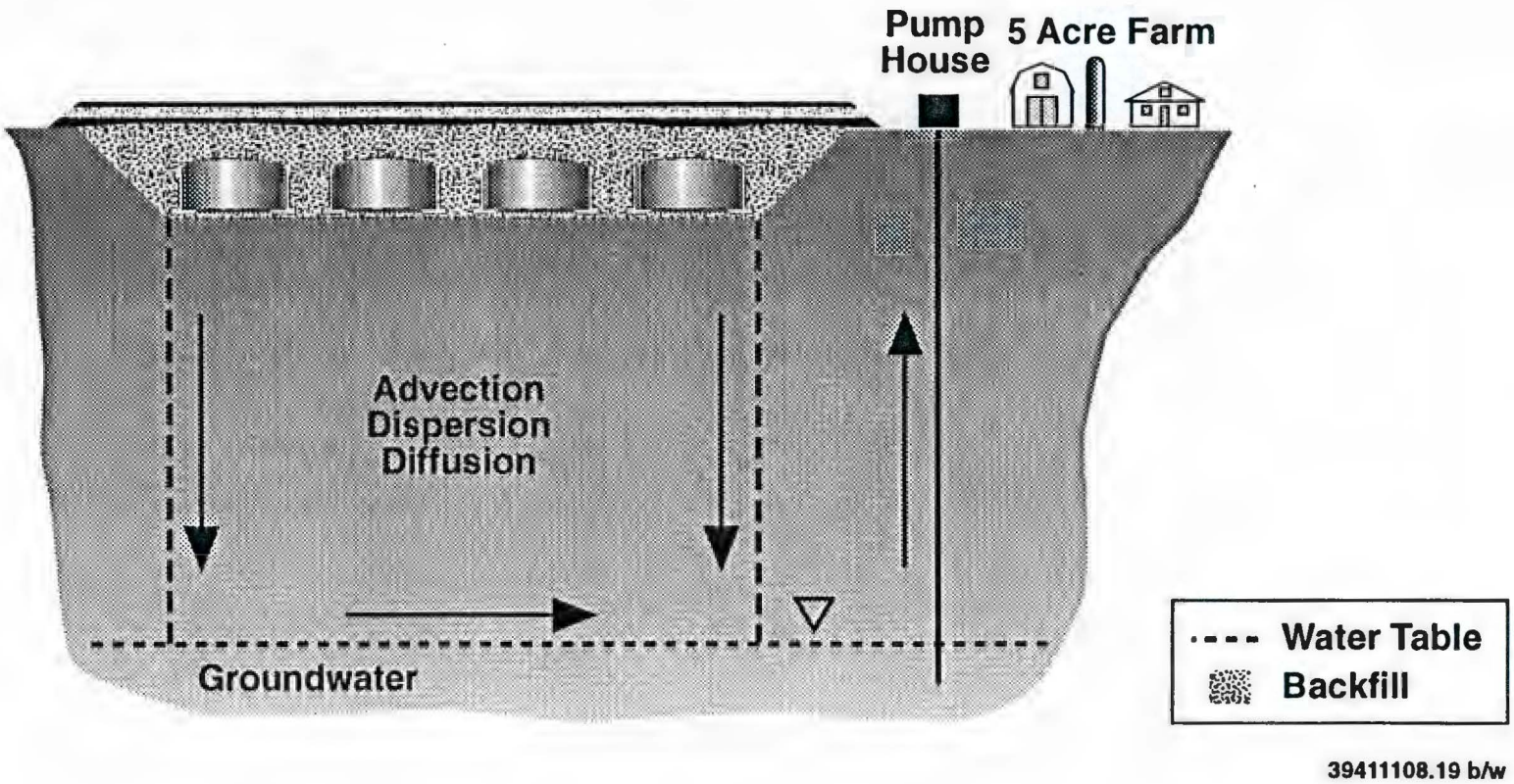

Figure 4. Conceptual Model for Groundwater Risk

Table 2. Alternatives Relative Risk and Total Net Present Worth.

Alternative		Relative Risk	TNPW ($M)
1	No Action	1.5×10^{-1}	0
2	Surface Barrier Only	3.7×10^{-4}	6
3	Traditional Sluicing of Tank Waste	1.1×10^{-5}	106
4	Robotic Sluicing of Tank Waste	2.5×10^{-6}	319
5	Mechanical Retrieval of Tank Waste	2.1×10^{-5}	243
6	Close-Coupled Chemical Barrier	5.2×10^{-6}	742
7	Close-Coupled Chemical Barrier without Soil Flushing	7.0×10^{-6}	378
8	Modified Close-Coupled Barrier without Soil Flushing	8.0×10^{-6}	264
9	Box-Shaped Stand-Off Chemical Barrier	4.9×10^{-6}	731
10	V-Shaped Chemical Barrier	4.9×10^{-6}	861
11	V-Shaped Freeze Wall Barrier	4.8×10^{-6}	941
12	Circulating Air Barrier	5.1×10^{-6}	705
13	Clean-Closure without a Barrier	1.1×10^{-7}	1,932
14	Clean-Closure with a Barrier	6.3×10^{-8}	1,781

TNPW = Total net present worth.

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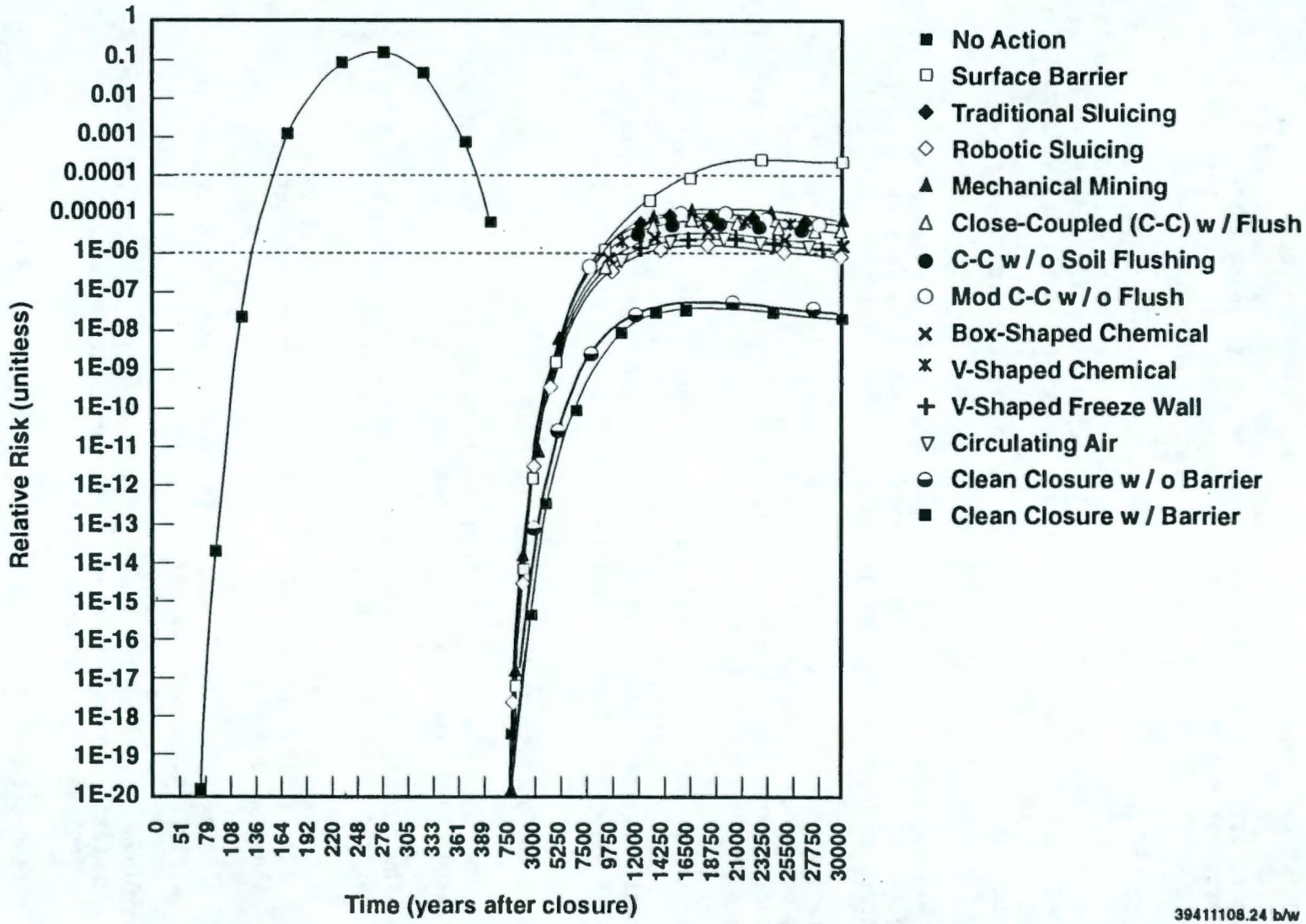

Figure 5. Summary of Carcinogenic Risks for All Alternatives

2.4.4 Cost-Benefit and Sensitivity Analyses (Russ Treat, FW)

A rough order-of-magnitude cost estimate for comparison purposes was also generated for each of the alternatives. The elements of cost included technological readiness, capital equipment requirements, operating and maintenance costs, and decontamination and decommissioning costs. An estimate of the total net present worth (TNPW) of each alternative was generated based upon these considerations and are summarized in Table 2.

Using the TNPW for each alternative, a cost-benefit analysis was performed to estimate the "bang for the buck." The "bang" was equated to the fractional risk reduction associated with each alternative and the "buck" was considered the estimated TNPW. An incremental cost-benefit analysis was also performed relative to the no-action alternative. The purpose of the incremental cost-benefit analysis was to quantify the reduction of risk achieved for each additional dollar spent.

It was suggested that the term "cost/relative risk assessment" may better describe the above analyses, since a relative reduction in risk is equivalent to an increased benefit, however insignificant the risk reduction may be.

A sensitivity analysis was performed to identify any significant impacts that may occur due to variability of the basic modeling assumptions, performance of the SSB alternatives, and assumptions made for the external parameters in the risk analysis.

The barrier performance parameters which were investigated during the sensitivity analysis included performance of soil flushing and the degree of contaminant penetration into the SSB. It was concluded that varying these performance parameters had little impact on the total risk and hazard indices.

2.4.5 Interim Conclusions (Russ Treat, FW)

The interim conclusions made from the risk assessments, the cost-benefit analyses, and the sensitivity analyses are summarized as follows:

- The "no action" and "use of a surface barrier only" alternatives appear to be not protective of the environment.
- Retrieval of tank waste by any retrieval method followed by stabilization and use of a surface barrier may adequately protect the environment.
- SSBs provide a small benefit in terms of reducing risk, but the cost-effectiveness is low.
- Clean-closure is the lowest risk alternative, but only if the contaminants are disposed offsite or contained with a highly effective onsite disposal system.
- Stand-off barriers offer no long-term benefit in terms of reducing risk unless soil flushing and/or excavation is used.

- SSBs are best suited to special-case applications only (e.g., complete tank failure).

The overall interim conclusion is that SSBs for large-scale application are not appropriate for SST waste retrieval.

2.5 QUESTIONS AND TECHNICAL ISSUES (ERT, Tom McLaughlin, AST)

Following presentation of the feasibility evaluation information, the ERT was given an opportunity to ask questions and/or raise any issues with the material presented thus far. The following are highlights from the discussion:

- It would be of interest to have some indication regarding the uncertainty in the estimates of past leakage volumes from the SSTs. (Grube)

- The evaluation should consider comparison of the risks associated with the tank residuals with other waste inventories at Hanford with the potential to migrate to groundwater. (Fort)

- Ongoing work involving further development of SSB concepts should consider the possibility of biological degradation of barrier materials. (Schneider)

- Relative changes in risk values cannot be directly related to benefit. It would be better to show the benefit in terms of more easily measured quantities; i.e., there should be no added value, in terms of benefit, for alternatives that reduce carcinogenic risk below 1E-06. (Moeller)

- Alternatives using subsurface barriers may show value in cases where large leaks would occur due to significant degradation of the tank containment boundaries. Ongoing work should assess this possibility. (Moeller)

2.6 DECISION PROCESS APPROACH (Russ Treat, FW)

Input from the ERT is needed regarding two possible decision analysis approaches that may serve to assist RL, Ecology, and EPA in making the decision per TPA Milestone M-45-07B. The first approach, included in the draft feasibility study, involves scoring the evaluated alternatives against a set of retained values. The second approach involves scoring the alternatives against a set of selected measures that represent the values of the stakeholders. There are advantages and disadvantages to both approaches. The values driven approach provides a straightforward means for verifying that all values are considered; however, some overlap may exist unless the process is conducted carefully. The measures driven approach avoids the potential for overlap in values, but introduces risk that some measures and subtle adjustments may not be counted.

2.7 DECISION VALUE STRUCTURE AND MEASURES (R. John, USC)

The decision process (measure-driven approach) includes the following primary steps:

- Define Frame
- Identify and Structure Values to be Addressed
- Develop Measures for the Values
- Evaluate Alternatives
- Make Decision.

Mr. John continued with a presentation of TWRS values and suggested methods for structuring the values to capture them with a set of appropriately weighted measures to yield a decision.

Thursday, August 11, 1994

2.8 REVIEW PREVIOUS DAY/OPENING REMARKS (Tom McLaughlin, AST)

The ERT was given the opportunity to comment on the previous day's material. The following are highlights from the discussion:

- The ongoing evaluation should consider selective application of SSB technology to situations that would warrant their use. In addition, when this evaluation is complete, the same approach should be used to evaluate SSBs for other applications. (Byrd)

- Cost should not be used as an indicator for operational risk, a more direct approach should be considered. (Schneider)

- EPA has made no serious consideration of using a horizontal SSB to confine waste; however, the Hanford tank farms are not characteristic of waste sites under consideration by EPA. (Grube)

- Selective application of SSB technologies should consider the impact of their use in potential high leakage cases. (Moeller)

2.9 ALTERNATIVES EVALUATION VS. TWRS VALUES (Russ Treat, FW)

The alternatives evaluation approach began by convening a panel of decision-makers capable of understanding the basic technical principles that underlie TWRS alternatives. The ERT served as this panel for the purpose of evaluating the various alternatives against the established TWRS values.

2.9.1 Means/Ends/Process Values

Table 4 shows a comprehensive list of stakeholder values derived from key guidance and decisional documents relevant to the TWRS Program. These documents included the future land use study (HFSUWG 1992) and the Hanford

Tank Waste Task Force Study. Other documents with value-relevant information include the Defense Waste Remediation Program redefinition study (Grygiel 1991), the TWRS Decision Analysis Report (Johnson et al. 1993), and Washington State Department of Ecology Policy Guidance for Hanford Environmental Restoration and Waste Management.

The values were grouped into "ends," "means," and "process" values. Ends Values are important in and by themselves (e.g., to protect health and safety). Means Values are important because each contributes to an end (e.g., "transport waste safely" is a means to protecting human health and safety). Process Values refer to the quality of the decision-making and management processes that surround the selection of technical alternatives, not to the evaluation of the technical alternatives themselves.

The next step in the decision analysis approach was to determine which values feature the potential for differentiation among the alternatives. Only those values that afford differentiation are useful in deciding which alternative(s) are best. The value "Protect Public Health and Safety," for example, can clearly be differentiated between alternatives by comparing which release fewer contaminants to the environment. The value "Ensure Fair and Open Processes" affords no ability for differentiation and among alternatives and was not included for purposes of decision-making. Upon review, the ERT decided to remove all of the process values and the means value "Clean up areas of high future use value" from consideration of the different alternatives. All other means and ends values were retained.

2.9.2 Scoring of Alternatives

Following the review of the alternatives (Table 1) and their assumptions, the next step was to evaluate the relative worth of each alternative to each retained value. For example, the alternative that would cause the most contamination of the Columbia River is worth the least to the "Protect the Columbia River" value. The process requires that a score of zero (0) be assigned to the worst alternative(s) and a score of one (1) to the best alternative(s). The remaining alternatives are scored between zero and one.

When real scales were used or when multiple criteria were used to evaluate the alternatives verses the subject value, the resulting scores were normalized for consistent scoring between values. The normalization equation is as follows with NS as "Normalized Score" and RS as "Raw Score":

$$NS_X = \frac{RS_X - RS_{Lowest}}{RS_{Highest} - RS_{Lowest}}$$

Table 3. TWRS Ends, Means, and Process Values.

Ends Values
• Protect public health • Protect worker health and safety • Protect the Columbia River • Protect the environment • (Clean up to the level necessary to) Enable future use alternatives to occur • Capture economic development opportunities locally • Protect rights of Native American Indians • Ensure compliance • Enhance technology development • Reduce cost.

Means Values
• Deal realistically and forcefully with groundwater contamination • Clean up areas of high future use value • "Get on with the cleanup" to achieve substantive progress in a timely manner • Use the central plateau wisely for waste management • Transport waste safely and be prepared • Do no harm during cleanup or with new development • Improve waste management • Use mature technologies.

Process Values
• Involve the public in future decisions about Hanford • Use a systems design approach that keeps end points in mind as intermediate decisions are made • Establish management practices that ensure accountability, efficiency, and allocation of funds to high priority items • Enhance public acceptance • Use open and fair processes • Increase efficiency.

In some instances, such as cost and risk evaluations, an inverse normalization equation was used:

$$Inverse\ NS_X = \frac{RS_{Highest} - RS_X}{RS_{Highest} - RS_{Lowest}}$$

Alternatives 1 and 2 (*No Action* and *Surface Barrier Only*) were not evaluated since they were deemed inappropriate solutions to the SSTs. The following sections summarize the scores given to each alternative relative to each value and the rational behind the scoring.

As part of the evaluation, the ERT discussed the relative risk (shown in Table 2) of the proposed alternatives. The discussion focussed on the acceptable risk range and its impact on the decision analysis scoring system. In the *Feasibility Study*, the target acceptable risk range following the use of the alternatives was set at 10^{-4} to 10^{-6} occurrences per lifetime. The study stated that the benefit of an alternative is valued at 100 times greater for a risk reduction from 10^{-2} to 10^{-8} than for a risk reduction of 10^{-2} to 10^{-6}. The ERT discussed the significance of this conclusion on the alternative scoring as compared to a methodology that would compare the actual value of the risk reduction as expressed in quantifiable terms such as person-REM.

The ERT discussed the validity of the suggested scoring algorithms used in the decision analysis process. Based on the discussions, some of the algorithms were modified. In addition, the ERT recommended that each scoring algorithm be researched and validated before the decision analysis process is repeated.

2.9.2.1 Protect Public Health and Safety. The ERT agreed that public health and safety may be degraded during the installation and operational periods for each alternative as a consequence of routine and accidental releases to the air and ground. Complex alternatives, especially those that involve extensive handling of solid waste or contaminated soil, would increase the risk of routine and accidental releases. As a result, the constructed scoring scale for the installation and operational period, as presented in the scoring guidance, was maintained as appropriate. The ERT also agreed that following closure of the tank farm, public health may also be degraded by the use of contaminated groundwater. However, the lowest relative risk acceptable for each alternative was changed to 10^{-6} to eliminate the perceived benefit of lowering risk below the perceived acceptable target of 10^{-6}. The weighting of the installation/operational and post-closure period was also changed to 40% and 60% respectively. Table 4 lists the scoring results.

Table 4. Protect Public Health and Safety Scoring.

Alt.	Installation/ Operational Period 40%	Post-Closure Period (60%)		Total Score	
		Relative Risk	Normalized	Raw	Normalized
3	1.00	1.1×10^{-5}	0.50	0.70	0.79
4	0.70	2.5×10^{-6}	0.93	0.84	1.00
5	0.50	2.1×10^{-5}	0.00	0.20	0.00
6	0.50	5.2×10^{-6}	0.79	0.67	0.75
7	0.60	7.0×10^{-6}	0.70	0.66	0.72
8	0.90	8.0×10^{-6}	0.65	0.75	0.87
9	0.50	4.9×10^{-6}	0.81	0.68	0.76
10	0.50	4.9×10^{-6}	0.81	0.68	0.76
11	0.50	4.8×10^{-6}	0.81	0.69	0.77
12	0.60	5.1×10^{-6}	0.80	0.72	0.81
13	0.10	1.0×10^{-6}	1.00	0.64	0.69
14	0.00	1.0×10^{-6}	1.00	0.60	0.63

2.9.2.2 Protect Worker Health and Safety. Risk to worker health and safety may result from routine and accidental exposure to ionizing radiation, hazardous chemicals, and mechanical, electrical, thermal, and other physical hazardous. The suggested scoring for these worker risks, based upon overall cost of each alternative, was modified by the ERT. Based on discussion, the ERT utilized the same logic as was used for the Public Health and Safety section (Section 2.9.2.1) during the operational period only, maintaining its constructed scale as shown in Table 5.

Table 5. Protect Worker Health and Safety Scoring.

Alternatives		Score
3	Traditional Sluicing of Tank Waste	1.00
4	Robotic Sluicing of Tank Waste	0.70
5	Mechanical Retrieval of Tank Waste	0.50
6	Close-Coupled Chemical Barrier	0.50
7	Close-Coupled Chemical Barrier without Soil Flushing	0.60
8	Modified Close-Coupled Barrier without Soil Flushing	0.90
9	Box-Shaped Stand-Off Chemical Barrier	0.50
10	V-Shaped Chemical Barrier	0.50
11	V-Shaped Freeze Wall Barrier	0.50
12	Circulating Air Barrier	0.60
13	Clean-Closure without a Barrier	0.10
14	Clean-Closure with a Barrier	0.00

2.9.2.3 Protect the Columbia River. The 8 to 12 mile distance from the tank farms to the Columbia River and the absence of any active streams on the Hanford Site obviates potential contamination of the river by surface pathways. Contaminants that leach from leaked tank wastes and migrate to the groundwater represent a potential source of future contamination of the Columbia River. However, the high flow rate of the Columbia River results in significant dilution of contaminant concentrations in the groundwater, resulting in reduced risk. Therefore, the ERT agreed with the suggested scoring for the protection of the Columbia River, and maintained the algorithm based on relative risk of the postclosure period. The ERT also chose to use the actual relative risks for Alternatives 13 and 14 instead of using the perceived acceptable target of 10^{-6}. The resulting scoring is listed in Table 6.

Table 6. Protect the Columbia River Scoring.

Alternatives	Post-Closure Period	
	Relative Risk	Normalized
3	1.1×10^{-5}	0.48
4	2.5×10^{-6}	0.88
5	2.1×10^{-5}	0.00
6	5.2×10^{-6}	0.75
7	7.0×10^{-6}	0.67
8	8.0×10^{-6}	0.62
9	4.9×10^{-6}	0.77
10	4.9×10^{-6}	0.77
11	4.8×10^{-6}	0.77
12	5.1×10^{-6}	0.76
13	1.1×10^{-7}	1.00
14	6.3×10^{-8}	1.00

2.9.2.4 Protect the Environment (Everything but the Columbia River). Risk to the environment may be affected by routine and accidental releases during installation and operations, and by releases to the groundwater following tank closure. The ERT agreed with this logic and the suggested scoring presented in the scoring guidance. However, the weighting of the installation/operational and postclosure periods was changed to 40% and 60%, respectively. Again, the ERT chose to use the actual relative risks for Alternatives 13 and 14 instead of using the perceived acceptable target of 10^{-6}. Table 7 lists the results of this scoring.

Table 7. Protect the Environment Scoring.

Alt.	Operational Period 40%	Post-Closure Period (60%)		Total	
		Relative Risk	Normalized	Raw	Normalized
3	1.00	1.1×10^{-5}	0.48	0.69	0.80
4	0.70	2.5×10^{-6}	0.88	0.81	1.00
5	0.50	2.1×10^{-5}	0.00	0.20	0.00
6	0.50	5.2×10^{-6}	0.75	0.65	0.74
7	0.60	7.0×10^{-6}	0.67	0.64	0.72
8	0.90	8.0×10^{-6}	0.62	0.73	0.87
9	0.50	4.9×10^{-6}	0.77	0.66	0.76
10	0.50	4.9×10^{-6}	0.77	0.66	0.76
11	0.50	4.8×10^{-6}	0.77	0.66	0.76
12	0.60	5.1×10^{-6}	0.76	0.70	0.81
13	0.10	1.1×10^{-7}	1.00	0.64	0.72
14	0.00	6.3×10^{-8}	1.00	0.60	0.66

2.9.2.5 (Clean up to the Level Necessary) Enable Future Use Alternatives to Occur. It was assumed that the clean-closure alternatives were able to unconditionally release the affected areas to unrestricted use. Therefore, these two alternatives received a score of one. The remaining alternatives would result in restricted areas since not all of the waste is removed and received a score of zero. It should be noted that all alternatives would require a landfill of approximately the same size to dispose of the removed tank waste. However, it was assumed by the ERT that with the clean-closure alternatives, the waste can be completely removed from the Hanford site, allowing unrestricted land use. The resulting scores are summarized in Table 8.

Table 8. Enable Future Use Alternatives to Occur Scoring.

	Alternatives	Score
3	Traditional Sluicing of Tank Waste	0.00
4	Robotic Sluicing of Tank Waste	0.00
5	Mechanical Retrieval of Tank Waste	0.00
6	Close-Coupled Chemical Barrier	0.00
7	Close-Coupled Chemical Barrier without Soil Flushing	0.00
8	Modified Close-Coupled Barrier without Soil Flushing	0.00
9	Box-Shaped Stand-Off Chemical Barrier	0.00
10	V-Shaped Chemical Barrier	0.00
11	V-Shaped Freeze Wall Barrier	0.00
12	Circulating Air Barrier	0.00
13	Clean-Closure without a Barrier	1.00
14	Clean-Closure with a Barrier	1.00

2.9.2.6 Capture Economic Development Opportunities Locally. The ERT agreed that the use of a higher cost alternative would provide greater opportunity for local economic development and was valid for the purposes of this analysis. The scoring algorithm using the TNPW of each alternative, as was presented in the scoring guidance, was maintained. Table 9 summarizes the scoring results.

Table 9. Capture Economic Development Opportunities Locally Scoring.

Alternatives		TNPW	Normalized Score
3	Traditional Sluicing of Tank Waste	106	0.00
4	Robotic Sluicing of Tank Waste	319	0.12
5	Mechanical Retrieval of Tank Waste	243	0.08
6	Close-Coupled Chemical Barrier	742	0.35
7	Close-Coupled Chemical Barrier without Soil Flushing	378	0.15
8	Modified Close-Coupled Barrier without Soil Flushing	264	0.09
9	Box-Shaped Stand-Off Chemical Barrier	731	0.34
10	V-Shaped Chemical Barrier	861	0.41
11	V-Shaped Freeze Wall Barrier	941	0.46
12	Circulating Air Barrier	705	0.33
13	Clean-Closure without a Barrier	1,932	1.00
14	Clean-Closure with a Barrier	1,781	0.92

2.9.2.7 Protect Rights of Native Americans. During the discussion, the ERT moved to define term "rights" as the "interests" of the Native Americans. The ERT modified the suggested scoring guidance to use the same logic and scoring as was used for the "enabling future use alternatives to occur" value. Therefore, the clean-closure alternatives received a score of one. The remaining alternatives would result in restricted areas since not all of the waste is removed and received a score of zero. The resulting scores are summarized in Table 10.

Table 10. Protect Rights of Native Americans Scoring.

	Alternatives	Score
3	Traditional Sluicing of Tank Waste	0.00
4	Robotic Sluicing of Tank Waste	0.00
5	Mechanical Retrieval of Tank Waste	0.00
6	Close-Coupled Chemical Barrier	0.00
7	Close-Coupled Chemical Barrier without Soil Flushing	0.00
8	Modified Close-Coupled Barrier without Soil Flushing	0.00
9	Box-Shaped Stand-Off Chemical Barrier	0.00
10	V-Shaped Chemical Barrier	0.00
11	V-Shaped Freeze Wall Barrier	0.00
12	Circulating Air Barrier	0.00
13	Clean-Closure without a Barrier	1.00
14	Clean-Closure with a Barrier	1.00

2.9.2.8 Ensure Compliance. The ERT modified the suggested scoring guidance of using relative risk. The ERT considered compliance as exclusively maintaining schedules and meeting milestones. The ERT assumed that regulatory compliance was a given for all alternatives. The ERT considered each alternative for its estimated complexity and need for development. The least complex and most refined alternative (traditional sluicing) received a score of one and the alternative deemed most complex (clean-closure with a barrier) received a zero. Using best judgment, scores were then assigned by the ERT to the remaining alternatives as follows: robotic and mechanical sluicing both received a score of 0.4; close-coupled barrier received 0.2; clean-closure without a barrier received 0.1; and remaining SSB alternatives received a score of 0.3. The resulting scores are summarized in Table 11.

Table 11. Ensure Compliance Scoring

Alternatives		Score
3	Traditional Sluicing of Tank Waste	1.00
4	Robotic Sluicing of Tank Waste	0.40
5	Mechanical Retrieval of Tank Waste	0.40
6	Close-Coupled Chemical Barrier	0.20
7	Close-Coupled Chemical Barrier without Soil Flushing	0.30
8	Modified Close-Coupled Barrier without Soil Flushing	0.30
9	Box-Shaped Stand-Off Chemical Barrier	0.30
10	V-Shaped Chemical Barrier	0.30
11	V-Shaped Freeze Wall Barrier	0.30
12	Circulating Air Barrier	0.30
13	Clean-Closure without a Barrier	0.10
14	Clean-Closure with a Barrier	0.00

2.9.2.9 Enhance Technology Development. The scoring algorithm as presented in the scoring guidance was modified. Instead, the ERT evaluated the alternatives using best engineering judgment to determine the level of technology development needed for each alternative. Traditional sluicing received a score of zero because it was considered an off-the-shelf technology. The alternatives using robotics were scored 1.0 since robotics were considered to be a technology that had other uses throughout society and the development of those alternatives would have many application spin-offs. The remaining alterative scorings are listed in Table 12.

Table 12. Enhance Technology Development Scoring.

Alternatives		Score
3	Traditional Sluicing of Tank Waste	0.00
4	Robotic Sluicing of Tank Waste	1.00
5	Mechanical Retrieval of Tank Waste	1.00
6	Close-Coupled Chemical Barrier	0.60
7	Close-Coupled Chemical Barrier without Soil Flushing	0.50
8	Modified Close-Coupled Barrier without Soil Flushing	0.40
9	Box-Shaped Stand-Off Chemical Barrier	0.80
10	V-Shaped Chemical Barrier	0.90
11	V-Shaped Freeze Wall Barrier	0.70
12	Circulating Air Barrier	0.80
13	Clean-Closure without a Barrier	0.30
14	Clean-Closure with a Barrier	0.50

2.9.2.10 Reduce Cost. The ERT interpreted "Reduce Cost" as getting the most "bang for the buck." Therefore, the use of cost effectiveness presented in the scoring guidance was maintained for the scoring of the alternatives. Cost effectiveness was defined as the risk reduction achieved by each alternative divided by the cost of that alternative. Again, the lowest relative risk acceptable for each alternative was changed to 10^{-6} to eliminate the perceived benefit of lowering risk below the perceived acceptable target of 10^{-6}. The resulting scoring values are summarized in Table 13.

Table 13. Reduce Cost Scoring.

Alt.	Relative Risk		TNPW	Cost Effectiveness (Risk/TNPW)	Normalized Total
	Risk	Normalized			
3	1.1×10^{-5}	0.50	106	0.0047	1.00
4	2.5×10^{-6}	0.93	319	0.0029	0.61
5	2.1×10^{-5}	0.00	243	0.0000	0.00
6	5.2×10^{-6}	0.79	742	0.0011	0.23
7	7.0×10^{-6}	0.70	378	0.0019	0.39
8	8.0×10^{-6}	0.65	264	0.0025	0.52
9	4.9×10^{-6}	0.81	731	0.0011	0.23
10	4.9×10^{-6}	0.81	861	0.0009	0.20
11	4.8×10^{-6}	0.81	941	0.0009	0.18
12	5.1×10^{-6}	0.80	705	0.0011	0.24
13	1.0×10^{-6}	1.00	1,932	0.0005	0.11
14	1.0×10^{-6}	1.00	1,781	0.0006	0.12

2.9.2.11 Deal Realistically and Forcefully with Groundwater Contamination. This value has two potentially competing components, dealing "realistically" and dealing "forcefully." Dealing realistically implies a bias toward the lowest cost and the most cost effective alternatives. Dealing forcefully implies a bias toward the lowest risk alternatives. The ERT agreed with this logic and with the algorithm presented Table 14. The ERT also accepted the suggested weightings for the three evaluation criteria. Again, the lowest relative risk acceptable for each alternative was changed to 10^{-6} to eliminate the perceived benefit of lowering risk below the perceived acceptable target of 10^{-6}.

Table 14. Deal Realistically with Groundwater Contamination Scoring.

Alt	Cost (20%)		Cost Effectiveness (30%)		Risk (50%)		Total	
	TNPW	Norm.	Table 10	Norm.	Relative	Norm.	Raw Score	Norm
3	106	1.00	0.0047	1.00	1.1×10^{-5}	0.50	0.75	0.88
4	319	0.88	0.0029	0.61	2.5×10^{-6}	0.93	0.82	1.00
5	243	0.92	0.0000	0.00	2.1×10^{-5}	0.00	0.18	0.00
6	742	0.65	0.0011	0.23	5.2×10^{-6}	0.79	0.59	0.64
7	378	0.85	0.0019	0.39	7.0×10^{-6}	0.70	0.64	0.71
8	264	0.91	0.0025	0.52	8.0×10^{-6}	0.65	0.66	0.75
9	731	0.66	0.0011	0.23	4.9×10^{-6}	0.81	0.60	0.66
10	861	0.59	0.0009	0.20	4.9×10^{-6}	0.81	0.58	0.62
11	941	0.54	0.0009	0.18	4.8×10^{-6}	0.81	0.57	0.60
12	705	0.67	0.0011	0.24	5.1×10^{-6}	0.80	0.60	0.66
13	1,932	0.00	0.0005	0.11	1.0×10^{-6}	1.00	0.53	0.54
14	1,781	0.08	0.0006	0.12	1.0×10^{-6}	1.00	0.55	0.58

2.9.2.12 Get on with Cleanup to Achieve Substantive Progress in a Timely Manner. The ERT agreed that each of the alternatives, except for Alternative 3 (traditional sluicing), would require significant development of SSB, soil flushing, and waste retrieval technologies. The time to complete technology development could delay initiation of tank cleanup. After traditional sluicing, the robotics alternatives were considered to be more technically mature than the remaining alternatives. Therefore, the ERT accepted the suggested scoring algorithm of using alternative cost and complexity as indicators of the degree of technology development that may be required before implementation. The suggested constructed scale for each alternative is listed in Table 15.

Table 15. Get on with Cleanup Scoring

Alternatives		Score
3	Traditional Sluicing of Tank Waste	1.00
4	Robotic Sluicing of Tank Waste	0.80
5	Mechanical Retrieval of Tank Waste	0.80
6	Close-Coupled Chemical Barrier	0.10
7	Close-Coupled Chemical Barrier without Soil Flushing	0.20
8	Modified Close-Coupled Barrier without Soil Flushing	0.30
9	Box-Shaped Stand-Off Chemical Barrier	0.20
10	V-Shaped Chemical Barrier	0.20
11	V-Shaped Freeze Wall Barrier	0.20
12	Circulating Air Barrier	0.20
13	Clean-Closure without a Barrier	0.00
14	Clean-Closure with a Barrier	0.00

2.9.2.13 Use the Central Plateau Wisely for Waste Management. It was assumed that the clean-closure alternatives were able to unconditionally release the affected areas for unrestricted use. Therefore, these two alternatives received a score of one. The remaining alternatives would result in restricted areas, therefore, received a score of zero. The resulting scoring is shown in Table 16.

Table 16. Use the Central Plateau Wisely for Waste Management Scoring.

Alternatives		Score
3	Traditional Sluicing of Tank Waste	0.00
4	Robotic Sluicing of Tank Waste	0.00
5	Mechanical Retrieval of Tank Waste	0.00
6	Close-Coupled Chemical Barrier	0.00
7	Close-Coupled Chemical Barrier without Soil Flushing	0.00
8	Modified Close-Coupled Barrier without Soil Flushing	0.00
9	Box-Shaped Stand-Off Chemical Barrier	0.00
10	V-Shaped Chemical Barrier	0.00
11	V-Shaped Freeze Wall Barrier	0.00
12	Circulating Air Barrier	0.00
13	Clean-Closure without a Barrier	1.00
14	Clean-Closure with a Barrier	1.00

2.9.2.14 Transport Waste Safely and Be Prepared. The ERT agreed with the suggested scoring. The clean-closure alternatives (13 and 14) would require a significant level of packaging of high- and low-level waste with subsequent transport to a soil washing facility. The washed soil and debris would then be repackaged and transported to a mixed waste landfill. Overpacks and containers used to transport soil and debris to the soil washing facility would be transported back to the tank farm for reuse. There are no significant differences in transportation requirements among other alternatives. Therefore, both clean-closure alternatives received a score of zero and all other alternatives received a score of one. These results are summarized in Table 17.

Table 17. Transport Waste Safely and Be Prepared Scoring.

Alternatives		Score
3	Traditional Sluicing of Tank Waste	1.00
4	Robotic Sluicing of Tank Waste	1.00
5	Mechanical Retrieval of Tank Waste	1.00
6	Close-Coupled Chemical Barrier	1.00
7	Close-Coupled Chemical Barrier without Soil Flushing	1.00
8	Modified Close-Coupled Barrier without Soil Flushing	1.00
9	Box-Shaped Stand-Off Chemical Barrier	1.00
10	V-Shaped Chemical Barrier	1.00
11	V-Shaped Freeze Wall Barrier	1.00
12	Circulating Air Barrier	1.00
13	Clean-Closure without a Barrier	0.00
14	Clean-Closure with a Barrier	0.00

2.9.2.15 Do No Harm During Cleanup or with New Development. The ERT modified the suggested scoring methodology and decided to use the average of the "Protect Public Health and Safety" and the "Protect Worker Health and Safety" scoring. The results for each alternative are shown in Table 18.

Table 18. Do No Harm Scoring.

Alt.	Protect Public H&S (50%)	Protect Worker H&S (50%)	Total	
			Raw	Normalized
3	0.79	1.00	0.89	0.91
4	1.00	0.90	0.95	1.00
5	0.00	0.80	0.40	0.13
6	0.75	0.70	0.72	0.64
7	0.72	0.50	0.61	0.47
8	0.87	0.50	0.68	0.58
9	0.76	0.70	0.73	0.65
10	0.76	0.70	0.73	0.65
11	0.77	0.70	0.73	0.66
12	0.81	0.50	0.66	0.54
13	0.69	0.00	0.35	0.05
14	0.63	0.00	0.31	0.00

2.9.2.16 Improve Waste Management. The ERT agreed with the suggested scoring methodology. Mechanical retrieval (Alternative 5) would prevent the migration of new leakage from tanks during retrieval operations. Close-coupled chemical barrier with flushing (Alternative 6) would clean-up previous leaks before sluicing and then restrict leakage from the tank to penetration into the close-coupled barrier. Close-coupled barrier alternatives without flushing (Alternatives 7, 8, & 14) would restrict new leakage, but would not clean up old leakage. Stand-off barrier alternatives (Alternatives 9 through 11) would not affect new or old leakage but would allow cleanup of soil after sluicing operations were completed. The continuous air barrier (Alternative 12) would not restrict the quantity of leakage but would limit its depth. The clean-closure alternatives would clean up present waste sites, but would also create new ones with lower hazards. Traditional sluicing alternative (Alternative 3) would allow the highest level of leakage without cleanup. The agreed scores are listed in Table 19.

Table 19. Improve Waste Management Scoring.

Alternatives		Score
3	Traditional Sluicing of Tank Waste	0.00
4	Robotic Sluicing of Tank Waste	0.60
5	Mechanical Retrieval of Tank Waste	0.60
6	Close-Coupled Chemical Barrier	1.00
7	Close-Coupled Chemical Barrier without Soil Flushing	0.50
8	Modified Close-Coupled Barrier without Soil Flushing	0.50
9	Box-Shaped Stand-Off Chemical Barrier	0.70
10	V-Shaped Chemical Barrier	0.70
11	V-Shaped Freeze Wall Barrier	0.70
12	Circulating Air Barrier	0.70
13	Clean-Closure without a Barrier	0.80
14	Clean-Closure with a Barrier	0.90

2.9.2.17 Use Mature Technologies. The ERT modified the suggested scoring rational and developed their own based on engineering experience and knowledge of the technologies associated with each alterative. Traditional sluicing was considered a proven and demonstrated technology and scored a 1.0. Robotics and clean-closure technologies were ranked second and third highest. These scores are listed in Table 20.

Table 20. Use Mature Technologies Scoring.

Alternatives		Score
3	Traditional Sluicing of Tank Waste	1.00
4	Robotic Sluicing of Tank Waste	0.80
5	Mechanical Retrieval of Tank Waste	0.70
6	Close-Coupled Chemical Barrier	0.00
7	Close-Coupled Chemical Barrier without Soil Flushing	0.20
8	Modified Close-Coupled Barrier without Soil Flushing	0.30
9	Box-Shaped Stand-Off Chemical Barrier	0.10
10	V-Shaped Chemical Barrier	0.20
11	V-Shaped Freeze Wall Barrier	0.60
12	Circulating Air Barrier	0.30
13	Clean-Closure without a Barrier	0.70
14	Clean-Closure with a Barrier	0.10

2.9.3 Ranking of Values

The next step involved the ranking of the retained values in order of importance to the ERT. The ranking was conducted without any consideration of the alternatives. A discussion of the meaning of each value was held before the ranking to ensure that each expert would evaluate each value on the same bases. Each expert first ranked the Ends Values and then ranked the Means Values into an overall ranking of all values. This process was followed by tabulating and averaging the results of the individual rankings.

The ERT then discussed the variability in the value rankings. Individual experts were encouraged to change their rankings when discussions evoked improved understanding. If separate rankings occurred, they were merged following discussion of the importance of the individual categories. For example, the importance of ends values versus the means values for achieving the ends was discussed. The merging process was conducted independently by each expert followed by tabulation of results. Discussion followed until a consensus was reached on a combined ranking of values. The results are shown in Table 21 with the highest ranked value listed first.

2.9.4 Informal Decision Process

The process to score alternatives against retained values and to rank the retained values marked completion of the ERT's formal scope in providing input to the proposed decision analysis process. However, the ERT continued informally with completion of the process as though they were making such a decision. This included development of weightings, discounts, and range factors and developing final results. In addition, after the results were developed, the ERT evaluated the results and the process.

The ERT generally felt that the decision analysis process was developed on a sound basis. However, because of the time constraints associated with the meeting, the weights and correction factors developed in the informal session should be considered only as an example of how the process could be conducted and should not be used as input to an actual decision process. The results of the informal sessions can be found in Lindberg and Rouse, 1994.

Table 21. Ranked Values.

1	Protect Public Health and Safety
2	Protect Worker Health and Safety
3	Protect the Environment
4	Protect the Columbia River
5	*Do no harm during cleanup or with new development.*
6	Ensure Compliance
7	*"Get on with the cleanup" to achieve substantive progress in a timely manner.*
8	Reduce Cost
9	*Deal realistically and forcefully with groundwater contamination.*
10	Enhance Technology Development
11	*Use Mature Technologies.*
12	Protect Rights of Native American Indians
13	Capture Economic Development Opportunities Locally
14	*Improve Waste Management*
15	*Transport waste safely and be prepared.*
16	*Use the central plateau wisely for waste management.*
17	(Clean up to the level necessary to) Enable future use alternatives to occur.

Italic Fonts are Means Values
Non-Italic Fonts are Ends Values

Friday, August 12, 1994

2.10 SUMMARY OF PREVIOUS DAY/OPENING REMARKS (McLaughlin)

The group discussed the information of the previous day. The ERT had no additional comments or issues at this time.

2.11 ALTERNATIVES EVALUATION VS. MEASURES (John)

Mr. John continued to present the alternative approach (measures driven) for decision analysis. This information was generally received as input to the proposed decision process. The ERT recommended some of the items should be evaluated for incorporation in the final process.

2.12 MANAGEMENT BRIEFING/ERT FINDINGS (Byrd)

The following information documents the conclusions and recommendations which were presented by the ERT in the closing portion of the meeting.

2.12.1 External Review Team Summary

The ERT panel provided varied backgrounds and levels of experience at Hanford. This was considered a bonus for the purposes of this meeting. It established a dialogue between the ERT and the study team which was considered extremely beneficial to the objectives of the meeting.

The general opinion was that the feasibility study, mission analysis, and functions and requirements documents were easy to read and presented the information at a level appropriate for their purposes. There were some comments directed at enhancement and improvement of the documents but the overall feedback was positive.

The presentations given on the first day of the meeting were considered to be an outstanding overview of the information and background required for the activities during the remainder of the meeting. They stimulated discussion among the experts on SSBs and UST issues that proved to be beneficial during subsequent activities.

2.12.2 Alternative Evaluations

The list of alternatives evaluated was considered to be an adequate representation of potential alternatives. None of alternatives could be identified as a base technology nor could an omission be identified.

With the selection of values, the lists were reviewed by the ERT. As a result of continued discussion, the values regarding Native American Rights and the Local Economy were reinstated as viable values. These values were considered to be of vital interest to the stakeholders, and removing them from the list of values may result in unnecessary problems during the negotiations

with the stakeholders. It was also felt that "Protect the Columbia River" was already covered in "Protect the Environment"; however, both were retained due to high interest with the stakeholders on the Columbia River issues.

As the ERT worked through the Ends, Means, and Process Values, it was found that much of the scoring relies upon subjective and perceptive means. As a result, different groups of evaluators could potentially arrive at different conclusions. It was also concluded that arriving at natural scales for each value as with the measures driven approach could be extremely costly due to the data collection requirements for the process. A combination of the two processes, however, could result in an objective evaluation. The value-driven approach could be used to identify alternatives that may pass or fail an initial screening and identify those values that could be considered discriminators among the alternatives. The discriminators identified would then need to be quantified by a measure-driven approach that develops a natural scale for scoring. The application of both evaluations in such a manner may prevent different conclusions from being reached by different groups.

2.12.3 Evaluation of the Two Decision Analysis Methodologies

Based on the presentation received and the associated discussions, the ERT concluded that each decision analysis methodology had benefits. The first methodology, values driven, would be most appropriate to (1) screen alternatives and eliminate those considerably less favorable and (2) determine the parameters that appear to have the most impact on the decision process. The second methodology, measures driven, would require additional data and information to be collected and would provide a more rigorous and traditional cost-benefit evaluation of the alternatives. The limiting factor in the use of the methodology is the apparent costliness of the required data collection; the use of the first methodology would minimize the required data collection needs. The ERT stated that the decision analysis methods need further evaluation and development.

2.12.4 Maturity of SSB Alternatives

Technical issues were revisited several times throughout the meeting proceedings such as determining worker safety or the historic documentation available. Identifying the technical maturity is essential to determine the degree of development required.

A major issue identified was that in-depth literature reviews and interviews are required in order to ensure a complete knowledge of SSB technology. It was felt that the current frontiers are identified but there is a need to be well informed and well rounded in all facets past and present relating to the technology.

The application of SSBs to waste management is probably less than 20 years old for the containment of chemical waste. It is considered to be a fairly young technology but may be able to mature rapidly. Certain aspects need to be considered and include:

- Barrier performance: will it provide required containment?
- Installability: geology, space requirements, impacts to schedule and worker health and safety, barrier geometry
- Monitoring to determine performance of a barrier
- Length of time of performance required.

The above aspects should be thoroughly addressed in the specifications and requirements for SSB demonstrations.

2.12.5 SSB Challenges

There are three primary challenges to a successful SSB program: construction of a continuous barrier, confirmation of barrier continuity (windows and gaps), and detection of leaks during operation. The hydrogeologic setting at the Hanford site is characterized by arid, mostly coarse-grained, sediments. Local regions of higher moisture content occur in the finer-grained sediments. These finer-grained regions may constitute preferential flow paths for contaminants. Placement of a continuous SSB, assurance of the barriers integrity, and detection of leaks are all difficult under these conditions. For example, a chemical grout SSB would probably fill large pores but may leave smaller pores in finer sediments open; the consequence could be a leak during soil flushing.

The challenges to successful barrier construction probably can be overcome with further development; however, significant improvements in geophysical characterization methods probably will be needed to confirm barrier integrity at the Hanford Site. Use of natural or injected soil gas tracers also may be useful in confirming barrier continuity as well as in detecting leaks. Recovering solutions that leak during soil flushing will be nearly impossible in the hydrogeologic setting at Hanford; therefore, confirmation of barrier integrity is of primary importance.

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