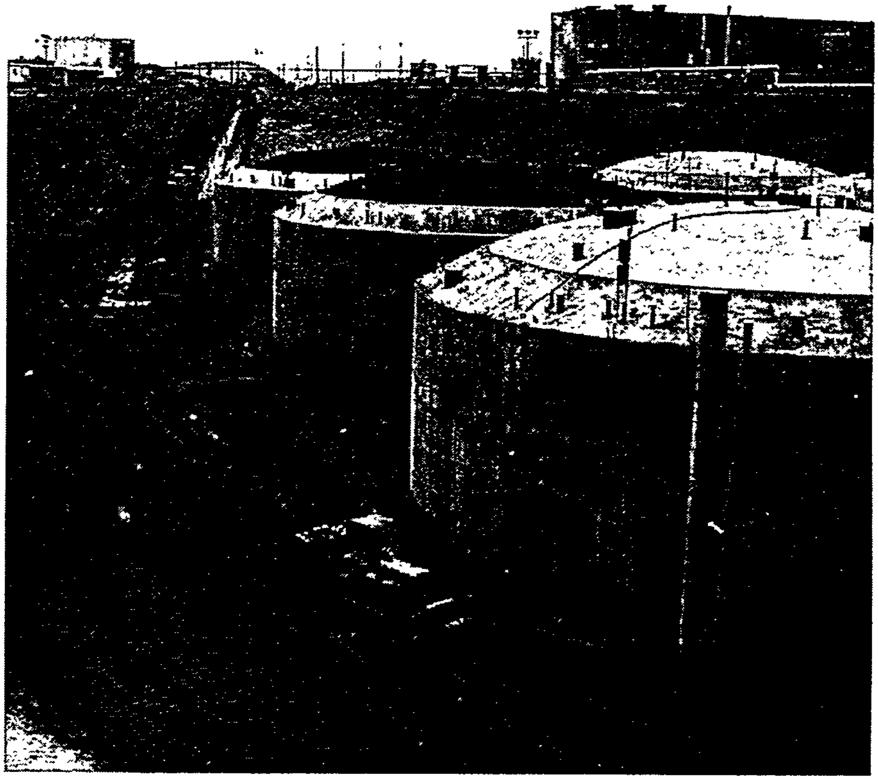
DOE/RL-92-61-
Rev. 2
February 28, 1995

Tank Waste Remediation System Integrated Technology Plan



Prepared by the
Technology Development Program Office of
The TWRS Program

United States
Department of Energy
P.O. Box 550
Richland, WA 99352

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Executive Summary

The Hanford Site, located in southeastern Washington State, is operated by the U.S. Department of Energy (DOE) and its contractors. Starting in 1943, Hanford supported fabrication of reactor fuel elements, operation of production reactors, processing of irradiated fuel to separate and extract plutonium and uranium, and preparation of plutonium metal. Processes used to recover plutonium and uranium from irradiated fuel and to recover radionuclides from tank waste, plus miscellaneous sources resulted in the legacy of approximately 227,000 m^3 (60 million gallons) of high-level radioactive waste, currently in storage.

This waste is currently stored in 177 large underground storage tanks, 28 of which have two steel walls and are called double-shell tanks (DSTs) and 149 of which are called single-shell tanks (SSTs). Much of the high-heat-emitting nuclides (strontium-90 and cesium-137) has been extracted from the tank waste, converted to solids, and placed in capsules, most of which are stored onsite in water-filled basins.

DOE established the Tank Waste Remediation System (TWRS) program in 1991. The TWRS program mission is to store, treat, immobilize and dispose, or prepare for disposal, the Hanford tank waste in an environmentally sound, safe, and cost-effective manner.

Technology will need to be developed or improved to meet the TWRS program mission. The Integrated Technology Plan (ITP) is the high-level consensus plan that documents all TWRS technology activities for the life of the program.

The ITP is divided primarily into 9 chapters, 6 of which are specific to TWRS program elements. The technology focus in each program element chapter is described below:

Waste Tank Safety

- Acquire and evaluate information on tanks with safety issues.
- Mitigate and/or resolve safety issues.
- Improve instrumentation for monitoring tank waste.
- Where needed, develop appropriate technologies for safety issue mitigation and/or resolution.

Characterization

- Reduce the significant sampling and laboratory capacity/throughput risks associated with meeting TWRS characterization requirements.
- Strengthen the technical basis for characterization.
- Minimize life-cycle cost and schedule.
- Minimize operations and personnel exposure during sampling and analysis.
- Minimize secondary wastes generated during characterization activities.

Retrieval

- Conduct scaled experiments to ensure effective application of mixer pumps for DST waste retrieval.
- Develop SST waste retrieval systems for backup to past-practice hydraulic sluicing methods that increase effectiveness and reduce tank leakage potential during retrieval.

- Develop methods for detecting and, potentially, confining leaks during retrieval of wastes from SSTs.

Pretreatment

- Develop processes to divide the wastes into a low-level waste stream (primarily treated supernatant and dissolved saltcake) and a high-level waste stream (primarily treated sludge).
- Develop technologies for separation of additional radionuclides from supernatant and dissolved saltcake.
- Continue evaluation of enhanced sludge washing (e.g., water wash/alkaline leach separation processes) for pretreatment of tank waste sludges.

LLW Immobilization

- Develop glass composition(s) for vitrification of Low-Level Waste (LLW).
- Develop a melter system for LLW vitrification.
- Develop a waste package and system for disposing of vitrified LLW in a retrievable manner.
- Conduct a performance assessment to determine the necessary performance of the waste form, and allowable waste form radionuclide loadings.

HLW Immobilization

- Define waste composition and processing parameters to ensure the borosilicate glass product will meet waste acceptance product and process specifications.
- Develop feed preparation and melter offgas treatment systems.
- Define and develop an optimized canister for the vitrified waste product.
- Develop a melter system for HLW vitrification.

All technologies included in the ITP are mapped to the systems engineering functions they support. The plan also identifies the technical strategy for each program element, key assumptions, key uncertainties, critical interfaces, the technology plan, and key deliverables. It provides an integrated, summary-level schedule illustrating the relationship between planned TWRS technology work defined by the ITP, TWRS programmatic drivers [such as Tri-Party Agreement (TPA) milestones and Data Quality Objectives (DQO)], and TWRS key decision points, and other high-level programmatic events and activities.

Each of the TWRS Program Elements has an associated schedule and life-cycle budget. The schedule identifies tasks necessary to accomplish the technology activities, deliverables, and critical interfaces. The life-cycle budget is an estimate of the costs (both capital and expense) necessary to accomplish the technology activities.

The ITP reflects a consensus TWRS program position on the required technology program. National and international experts were involved with the Hanford Site contractors in the technology planning process. All budgets and schedules contained in the ITP are unofficial; they are for planning purposes only. The ITP is a planning document (rather than a management document) that will be used as input into the TWRS program baseline documents.

Prioritization Process

A limited effort to prioritize nonbaseline technology development activities for the ITP was conducted. A typical multi-attribute utility prioritization approach was used to guide the process. Specific modifications and shortcuts are discussed in subsequent sections of the ITP. Teams of representatives from the Technology Development Program Office (TDPO), Architecture Group (AG), TWRS Program Office, and TWRS Engineering for each program element evaluated and prioritized nonbaseline activities in their program area.

The technology development activities/tasks selected for prioritization were those that for FY 1996 or beyond either did not appear in the TWRS Multi-Year Work Plan (MYWP) or appeared in the MYWP but may be in jeopardy. An assumption of this approach is that FY 1995 activities/tasks that were not funded in the FY 1995 MYWP were pushed into FY 1996 or deleted. Those activities/tasks from FY 1995 not deleted were also candidates for this prioritization, unless they appeared as budgeted items for the FY 1996 MYWP.

Preface

Purpose and Objectives of the Integrated Technology Plan (ITP)

The Integrated Technology Plan (ITP) is the high-level plan that documents all Tank Waste Remediation System (TWRS) technology activities for the life of the program.

The **purpose** of the ITP is to provide a plan for developing *timely, comprehensive* technology solutions directly coupled to high-priority TWRS needs.(a)

The **objectives** of the ITP are to:

- identify TWRS functions and requirements that drive TWRS technology needs
- identify and clearly articulate technology needs and timing in response to these functions and requirements through the end of the project (as currently understood)
- highlight key technical uncertainties (and enhancements or alternatives where considerable technical uncertainties exist), in the context of a comprehensive, strategic approach
- provide a high-level plan for activities to address the technology needs of the TWRS program; this plan includes activities that can be completed within the constraints of anticipated budgets as well as additional activities that should be considered if additional funding sources were to be identified
- help facilitate coordination of EM-50 and EM-30 technology efforts through better understanding of needed activities
- foster national involvement in the technology planning process.

Relationship to previous versions of the ITP

Rev. 0: The first draft of the ITP was issued on March 31, 1993. It was provided to the Secretary of Energy along with other TWRS baseline documents to assist in evaluating potential changes to the TPA. Rev. 0 defined a proposed technology development strategy based on a planned approach to tank remediation that included options to either reduce high-level waste (HLW) glass volume through extensive separations techniques, or increase the capacity of the HLW vitrification facility.

Rev. 1: Rev. 1 of the ITP was issued on June 10, 1994. It was based on the revised technical strategy developed during the renegotiation of the TPA. Rev.1 focused on providing a plan for technology activities required to implement that technical strategy. It reflected planned and recommended FY 1995 program activities. It organized and prioritized the technology development activities into four program levels. The Recommended Program was the list of activities recommended by the technologists who prepared the ITP. The TWRS Baseline Program was a subset of the Recommended Program that identified activities and associated funding levels included in the TWRS baseline at the time the ITP was prepared. Two decrement programs were also identified: Minimum Safe Operations and Tri-Party Agreement (MSO&TPA), which identified the minimum activities needed to achieve compliance with the TPA milestones, regulatory requirements, and health and safety standards; and Health and Safety Only, which was a subset of MSO&TPA in that it addressed only activities required to maintain safe operations without remediating the tanks.

(a) "Timely" means available for insertion into the TWRS program baseline at the appropriate time. "Comprehensive" means technically sound, responsive to user requirements, and acceptable to stakeholders.

Rev. 2: This draft of the ITP updates and further refines the plan for technology activities described in Rev. 1. Rev. 2 reflects substantially increased involvement of TWRS Engineering. It also reflects the updated funding projections for TWRS technology activities and clarifies which activities will likely be pursued within existing funding and which would require additional funding or may be conducted by other programs, e.g., EM-50. The program and prioritization scheme has been simplified to two program levels. Technology development activities are identified as either baseline or nonbaseline. The nonbaseline activities were formally prioritized to facilitate their inclusion in future budget scenarios.

Relationship of the ITP to other TWRS documents

Figure P.1 shows the relationship of the ITP to other TWRS baseline documents and plans. The relationship is also described in the TWRS MYWP, DOE/RL-92-59, "Tank Waste Remediation System Program Multi-Year Work Plan." (U.S. Department of Energy, Richland Operations Office, 1994a.)

TWRS program functions and requirements supported by technology were taken from DOE/RL-92-60, Rev. 1, "Tank Waste Remediation System Functional Requirements." (U.S. Department of Energy, Richland Operations Office, 1994b.) TWRS technology needs were supplied by TWRS engineering in WHC-SD-WM-DTP-033, Rev. 0, "*Technology Development in Support of the TWRS Process Flowsheet.*"

The ITP is not a work plan, nor is it a management plan. It is a planning document that describes technology activities to be performed in support of TWRS. The ITP provides input that is used to prepare the technology development portions of the TWRS Fiscal Year Work Plan (FYWP). The ITP does not identify the organizations that will perform all the work. Negotiations related to identifying who will take the lead in funding and managing each activity, and who will perform the work, are key steps in the process of implementing the ITP.

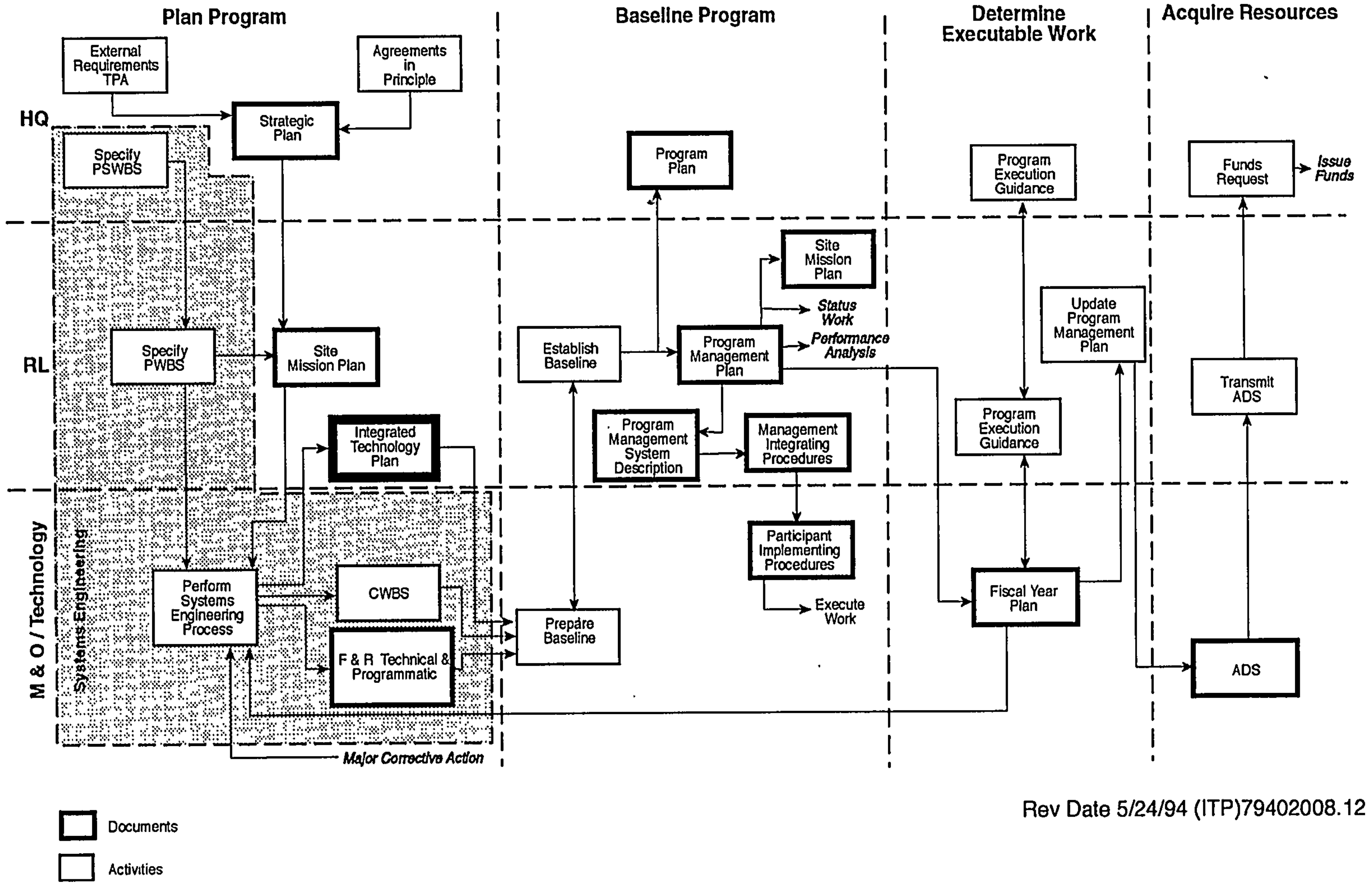
Preparation of the ITP

The ITP was prepared by Pacific Northwest Laboratory's (PNL's) Technology Development Program Office (TDPO) in conjunction with Westinghouse Hanford Company (WHC) TWRS staff and two Systems Architecture Groups.

WHC staff included representatives from TWRS Engineering and Programs. WHC also provided high-level technology needs and functions, program schedules, and projected funding profiles.

The Engineering Technology Interface Group (ETIG), which consists of TDPO program element managers and members representing the corresponding Integrating Contractor's TWRS program elements, confirmed and characterized the technology needs, helped to ensure that the technology needs were integrated and appropriately prioritized, and helped identify engineering and technology solutions.

The two Systems Architecture Groups involved in preparing the ITP were the Characterization Architecture Group (CAG) and the Waste Processing Architecture Group (WPAG). Membership on the Architecture Groups consisted of technologists from DOE's national laboratories, maintenance and operations contractors, private industry, universities, and foreign sources. The Architecture Groups were the primary source of technical input for the ITP. They helped prepare first drafts of templates (found in Appendix E) that recommend technology activities based on the TWRS "baseline" funding profiles, and additional recommended work related to reference, alternative, and enhancement technologies. They were also involved in drafting program element chapter narratives, including technical uncertainties, assumptions, strategies, etc.



Rev Date 5/24/94 (ITP)79402008.12

Figure P.1. Relationship of ITP to Other Baseline Documents

A team of decision analysts worked with the ETIG to select and organize technologies into **baseline** and **nonbaseline** technology development activities for further prioritization. They determined that the best use of prioritization resources for this ITP revision would be to concentrate on the nonbaseline activities. The ETIG was instrumental in prioritizing the nonbaseline technology development activities for each program to show their relative importance and to provide guidance for including those technology development activities in future TWRS baselining and budget exercises.

Issues in Preparing the ITP

The ITP is prepared without the benefit of "perfect information." Funding profiles are in a state of constant flux. Information on program design, product requirements, and scheduling needs is still being developed by the TWRS programs. As a result, a number of assumptions (which are documented in Chapters 3-8) had to be made, and technical and programmatic risks are increased. All cost and schedule information in the ITP is unofficial, to be used for planning purposes only.

Because Rev. 2 of the ITP was prepared in advance of the TWRS MYPP, budget estimates in this document may not be consistent with those in final TWRS baseline documents. The ITP budget estimates presented here are consistent with the draft MYWP and approved changes effective on January 1, 1995.

Rev. 2 of the ITP is a "snapshot" of technology activities. It provides a baseline for continuous evaluation and integration of improved technologies based on expected performance improvements in the TWRS program. Current plans are to revise this document at least annually while the program is evolving. Future revisions will incorporate enhanced information, such as updated TWRS program and scheduling logic and systems engineering data on programmatic risk. As the TWRS program becomes more settled, updates will be prepared on an as-needed basis.

Organization of the ITP

The ITP is organized as follows (see Figure P.2):

The **Preface** describes the purpose, scope, and objectives of the plan, explains how the ITP relates to other TWRS documents, and provides an overview of how the document was prepared. **Chapter 1** provides background information on the Hanford Site, tanks, and tank waste inventory, and the scope of the TWRS program. **Chapter 2** summarizes the technical baseline for the TWRS. It discusses the technical strategy and presents a summary of the baseline technology programs for each program element. It summarizes the drivers and constraints that impact the technology program. It also documents integrating information, such as summary schedule and budget information, and interface requirements for the TWRS program.

Chapters 3-8 are the technical core of the document. They summarize the purpose, objectives, scope, and strategy for each of the six TWRS program elements (Safety, Characterization, Retrieval, Pretreatment, HLW, and LLW), and identify key assumptions and uncertainties affecting technology planning, and critical interfaces with others parts of the TWRS program. There is also a summary appendix of this program information (Appendix E) on the technology responses to TWRS program needs.

Appendices A and B explain the process used for preparing the plan and prioritizing technologies, and the source of information, participants, and roles.

Appendix C defines the functions that come from the TWRS Systems Engineering Functional Requirements.

Appendix D summarizes the key federal laws and requirements that will impact technology activities described in the ITP.

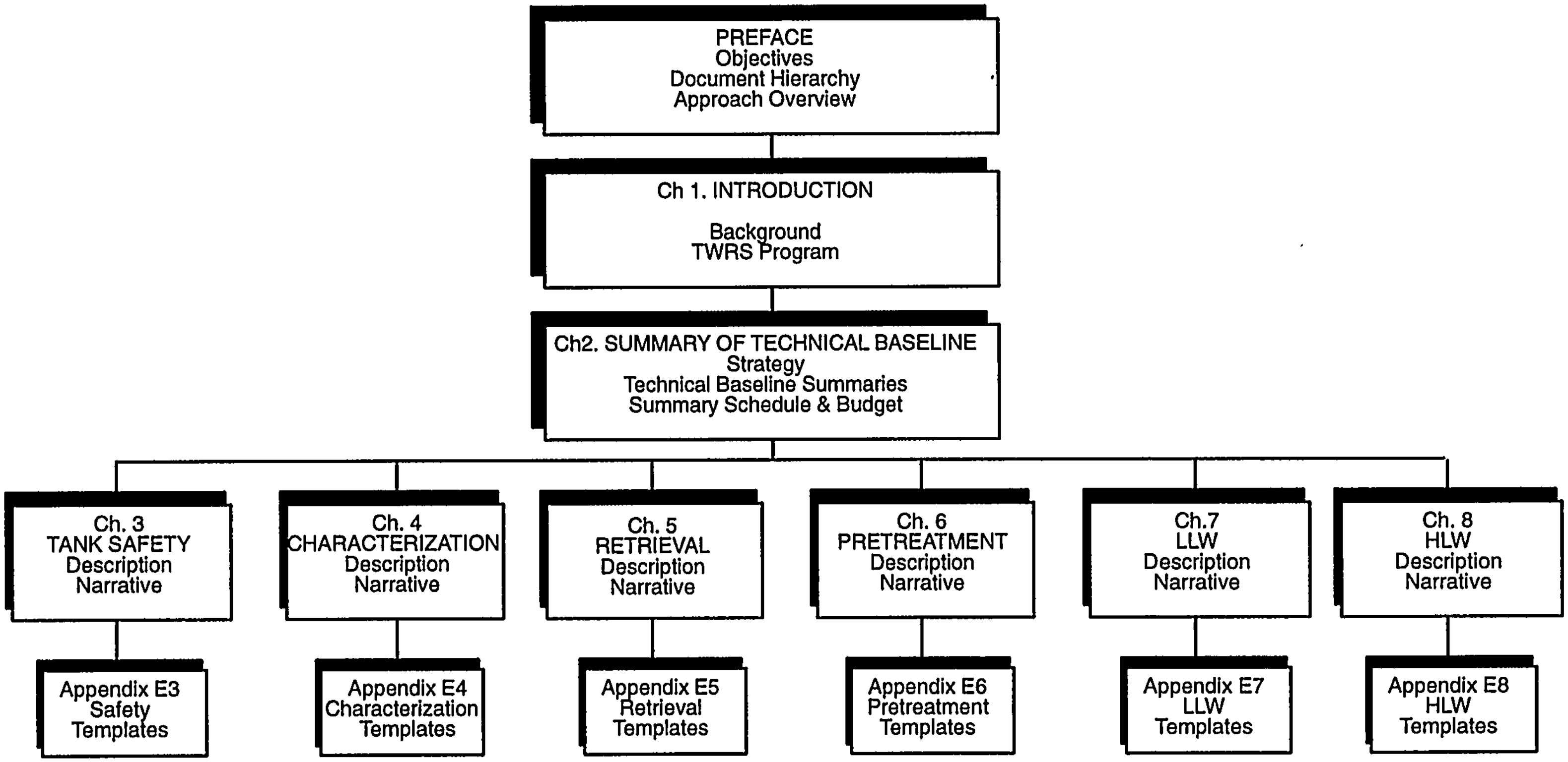


Figure P.2. Structure of the ITP

Appendix E contains the instructions provided to technical staff for completing the templates, and the completed templates themselves. The completed templates show the relationship of the technology activities to systems engineering functions and requirements and the Work Breakdown Structure (WBS). For each suite of technologies, the scope, justification, drivers, level of maturity, key uncertainties, critical interfaces, and the plan (tasks, schedule, budget, deliverables) are described.

Appendix F is a cumulative list of technologies considered but not carried forward and technologies that have been developed and successfully implemented.

Appendix G contains a glossary of terms used in the ITP.

Appendix H contains all acronyms used in the ITP.

Acknowledgments

The Technology Development Program Office (TDPO) wishes to recognize the efforts that went into the preparation of this document. It was prepared under a very aggressive schedule, with numerous staff at PNL, WHC, and offsite organizations contributing to this revision. Among the key contributors were the following; without this invaluable expertise and hard work, preparation of this document would not have been possible:

- **Safety** - Roger Bean, PNL; Greg Hanson, WHC; and Joan Young, ASI.
- **Characterization** - Harry Babad, WHC; David Bratzel, WHC; Gary Eller, LANL (TDPO); David Forehand, WHC; William Zuroff, WHC; and members of the Characterization Architecture Group (listed in Appendix B), chaired by Wally Schulz.
- **Retrieval** - Les Fort, WHC; Peter Gibbons, WHC; Deborah Iwatate, WHC; Jim Lee, SNL (TDPO); Michael McKinney, PNL; Paul Scott, PNL; Eric Shen, WHC.
- **Pretreatment** - John Appel, WHC; Tom Slankas, PNL (TDPO); and members of the Waste Processing Architecture Group (listed in Appendix B), chaired by Ray Wymer, PNL.
- **Low-Level Waste** - Ken Burgard, WHC; Ron Gibby, WHC; John Holbrook, PNL (TDPO); Richard Karnesky, WHC; Joe Westsik, PNL; and members of the Waste Processing Architecture Group (listed in Appendix B), chaired by Ray Wymer, PNL.
- **High-Level Waste** - John Carr, BWO (TDPO); Don Larson, PNL; Steve Schaus, WHC; and members of the Waste Processing Architecture Group (listed in Appendix B), chaired by Ray Wymer, PNL.
- **Decision Analysis** - Ray Fleshman, PNL;.
- **Development of the Integrated Schedules and Budgets** - Joe Northrop and Steve Schlahta, PNL.
- **Editing** - Barbara Eaton, PNL; Audrey Ignatov, PNL; Sharon Johnson, PNL; Michaela Mann, PNL; Launa Morasch, PNL; Sallie Ortiz,PNL; and Pam Novak, PNL.
- **Publication Support** - Deanna Kratzer, PNL; Anita Lebold (Leader), PNL; Jodi Melland, PNL; Shannon Osborn, PNL; Annette Taylor, PNL; and Susan Widener, PNL.
- **Graphics and Tables** - Howard Bullock, BCS; Chris Culmer, PNL; Wendy Francis, BCS; and John Lawson, WHC.
- **Systems Analyst** - Andy Alcorn, PNL.
- **Coordination and Administrative Support** - Chris Culmer, PNL; Mary McFall, PNL; and Lorrie Short, PNL.
- **Project Management** - Gary Dunford, WHC; Elizabeth Flores, PNL; Michael McKinney, PNL; George Mellinger, PNL (TDPO); Eric Schmieman, PNL (TDPO); Jennifer Stitzel, PNL; and Don Wodrich, WHC.

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1.0 Introduction

1.1 Background

1.1.1 The Hanford Site

The Hanford Site in southeastern Washington State covers 1,450 square kilometers (560 square miles) of semi-arid shrub and grasslands. Hanford is located just north of the confluence of the Yakima River with the Columbia River (Figure 1.1).

The Hanford Site was acquired by the federal government in 1943. For the first 45 years, the government's primary mission was the production of plutonium for national defense, and management of the resulting waste. With the shutdown of production facilities in the 1970s and 1980s, missions have been diversified to include technology development and waste management/restoration (Hanford Site Environmental Report, 1993 [PNL-9823]). Operations and activities are managed by the U.S. Department of Energy (DOE) Richland Operations Office (RL) through several prime contractors and numerous subcontractors.

1.1.2 The Tanks and Tank Waste

Historically, Hanford supported fabrication of reactor fuel elements, operation of production reactors, processing of irradiated fuel to separate and extract plutonium and uranium, and preparation of plutonium metal. Processes used to recover plutonium and uranium from irradiated fuel and to recover radionuclides from tank waste, plus miscellaneous sources (e.g., laboratory waste and reactor decontamination solutions), resulted in the generation of over 232,000 m^3 (60 M gal) of wastes. Table 1.1 presents the current inventory of waste in the tanks.

These wastes are currently stored in 177 tanks in the 200 East and 200 West Areas, which lie in the center of the Hanford Site. Of these 177 underground tanks, 149 are single-shell tanks (SSTs) and 28 are double-shell tanks (DSTs).

1.1.3 SSTs

The SSTs, built between 1943 and 1964, are reinforced concrete tanks with carbon steel liners (Figure 1.2). SST nominal capacities range from 208 m^3 (55,000 gal) to 3,785 m^3 (1M gal). Most of the pumpable liquids have been transferred to DSTs for safer storage. The remaining waste is multi-phased: some is an insoluble sludge with interstitial liquids, some is in the form of crystalline, water-soluble solids ("saltcake"), and some is in the form of supernatant liquids.

Since 1956, 67 SSTs have leaked or are suspected to have leaked between two and three million L (600,000 - 900,000 gallons) of waste (WHC-EP-0182-78, PNL-9823, p.39). All 149 SSTs were removed from service (i.e., no longer authorized to receive waste) as of November 21, 1980 (WHC-EP-O182-78). So far, 106 SSTs have been stabilized.

1.1.4 DSTs

The first DST was placed in service in 1971. A DST consists of a carbon steel primary tank, an annular space, and a secondary steel tank encased in reinforced concrete (Figure 1.3). Each DST has a nominal capacity of 3,785 m^3 (1 M gal). These tanks are still in service, and there is no evidence that any of the DSTs have leaked.

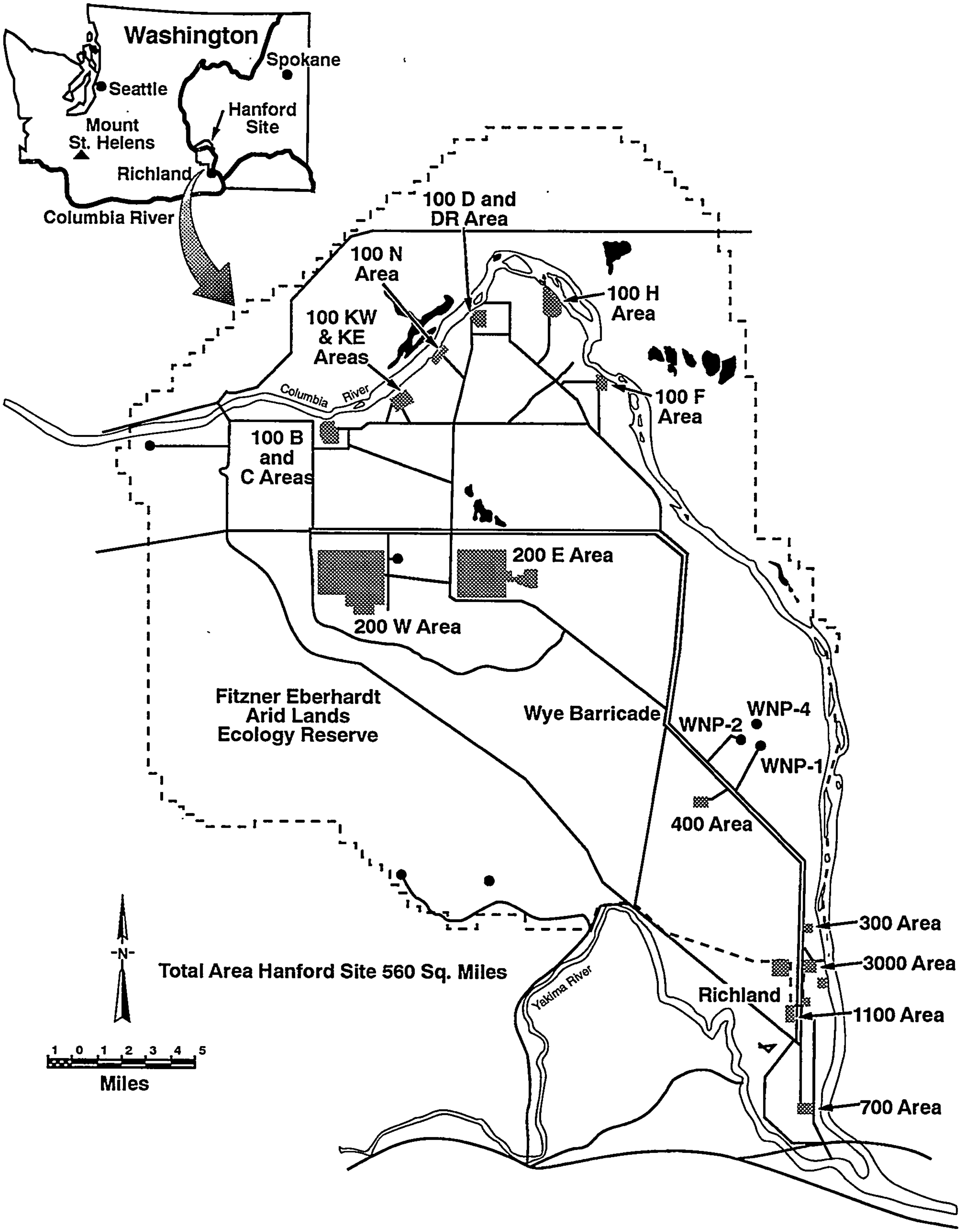

Figure 1.1. Hanford Site in Southeastern Washington State

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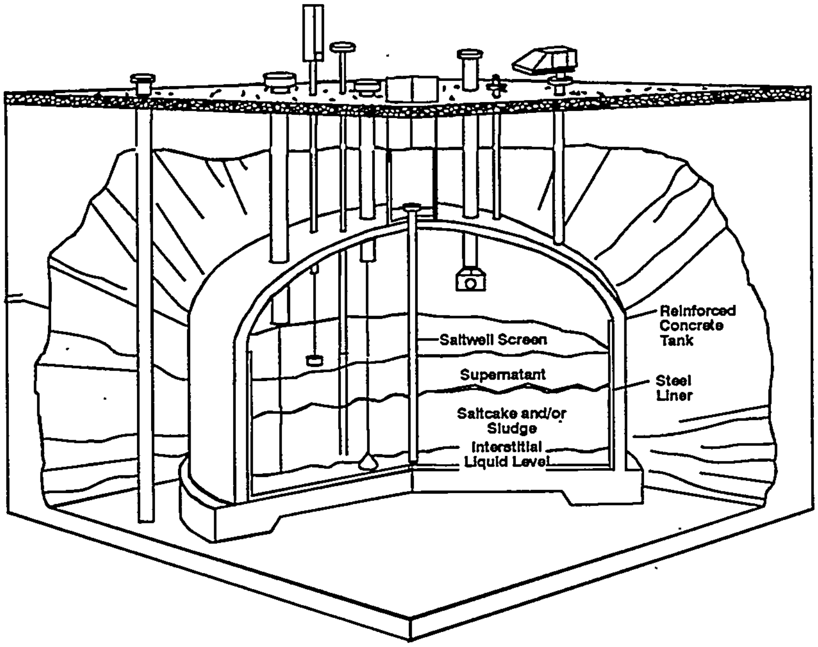

Figure 1.2. Single-Shell Tanks on the Hanford Site

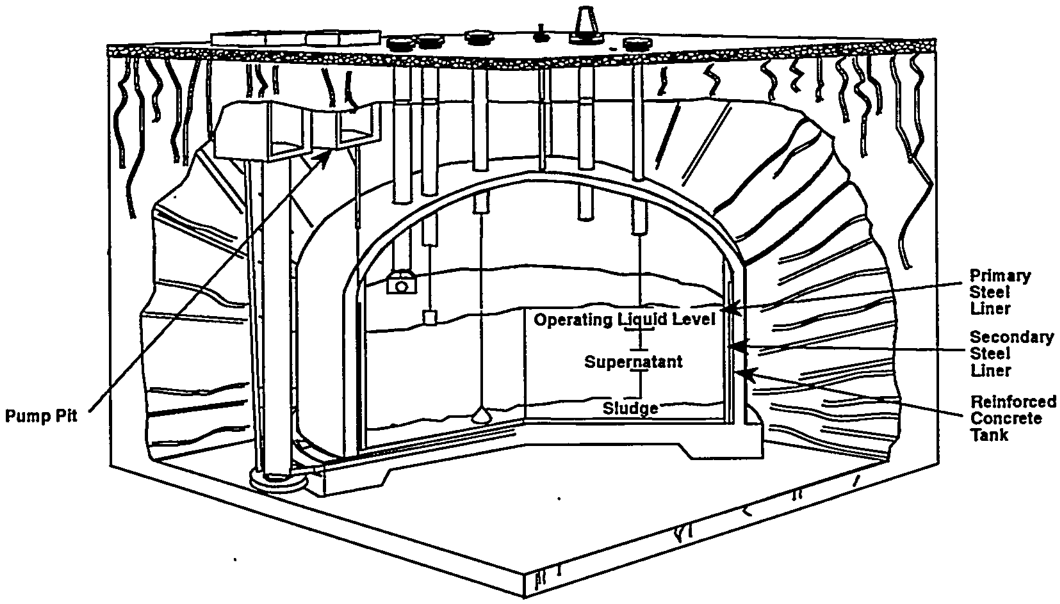

Figure 1.3. Double-Shell Tanks on the Hanford Site

Table 1.1 Tank Inventory by Waste Type

WASTE TYPE (see Glossary for description)	SSTs (Kgal)	DSTs (Kgal)	TOTAL VOLUME (Kgal)
SUPERNATANT Aging waste	0	1795	1795
Complexant concentrate waste	3	2101	2104
Concentrate phosphate waste	0	1103	1103
Dilute complexed waste	1	783	784
Dilute non-complexed waste	0	6492	6492
Dilute non-complex/PUREX TRU solids	0	1061	1061
Dilute non-complex/PFP TRU solids	0	692	692
Double-shell slurry feed	57	4210	4267
Non-complexed waste	510	0	510
TOTAL SUPERNATE	571	18237	18808
SOLIDS Double-shell slurry	0	2040	2040
Sludge	12158	1955	14113
Saltcake	23346	760	24106
TOTAL SOLIDS	35504	4755	40259
TOTAL INVENTORY	**36075**	**22992**	**59067**
Source: Tank Farm Surveillance and Waste Status Summary Report for September 1994, WHC-EP-0182-78, p. E-3			

Most of the tank wastes have undergone one or more treatment steps (e.g., neutralization, precipitation, decantation, or evaporation). The neutralized wastes contain sodium nitrate and nitrite, sodium hydroxide, sodium aluminate, sodium phosphate, various insoluble hydroxides and phosphates, significant quantities of organic materials, and approximately 250 MCi of many different radiochemical species.

1.1.5 Strontium and Cesium Capsules

From 1968 to 1985, much of the high-heat-emitting nuclides (strontium-90 and cesium-137) were extracted from the tank waste, converted to solids (strontium fluoride and cesium chloride), and placed in double-walled metal cylinders (capsules) about 52 cm (20.5 in.) in length and 6.7 cm (2.6 in.) in diameter. At present, 1,328 cesium capsules and 605 strontium capsules exist, with most of the capsules stored onsite in water-filled basins (Figure 1.4).

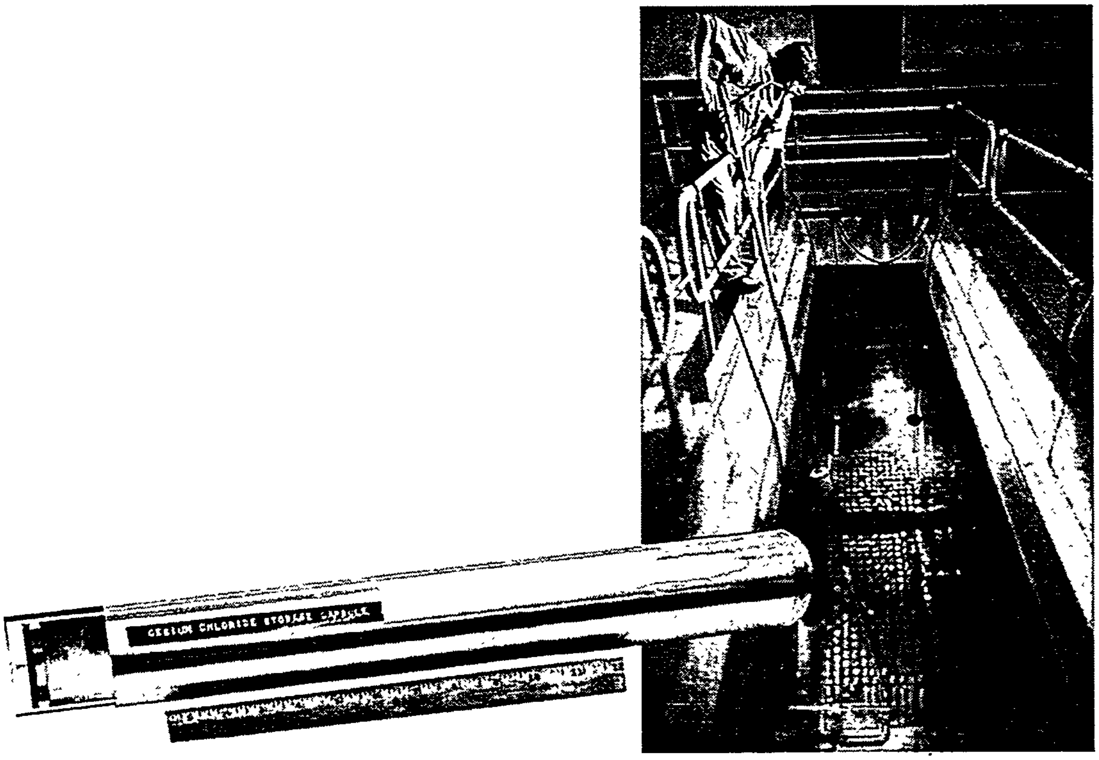

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Figure 1.4. Capsules in Water-Filled Basins

1.2 Tank Waste Remediation System (TWRS) Program

DOE established the Tank Waste Remediation System (TWRS) program in 1991.(a) Figure 1.5 shows the system strategy planned for TWRS.

1.2.1 TWRS Program Scope(b)

The TWRS program oversees receiving, safely storing, maintaining, and treating existing and new tank waste generated during facility operations and TWRS activities, interim storage of high-level waste (HLW) packaging and for offsite disposal, and disposing low-level waste (LLW) in a retrievable form onsite.

The TWRS program also supports maintaining, operating, and upgrading existing facilities and equipment, such as waste storage tanks, evaporators, and pipelines, and adding new facilities. Major facility additions currently planned include new DSTs, a new cross-site transfer line, tank waste retrieval facilities, and pretreatment and vitrification facilities.

(a) The TWRS Program is described in detail in the *Tank Waste Remediation System Implementation Plan*, DOE/RL-92-58 (U.S. DOE/RL 1994c).
(b) The scope of the TWRS program is described in detail in the *Tank Waste Remediation System Mission Analysis* (Baynes et al. 1993).

Hanford Tank Waste Remediation System Strategy

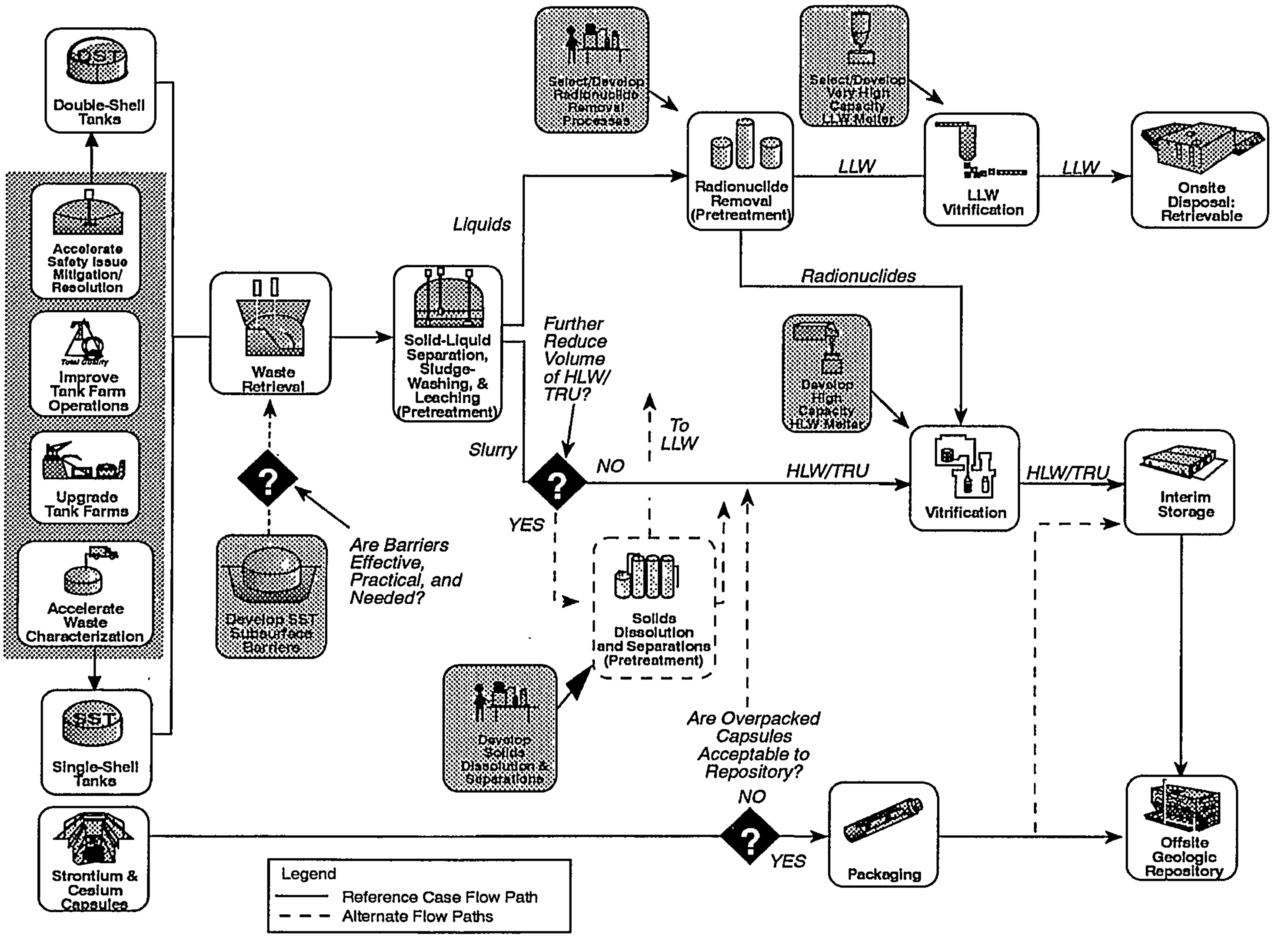

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Figure 1.5. Strategy for the Hanford Tank Waste Remediation System

Tank closure and development of a geologic repository for HLW disposal are not part of the TWRS program scope.(a)

1.2.2 TWRS Program Element Descriptions

Six major elements of the TWRS program that are responsible for meeting TWRS objectives have significant technology needs.

- **Waste Tank Safety** ensures that tank safety issues are identified, resolved, or mitigated, and that tank waste is stabilized and safely stored until it can be retrieved for pretreatment and immobilization.
- **Characterization** provides tank waste physical, chemical, and radiochemical characterization information and samples to TWRS program elements responsible for tank farms process control; tank waste safety issue resolution; and waste retrieval, treatment, storage, and disposal decisions.
- **Retrieval** mobilizes and conveys tank waste out of the tanks and transfers it to holding facilities for treatment and disposal. Conveyance and lag storage will blend wastes, improving homogeneity.
- **Pretreatment** separates waste into a HLW fraction and a LLW fraction. The TWRS technical strategy calls for initial pretreatment operations to focus on supernatant and dissolved saltcake, followed by pretreatment of sludges.
- **LLW Immobilization** transforms LLW to glass that can be retrievably disposed onsite and will meet agreed-upon performance standards.
- **HLW Immobilization** provides a glass waste form for HLW and TRU tank wastes that will be acceptable for disposal in an offsite geologic repository.

Chapters 3.0, 4.0, 5.0, 6.0, 7.0, and 8.0 are organized by these program elements.

(a) It is currently proposed that closure of SSTs and DSTs will be addressed in the Environmental Restoration Program. Development of a geologic repository for HLW disposal is the responsibility of the Office of Civilian Radioactive Waste Management.

2.0 Summary of TWRS Technical Baseline

2.1 TWRS Program Mission and Technical Strategy

The Tank Waste Remediation System (TWRS) program mission is to store, pretreat, immobilize and dispose, or prepare for disposal, the Hanford Site radioactive tank waste in an environmentally sound, safe, and cost-effective manner. The technical strategy for the TWRS program is shown schematically in Figure 1.5, page 1-6.

2.2 TWRS Objectives

The program summary logic for accomplishing the TWRS mission is shown in Figure 2.1. To successfully accomplish its mission, the TWRS program must achieve a number of objectives, which are summarized in the following paragraphs.

Mitigation and resolution of tank **safety** issues is the highest priority for the TWRS program. TWRS must ensure that no site worker or member of the general public will be exposed to any radiological or chemical hazard that results in exceeding radiation or industrial hygiene exposure limits.

TWRS must **characterize** the waste to provide the physical, chemical, and radiological information necessary to resolve safety issues and to store, retrieve, pretreat, immobilize, and dispose of the waste. Waste characterization activities include sample acquisition and transfer to laboratory, laboratory analysis of samples, performance of in situ measurements, and review of historical data and lab results as necessary.

All the waste from the double-shell tanks (DSTs) and single-shell tanks (SSTs) must be **retrieved** to the extent necessary for closure (TPA milestone M-45-001). Wastes to be removed from the tanks include liquids, saltcake, sludges, slurries, and possibly miscellaneous solids (e.g., failed equipment, concrete, rocks, lead bricks, samarium balls, and cobalt slugs). Solids will be removed only to the extent necessary to prevent interference with the retrieval of other wastes or as required to allow completion of closure activities.

All retrieved tank waste will then be **pretreated**. Pretreatment includes blending and other preparation for separations processes, separating out waste constituents suitable for immobilization as low-level waste (LLW) and for reuse, and then converting the remaining waste into feeds to the high-level waste (HLW) and transuranic (TRU) waste immobilization system. Excess water will be removed from liquid DST waste to reduce the volume of waste feed for immobilization and to free storage capacity in existing tanks.

Separations processes will be used, to the extent practical, to reduce the volume of the **HLW** stream so the immobilized volume is cost-effective and acceptable to the Geologic Repository Program. The waste will be separated into HLW waste and LLW fractions so that most of the radionuclides and only a small part of the other waste materials are in the HLW, and the remainder is in the LLW. Radionuclides will be removed from the waste stream destined to become LLW to the extent needed to 1) meet the U.S. Nuclear Regulatory Commission's (NRC) "incidental waste" classification; and 2) meet Department of Energy's (DOE's) LLW disposal requirements, which include an As Low As Reasonably Achievable (ALARA) exposure policy and an acceptable disposal system performance assessment.

Pretreated **LLW** will be vitrified and disposed of onsite in a near-surface retrievable form. Pretreated HLW and TRU waste will be vitrified and stored in canisters that meet the Geological Repository Program waste acceptance criteria. The canisters will then be stored until they can be shipped to a geologic repository for disposal.

The strontium and cesium **capsules** will also be stored onsite until they can be packaged or processed in a manner that conforms to the Geologic Repository Program requirements and shipped to an offsite HLW geologic repository for disposal.

Tank Waste Remediation System Summary Activity Network Logic

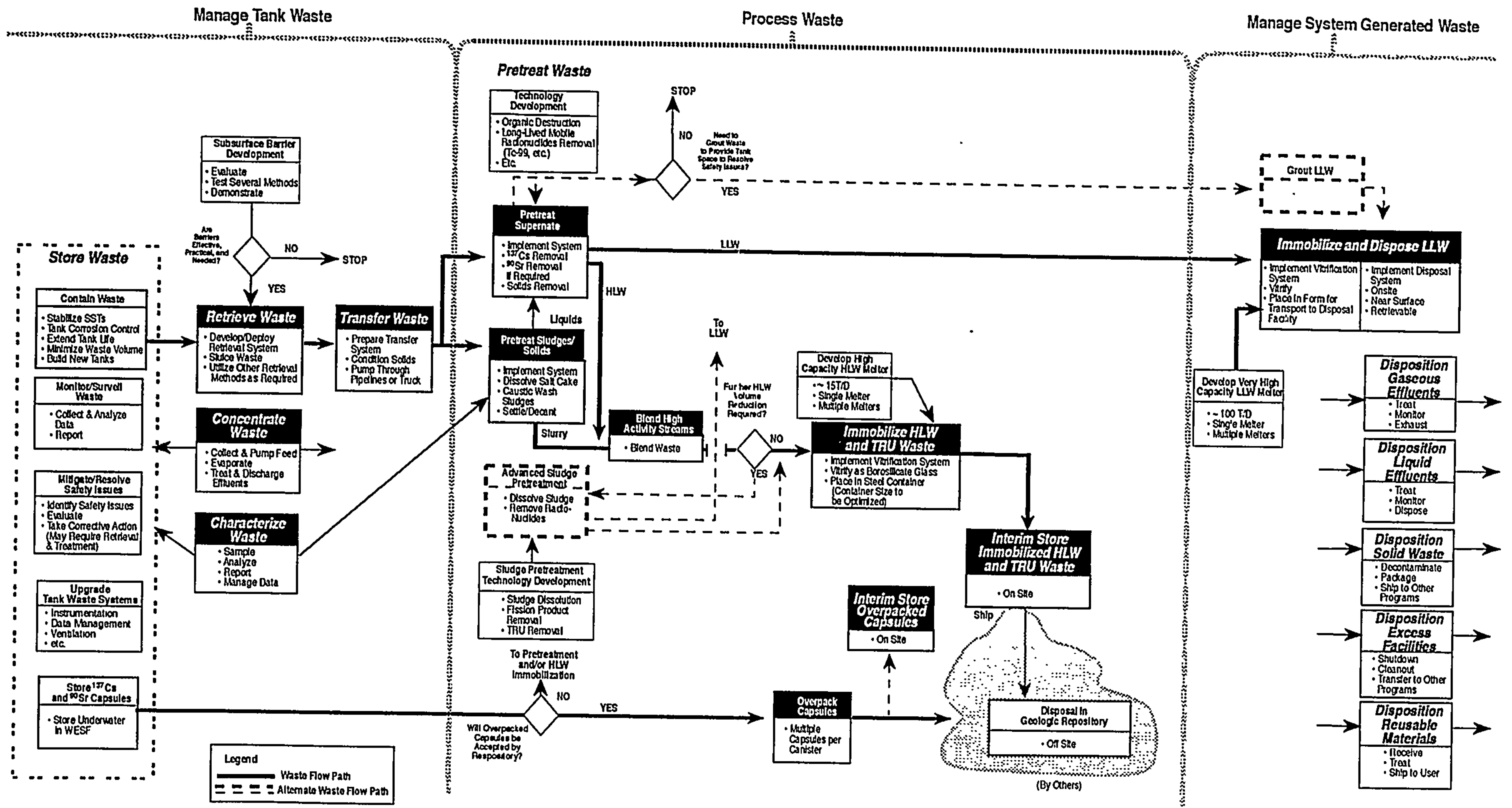

Figure 2.1. Proposed Summary Logic for the Tank Waste Remediation System

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Secondary wastes (including effluents and emissions) will be generated. Gaseous effluents generated from facilities, tanks, and processes will be filtered and/or scrubbed. The treated exhaust effluents will be handled in an external system. Liquid effluents will need to be collected, stored, and treated before disposal. The TWRS will also need to manage the disposition of excess facilities. These facilities (DSTs, SSTs, transfer lines, pretreatment structures, LLW and HLW facilities, etc.) will need to be emptied, decontaminated, deactivated, and either reused or disposed of. Closure of SSTs and DSTs will be addressed in the Environmental Restoration Program.

2.3 Overarching Drivers and Constraints

One of the goals of the TWRS program is to ensure that the best available technologies are identified, accessed or developed, validated, and applied to the tank cleanup problem. However, a number of drivers and constraints can affect selection, development, and application of the technologies (Figure 2.2).

Successful development and deployment of technology for the TWRS program is critically dependent upon early consideration of these drivers and constraints. For example, researchers could develop highly effective technologies for resolving tank waste remediation problems. However, if these technologies are unacceptable to stakeholders, fail to accommodate regulatory requirements, or are not developed within the appropriate window of opportunity defined by the Tri-Party Agreement (TPA) schedule, they could not be deployed and valuable time and resources would be wasted.

Some of the key drivers and constraints that must be considered when planning technology activities are listed here:

- **Health and Safety Issues:** Safe operations and elimination of urgent risks or any inherent threats to the public or Hanford employees is the top priority of the TWRS program. This priority drives efforts to reduce and eliminate safety problems, such as the potential for flammable gas concentrations, reactive mixtures of ferrocyanide and nitrates, propagating organic-nitrate chemical reactions, overheating of tank contents, and the release of toxic or hazardous gases.
- **TPA Milestones:** The TPA outlines a detailed schedule and establishes key decision points for selecting the technology to be used for achieving Hanford Site cleanup milestones, which define the "windows of opportunity" during which technology can be developed. Table 2.1 lists major milestones that need to be supported by technology from Part 1 of Amendment 4 of the *Hanford Federal Facility Agreement and Consent Order* (also known as the TPA) (Ecology et al. 1994), signed January 25, 1994.(a)

(a) See Part 1, Amendment 4 of the TPA (Ecology et al. 1994) for a description of these milestones and the additional sub-tier milestones.

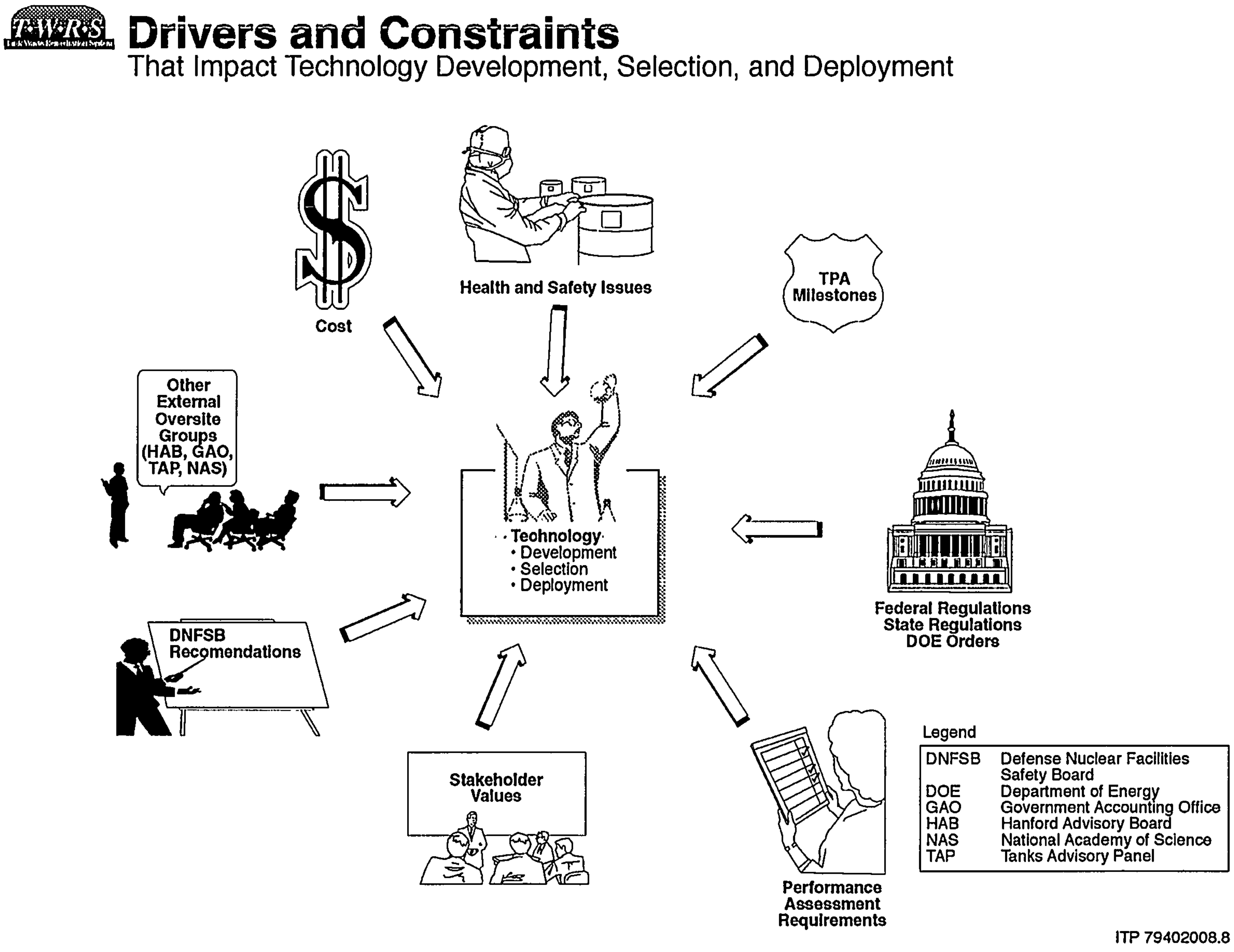

Figure 2.2. Drivers and Constraints that Impact Technology Development, Selection, and Deployment

Table 2.1. TWRS Major Milestones Impacted by Technology

Milestone Title (followed by milestone number in parenthesis)	**Scheduled Completion Date**
• Mitigate/Resolve Tank Safety Issues (M-40-00)	09/2001
• Tank Waste Characterization (M-44-00)	09/1999
• Complete Closure of All SST Farms (M-45-00)	09/2024
- Develop SST Waste Retrieval Technology (M-45-01)	09/1994
- Complete Evaluation and Testing of Small-Scale SSBs (M-45-07)	09/1997
• Complete Pretreatment Processing of Hanford Waste (M-50-00)	12/2028
- Start Construction of LLW Pretreatment Facility (M-50-01)	11/1998
- Start Hot Operations of LLW Pretreatment Facility (M-50-02)	12/2004
- Start Hot Operation of HLW Pretreatment Facility (M-50-04)	06/2008
• Complete Vitrification of Hanford HLW (M-51-00)	12/2028
- Complete Melter Tests and Select Reference Melter (M-51-02)	09/1998
- Initiate Hot Operations of HLW Vitrification Facility (M-51-03)	12/2009
• Complete Vitrification of Hanford LLW (M-60-00)	12/2028
- Select Reference Melter (M-60-02)	06/1996
- Initiate Construction of LLW Vitrification Facility (M-60-04)	12/1997
- Initiate Hot Operations of LLW Vitrification Facility (M-60-05)	06/2005

- **Federal Requirements, their State counterparts, and related U.S. Department of Energy (DOE) Orders** may directly or indirectly affect technology development and deployment in all TWRS program elements. For example:

  - Efforts to obtain tank waste samples needed for process development must comply with worker health and safety requirements established by the Occupational Safety and Health Administration (OSHA) and DOE Orders.

  - Retrieval operations will generate hazardous waste subject to the Resource Conservation and Recovery Act (RCRA).

  - Pretreatment technologies will have to comply with Clean Air Act (CAA) air emission limits.

  - HLW products will have to comply with waste acceptance specifications for disposal in a geological repository.

  - Some of the key federal laws and requirements that will impact technology activities include the Atomic Energy Act (AEA), the CAA, the Clean Water Act (CWA), the Federal Facilities Compliance Act (FFCA), the National Environmental Policy Act (NEPA), the Nuclear Waste Policy Act (NWPA), the Pollution Prevention Act (PPA), RCRA, and permitting and waste minimization requirements. These laws and requirements are briefly described in Appendix E.

- **Performance Assessment Requirements:** DOE Order 5820.2A requires that a site-specific radiological performance assessment be conducted for a LLW disposal site to demonstrate compliance with performance objectives.

- **Stakeholder Values**: Stakeholder involvement enhances technology acceptance, and the stakeholder's concerns about technical approaches need to be considered. One of the goals of the TWRS program is to establish a communication climate between Hanford and stakeholders that facilitates meaningful stakeholder involvement in key TWRS decisions, such as technology selection.
- **Defense Nuclear Facilities Safety Board (DNFSB)**: The Board reviews and evaluates standards relating to the design, construction, operation, and decommissioning of defense nuclear facilities; investigates activities that may adversely affect public health and safety; and makes recommendations regarding operations, standards, and research needs it deems necessary to ensure adequate protection of public health and safety, upon consideration of the technical and economic feasibility of implementing the recommended measures.
- **Other External Oversite Groups**: Some of the External Oversite Groups that impact technology planning are HLW Tanks Technical Advisory Panel (TAP), Government Accounting Office (GAO), National Academy of Sciences (NAS), and Hanford Advisory Board (HAB).
- **Cost**: Competing demands on limited resources (budget constraints) are a reality. The current cost projection for cleaning up the Hanford Site is very high, and an aggressive initiative to achieve productivity gains, improve products and services, and reduce costs is required. The technology development and selection process can potentially result in substantial cost savings.
- **Data Quality Objectives:** Data Quality Objectives (DQO) are a formalized method developed by the Environmental Protection Agency to document the minimum sampling/analyses required to support specific site remediation goals. The DQO process has been adapted and adopted for TWRS work and strongly impacts technology development planning.

2.4 Enhancements and Alternatives

Although a reference strategy has been selected, enhancements and alternatives will continue to be evaluated because of technical uncertainties and programmatic risks associated with the reference case. The primary reasons for considering enhancements and alternatives are as follows:

- Varying degrees of uncertainty exist regarding whether or not the reference technologies will perform as planned.
- A continuing need exists to identify better, safer, faster, and cheaper remediation technologies because of the extensive cost and time required to carry out the program.
- Retrieving waste by sluicing SSTs that have leaked may not be acceptable. The cost of waste retrieval by any means is high.
- Uncertainties exist regarding certain constituents volatilizing in a melter and not being captured in the vitrified waste product.
- Additional radionuclides may have to be removed from the LLW stream to satisfy performance assessment. The performance assessment may impact development of glass compositions.
- The estimated costs for repository disposal fees are high; thus, the number of HLW canisters sent to the repository needs to be optimized with respect to the total TWRS program cost. Also, the baseline sludge pretreatment technology may not produce a volume of vitrified HLW acceptable to the repository, independent of cost.

2.5 Summary of TWRS Functions and Technology Needs

The TWRS mission presents a number of technical challenges. Technologies are not yet adequately developed to provide assurance of permanent, safe, and cost-effective solutions to many of the TWRS problems within the timeline established by the TPA. The Integrated Technology Plan (ITP) seeks to identify those TWRS functions that have technology needs associated with them. Figure 2.3 shows how the technology activities documented in this ITP relate to the TWRS functions defined in the systems engineering process. Appendix C provides definitions of these functions.

2.6 Description of the Technology Baseline

This section provides an overview of Chapters 3.0, 4.0, 5.0, 6.0, 7.0, and 8.0. This overview summarizes, by program element, the technical strategy and reference approach, as well as key assumptions and key uncertainties associated with that approach. Important programmatic and technical drivers for the technology program are also summarized, along with enhancements and alternatives to the reference technologies where considered.

2.6.1 Safety

2.6.1.1 Technical Strategy For Safety

- Mitigate or resolve tank safety issues to the fullest extent practicable without retrieving tanks.

2.6.1.2 Reference Approach For Safety

- Conditions in many of the flammable gas Watch List DSTs may be mitigated by mixer pumps. Retrieval of the waste will be required if in-tank mitigation is not successful. If waste retrieval is necessary, the waste will be stored in a diluted form to resolve the safety issue.
- No flammable gas-containing SSTs will be retrieved to resolve the safety issue, but in situ vapor monitoring may be required.
- The safety issues for the 18 ferrocyanide-containing tanks and the 19 organic-containing tanks on the Watch List will be resolved in-tank without retrieval or pretreatment.
- Waste from the high-heat SST, Tank 241-C-106, may be retrieved to resolve the high-heat tank safety issue. No pretreatment will be required to resolve this safety issue.
- The tank vapor safety issue will be resolved by vapor flow monitoring and treatment.
- The organic liquid layer floating on the waste in Tank 241-C-103 will be pumped out of the tank to resolve the tank vapor safety issue, unless it is determined that organics in the aqueous solution are a source of tank noxious vapor.
- The criticality safety issue will be resolved by administrative controls and by gathering data to determine if a criticality issue is credible.

2.6.1.3 Key Assumptions For Safety

- No new major safety issues requiring diversion of resources will be identified.
- Most safety issues can be adequately mitigated without removing waste from tanks. Monitoring and control systems may need to be installed.
- The contents of flammable gas DSTs and the high-heat SST (Tank 241-C-106) may be retrieved to resolve safety issues.
- No ex-situ pretreatment of tank wastes will be required to resolve any safety issues.

Summary of TWRS Functions and Technology Packages

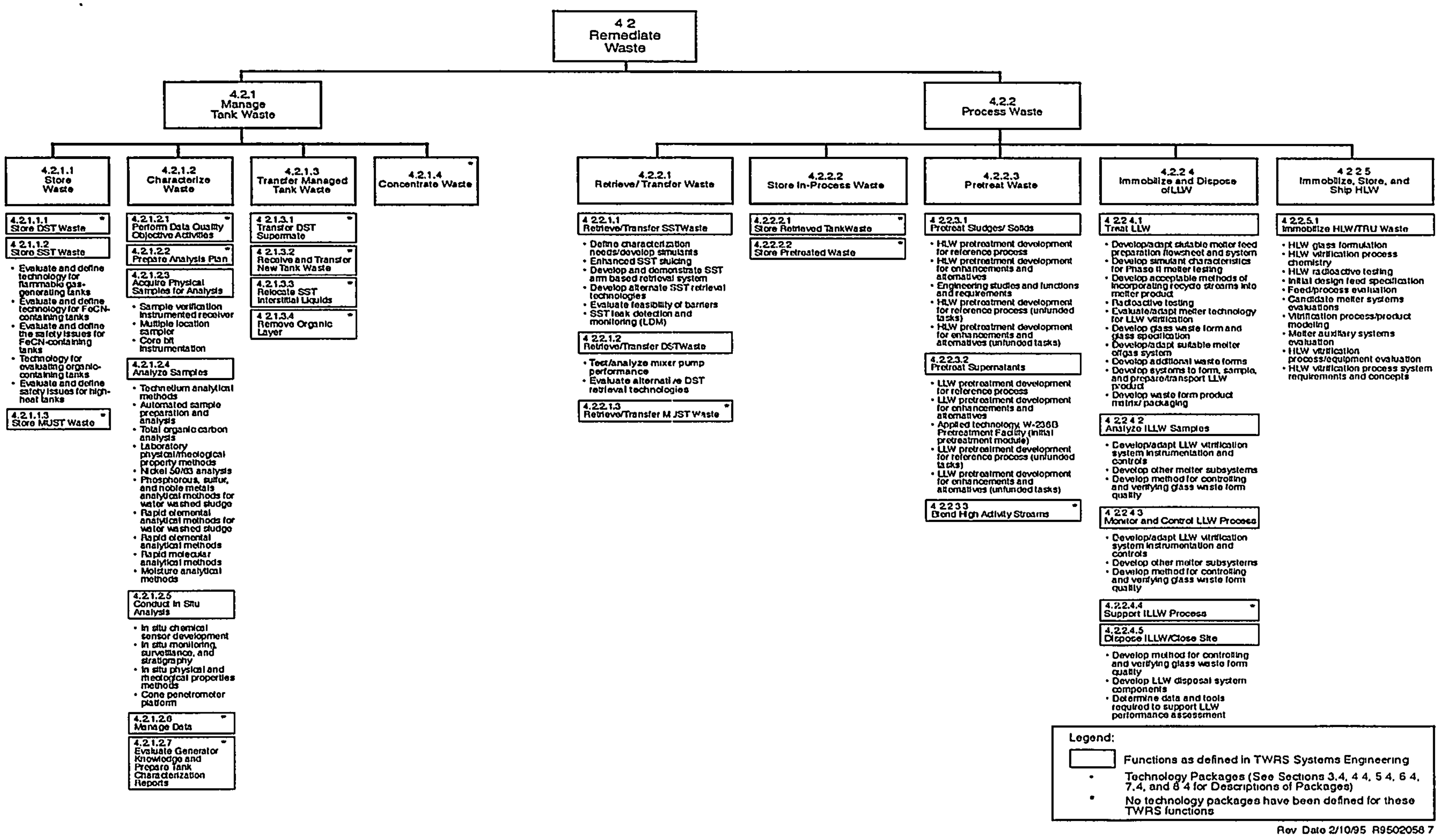

Figure 2.3. Summary of TWRS Functions and Technology Needs

2.6.1.4 Key Uncertainties For Safety

- The amount of DST space required to resolve the safety issues is uncertain.
- Methods to mitigate and/or resolve waste tank safety issues are not fully developed.
- Operational records and inventory data are incomplete and lack of chemical analysis and physical property data for waste are lacking, so that the evaluation and definition of the safety issues is difficult.
- It is not known if the mechanisms for flammable gas generation/retention and release for Tank 241-SY-101 are also causing the behavior of the other flammable gas-containing tanks.
- The amount of moisture needed to ensure safety during storage, retrieval, and treatment of ferrocyanide-containing wastes is uncertain.
- The amount of pretreatment required to resolve the safety issues for the 19 organic-containing tanks is uncertain.
- The need to install mixer pumps or to retrieve the six flammable gas-generating DSTs to resolve the safety issue is uncertain, although the safety issue will remain unless mitigating actions are taken.

2.6.1.5 Alternatives and Enhancements For Safety

- Dilution and heating are being considered as alternatives to mixer pump technology for mitigating flammable gas-containing tanks.

2.6.1.6 Key Features of Technology Plan For Safety

- Laboratory studies and modeling are conducted to determine waste properties as a function of age, moisture, and reactant concentration.
- Appropriate technologies are recommended for safety issue resolution.
- Analytical methods are developed to support characterization of the wastes to resolve safety issues.

2.6.1.7 Key Deliverables For Safety

Key deliverables for technology include:

- Reports on flammable gas generation, mechanisms for gas bubble retention, and tank physics modeling for Flammable Gas Watch List (FGWL) tanks.
- Waste-aging and energetics studies for flammable gas- and ferrocyanide-containing Watch List tanks.
- Instrumentation for ferrocyanide-containing tanks for in situ moisture monitoring in support of safety issue resolution.
- Analytical methods to measure organic species and ferrocyanide species in dissolved waste samples.
- Surface moisture measuring methods for ferrocyanide-containing and organic-containing tanks.
- Thermal modeling to determine the effect of reduced water addition in Tank 241-C-106.

2.6.2 Characterization

2.6.2.1 Technical Strategy For Characterization

Characterization technology will provide data to achieve the following goals:

- Address specific characterization requirements identified by the TWRS program elements and generally documented in Data Quality Objectives (DQO) and test plans.

- Provide data to resolve high priority waste tank safety issues.
- Strengthen the TWRS technical basis.
- Meet relevant characterization needs of retrieval, pretreatment, and vitrification programs.
- Improve throughput and reduce the cost of sampling and analysis.
- Reduce characterization personnel exposure.
- Minimize secondary waste generation associated with sampling and analysis.

2.6.2.2 Reference Approach for Characterization

The characterization reference approach in designed to accomplish the following objects:

- Provide for the capture, integration, and reporting of tank waste information, including process history (e.g., transfer records, historical assays), field measurements, and laboratory data.
- Meet sampling and analysis requirements of TWRS program elements as specified in DQO and test plans, consistent with planning for removal, pretreatment, and vitrification of the wastes.
- Provide data to accelerate resolution of waste tank safety issues.
- Continuously improve the efficiency of the characterization work.
- Verify historical records of tank contents by minimal sampling and analysis to bound waste properties for pretreatment flowsheet development.
- Technology development is recommended where appropriate in each focus area.

2.6.2.3 Key Assumptions for Characterization

- Safety concerns will not prevent tank sampling and characterization.
- Methods will be needed to improve representativeness of sampling.
- Technical and efficiency improvements will be needed for some key laboratory analytical methods.
- Sensor deployment and in situ measurement technologies will be needed to measure key parameters, relevant to tank waste safety issue resolution and retrieval system design.
- Changes in the characterization technical strategy are likely to affect characterization technology needs.
- Funding will be available for meeting technology needs.

2.6.2.4 Key Uncertainties for Characterization

- All TWRS sampling and analysis technology needs may not be identified in a timely manner.
- Applicable, proven technologies elsewhere in the DOE-wide laboratory complex, industry, and universities may not be identified and implemented at Hanford in a timely manner for routine applications.
- Technology development and implementation for beneficial use may adversely affect existing and highly constrained schedules.

- Major changes in the characterization technical strategy could occur, with drastic impact on characterization needs.

- Funding constraints may limit capability to meet technology needs.

2.6.2.5 Alternatives and Enhancements Being Considered for Characterization

Alternatives and enhancements to the characterization reference case are being made for the following reasons:

- Accelerate in situ characterization, minimizing the need for sampling and laboratory analysis.

- Accelerate and improve the quality, quantity, and efficiency of laboratory analysis.

- Improve the representativeness of HLW waste tank samples.

- Facilitate the interpretation of characterization information.

2.6.2.6 Key Features of Technology Plan for Characterization

Key features of the revised characterization technology plan include the following:

- Deploy a cone penetrometer platform with associated sensors for in situ measurements.

- Provide improved methods for tank waste sampling.

- Develop faster, more cost-effective alternatives to existing analytical methods.

- Provide analytical technology to meet needs that cannot be met by existing methods.

- Automate laboratory and hot cell sample preparation and analysis methods, where appropriate.

2.6.2.7 Key Deliverables for Characterization

- integrated life-cycle plans and processes for characterization technologies

- in-tank technologies for characterizing waste surface and volume, including layering information

- core bit instrumentation for temperature and proximity measurement. Instrumented receiver to determine fullness of core sampler at the riser

- alternative sampling methods to improve representativeness of sampling

- improved methodology for noble metals, phosphorus, and technetium analysis

- methods for rapid hot cell chemical, molecular, and moisture analysis of HLW

- automation of sample preparation and analysis

- cone penetrometer platform for in situ sensing

- sensors and methods for in situ measurement of moisture, molecular speciation, and physical properties

- more robust and generally applicable methods for measuring moisture near the waste surface and at depth.

2.6.3 Retrieval

2.6.3.1 Technical Strategy for Retrieval

- DST waste will be hydraulically retrieved using mixer pumps to mobilize the waste.
- SST waste will be removed using sluicing techniques with alternatives such as arm-based retrieval systems which have been developed for difficult waste or for use in tanks where sluicing is not allowed.
- To lower costs of retrieval for difficult SST wastes or when sluicing is not practical, alternative retrieval methods will be developed.
- Subsurface barriers (SSBs) will be evaluated for leak containment or prevention.

2.6.3.2 Key Assumptions for Retrieval

- Mixer pumps will successfully mobilize all sludge in each DST.
- Sluicing will be acceptable as the primary SST retrieval method. Sluicing and/or alternatives such as arm-based retrieval systems, will allow the Retrieval Program to achieve TPA objectives for SST retrieval. The initial retrieval goal of 99% removal will be acceptable and achievable.
- Limited leakage from SSTs during sluicing will be acceptable.
- SSBs will not be required during retrieval, although the TPA requires their evaluation.

2.6.3.3 Key Uncertainties for Retrieval

- A key uncertainty is the acceptability of use of high-water-volume retrieval systems such as past-practice sluicing. This results in uncertainty when enhancements and alternatives to these high-water-volume systems must be available (e.g., confined sluicing, arm-based systems, etc.).
- Ninety-nine percent retrieval using past-practice sluicing may not be achievable, or it may not be adequate for closure.
- The effects of solid waste disposal requirements and repair and maintenance requirements on important retrieval system design considerations must be determined.
- The acceptability of limited leakage from SSTs during sluicing must be determined.

2.6.3.4 Alternatives and Enhancements Being Considered for Retrieval

- Alternative DST and SST retrieval methods are under evaluation (e.g., tethered system, PULSAIR, etc.).
- SSBs are being considered for ensuring leak containment during waste retrieval.

2.6.3.5 Key Features of Technology Plan for Retrieval

- Develop mixer pump technology for retrieval of wastes from DSTs. (Reference Technology)
- Develop enhanced sluicing technology. (Enhancement Technology)
- Develop arm-based retrieval system for SSTs. (Reference Technology)

- Identify and develop alternatives to sluicing and arm-based retrieval systems that may be implemented at a lower cost. (Alternative Technology)

- Evaluate the efficacy and need of SSBs. (Reference Technology, if needed)

2.6.3.6 Key Early Deliverables for Retrieval

- information required for design/procurement of mixer pumps for retrieval of wastes from DSTs

- information for design/procurement/evaluation of arm-based systems (arms, end effectors, instrumentation, control systems) for retrieval of waste from SSTs

- concepts for alternative retrieval systems

- DQO for the waste properties needed by the Retrieval Program

- Leak detection and monitoring functions and requirements as well as technology evaluation.

- SSB evaluation

2.6.4 Pretreatment

2.6.4.1 Technical Strategy for Pretreatment

- Radionuclides will be removed from the LLW stream (primarily supernate and dissolved saltcake) so the treated waste does not exceed the comparable limits for commercial LLW, the requirements for the NRC "incidental waste" classification for Hanford, DOE's ALARA policy, and the disposal system performance requirements.

- Nonradioactive (inert) components must be removed from the HLW stream (primarily sludge) to the extent practicable to enable production of a reasonable volume of a suitable HLW glass.

- Development of processes to remove long-lived radionuclides such as technetium and uranium from the LLW stream must continue as an enhancement until implemented or deemed unnecessary.

- Simple processes to pretreat sludge must be emphasized.

2.6.4.2 Reference Approach for Pretreatment

- Supernate/dissolved saltcake treatment will consist primarily of cesium removal by ion exchange.

- Sludge treatment will consist primarily of sludge washing, alkaline leaching and metathesis, and blending.

2.6.4.3 Key Assumptions for Pretreatment Reference Approach

- Sludge washing, alkaline leaching and metathesis, and blending will provide adequate pretreatment to achieve acceptable HLW composition and glass volume.

- Organic destruction will not be implemented unless radionuclide removal from complexant concentrate (CC) waste requires complexant destruction.

- TRU and strontium removal will not be implemented (except for TRU from CC waste).

- Technetium removal will not be implemented.

- Initial sludge washing/alkaline leaching will be performed within the DSTs.

- Waste will be blended to increase waste loading and minimize glass volumes of the HLW and LLW forms.

- For radionuclides, the LLW feed stream specification to the LLW vitrification facility will be met if cesium-137 is reduced to 1 Ci/m^3, and TRU is removed when necessary. No other radionuclides require removal.

- Separate facility complexes will be constructed to accommodate enhanced sludge washing and radionuclide removal processes.

2.6.4.4 Key Uncertainties for Pretreatment Reference Approach

- The effectiveness of sludge washing, alkaline leaching, and metathesis to produce an acceptable volume of HLW glass is uncertain.

- The ability to meet all needed LLW stream criteria without removing TRUs, strontium, and technetium is uncertain.

- The retrieval sequence to support blending and process rates necessary for storage, pretreatment, and LLW and HLW vitrification is uncertain.

- Adequacy of sludge washing within DSTs is uncertain.

- Waste blending to increase waste loading in the HLW and LLW forms may be impacted by tank space and retrieval system availability.

2.6.4.5 Alternatives and Enhancements Being Considered for Pretreatment Reference Approach

- strontium, transuranics (TRU), and technetium removal from alkaline solutions

- acid leach

- organic complexant destruction for LLW processing

2.6.4.6 Key Features of Technology Plan for Pretreatment

- Determine the effectiveness of sludge washing, alkaline leaching and metathesis, and blending in producing an acceptable volume of HLW glass.

- Evaluate limited advanced separations processes as a contingency to sludge washing, alkaline leaching, and metathesis.

- Remove several key radionuclides from the LLW stream as a contingency in case cesium removal alone is not adequate to meet LLW treatment and disposal requirements.

- Develop organic destruction technologies as contingencies to support complexant destruction necessary for radionuclide removal. This implies both out-of-tank and in-tank technologies.

2.6.4.7 Key Deliverables for Pretreatment

- data for reference flowsheet and for trade study leading to the 03/98 decision on enhanced sludge washing (alkaline leaching and metathesis)

- data for promising sludge treatment alternatives to be evaluated in a trade study leading to the 03/98 decision on enhanced sludge processing

- design data for cesium removal using ion exchange
- design data for removal of other radionuclides from the LLW (TRUs, strontium, and technetium).

2.6.5 LLW Immobilization

2.6.5.1 Technical Strategy for LLW Immobilization

- The LLW will be vitrified to produce an acceptably durable glass waste form.
- The vitrification facility will be designed using available, industrial glass-melting technology.
- Chemicals volatized during vitrification will be captured and treated to meet effluent release limits.
- The LLW vitrification facility will match waste retrieval rates to minimize the amount of DST storage needed.
- Vitrified LLW will be disposed of onsite with a 50-year provision for retrieval.

2.6.5.2 Reference Approach for LLW Immobilization

- Melter technology will be selected by testing vendor products using simulants.
- A LLW vitrification facility is planned for construction onsite beginning in 1997. The facility will begin hot operation in 2005 and will have adequate capacity to vitrify all LLW in approximately 15 years.
- The vitrified LLW will be placed in an onsite, near-surface disposal system that permits retrieval for up to 50 years from the time of placement.

2.6.5.3 Key Assumptions for LLW Immobilization

- Pretreatment of tank wastes can provide a waste feed that falls within an acceptable range of process parameters for the vitrification facility, and which can be used to produce an acceptable, durable waste form for disposal.
- Retrievable, onsite disposal of the vitrified LLW will continue to be the reference approach.
- The LLW vitrification process will be designed based upon vendor testing of simulants, laboratory- and bench-scale testing of radioactive waste samples, and cold testing of facility components. A hot pilot plant will not be required for verification of the design concept.
- The LLW vitrification facility will contain two or more parallel vitrification lines, which will be constructed and started in phases.

2.6.5.4 Key Uncertainties for LLW Immobilization

- Product specifications for vitrified LLW have not yet been established (physical form, matrix material, radionuclide concentrations, etc.).
- Pretreated waste compositions and ranges have not been defined.
- Waste forms and acceptance criteria for non-vitrifiable, recycle streams have not yet been identified.
- Performance requirements for the retrievable waste form in an onsite, near-surface disposal facility have not been determined.

- The level of shielding for the LLW vitrification facility has not been determined.
- The required high-capacity melter technology for radioactive waste has not been demonstrated.

2.6.5.5 Alternatives and Enhancements Being Considered for LLW Immobilization

- Although not part of the TWRS baseline, calcining and grouting of waste are valid alternatives for LLW immobilization.
- Pre-calcining of waste as feed to a glass melter offers many advantages.

2.6.5.6 Key Features of Technology Plan for LLW Immobilization

- Develop product requirements for vitrified LLW, guided by preliminary PA.
- Develop an acceptable LLW glass composition, packaging approach, and melter feed specifications.
- Evaluate, select, and develop melter systems to produce acceptable, vitrified LLW.
- Develop a retrievable LLW disposal system.

2.6.5.7 Key Deliverables for LLW Immobilization

- melter technology evaluation and selection
- pretreated feed composition requirements for feed to the LLW vitrification plant, and for performance specifications of the glass going into the disposal facility; packaging requirements for final immobilized products
- process flowsheet and equipment recommendations for melter feed preparation and melter subsystems to support design
- melter feed specifications - chemical and physical properties, and feed process steps
- design concepts for retrievable LLW disposal facility
- recommended glass composition
- design off-gas system to deal with volatile radionuclides and heavy metals
- data reports to support design and regulatory documentation.

2.6.6 HLW Immobilization

2.6.6.1 Technical Strategy for HLW Immobilization

- The HLW will be vitrified for disposal at a geologic repository.
- The vitrification facility will allow vitrification of all HLW in 20 years.
- The volume of HLW will be minimized considering tradeoffs with pretreatment, vitrified waste loading, and geologic disposal-related requirements.
- TRU waste in the tanks will be blended with HLW unless it is shown to be more economical and programatically acceptable to vitrify it separately for disposal in the Waste Isolation Pilot Plant (WIPP).

- Cesium and strontium capsules will be vitrified only if overpacked capsules are not acceptable for geologic disposal or if there is sufficient incentive to vitrify.
- The vitrified waste will be stored onsite at Hanford until it can be shipped to an offsite geologic repository.

2.6.6.2 Reference Approach for HLW Immobilization

- Canisters larger than the current Savannah River Defense Waste Processing Facility (DWPF) canisters will be used to contain vitrified waste.
- The vitrified HLW form will be borosilicate glass or equivalent with an optimized loading (amount) of waste.
- Methods of reducing the volume of HLW glass and the number of containers will be developed and evaluated. System tradeoff studies will be conducted to select the most cost-effective options for the TWRS program.
- Two candidate melter systems will be selected either at the beginning of FY 1995, or at the end if more testing and evaluation is needed. Additional testing and evaluation of these two melter systems will continue during the conceptual design phase, when the reference design will be selected.

2.6.6.3 Key Assumptions for HLW Immobilization

- Adequate development/demonstration of HLW melters and associated systems will be completed in time to support facility design.
- All of the HLW can be incorporated into a vitrified waste form that meets specifications for disposal.
- The estimated volume of vitrified HLW ranges from 10,000 to 28,000 m^3 (9,000-25,000 DWPF Containers), which is acceptable to the Geologic Repository Program.

2.6.6.4 Key Uncertainties for HLW Immobilization Technology

- The compositions and ranges of pretreated vitrification feed have not yet been adequately defined.
- Waste, melter feed, and glass property-composition relationships for various melter types and operating conditions have not been defined.
- The optimum type of melter technology for vitrifying Hanford Site HLW has not been determined.
- The capability to incorporate all HLW and recycle stream material into a single waste form, thus eliminating the need for multiple waste forms, is not certain. Also, the number of distinct vitrified waste forms that must be qualified under the waste acceptance product specifications is not certain.
- Acceptance by the geologic repository of large HLW canisters, or of overpacked cesium and strontium capsules, has not yet been determined. Also, acceptance by the WIPP of vitrified tank TRU waste has not been established.

2.6.6.5 Alternatives and Enhancements Being Considered for HLW Immobilization

2.6.6.6 Key Features of Technology Plan for HLW Immobilization

- Define acceptable range of waste feed composition.

- Determine waste, melter feed, and glass property-composition relationships for various melter types and operating conditions.
- Test and evaluate candidate melter systems with the goal of selecting a melter concept for design.
- Determine disposition of TRU tank waste and cesium/strontium capsules.
- Determine optimum acceptable container configuration and volume for geologic disposal.

2.6.6.7 Key Deliverables for HLW Immobilization

- feed simulant compositions for testing
- data to support melter-feed definition and preparation
- glass formulation and properties for melter evaluation, selection, and plant design
- glass properties for waste-form qualification, systems assessments, and tradeoff studies
- melter test data for plant design
- melter test and evaluation reports
- studies to support assessments of TRU tank waste and cesium/strontium capsule disposition
- waste feed specification
- melter system selection
- methods to address radionuclide volatility and heavy metal accumulation in monitoring systems
- melter system design support data.

2.7 Programmatic Critical Interfaces

The critical interfaces related to technology activities supporting all six program elements of the TWRS program are integrated in Table 2.2. A critical interface is an important system boundary/point of coordination between two TWRS program elements for one or both elements to successfully meet program objectives. These interfaces are generally technology-to-TWRS program element or TWRS program element-to-technology (not technology-to-technology or program element-to-program element).

Critical interfaces for each program element are also listed in Chapters 3.0 through 8.0.

2.8 Integrated Technology Summary Schedule

The Integrated Technology Summary Schedule (Figure 2.4) illustrates the relationship between planned TWRS technology work, as defined in the ITP, and the overall schedule for the TWRS program. Schedule bars are shown for each program element:

- The first schedule bar represents the programmatic schedule and key milestones for that program element.
- The second schedule bar shows technology deliverables compiled from the technology needs templates in Appendix E. Some technology activities have been grouped together at a higher level than the technology packages that appear in templates.

Table 2.2. Combined Critical Interfaces for Technology Activities Supporting TWRS Program

No.	From	To	Need By	Item Provided
Safety				
S1	ST	PT	9/95	Notification that mitigation measures for resolving waste tank safety issues have been validated
S2	ST	PT,HLW	10/94+	Identify potential chemical additions that may be used for safety issue resolution
S3	ST	CH	10/94+	Data requirements and Data Quality Objectives (DQO)
S4	CH	ST	10/94+	Sample analysis to support studies
S5	ST	CH	9/96	Organic analysis methods to evaluate and define the organic safety issue
S6	ST	CH	9/95	Parameters to be measured to predict moisture movement in sludge
S7	OPS	ST	9/96	Install moisture monitoring instruments and remove ferrocyanide tanks from Watch List
S8	ST	CH	10/97	Provide information on the nature of organics in the waste tanks
S9	RT	ST	9/95	Identify potential chemical addition that may be used during retreival
S10	ST	RT	9/97	Define chemical addition limitations
Characterization				
C1	OPS	CH	10/94+	Waste compatibility sampling and analysis DQO and test plans.
C2	RT	CH	10/94+	Retrieval DQO and test plans.
C3	PT	CH	10/94+	Pretreatment DQO and test plans.
C4	HLW	CH	10/94+	HLW DQO and test plans.
C5	LLW	CH	10/94+	LLW DQO and test plans.
C6	ST	CH	10/94+	Waste Tank Safety DQO and test plans.
C7	CH	PT	10/94+	Waste characteristics data and samples.
C8	CH	OPS	09/95	Core bit temperature sensing package.
C9	CH	OPS	03/95	Sample verification instrumented receiver.
C10	CH	Labs	10/94+	Improved analytical procedures.

No.	From	To	Need By	Item Provided
C11	CH	RT	10/94+	Waste characteristics data and samples.
C12	CH	ST	10/94+	Sampling methods and studies.
Retrieval				
R1	OPS,UPG	RT	9/96	Operation of pipelines, upgrading, and other tank farm infrastructure supporting waste retrieval
R2	RT	OPS	9/95	Input on infrastructure needs and requirements for tank farm upgrades to support retrieval
R3	RT	OPS	9/97	Design, installation, and operation of waste retrieval systems to resolve safety issues (Tank C-106, then sequential need)
R4	CH	RT	1/95	Physical and chemical properties of waste in SSTs and DSTs
R5	RT	CH	10/94+	Data requirements and DQOs
R6	RT	PT, HLW, ST	9/95	Identify potential chemical addition that may be used during retrieval
R7	SW	RT	9/95	Capability to handle retrieval solid waste
R8	RT	OPS	9/95	Need for maintenance facilities
R9	HLW,PT,ST	RT	9/97	Define chemical addition limitations
R10	ER/WM	RT	9/95	Requirements for tank closeout
Pretreatment				
P1	CH	PT	10/94-9/99	Supernate/salt cake samples of tank wastes
P2	PT	CH	10/94+	Sampling needs through requirements documents using DQO process and through test plans
P3	CH	PT	10/94-9/99	Sludge samples of tank waste
P4	CH	PT	10/94-9/99	Sludge samples for settling tests
P5	CH	PT	10/94+	Waste characteristic data
P6	LLW	PT	10/94+	LLW feed specifications
P7	HLW	PT	10/94+	HLW feed specifications, alternate disposal
P8	ER/WM/ NRC+	PT	10/94+	Requirements for decontamination and decommissioning
P9	PT	LLW	10/94+	Projected feed composition

No.	From	To	Need By	Item Provided
P10	PT	LLW	10/94+	Projected feed composition
P11	ST	PT	9/95	Notification that mitigation measures for resolving waste tank safety issues have been validated
P12	ST	PT	10/94+	Identify potential chemical additions that may be used for safety issue resolution
P13	PT	LLW,HLW	3/98	Impact of pretreatment decision on enhanced sludge washing of low-level feeds
P14	PT	IPM	10/94+	Test results
P15	PT	NRC	10/95+	Technical performance/decontamination factors
Low-Level Waste				
L1	HLW	LLW	9/96	Characteristics and volume of HLW plant-generated LLW streams
L2	PT,OPS, RT	LLW	10/94-9/98	Pretreatment product composition envelope
L3	PT	LLW	3/98	Impact of pretreatment decision on enhanced sludge washing of low-level feed
L4	LLW	DSP	6/99	Waste form system configuration
L5	LLW	DSP	6/99	Performance assessment data
L6	LLW	DSP	6/96	Reference Glass Formulation
L7	LLW	LPD	10/94+	Support systems: recycle streams, offgas, feed, and other subsystems
L8	DSP	LLW	9/98	Waste packaging performance requirements
L9	LLW	CH	10/94+	LLW DQO and test plans
High-Level Waste				
H1	PT	HLW	9/99	Pretreated feed for hot bench-scale testing (100's liters)
H2	TWRS	HLW+	6/95	TWRS integration site selection study
H3	PT	HLW	1/95+	Updated pretreated feed characteristics
H4	PT,S,R	HLW	3/98	Final pretreated feed characteristics for detailed design
H5	HLW	PT,R	10/94+	Updated HLW Feed Specification and bench test feed requirements
H6	HLW	PT	9/96	Feed concentration requirements

No.	From	To	Need By	Item Provided
H7	HLW	CH	10/94+	Characterization data requirements for HLW process development (coordinated with PT, LLW, and RT)
H8	PT	HLW	9/95	Corrosion effects of washed sludge
H9	CH	HLW+	10/94+	Characterization data when published
H10	CH	HLW+	10/94+	Quantities of core sample material for PT and HLW process development tests
H11	TWRS	HLW	10/94+	TWRS site flow sheet
H12	HLW	ER/WM/ NRC	12/96	Decision for processing cesium and strontium capsules
H13	TWRS	HLW+	12/98	Approved TWRS EIS

Note: + = More than one update or user.

LEGEND:
CH = Characterization Program Element.
DSP = Disposal
ER/WM = Environmental Remediation/Waste Management.
ER/WM/NRC = Environmental Restoration and Waste Management, Nuclear Regulatory Commission.
HLW = High-Level Waste Immobilization Program Element.
IPM = Initial Pretreatment Module (within Pretreatment Program Element but a key transferee of results).
Labs = Analytical laboratories.
LLW = Low-Level Waste Immobilization Program Element.
LPD = Low-Level Plant Design
OPS = Operations and Maintenance.
PT = Waste Pretreatment Program Element.
RT = Waste Retrieval Program Element.
ST = Waste Tank Safety Program Element.
SW = Solid Waste.
UPG = Upgrades.

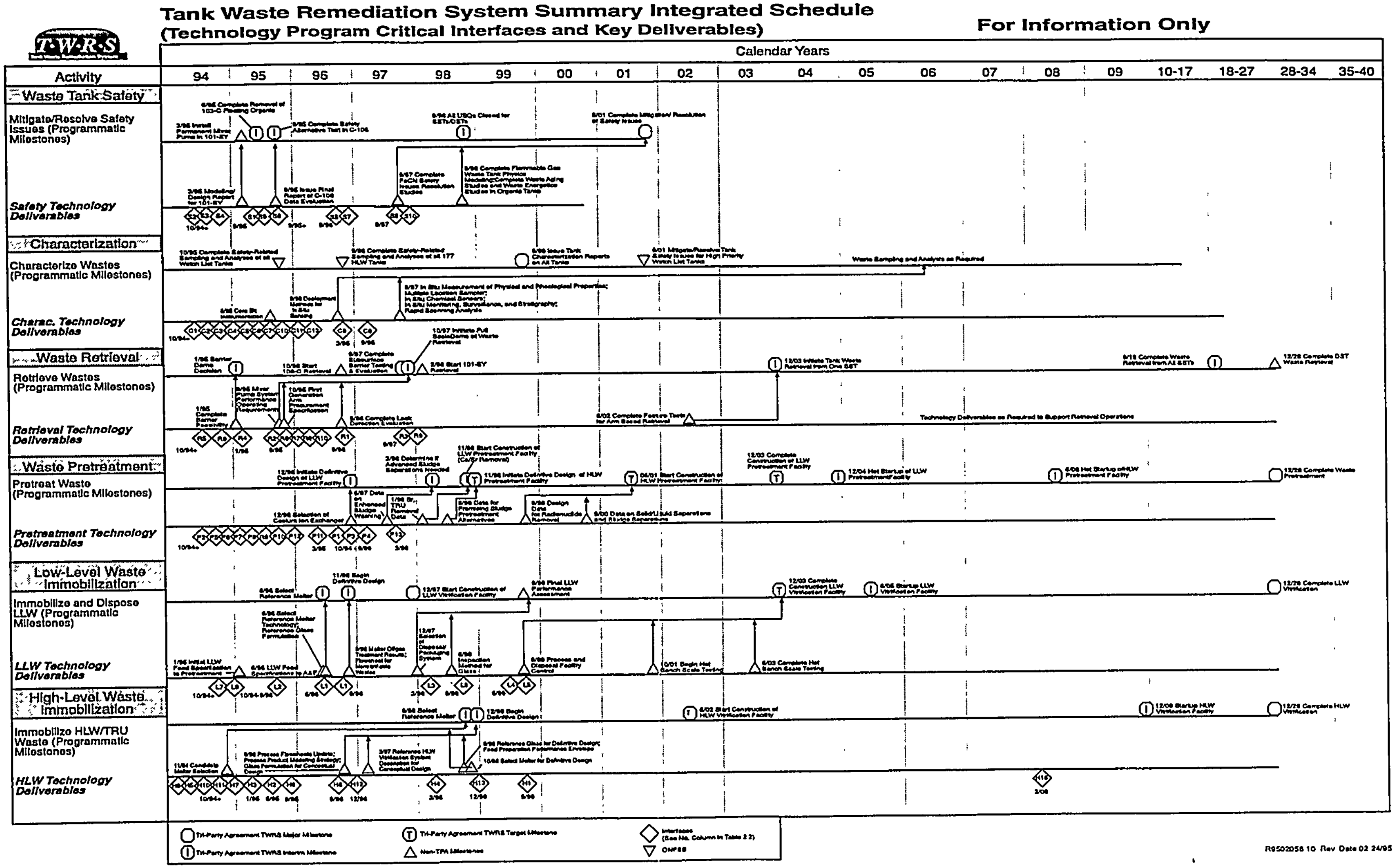

Figure 2.4. Summary Schedule of the TWRS Program

In addition to showing the links between technology activities and the TWRS program, the critical interfaces for each program element are shown for each of the technology date lines.

- Relationships between technology work and program work (intraprogram interfaces) are represented by arrows connecting the schedule line items.
- Relationships between technology activities and other program elements (interprogram interfaces) are represented by diamond-shaped connectors keyed to Table 2.2, the critical interfaces table.

2.9 Summary Budget

Tables 2.3 and 2.4 show the TWRS technology budget summarized from the detailed information contained in Chapters 3.0 through 8.0 of this document. Table 2.3 presents two sets of budget estimates by program element and fiscal year. The first profile consists of activities currently included in the TWRS MYWP and reflects the estimated budget available for technology. The second profile reflects the estimated budget required to perform all tasks shown in the ITP, including activities that are anticipated to be funded and those that are not (unfunded activities have been prioritized for inclusion in the MYWP at the first opportunity). Table 2.4 presents this information for FY 1996 by program element and technology package.

All budget profile and forecasts are preliminary, rough-order estimates and may change significantly as processes are defined, facilities are designed, and engineering estimates are made. *All cost estimates in the ITP are unofficial; they are for planning purposes only.*

2.10 Prioritization Process

A prioritization process was conducted to prioritize non-baseline technology development activities for the ITP. A typical multi-attribute utility prioritization approach was used to guide the process. Specific modifications and shortcuts employed are discussed in Appendix A of the ITP. Teams composed of individuals from the TDPO, Architecture Groups, TWRS Program Office, and TWRS Engineering for each program element evaluated and prioritized non-baseline activities within their program area.

The selected technology development activities/tasks to prioritize were those that for FY 1996 or beyond either did not appear in the TWRS MYWP, or appeared in the MYWP but may be in jeopardy. An assumption of this approach is that FY 1995 activities/tasks that were not funded in the FY 1995 MYWP were pushed into FY 1996 or deleted. Those activities/tasks from FY 1995 not deleted were also candidates for this prioritization, unless they appeared as budgeted items for the FY 1996 MYWP.

Table 2.3. Summary of Total TWRS Technology Budget

TWRS TECHNOLOGY BUDGET ESTIMATES
(Unescalated Dollars in Thousands by Fiscal Year)

PROGRAM ELEMENT	1995	1996	1997	1998	1999	2000	2001 +	TOTAL
["Expected Budget Available for Technology" consists of activities in TWRS Multi-Year Work Plan]								
WASTE TANK SAFETY								
Expected Budget Available for Technology	7,257	6,522	4,208	720	0	0	0	18,707
Total Estimated Budget for Technology Activities in ITP	7,257	6,522	4,208	720	0	0	0	18,707
CHARACTERIZATION								
Expected Budget Available for Technology	3,877	10,795	5,415	0	0	0	0	20,087
Total Estimated Budget for Technology Activities in ITP	3,877	10,795	5,415	0	0	0	0	20,087
WASTE RETRIEVAL								
Expected Budget Available for Technology	16,483	24,037	22,139	11,105	7,400	7,400	14,795	103,359
Total Estimated Budget for Technology Activities in ITP	16,483	24,837	22,972	12,939	9,067	9,567	14,795	110,660
WASTE PRETREATMENT								
Expected Budget Available for Technology	38,367	37,988	43,787	11,500	11,944	5,695	7,254	156,535
Total Estimated Budget for Technology Activities in ITP	38,867	39,988	45,262	11,650	11,944	5,695	7,254	160,660
LOW-LEVEL WASTE IMMOBILIZATION								
Expected Budget Available for Technology	21,555	19,530	8,700	6,800	3,100	2,900	13,000	75,585
Total Estimated Budget for Technology Activities in ITP	21,905	22,830	14,775	15,600	7,150	5,225	30,500	117,985
HIGH-LEVEL WASTE IMMOBILIZATION								
Expected Budget Available for Technology	15,313	17,691	18,699	12,743	13,087	9,592	56,902	144,027
Total Estimated Budget for Technology Activities in ITP	15,313	17,691	18,699	12,743	13,087	9,592	56,902	144,027
INTEGRATED TECHNOLOGY PLAN TOTALS:								
Expected Budget Available for Technology	102,852	116,563	102,948	42,868	35,531	25,587	91,951	518,300
Total Estimated Budget for Technology Activities in ITP	103,702	122,663	111,331	53,652	41,248	30,079	109,451	572,126

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Table 2.4. Budget

TWRS INTEGRATED TECHNOLOGY PLAN FY 1996 BUDGET SUMMARY
(Unescalated Dollars in Thousands by Fiscal Year)

Technology Package No.	Title	Expected Budget Available For Technology	Total Est. Budget for Technology Activities in ITP
Waste Tank Safety			
3.4.1.1	Evaluate and Define Technology for Flammable Gas Generating Tanks	2,902	2,902
3.4.2.1	Evaluate and Define Technology for Ferrocyanide-Containing Tanks	-	-
3.4.2.2	Evaluate and Define the Safety Issues for Ferrocyanide-Containing Tanks	1,289	1,289
3.4.3.1	Technology for Evaluating Organic-Containing Tanks	2,331	2,331
3.4.4.1	Evaluate and Define Safety Issues for High-Heat Tanks	-	-
TOTAL WASTE TANK SAFETY		**6,522**	**6,522**
Characterization			
4.4.1.1	Technetium Analytical Methods	205	205
4.4.1.2	Automated Sample Preparation and Analysis	200	200
4.4.1.3	Total Organic Carbon Analysis	200	200
4.4.1.4	Laboratory Physical/Rheological Property Methods	200	200
4.4.1.5	Nickel 59/63 Analysis	140	140
4.4.1.6	Phosphorous, Sulfur and Noble Metals Analytical Methods for Water Washed Sludge	100	100
4.4.2.1	Sample Verification Instrumented Receiver	200	200
4.4.2.2	Multiple Location Sampler	1,400	1,400
4.4.2.3	Core Bit Instrumentation	500	500
4.4.3.1	In Situ Chemical Sensor Development	400	400
4.4.3.2	In Situ Monitoring, Surveillance and Stratigraphy	600	600
4.4.3.3	In Situ Physical and Rheological Properties Methods	200	200
4.4.3.4	Cone Penetrometer Platform	1,200	1,200
4.4.4.1	Rapid Elemental Analytical Methods for Water Washed Sludge	-	-
4.4.4.2	Rapid Elemental Analytical Methods	2,200	2,200
4.4.4.3	Rapid Molecular Analytical Methods	2,050	2,050
4.4.4.4	Moisture Analytical Methods	1,000	1,000
TOTAL CHARACTERIZATION		**10,795**	**10,795**
Waste Retrieval			
5.4.1.1	Define Characterization Needs/Develop Simulants	830	830
5.4.1.2	Enhanced SST Sluicing	2,000	2,000
5.4.1.3	Develop and Demonstrate SST Arm-Based Retrieval System	6,580	6,580
5.4.1.4	Develop Alternate SST Retrieval Technologies	520	1,320
5.4.1.5	Evaluate Feasibility of Barriers	4,600	4,600
5.4.1.6	Single-Shell Tank Leak Detection and Monitoring (LDM)	1,000	1,000
5.4.2.1	Test/Analyze Mixer Pump Performance	7,189	7,189
5.4.2.2	Evaluate Alternative DST Retrieval Technologies	1,318	1,318
TOTAL WASTE RETRIEVAL		**24,037**	**24,837**

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Table 2.4 Budget (cont.)

TWRS INTEGRATED TECHNOLOGY PLAN FY 1996 BUDGET SUMMARY (Continued)
(Unescalated Dollars in Thousands by Fiscal Year)

Technology Package No.	Title	Expected Budget Available For Technology	Total Est. Budget for Technology Activities in ITP
***Waste Pretreatment**			
6.4.1	LLW Pretreatment Development for Reference Process	889	889
6.4.2	LLW Pretreatment Development for Enhancements and Alternatives	2,504	2,504
6.4.3	HLW Pretreatment Development for Reference Process	12,070	12,070
6.4.4	HLW Pretreatment Development for Enhancements and Alternatives	500	500
6.4.5	Engineering Studies and Functions and Requirements (F&R)	4,382	4,382
6.4.6	Applied Technology, W-236B Pretreatment Facility (IPM)	17,643	17,643
6.4.7	LLW Pretreatment Development for Reference Process(Unfunded)	0	750
6.4.8	LLW Pretreatment Development for Enhancements and Alternatives (Unfunded)	0	450
6.4.9	HLW Pretreatment Development for Reference Process(Unfunded)	0	300
6.4.10	HLW Pretreatment Development for Enhancements and Alternatives (Unfunded)	0	500
* See Table 6.3 for a more detailed analysis of the Waste Pretreatment Budget			
TOTAL WASTE PRETREATMENT		37,988	39,988
Low-Level Waste Immobilization			
7.4.1	Develop/Adapt Suitable Melter Feed Preparation Flowsheet and System	1,250	1,250
7.4.2	Define Simulant Characteristics for Phase II Melter Testing	430	430
7.4.3	Develop Acceptable Methods of Incorporating Recycle Streams into Melter Product	490	990
7.4.4	Radioactive Testing	0	200
7.4.5	Evaluate/Adapt Melter for LLW Vitrification	7,000	7,000
7.4.6	Develop Glass Waste Form and Glass Speciation	3,960	3,960
7.4.7	Develop/Adapt Suitable Melter Offgas System	950	950
7.4.8	Develop Additional Waste Forms	490	490
7.4.9	Develop/Adapt LLW Vitrification System Instrumentation and Controls	0	1,100
7.4.10	Develop Systems to Form, Sample and Prepare/Transport LLW Product	260	460
7.4.11	Develop Other Melter Subsystems	200	1,500
7.4.12	Develop Waste Form Product Matrix/Packaging	1,400	1,400
7.4.13	Develop Method for Controlling and Verifying Glass Waste Form Quality	400	400
7.4.14	Develop LLW Disposal System Components	100	100
7.4.15	Determine Data and Tools Required to Support Low Level Waste Performance Assessment	2,600	2,600
TOTAL LOW-LEVEL WASTE IMMOBILIZATION		19,530	22,830

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Table 2.4 Budget (cont.)

TWRS INTEGRATED TECHNOLOGY PLAN FY 1996 BUDGET SUMMARY (Continued)
(Unescalated Dollars in Thousands by Fiscal Year)

Technology Package No.	Title	Expected Budget Available For Technology	Total Est. Budget for Technology Activities in ITP
High-Level Waste Immobilization			
8.4.1.1	HLW Glass Formulation	2,176	2,176
8.4.1.2	HLW Vitrification Process Chemistry	1,359	1,359
8.4.1.3	Radioactive Testing	649	649
8.4.1.4	Initial Design Feed Specification	220	220
8.4.1.5	Feed/Process Evaluation	675	675
8.4.2.1	Candidate Melter System Evaluations	8,719	8,719
8.4.2.2	Vitrification Process/Product Modeling	306	306
8.4.2.3	Melter Auxilliary Systems Evaluation	27	27
8.4.2.4	HLW Vitrification Process/Equipment Evaluation	795	795
8.4.2.5	HLW Vitrification Process System Requirements and Concepts	2,765	2,765
TOTAL HIGH-LEVEL WASTE IMMOBILIZATION		17,691	17,691
GRAND TOTAL		116,563	122,663

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3.0 Waste Tank Safety

3.1 Purpose, Objectives, Scope, and Strategy

As a result of past processes and aging of waste in approximately 56 Watch List tanks, concerns have arisen over the potential for release of high-level waste (HLW) from the tanks to the environment. Releases may result from uncontrolled increases in temperature or pressure in the tanks. Specific safety issues that must be addressed by technology for the Waste Tank Safety Program for Watch List tanks include mitigating or resolving the following:

- Conditions in the tanks that could lead to
    - generation, accumulation, and possible ignition of combustible mixtures of hydrogen, ammonia, nitrogen, and organic vapors
    - potential reactions of ferrocyanides in waste tanks
    - uncontrolled oxidation by nitrate or nitrite of highly concentrated mixed organic chemicals
    - combustion of organic solvents entrained in the saltcake.
- Structural failure if, in the event of a leak, cooling-water additions are discontinued to Tank 241-C-106, a high-heat tank

The **purpose** of the Waste Tank Safety Program is to mitigate and/or resolve the waste tank safety issues at the Hanford Site. The **objectives** are 1) to serve as a focal point to identify and resolve selected high-priority waste tank safety issues and 2) to ensure safe storage until retrieval or disposal operations occur. The **scope** includes activities to mitigate and/or resolve tank safety issues.

To successfully meet its objectives, the Waste Tank Safety Program will use the following overall **strategy**: mitigate or resolve tank safety issues to the fullest extent practicable by evaluating the in-tank hazard, develop criteria to define the safety issue, resolve any Unreviewed Safety Questions (USQs), monitor the hazard, ensure interim safe storage conditions, and mitigate the hazard if necessary.

The strategy for technology to support mitigation and resolution of waste tank safety issues focuses on implementing proven solutions that will minimize the overall risk to operations personnel and the public. The Waste Tank Safety Program is a mature program involving technology development and applied engineering. In general, breakthroughs in technology are not considered prerequisites to resolving the safety issues; however, considerable laboratory research may be necessary. All safety issues should be closed out within another 2 to 5 years.

3.1.1 Key Assumptions

The general assumptions listed below are based on current knowledge. They will be revised as necessary and as new information becomes available.

- All the major waste tank safety issues have been identified. No new major safety issues requiring diversion of resources will be identified.
- Safety issues will be mitigated in-tank, if possible. Resolution of safety issues for some tanks may be delayed if mitigation external to the tank is required.
- Activities to resolve waste tank safety issues will be based on continued in situ safe storage of the waste until the waste is retrieved for mitigation, treatment, or disposal.

- Safe interim storage will support waste retrieval, pretreatment, vitrification, and other operational requirements for cleanup activities.
- Priorities will be established consistent with legal requirements for protecting health, safety, and the environment.
- No pretreatment requirements have been identified to resolve the safety issues.

Specific assumptions by safety issues for the Safety Program are as follows:

3.1.1.1 Hydrogen Mitigation

- Permanent mixer pumps may be installed in some of the six double-shell flammable gas tanks on the Watch List (Tanks 241-SY-101, 241-SY-103, 241-AW-101, 241-AN-103, 241-AN-104, and 241-AN-105) to mitigate the waste hazard until the waste has been retrieved.
- The retrieval operation for the flammable gas DSTs will be initiated during 1998, if retrieval is required for safety issue resolution.

3.1.1.2 Ferrocyanide Safety Program

- Resolution of the safety issue for the 18 ferrocyanide tanks on the Watch List will not require retrieval or pretreatment of the waste. If mitigation is needed, moisture monitoring and control systems will be installed in the tanks.

3.1.1.3 Flammable Gas Program

- The safety issue for the six double-shell flammable gas tanks on the Watch List (241-SY-101, 241-SY-103, 241-AW-101, 241-AN-103, 241-AN-104, and 241-AN-105) will remain until the tanks are retrieved. Appropriate monitoring and operating controls will allow tank waste to be safely stored prior to mitigation or remediation.
- Retrieval will not be necessary to resolve safety issues for any single-shell flammable-gas tanks.

3.1.1.4 Organic Safety Program

- Retrieval or pretreatment will not be required for resolution of the safety issue for 19 organic containing tanks (Tank 241-C-103 not included).
- Characterization and historic review may identify more organic Watch List tanks.
- Moisture monitoring and operating controls will be implemented in organic tanks requiring mitigation.
- The organic liquid layer floating on the waste in Tank 241-C-103 may be pumped out of the tank to resolve the flammability safety issue related to that layer as well as the potential noxious vapor safety issue.

3.1.1.5 High Heat Safety Program

- Tank 241-C-106 will be retrieved to resolve the high-heat tank safety issue.

3.1.1.6 Tank Vapor Issue Resolution

- Vapor flow monitoring devices with alarms are being installed to investigate weather factors leading to vapor release and to ensure safe operating conditions for workers in the vicinity of tanks.

3.1.1.7 Criticality Safety Program

- The criticality safety issue will be resolved by administrative controls and by gathering data to determine if a criticality issue is credible.

3.1.2 Key Uncertainties

The uncertainties being addressed by the Waste Tank Safety Program are considerable. One of these uncertainties is the specification to safety screen all tanks by October 1996 (DOE/RL 1994d). Other uncertainties include the following:

- The operational records are incomplete, because inventory data and chemical analysis of in-tank contents are lacking. The incomplete records make removal of a tank from the Watch List difficult without additional characterization.
- The regulatory acceptability of mitigation strategies is unclear, especially if more stringent environmental and safety regulations are implemented.
- The extent of mixing, dilution, or heating that will be required to mitigate the six flammable gas-containing DSTs has not yet been determined.
- None of the 19 organic/nitrate-containing tanks (other than Tank 241-C-103) is expected to require pretreatment. This assumption is largely based on the similarity of these wastes to the wastes in the ferrocyanide tanks. The evaluation and definition of the safety issue conducted to-date for these organic tanks has been limited, and the results may change this assumption.
- A certain level of moisture may be required during storage, retrieval, and treatment of ferrocyanide-containing wastes to prevent exothermic reactions. However, if the studies described in this plan show aging to be the solution for organic- and ferrocyanide-containing tanks, the need for technology to maintain adequate moisture will be reduced.
- The shortage of tank space could delay safety issue resolution or the responses to certain emergencies (e.g., the gas-generating waste in Tank 241-SY-101, leaking tanks, overheating tanks, tanks with noxious vapors).
- Methods to mitigate or resolve waste tank safety issues have not yet been fully developed. For example, the proposed one-to-one dilution for Tank 241-SY-101 may not be adequate, and greater dilution ratios may be required.
- The limited availability of tank risers may impact installation of mitigating equipment and tank monitoring devices.

The strategy is to use available technologies to resolve the safety issues in short operational timeframes.

3.1.3 Critical Interfaces

A *critical interface* is an important system boundary or point of coordination between two TWRS program elements needed for one or both elements to meet program objectives. The critical interfaces related to safety are listed in Table 3.1. These interfaces are generally technology-to-TWRS program element or TWRS program element-to-technology (not technology-to-technology or program element-to-program element).

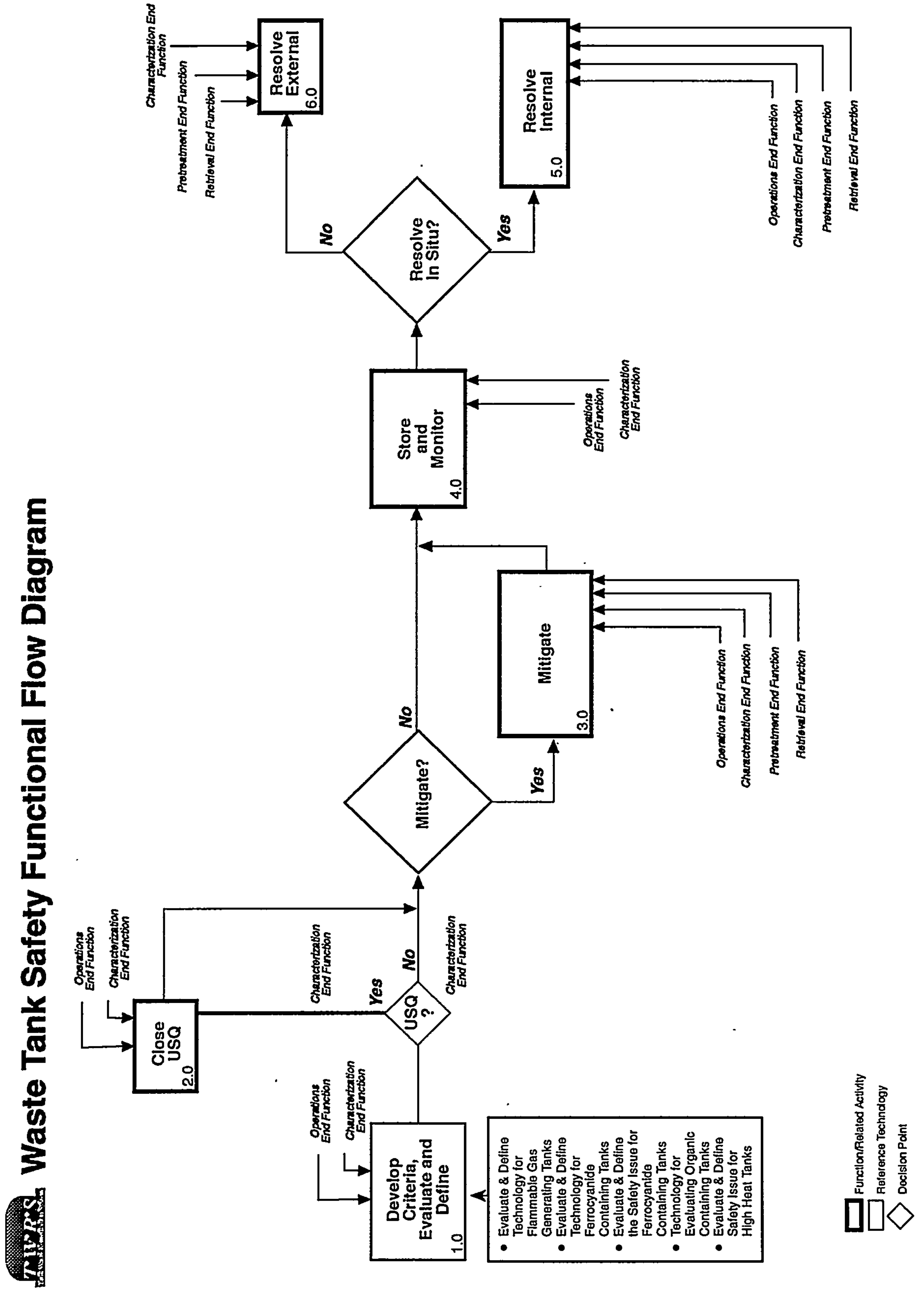
Table 3.1 Critical Interfaces for Technology Activities Supporting Waste Tank Safety

No.	From	To	Need By	Item Provided
S1	ST	PT	9/95	Notification that mitigation measures for resolving waste tank safety issues have been validated
S2	ST	PT,HLW	10/94+	Identify potential chemical additions that may be used for safety issue resolution
S3	ST	CH	10/94+	Data requirements and Data Quality Objectives (DQO)
S4	CH	ST	10/94+	Sample analysis to support studies
S5	ST	CH	9/96	Organic analysis methods to evaluate and define the organic safety issue
S6	ST	CH	9/95	Parameters to be measured to predict moisture movement in sludge
S7	OPS	ST	9/96	Install moisture monitoring instruments and remove ferrocyanide tanks from Watch List
S8	ST	CH	10/97	Provide information on the nature of organics in the waste tanks
S9	RT	ST	9/95	Identify potential chemical addition that may be used during retreival
S10	ST	RT	9/97	Define chemical addition limitations

Note: + = More than one update or user.
LEGEND:
CH = Characterization Program Element.
ST = Waste Tank Safety Program Element.
RT = Waste Retrieval Program Element.
PT = Waste Pretreatment Program Element.
HLW = High-Level Waste Immobilization Program Element.
LLW = Low-Level Waste Immobilization Program Element.
OPS = Operations and Maintenance.

3.2 Functional Flow Diagram

Functions are simple statements that define what a system must do. Functions form the basis for identifying work required to support TWRS program needs. A block diagram that maps the relationship between functions and technology for the Waste Tank Safety Program is provided in Figure 3.1 The work required to support the Waste Tank Safety Program is represented by the following major functions:



Rev./Date 02-10-95 R9502058.6

Figure 3.1. Functional Flow Diagram

- **Evaluate and Define Safety Issues** - establishes the work to be done using historical data, sampling and analysis, simulant waste studies, laboratory tests, monitoring data, mathematical modeling, and sensitivity analysis. This function defines safe conditions for operation and decides on the appropriate path to resolve the safety issues. This function also includes the choice of the "no-action" option if it is determined that no safety issue can be identified for a single waste type or group of similar wastes. Finally, this function makes recommendations for closure of USQs.

- **Close USQs** - establishes the technical bases for closure of the USQs. This function redefines the safety envelope, modifies operating procedures, establishes control limits, and documents recommendations for safety issue resolution.

- **Mitigate Safety Condition** - develops a corrective action plan for safety issues that addresses possible in-tank treatment to reduce the severity of the safety issue. Work includes development, design, fabrication, installation, testing, and demonstration of equipment for moisture control, mixer pumps, heating and dilution, and vapor treatment.

- **Store and Monitor** - provides monitoring systems to ensure safe storage until the safety issue is resolved. Work includes developing, procuring, and installing additional equipment to continuously monitor tank temperature, pressure, gas concentration, and surface level.

- **Resolve Safety Issue - Internal** - implements in-tank corrective actions to eliminate the safety issue.

- **Resolve Safety Issue - External** - resolves the safety issue with technologies developed in the Retrieval and Pretreatment Programs.

3.3 Functions and Associated Technology Packages for Waste Tank Safety

Table 3.2 presents the program recommended by the Waste Tank Safety (WTS) staff for the Integrated Technology Plan (ITP). In addition to the TWRS Baseline Program, Table 3.2 presents nonbaseline activities. These programs are defined in the Preface.

The TWRS Baseline Program is consistent with the most recent version of the Multi-Year Program Plan (MYPP). The nonbaseline activities shown are those that are vital to the overall TWRS mission, but are not currently projected to be funded. They were prioritized for inclusion in the baseline at the first opportunity. The technology activities in both programs were identified and prioritized through a process described in Appendix A, Section A.6.

3.3.1 Key to Table 3.2

Technology packages and tasks in the TWRS Baseline Program appear in normal font; those in the nonbaseline program appear in *italics*.

Function: The systems engineering function (as described in the TWRS Functional Requirements document, U.S. DOE/RL 1994b) associated with this technology package (followed by the number for the appropriate systems engineering level in parenthesis).

Technology Package: A set of technology activities that need to be completed to respond to a functional need. May include activities to address/support the reference case, or enhancements or alternatives to the reference case (followed by the program element chapter number in parenthesis).

Tasks: The tasks must be performed to resolve this technology need. Dates are unofficial; they are for planning purposes only.

Table 3.2. Waste Tank Safety: Recommended Technology Program

Function and Technology Package		Tasks		FY 1996 Cost Estimate ($K)		
Functional Need Level 4	Template Title (number)	No.	Title	Funded	Not Funded	Benefit
Store Waste (4.2.1.1)	**Evaluate and Define Technology for Flammable Gas-Generating Tanks** **3.4.1.1** Reference	1.	Gas generation studies	390		Safety: Resolve priority tank safety issues. Commitment: TPA; Public Law 101–5110; DOE Order 5820.2A
		2.	Gas bubble retention studies	232		
		3.	Gas reaction studies	196		
		4.	Organic analysis and methods development	232		
		5.	Waste tank physics modeling	669		
		6.	Gas release mechanisms/waste modeling	515		
		7.	Thermal/hydraulic analysis	446		
		8.	Theory development	234		
		9.	Phase equilibria studies-gases	222		

LEGEND: Baseline is normal font/*nonbaseline is italics.*
(a) Fund Immediately.
(b) Fund If Possible.

Table 3.2. Waste Tank Safety: Recommended Technology Program (contd)

Function and Technology Package		Tasks		FY 1996 Cost Estimate ($K)		
Functional Need Level 4	Template Title (number)	No.	Title	Funded	Not Funded	Benefit
Store Waste (4.2.1.1)	**Evaluate and Define the Safety Issue for Ferrocyanide-Containing Tanks** **3.4.2.2** Reference	1.	Surface moisture measuring (CPAC)	421		Safety: Resolve priority tank safety issues Commitment: TPA; Public Law 101–5110; DOE Order 5820.2A
		2.	Neutron probe moisture monitor	202		
		3.	Electromagnetic induction probe	666		
Store Waste (4.2.1.1)	**Technology for Evaluating Organic-Containing Tanks** **3.4.3.1** Reference	1.	Organic concentrations mechanisms	232		Safety: Resolve priority tank safety issues Commitment: TPA; Public Law 101–5110; DOE Order 5820.2A
		2.	Waste energetics	464		
		3.	SST waste carbon and moisture study	93		
		4.	Organic analytical methods development	464		
		5.	Waste energetics with simulants	409		
		6.	Waste moisture with simulants	102		

LEGEND: Baseline is normal font/*nonbaseline is italics.*
(a) Fund Immediately.
(b) Fund If Possible.

Table 3.2. Waste Tank Safety: Recommended Technology Program (contd)

Function and Technology Package		Tasks		FY 1996 Cost Estimate ($K)		
Functional Need Level 4	Template Title (number)	No.	Title	Funded	Not Funded	Benefit
		7.	Basis Safe Ops SSTs—Organic/Nitrate (FAI)	515		
		8.	Basis Safe Ops SSTs—Organic Layer	88		
		9.	Basis Safe Ops SSTs—Absorbed Organic	52		
Total						

LEGEND: Baseline is normal font/*nonbaseline is italics.*
(a) Fund Immediately.
(b) Fund If Possible.

FY 1996 Cost Estimate: An estimate of the funding that would be needed to conduct FY 1996 tasks. (Note: Tasks are listed for the entire TWRS life-cycle, but costs for outyear tasks are not shown on this table. See Appendix E for more information on each technology package.)

FY 1996 estimated costs are listed for each program. Dollar figures are unescalated, burdened FY 1995 dollars, in thousands. Costs are unofficial; they are for planning purposes only.

Benefit: The reasons these tasks are important to the program element.

3.4 Narrative on Technology Packages

The technology packages associated with each function of the Waste Tank Safety Program as shown on Figure 3.1 are described in this section. The description provides a brief summary of

- the justification for this activity
- current status of the technology
- technical approach
- other issues that need to be highlighted.

More detailed information is found in the templates for the Waste Tank Safety Program, in Appendix E.

3.4.1 Resolve Safety Issue for Flammable Gas-Generating Tanks

3.4.1.1 Evaluate and Define Technology for Flammable Gas-Generating Tanks

A number of HLW tanks have been identified as having significant potential for flammable gas generation, entrapment of gas in the waste, and periodic gas releases. There is also the potential for gradual cooling to lead to more gas retention in these tanks. The possible presence of a flammable gas mixture and an ignition source could increase the risk of release of radioactive waste.

For flammable gas tanks, technology is needed to assess the potential for 1) generation and release of flammable gas mixtures and 2) for the concentration of tank vapors to exceed 25% of the lower flammability limit.

- Studies of the gas bubble retention behavior of the waste are planned for gases retained in Hanford tank waste as bubbles attached to solid particles.
- Gas phase equilibria studies will determine the concentration of gaseous degradation products that may be present in bubbles trapped in the waste.
- Extensive chemical reactions can occur in the gas bubbles under the thermal and radiolytical conditions in the tanks. Gas reactions studies are planned to understand gas phase reactions in the HLW tanks as well as the role of water vapor in gas phase reactions.
- Computational modeling will be used to simulate the physical behavior of waste material in the DSTs. This will include fluid dynamics and heat and mass transfer behavior of the waste during quiescent periods as well as during roll-over events. This computational modeling will predict gas retention, gas mobility and release, and solids dissolution and precipitation behavior in flammable-gas-generating tanks.
- Studies of gas-generating mechanisms will establish time profiles of the appearance and disappearance of degradation products. The degradation products known to be formed are ammonia, hydro-

gen, nitrous oxide, nitrogen, and methane. The conditions and waste components that favor ammonia and methane production are of particular concern.

- Organic analysis methods will be developed for analyzing and quantifying the amount of a particular organic species in the tank wastes, including surfactants and peroxides. Methods will also be sought for the removing nitrate and nitrite, which are interfering analytes in tank samples.

3.4.2 Resolve Safety Issue for Ferrocyanide-Containing Tanks

3.4.2.1 Evaluate and Define Technology for Ferrocyanide-Containing Tanks

The ferrocyanide layer inside these tanks could trigger a propagating reaction if the fuel (ferrocyanide), oxidizer (nitrates), and heat (from radioactive decay) are present in sufficient quantities. This reaction could generate aerosols that might plug and rupture the high-efficiency particulate air (HEPA) filter and release radioactive materials into the environment. In addition, heat-generating radionuclides might somehow concentrate in a hot spot, creating sufficient heat to cause local heating of the sludge and, possibly, vaporization and removal of water. These hot spots could concentrate waste sufficiently and cause waste temperatures to exceed the boiling point to set the stage for a propagating reaction.

Technology to evaluate and define the safety issue associated with wastes containing potentially reactive mixtures of ferrocyanide consists of the following:

- conduct studies on waste aging to investigate the extent of ferrocyanide destruction that may have occurred during decades of storage
- investigate studies of cesium uptake of ferrocyanide salts in Hanford waste tanks to assess the potential for aggregation of cesium-137 exchanged materials to form tank "hot spots"
- perform modeling calculations to predict the moisture- retaining capabilities of ferrocyanide wastes in a typical tank system.

3.4.2.2 Evaluate and Define the Safety Issue for Ferrocyanide-Containing Tanks

Evaluating and defining the safety issue associated with wastes containing potentially reactive mixtures of ferrocyanide compounds is necessary to establish safe operating conditions and to select an appropriate path for resolving the safety issue. Technology is required to support these studies. Technology activities include the design and engineering of in situ moisture monitoring equipment.

3.4.3 Resolve Safety Issue for Organic-Containing Tanks

3.4.3.1 Technology for Evaluating Organic-Containing Tanks

The Organic Safety Issue involves potential reactions of organic complexants, organic degradation products, and solvents added to the SSTs during Hanford operations. These waste tanks contain a presumed stoichiometric excess of sodium nitrite and sodium nitrate oxidizers that is sufficient to exothermically oxidize the organic compounds. Analyses show that propagating organic reactions could occur if sufficient fuel and oxidizer are present in the waste and a portion of the waste is dried out and heated to temperatures above 180°C. There is also the potential for a fire in the tanks from ignition of solvents entrained in the waste. DSTs containing organics are not considered a safety issue because the tanks contain large quantities of water (Babad 1993).

Technology to evaluate and define the Organic Safety Issue through an understanding of the risk from fuel-waste oxidizer reactions includes the following activities:

- Evaluate potential organic waste concentration mechanisms resulting in the formation of small floating layers of organic solvents.
- Conduct studies to determine energetics of potential reaction systems in the tank. These studies will allow identification of additional analysis requirements that supplement use of total organic content (TOC) measurements to estimate tank reactivity.
- Develop and model the organic laydown resulting from the addition of different organic waste streams to the tanks at different times.
- Estimate SST moisture and organic carbon content from best available information and extrapolation.
- Establish the basis for safe operation of the organic-containing SSTs. There is potential for initiating events to lead to 1) ignition of organic-rich fuel and nitrate-nitrite oxidizers or 2) ignition of absorbed solvent entrained in the saltcake. Safety issue resolution will require demonstration that adequate moisture is present in the waste.

Because of the limited amount of available waste samples and the high dose rates of the samples, a substantial portion of the research efforts for determining waste energetics and waste moisture content will initially be done with waste simulants.

Technology development for evaluation and definition of the Organic Safety Issue also involves developing analytical methods for analyzing chelators, chelator fragments, organic acids, other organic functional groups, and high molecular weight compounds. These methods are required to support evaluating and defining the Organic Safety Issue and the Flammable Gas Safety Issue.

3.4.4 Resolve Safety Issue for High-Heat Generating Tank Waste

3.4.4.1 Evaluate and Define Safety Issue for High-Heat Tanks

Excessive radiogenic heat generation (unless cooling water is added periodically) can potentially compromise tank structural integrity. Tank 241-C-106 is the only tank identified within the high-heat safety issue. Structural failure might occur if, in the event of a leak, water currently added for cooling is discontinued.

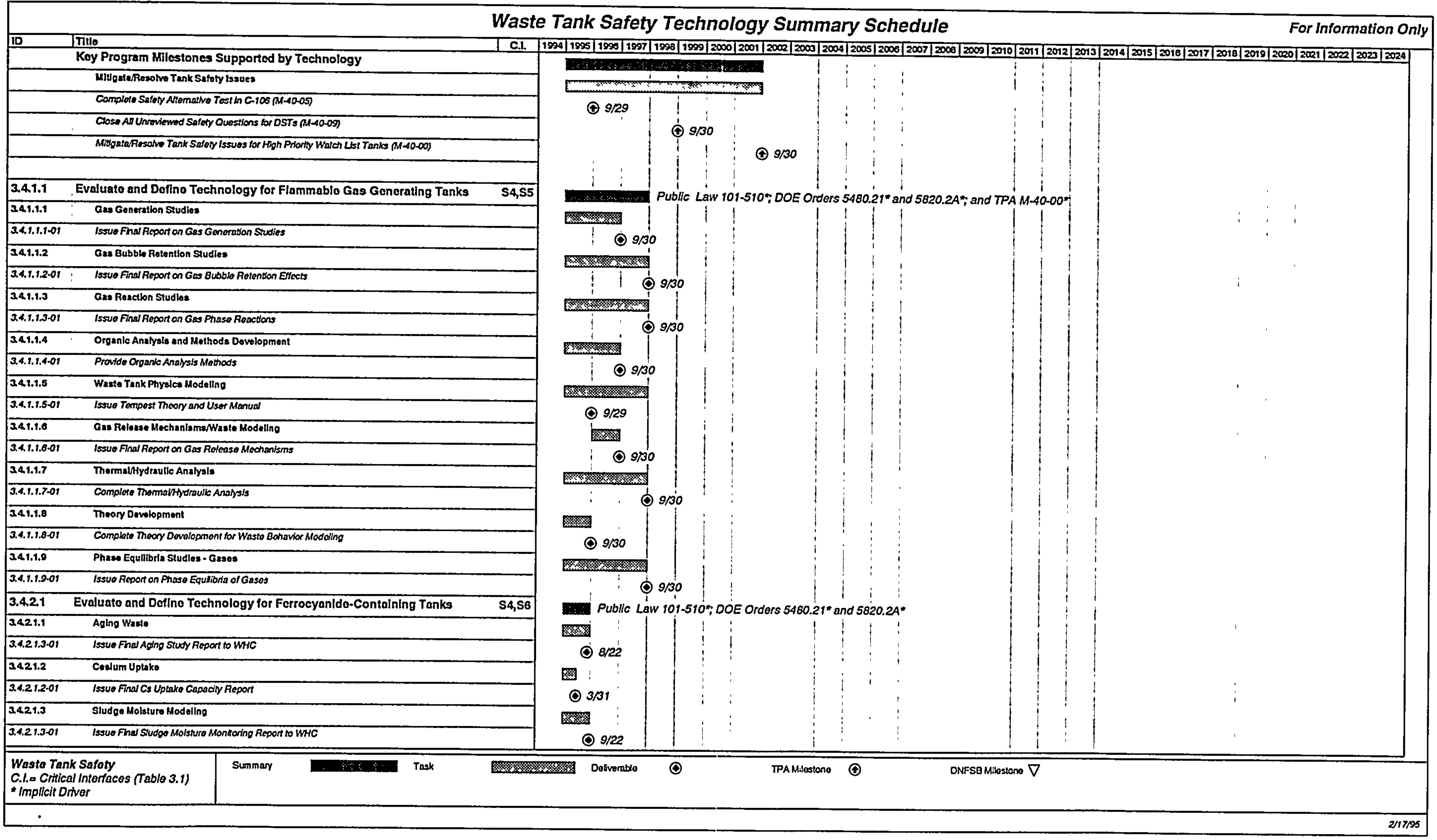
The focus of initial activities for resolution of the high-heat generation safety issue is on 1) developing a thermal model for predicting cooling liquid requirements, and 2) validating the model with characterization data from core samples. When the minimum liquid inventory for cooling is determined, activities will focus on the identification, selection, and implementation of contingency action plans.

3.5 Schedule and Budget

The schedule and budget for technology activities supporting the Waste Tank Safety Program are shown in Figure 3.2 and Table 3.3, respectively. Figure 3.2 identifies template activities, tasks within each template, deliverables, critical interfaces and drivers (depicted to the right of each template activity bar). Table 3.3 presents two sets of budget estimates by program element and fiscal year. The first profile consists of activities currently included in the TWRS Multi-Year Work Plan (MYWP) and reflects the estimated budget available for technology. The second profile reflects the estimated budget required to perform all tasks shown in the ITP, including activities that are anticipated to be funded and those that are not (unfunded activities have been prioritized for inclusion in the MYWP at the first opportunity).

3.6 Prioritization (Results)

Table 3.2 presented the functions, technology packages, tasks, FY 1996 budget and a brief statement regarding the benefit of funding these technology activities. For the Waste Tank Safety Program element, all technology work is funded within the TWRS Baseline Program for FY 1996 and beyond.



Waste Tank Safety Technology Summary Schedule

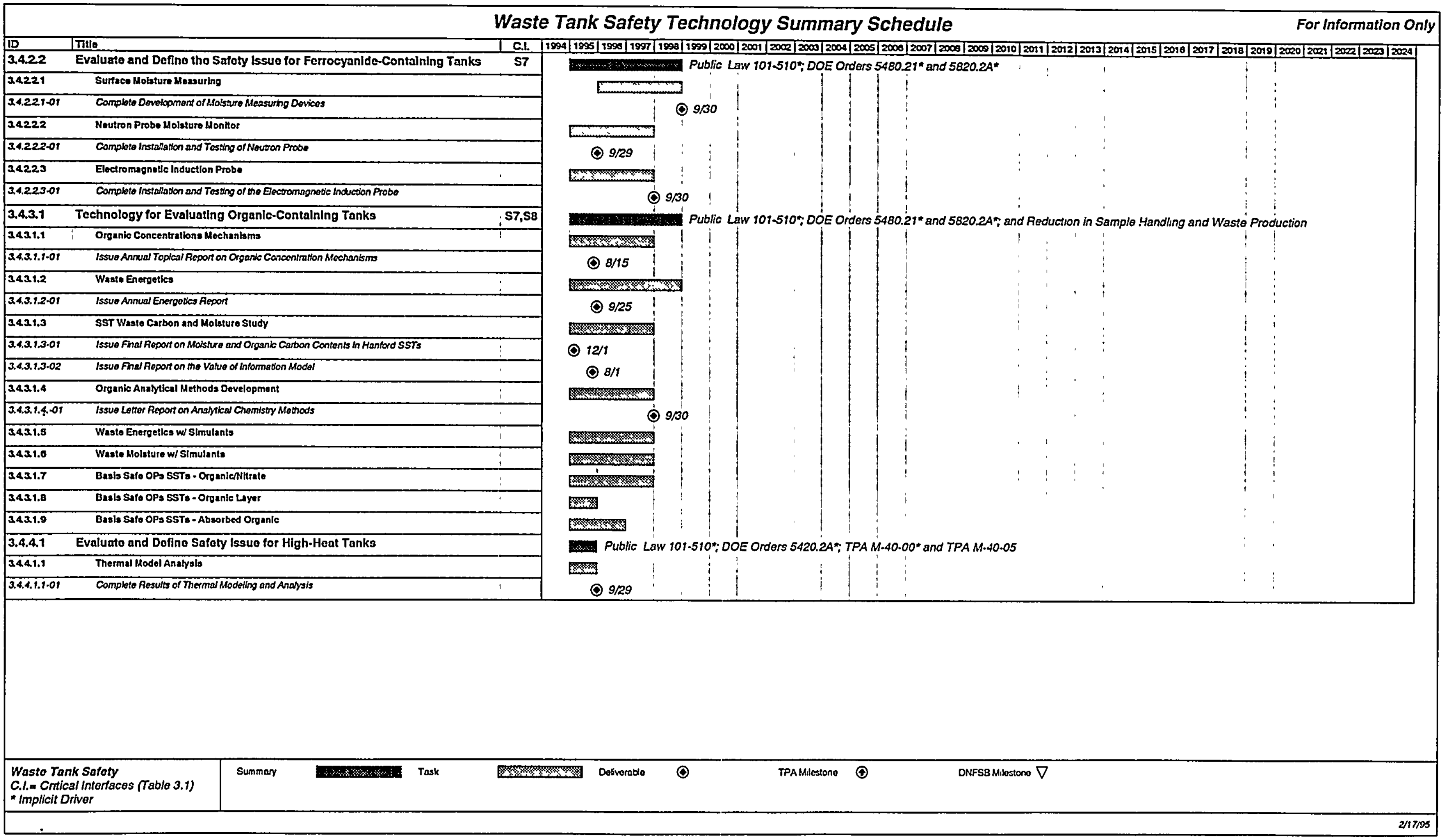
For Information Only

ID	Title	C.I.
	Key Program Milestones Supported by Technology	
	Mitigate/Resolve Tank Safety Issues	
	Complete Safety Alternative Test in C-106 (M-40-05)	
	Close All Unreviewed Safety Questions for DSTs (M-40-09)	
	Mitigate/Resolve Tank Safety Issues for High Priority Watch List Tanks (M-40-00)	
3.4.1.1	Evaluate and Define Technology for Flammable Gas Generating Tanks	S4,S5
3.4.1.1.1	Gas Generation Studies	
3.4.1.1.1-01	*Issue Final Report on Gas Generation Studies*	
3.4.1.1.2	Gas Bubble Retention Studies	
3.4.1.1.2-01	*Issue Final Report on Gas Bubble Retention Effects*	
3.4.1.1.3	Gas Reaction Studies	
3.4.1.1.3-01	*Issue Final Report on Gas Phase Reactions*	
3.4.1.1.4	Organic Analysis and Methods Development	
3.4.1.1.4-01	*Provide Organic Analysis Methods*	
3.4.1.1.5	Waste Tank Physics Modeling	
3.4.1.1.5-01	*Issue Tempest Theory and User Manual*	
3.4.1.1.6	Gas Release Mechanisms/Waste Modeling	
3.4.1.1.6-01	*Issue Final Report on Gas Release Mechanisms*	
3.4.1.1.7	Thermal/Hydraulic Analysis	
3.4.1.1.7-01	*Complete Thermal/Hydraulic Analysis*	
3.4.1.1.8	Theory Development	
3.4.1.1.8-01	*Complete Theory Development for Waste Behavior Modeling*	
3.4.1.1.9	Phase Equilibria Studies - Gases	
3.4.1.1.9-01	*Issue Report on Phase Equilibria of Gases*	
3.4.2.1	Evaluate and Define Technology for Ferrocyanide-Containing Tanks	S4,S6
3.4.2.1.1	Aging Waste	
3.4.2.1.3-01	*Issue Final Aging Study Report to WHC*	
3.4.2.1.2	Cesium Uptake	
3.4.2.1.2-01	*Issue Final Cs Uptake Capacity Report*	
3.4.2.1.3	Sludge Moisture Modeling	
3.4.2.1.3-01	*Issue Final Sludge Moisture Monitoring Report to WHC*	

Waste Tank Safety
C.I.= Critical Interfaces (Table 3.1)
** Implicit Driver*

2/17/95

Figure 3.2. Schedule



Waste Tank Safety Technology Summary Schedule

For Information Only

ID	Title	C.I.
3.4.2.2	**Evaluate and Define the Safety Issue for Ferrocyanide-Containing Tanks**	S7
3.4.2.2.1	**Surface Moisture Measuring**	
3.4.2.2.1-01	*Complete Development of Moisture Measuring Devices*	
3.4.2.2.2	**Neutron Probe Moisture Monitor**	
3.4.2.2.2-01	*Complete Installation and Testing of Neutron Probe*	
3.4.2.2.3	**Electromagnetic Induction Probe**	
3.4.2.2.3-01	*Complete Installation and Testing of the Electromagnetic Induction Probe*	
3.4.3.1	**Technology for Evaluating Organic-Containing Tanks**	S7,S8
3.4.3.1.1	**Organic Concentrations Mechanisms**	
3.4.3.1.1-01	*Issue Annual Topical Report on Organic Concentration Mechanisms*	
3.4.3.1.2	**Waste Energetics**	
3.4.3.1.2-01	*Issue Annual Energetics Report*	
3.4.3.1.3	**SST Waste Carbon and Moisture Study**	
3.4.3.1.3-01	*Issue Final Report on Moisture and Organic Carbon Contents in Hanford SSTs*	
3.4.3.1.3-02	*Issue Final Report on the Value of Information Model*	
3.4.3.1.4	**Organic Analytical Methods Development**	
3.4.3.1.4-01	*Issue Letter Report on Analytical Chemistry Methods*	
3.4.3.1.5	**Waste Energetics w/ Simulants**	
3.4.3.1.6	**Waste Moisture w/ Simulants**	
3.4.3.1.7	**Basis Safe OPs SSTs - Organic/Nitrate**	
3.4.3.1.8	**Basis Safe OPs SSTs - Organic Layer**	
3.4.3.1.9	**Basis Safe OPs SSTs - Absorbed Organic**	
3.4.4.1	**Evaluate and Define Safety Issue for High-Heat Tanks**	
3.4.4.1.1	**Thermal Model Analysis**	
3.4.4.1.1-01	*Complete Results of Thermal Modeling and Analysis*	

Waste Tank Safety
C.I.= Critical Interfaces (Table 3.1)
** Implicit Driver*

2/17/95

Figure 3.2. Schedule (cont.)

Table 3.3. Budget

WASTE TANK SAFETY
TWRS Technology Budget Estimates
(Unescalated Dollars in Thousands by Fiscal Year)

TECHNOLOGY PACKAGE NUMBER AND TITLE	1995	1996	1997	1998	1999	2000	2001 +	TOTAL
["Expected Budget Available for Technology" consists of activities in TWRS Multi-Year Work Plan]								
3.4.1.1--Evaluate and Define Technology for Flammable Gas Generating Tanks								
Expected Budget Available for Technology	2,687	2,902	1,552	0	0	0	0	7,141
Total Estimated Budget for Technology Activities in ITP	2,687	2,902	1,552	0	0	0	0	7,141
3.4.2.1--Evaluate and Define Technology for Ferrocyanide-Containing Tanks								
Expected Budget Available for Technology	760	0	0	0	0	0	0	760
Total Estimated Budget for Technology Activities in ITP	760	0	0	0	0	0	0	760
3.4.2.2--Evaluate and Define the Safety Issues for Ferrocyanide-Containing Tanks								
Expected Budget Available for Technology	1,262	1,289	1,558	481	0	0	0	4,590
Total Estimated Budget for Technology Activities in ITP	1,262	1,289	1,558	481	0	0	0	4,590
3.4.3.1--Technology for Evaluating Organic-Containing Tanks								
Expected Budget Available for Technology	2,413	2,331	1,098	239	0	0	0	6,081
Total Estimated Budget for Technology Activities in ITP	2,413	2,331	1,098	239	0	0	0	6,081
3.4.4.1--Evaluate and Define Safety Issues for High-Heat Tanks								
Expected Budget Available for Technology	135	0	0	0	0	0	0	135
Total Estimated Budget for Technology Activities in ITP	135	0	0	0	0	0	0	135
WASTE TANK SAFETY TOTALS:								
Expected Budget Available for Technology	**7,257**	**6,522**	**4,208**	**720**	**0**	**0**	**0**	**18,707**
Total Estimated Budget for Technology Activities in ITP	**7,257**	**6,522**	**4,208**	**720**	**0**	**0**	**0**	**18,707**

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4.0 Characterization

4.1 Purpose, Objectives, Scope, and Strategy

The **purpose** of the Characterization Program is to provide the necessary physical, chemical, and radiochemical characterization information required to support Tank Waste Remediation System (TWRS) safety issue resolution and retrieval, treatment, storage, and disposal decisions. The characterization program will provide the field sampling systems, in situ sensors and deployment equipment, and analytical methodology required to accomplish TWRS objectives in a timely, reliable, and cost-effective manner.

The Characterization Program manages the overall TWRS tank waste characterization effort and provides characterization data to meet the needs of all other program elements. The program provides leadership to establish technical bases, determine characterization requirements [via Data Quality Objectives (DQO) and test plans], obtain samples for analysis, evaluate recent and historical data, recommend actions, develop analytical equipment and methods, and manage technical activities associated with tank waste characterization. The program seeks to reach out to universities, industry, and the DOE laboratory system for applicable technology to meet TWRS needs.

Specific **objectives** of the Characterization Program include the following:

- Capture, integrate, and report known tank waste information, including
  - process history (i.e., transfer records, historical assays)
  - field data
  - laboratory data.
- Ensure that all TWRS program element sampling and analysis requirements are formally specified through DQO or test plans, and that sampling and analysis specified therein are acquired in a timely, reliable, and cost-effective manner.
- Identify, integrate, and prioritize needs of TWRS program elements requiring sampling and analysis.
- Ensure development of technologies required to satisfy documented and approved sampling and analysis needs of all TWRS program elements.
- Conduct tank waste sampling, analysis, and data reporting responsive to specifications in the *Recommendation 93-5 Implementation Plan (DOE/RL0001; U.S. DOE/RL 1994d).* This includes provision of data for prompt resolution of waste tank safety issues by completing all sampling and analysis of Watch List tanks per applicable DQO by October 1995 and safety screening of all tanks by October 1996.
- Define characterization schedule and performance to meet selection, design, and development requirements for waste retrieval, waste classification, and waste pretreatment and vitrification.
- Improve efficiency to minimize cost and schedule of characterization activities.
- Ensure that characterization requirements of the Tri-Party Agreement (TPA) are met. Specifically, issue Tank Characterization Reports (TCRs) for all 177 high-level waste (HLW) tanks by September 1999, based on process knowledge, prior characterization data, and validated empirical data, as required by major milestone M-44-00.
- Characterize double-shell tank (DST) supernate for Part B RCRA Permit requirements.

The **scope** of the Characterization Program includes acquisition of tank waste samples and transfer of the samples to laboratories, laboratory analysis of samples, in situ measurements, review of historical data and laboratory results, and the integration and reporting of characterization information.

The essential elements of the Characterization Program **strategy**, including technology requirements, are driven by DQO and test plans from all TWRS program elements and by the need to maximize the efficiency of characterization. Characterization needs are validated through formal DQO methodology, from which sampling requirements, schedules that support program decisions, and data specifications are formally documented. These validated needs provide the basis for planning and integration, resource use (i.e., sampling systems, laboratories), modeling, and prioritization. The needs also provide the basis for technology selection and delivery schedules to ensure that implementation is consistent with specified sampling and/or analysis requirements. Because DQO and test plans undergo revision and development times can be extended, technology development must attempt to anticipate future DQO requirements. In addition, technology development must pursue opportunities for reducing the cost and time of characterization while meeting programmatic needs.

In addition to securing technologies to satisfy specific reference sampling and/or analysis requirements, the characterization technology strategy pursues enhancements and alternatives that can

- reduce sampling and laboratory capacity and throughput risks associated with meeting TWRS characterization requirements
- minimize operations and personnel exposure during sampling and analysis
- minimize secondary wastes generated during characterization activities
- strengthen the technical basis for characterization
- minimize characterization life cycle cost and schedule.

The availability of software systems for sample tracking, data assessment, and report preparation is important to TWRS in general and to the Characterization Program in particular. Laboratory information management systems (LIMS) are being developed to facilitate these needs. Although the evolution of LIMS is closely coupled to TWRS technology systems and is closely tracked by the Characterization Program, LIMS development is considered to be outside the focus of the Integrated Technology Plan (ITP) and will not be addressed further in this document.

4.1.1 Key Assumptions

The key Characterization Program assumptions that drive characterization technology are the following:

- TPA sampling and analysis needs and schedule are driven primarily by the needs and schedules of the other TWRS program elements.
- Defense Nuclear Facility Safety Board (DNFSB) issue resolution is the joint responsibility of the Characterization and Safety Programs.
- Minimization of characterization cost and time is a strong TWRS programmatic driver that is primarily "owned" by the Characterization Program.
- Current tank waste sampling may not be adequately representative for TWRS programmatic needs.
- Onsite hot cell and laboratory capacity may not be adequate to satisfy all TWRS waste analysis and testing needs.

- Qualitative and quantitative laboratory analytical methods for some key analytes need to be improved and/or developed.

- In situ measurement technologies are required to address specific tank waste safety and retrieval-system design issues.

- A life-cycle technology development philosophy is embraced in which development does not conclude until deployment for routine beneficial use is achieved.

- Tank safety concerns will not prevent sampling and characterization.

- The need for large volumes of supernatant for pretreatment development purposes will be addressed by application of existing small volume samples in combination with implementation of large volume samples available elsewhere.

- Significant analyses will be required to support pretreatment and retrieval test plans, the load being heaviest during process selection, definition, and design stages.

- Demand will be significant for on-line instrumentation to support real-time process control of large-scale pretreatment and retrieval tests.

4.1.2 Key Uncertainties

Key uncertainties for Characterization Program technology include the following:

- Sampling and analysis technology needs for all TWRS program elements may not be identified.

- Technologies in the DOE national laboratory complex, industry, and universities may not be adapted readily for routine TWRS applications.

- Time and cost of technology development and implementation for routine beneficial use may not match required schedules and projected budgets.

- Technical risks may not be sufficiently acceptable for development to be pursued.

- EM-50 development of enhancement and alternative technologies may not be fully integrated with EM-30 needs.

4.1.3 Critical Interfaces

A *critical interface* is an important system boundary/point of coordination between two TWRS program elements for one or both elements to successfully meet program objectives. The critical interfaces related to technology activities supporting all six program elements of the TWRS program are integrated in Table 4.1. These interfaces are generally technology-to-TWRS program element or TWRS program element-to-technology (not technology-to-technology or program element-to-program element).

Critical interfaces for each program element are also listed in Chapters 3.0, 4.0, 5.0, 6.0, 7.0, and 8.0.

Table 4.1 Critical Interfaces for Characterization Program Technology Activities

No.	From	To	Need By	Item Provided
C1	OPS	CH	10/94+	Waste compatibility sampling and analysis DQO and test plans.
C2	RT	CH	10/94+	Retrieval DQO and test plans.
C3	PT	CH	10/94+	Pretreatment DQO and test plans.
C4	HLW	CH	10/94+	HLW DQO and test plans.
C5	LLW	CH	10/94+	LLW DQO and test plans.
C6	ST	CH	10/94+	Waste Tank Safety DQO and test plans.
C7	CH	PT	10/94+	Waste characteristics data and samples.
C8	CH	OPS	09/95	Core bit temperature sensing package.
C9	CH	OPS	03/95	Sample verification instrumented receiver.
C10	CH	Labs	10/94+	Improved analytical procedures.
C11	CH	RT	10/94+	Waste characteristics data and samples.
C12	CH	ST	10/94+	Sampling methods and studies.

Note: + = More than one update or user.

Legend:
CH = Characterization program element.
ST = Waste Tank Safety program element.
RT = Waste Retrieval program element.
PT = Waste Pretreatment program element.
HLW = High-Level Waste Immobilization program element.
LLW = Low-Level Waste Immobilization program element.
OPS = Operations and maintenance.
Labs = Analytical laboratories.

4.2 Functional Flow Diagram

Functions are simple statements that define what a system must do. Functions form the basis for identifying technology deliverables required to support TWRS program needs. A block diagram that maps the relationship between functions and technology packages for the Characterization Program is provided in Figure 4.1.

4.3 Functions and Associated Technology Packages for Waste Characterization

Table 4.2 presents the program recommended by the TWRS staff who prepared the ITP for Waste Characterization in FY 1996. The program is discussed further in Appendix E and is consistent with the most recent version of the Multi-Year Program Plan (MYPP).

4.3.1 Key to Table

Function: The systems engineering function (as described in the TWRS Functional Requirements [F&R] document, U.S. DOE/RL 1994b) associated with this technology package (followed by the number for the appropriate systems engineering level in parenthesis).

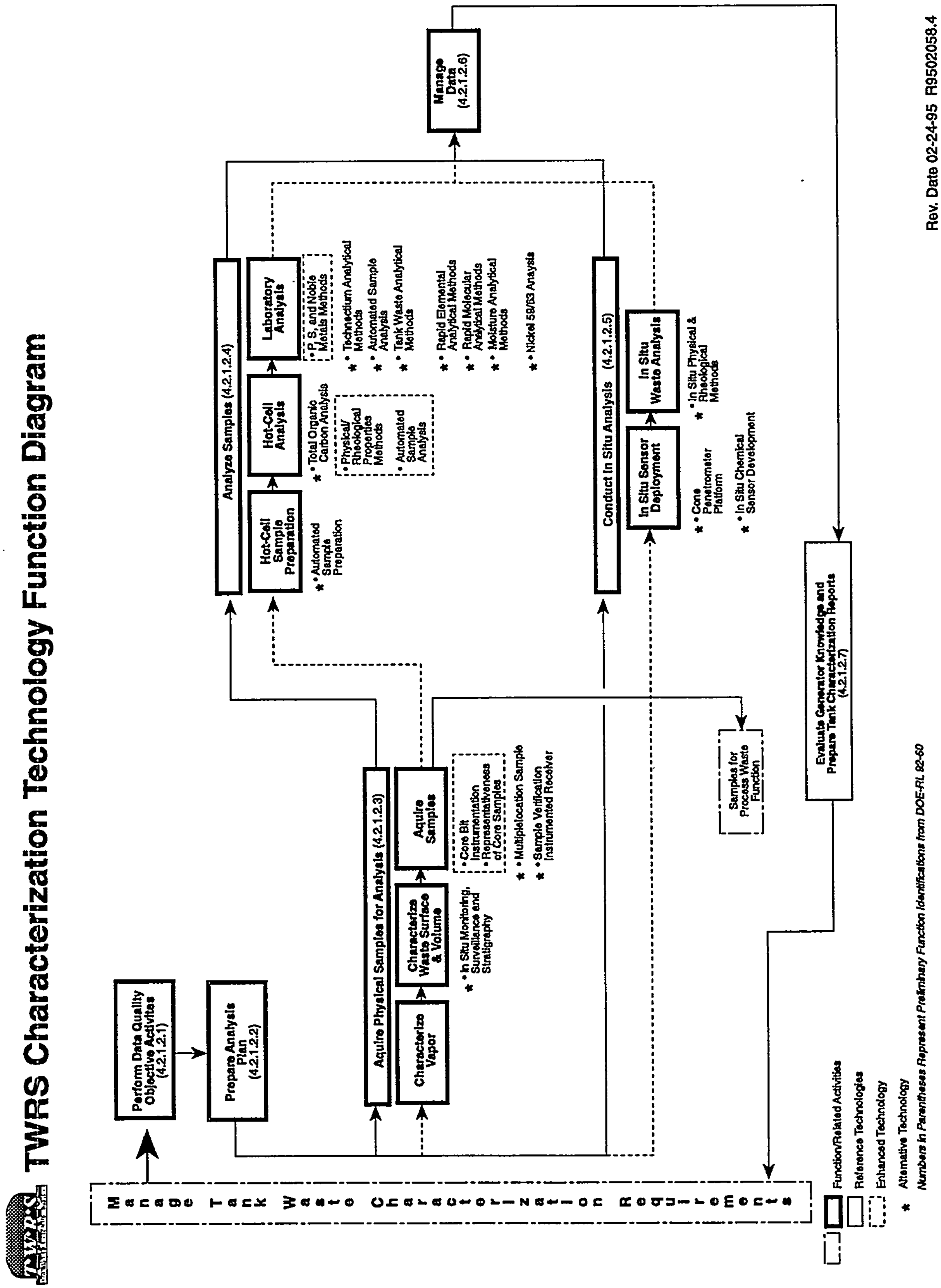
Technology Package: A set of technology activities that need to be completed to respond to a functional need. May include activities to address/support the reference case, or enhancements or alternatives to the reference case (followed by the program element chapter number in parenthesis).

Tasks: The tasks that need to be performed to resolve this technology need. Dates are unofficial; they are for planning purposes only.

FY 1996 Cost Estimate: An estimate of the funding that would be needed to conduct FY 1996 tasks. (Note: Tasks are listed for the entire TWRS life cycle, but costs for outyear tasks are not shown on this table. See Appendix E for more information on each technology package.)

FY 1996 estimated costs are listed for each program. Dollar figures are unescalated, burdened FY 1995 dollars, in thousands. Costs are unofficial; they are for planning purposes only.

Benefit: The reasons these tasks are important to the program element.



Rev. Date 02-24-95 R9502058.4

Figure 4.1. Functional Flow Diagram

Table 4.2. Characterization: Recommended FY 1996 Technology Program

Function and Technology Package		Tasks		FY 1996 Cost Estimate ($K)		
Functional Need Level 4	Template Title (number)	No.	Title	Funded	Not Funded	Benefit
Characterize Waste (4.2.1.2)	**Automated Sample Preparation and Analysis** **4.4.1.2** Alternative	1.	Develop and implement automated laboratory procedure or procedures identified in Task 1 (FY 1995).	200		Provides laboratory automation to reduce analytical costs and turnaround time and to minimize personnel exposure.

LEGEND: Baseline is normal font/*nonbaseline is italics.*
(a) Fund Immediately.
(b) Fund If Possible.
*Funded by EM-50, subject to change.
**EM-50 cofunding not indicated.
***FY 1995 activities are being funded by the Pretreatment Program under template number 6.4.3, task entitled "Evaluate Sludge Processing Sciences."

Table 4.2. Characterization: Recommended FY 1996 Technology Program (contd)

Function and Technology Package		Tasks		FY 1996 Cost Estimate ($K)		
Functional Need Level 4	Template Title (number)	No.	Title	Funded	Not Funded	Benefit
Characterize Waste (4.2.1.2)	**Total Organic Carbon (TOC) Analysis** **4.4.1.3** Alternative	1.	This task consists of the development of an improved TOC analytical method; conditional on Task 1.	200		Commitment: Improves ability to meet the following: DNFSB 93, TOC required for safety analysis; TPA M-44-00, issue tank characterization reports; TPA M-44-00, mitigate/resolve tank safety issues for high-priority Watch List tanks. Determines efficiencies of organic destruction techniques and determines fuel content in tank wastes. Supports Pretreatment, LLW, HLW and Safety programs.

LEGEND: Baseline is normal font/*nonbaseline is italics.*
(a) Fund Immediately.
(b) Fund If Possible.
*Funded by EM-50, subject to change.
**EM-50 cofunding not indicated.
***FY 1995 activities are being funded by the Pretreatment Program under template number 6.4.3, task entitled "Evaluate Sludge Processing Sciences."

Table 4.2. Characterization: Recommended FY 1996 Technology Program (contd)

Function and Technology Package		Tasks		FY 1996 Cost Estimate ($K)		
Functional Need Level 4	Template Title (number)	No.	Title	Funded	Not Funded	Benefit
Characterize Waste (4.2.1.2)	**Laboratory Physical/ Rheological Property Methods** **4.4.1.4** Enhancement	1.	Development of a suite of laboratory analytical methods that can be used to provide data to infer pertinent in situ HLW physical properties.	200		Commitment: Improves ability to meet the following: TPA M-45-04-T2, complete design for initial SST retrieval systems; TPA M-45-04-T1, provide initial SST retrieval systems. Operations: Aids design on retrieval equipment, preparation of accurate sludge simulants, and prediction of effective cleaning radius.

LEGEND: Baseline is normal font/*nonbaseline is italics.*
(a) Fund Immediately.
(b) Fund If Possible.
*Funded by EM-50, subject to change.
**EM-50 cofunding not indicated.
***FY 1995 activities are being funded by the Pretreatment Program under template number 6.4.3, task entitled "Evaluate Sludge Processing Sciences."

Table 4.2. Characterization: Recommended FY 1996 Technology Program (contd)

Function and Technology Package		Tasks		FY 1996 Cost Estimate ($K)		
Functional Need Level 4	Template Title (number)	No.	Title	Funded	Not Funded	Benefit
Characterize Waste (4.2.1.2)	**Nickel 59/63 Analysis** **4.4.1.5** Alternative	1.	Develop and identify practical, cost-effective laboratory radiochemical methods for quantification of nickel-59 and nickel-63.	140		Provides analytical methods for nickel 59/63 analysis, a potential waste form performance assessment driver, which may need to be removed in pretreatment. Improves the ability to meet TPA M-50-03 and M-50-04 and assists in definition of pretreatment, HLW and LLW operating envelopes.
		2.	Implement for routine beneficial use a practical, cost-effective laboratory method for quantification of nickel-59 and nickel-63.	165		

LEGEND: Baseline is normal font/*nonbaseline is italics.*
(a) Fund Immediately.
(b) Fund If Possible.
*Funded by EM-50, subject to change.
**EM-50 cofunding not indicated.
***FY 1995 activities are being funded by the Pretreatment Program under template number 6.4.3, task entitled “Evaluate Sludge Processing Sciences.”

Table 4.2. Characterization: Recommended FY 1996 Technology Program (contd)

Function and Technology Package		Tasks		FY 1996 Cost Estimate ($K)		
Functional Need Level 4	Template Title (number)	No.	Title	Funded	Not Funded	Benefit
Characterize Waste (4.2.1.2)	**Phosphorus, Sulfur, and Noble Metals Analytical Methods for Water-Washed Sludge** **4.4.1.6** Enhancement	1.	This task consists of a technical survey to identify analytical methods and concepts for sludge dissolution and/or methods that could be applied for routine analysis of phosphorus and sulfur in water-washed sludge. This task will include an assessment of known fusion methods.	100		Provides a practical method for determining phosphorus, sulfur, and noble metal content in water-washed sludge. Assists in definition of pretreatment, LLW, and HLW operating envelopes. Improves ability to meet TPA M-57-00-T1, submit conceptual design of HLW vitrification facility, and 3/98 sludge washing decision.
Characterize Waste (4.2.1.2)	**Sample Verification Instrumented Receiver** **4.4.2.1** Alternative	1.	This task includes a decision point on the need for further instrumented receiver development. If the decision is to proceed, further development and implementation would be conducted in FY 1996.	200		Commitment: Improves ability to meet the following: DNFSB 93-5; TPA M-44-00, issue tank characterization report. Provides a method for determining sampler fullness at the tank before shipment to analytical laboratory.

LEGEND: Baseline is normal font/*nonbaseline is italics.*
(a) Fund Immediately.
(b) Fund If Possible.
*Funded by EM-50, subject to change.
**EM-50 cofunding not indicated.
***FY 1995 activities are being funded by the Pretreatment Program under template number 6.4.3, task entitled "Evaluate Sludge Processing Sciences."

Table 4.2. Characterization: Recommended FY 1996 Technology Program (contd)

Function and Technology Package		Tasks		FY 1996 Cost Estimate ($K)		
Functional Need Level 4	Template Title (number)	No.	Title	Funded	Not Funded	Benefit
Characterize Waste (4.2.1.2)	**Multiple Location Sampler** **4.4.2.2** Alternative	1.	The first phase of this task consists of an assessment leading to an early decision point on whether or not to pursue development of multiple sampling capability identified in Task 1 (industry survey). If the decision is made to proceed, a specific technical approach will be selected, developed, and implemented.	1,400		Provides ability to sample spatially from a single riser access point. Assists in definition of pretreatment and safety operating envelopes. Supports ability to meet TPA M-44-00, TPA 3/98 sludge washing decision and DNFSB Recommendation 93-5.
Characterize Waste (4.2.1.2)	**Core Bit Instrumentation** **4.4.2.3** Enhancement	1.	Develop proximity sensing package, deliver prototype to WHC, and implement for routine beneficial use; conditional on Task 1 decision point.	500		Provides increased operational safety assurance when drilling potentially high-energetic wastes. Commitment: Explicitly required by DNFSB recommendation 93-5 commitment 3-16.

LEGEND: Baseline is normal font/*nonbaseline is italics.*
(a) Fund Immediately.
(b) Fund If Possible.
*Funded by EM-50, subject to change.
**EM-50 cofunding not indicated.
***FY 1995 activities are being funded by the Pretreatment Program under template number 6.4.3, task entitled "Evaluate Sludge Processing Sciences."

Table 4.2. Characterization: Recommended FY 1996 Technology Program (contd)

Function and Technology Package		Tasks		FY 1996 Cost Estimate ($K)		
Functional Need Level 4	Template Title (number)	No.	Title	Funded	Not Funded	Benefit
Characterize Waste (4.2.1.2)	**In Situ Chemical Sensor Development** **4.4.3.1** Alternative	1.	Implement Raman/NIR probes on cone penetrometer platform, conditional on Task 1 and cone penetrometer status.	300		Provides in situ probes for measuring molecular species and water content. Assists in definition of pretreatment and safety operating envelopes. Commitment: Improves ability to meet the following: TPA M-44-00, issue tank characterization report; TPA M-40-00, mitigate/resolve tank safety issues for high-priority Watch List tanks; TPA M-4000-12, resolve nuclear criticality safety issue; DNFSB recommendation 93-5.
		2.	Conduct surveys to establish additional in situ sensor needs and identify promising technology.	100		

LEGEND: Baseline is normal font/*nonbaseline is italics.*
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**EM-50 cofunding not indicated.
***FY 1995 activities are being funded by the Pretreatment Program under template number 6.4.3, task entitled "Evaluate Sludge Processing Sciences."

Table 4.2. Characterization: Recommended FY 1996 Technology Program (contd)

Function and Technology Package		Tasks		FY 1996 Cost Estimate ($K)		
Functional Need Level 4	Template Title (number)	No.	Title	Funded	Not Funded	Benefit
Characterize Waste (4.2.1.2)	**In Situ Monitoring, Surveillance, and Stratigraphy** **4.4.3.2** Alternative	1.	This activity develops and implements acoustic imaging as a routine tool for HLW tank characterization, following a decision point to proceed. Also included in this activity is a compilation of an historical record of physical items of retrieval significance known or strongly suspected to be present in the tanks.	200		
		2.	This activity develops and implements promised technology identified in Task 3, including survey to identify methods for characterization subsurface properties beneath risers.	400		

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(b) Fund If Possible.
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**EM-50 cofunding not indicated.
***FY 1995 activities are being funded by the Pretreatment Program under template number 6.4.3, task entitled "Evaluate Sludge Processing Sciences."

Table 4.2. Characterization: Recommended FY 1996 Technology Program (contd)

Function and Technology Package		Tasks		FY 1996 Cost Estimate ($K)		
Functional Need Level 4	Template Title (number)	No.	Title	Funded	Not Funded	Benefit
Characterize Waste (4.2.1.2)	**In Situ Physical and Rheological Properties Methods** **4.4.3.3** Alternative	1.	Document F&R and implement waveguide sensor technology or evaluate alternative technology, as appropriate.	200		Supports design retrieval equipment, preparation of sludge simulants, and prediction of effective cleaning radius.
Characterize Waste (4.2.1.2)	**Cone Penetrometer Platform** **4.4.3.4** Alternative	1.	Complete cone penetrometer platform design fabrication, acceptance testing, delivery, and training.	1,200		Provides platform for deploying sensors through 4” risers to bottom of tanks. Assists in definition of pretreatment, retrieval, and safety operating envelopes. Explicitly required by DNFSB recommendation 93-5 commitment. Essential for in-tank physical/rheological measurements for retrieval program.

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(a) Fund Immediately.
(b) Fund If Possible.
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**EM-50 cofunding not indicated.
***FY 1995 activities are being funded by the Pretreatment Program under template number 6.4.3, task entitled “Evaluate Sludge Processing Sciences.”

Table 4.2. Characterization: Recommended FY 1996 Technology Program (contd)

Function and Technology Package		Tasks		FY 1996 Cost Estimate ($K)		
Functional Need Level 4	Template Title (number)	No.	Title	Funded	Not Funded	Benefit
Characterize Waste (4.2.1.2)	**Rapid Elemental Analytical Methods for Water-Washed Sludge** **4.4.4.1** Alternative	1.	Implement XRF microfluorescence method in TWRS production analytical laboratories; conditional on Task 1 development work.	***		Provides a rapid, cost-effective elemental analysis method to improve ability to meet TPA M-44-00 and 3/98 sludge washing decision and sharply reduce analytical costs and turnaround time. Assists in definition of safety, pretreatment, HLW, and LLW operating envelopes.
Characterize Waste (4.2.1.2)	**Rapid Elemental Analytical Methods** **4.4.4.2** Alternative	1.	Develop and implement LA/MS for routine, rapid HLW elemental and isotopic analysis. Conduct workshop on global status of scanning technology and tradeoffs of new technology versus upgrades of existing technology in view of new TWRS sample load projections.	2,200		Provides an elemental analysis system with potential to sharply reduce the cost and time of analysis. Improves the ability to meet TPA M-44-00, TPA M-40-00, TPA M-40-12, and DNFSB Recommendation 93-5. Assists in definition of safety, pretreatment, HLW, and LLW operating envelopes.

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*Funded by EM-50, subject to change.
**EM-50 cofunding not indicated.
***FY 1995 activities are being funded by the Pretreatment Program under template number 6.4.3, task entitled "Evaluate Sludge Processing Sciences."

Table 4.2. Characterization: Recommended FY 1996 Technology Program (contd)

Function and Technology Package		Tasks		FY 1996 Cost Estimate ($K)		
Functional Need Level 4	Template Title (number)	No.	Title	Funded	Not Funded	Benefit
Characterize Waste (4.2.1.2)	**Rapid Molecular Analytical Methods** **4.4.4.3** Alternative	1.	Develop and implement LA/MS for routine molecular analysis.	850		Provides molecular analysis system with potential to sharply reduce the cost and time of analysis. Imporvies the ability to meet TPA M-44-00, TPA M-40-00, TPA M-40-12, and DNFSB Recommendation 93-5. Assists in definition of safety, pretreatment, HLW, and LLW operating envelopes.
		2.	Develop and implement Raman spectroscopy for routine, rapid HLW molecular analysis.	1,200**		

Note: The molecular LA/MS costs are based on the assumption that the elemental LA/MS ablation source, control computer system, and in-cell components will be installed and available to support the operation of the molecular LA/MS system by delivering an ablation plume for analysis.

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(a) Fund Immediately.
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*Funded by EM-50, subject to change.
**EM-50 cofunding not indicated.
***FY 1995 activities are being funded by the Pretreatment Program under template number 6.4.3, task entitled "Evaluate Sludge Processing Sciences."

Table 4.2. Characterization: Recommended FY 1996 Technology Program (contd)

Function and Technology Package		Tasks		FY 1996 Cost Estimate ($K)		
Functional Need Level 4	Template Title (number)	No.	Title	Funded	Not Funded	Benefit
Characterize Waste (4.2.1.4)	**Moisture Analytical Methods** **4.4.4.4** Alternative	1.	Develop and Implement NIR Spectroscopy for routine, rapid HLW moisture analysis.	1,000**		Provides moisture analysis system with potential to sharply reduce the cost and time of analysis. Improves the ability to meet TPA M-44-00, TPA M-40-00, TPA M-40-12, and DNFSB Recommendation 93-5. Assists in definition of safety, pretreatment, HLW, and LLW operating envelopes.
Total						

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(a) Fund Immediately.
(b) Fund If Possible.

*Funded by EM-50, subject to change.

**EM-50 cofunding not indicated.

***FY 1995 activities are being funded by the Pretreatment Program under template number 6.4.3, task entitled "Evaluate Sludge Processing Sciences."

4.4 Narrative on Technology Packages

The technology packages associated with each Characterization Program functional need are described in the following sections. More detailed information is found in the templates for the Characterization Program, located in Appendix E.

4.4.1 Laboratory Methods

4.4.1.1 Technetium Analytical Methods

Technetium quantitation is needed to bound the total technetium quantity because volatile technetium oxides could impact melter design. Technetium content also impacts LLW performance assessment and durability requirements. For these reasons, the process flowsheet may need to address technetium separation, which would be impacted by the technetium chemical form (speciation).

The current TWRS method for technetium quantitation is based on neutron activation. This method is expensive, inconvenient, and not well suited for routine production applications. Inductively coupled plasma-mass spectrometry (ICP-MS) is the preferred method for technetium quantitation elsewhere in the DOE complex and is being actively pursued in TWRS. However, no generally accepted TWRS procedure currently exists for technetium speciation. The implementation of ICP/MS capability for HLW analysis by TWRS is expected in FY 1996. Concepts have been promoted for technetium speciation by ion chromatography (IC) and X-ray absorption spectroscopy. X-ray absorption is exquisitely specific for certain speciation problems shown in FY 1994 to be feasible for HLW samples, and is being supported by the sludge science task of the Pretreatment Program. However, the method requires taking samples to an offsite synchrotron radiation source and therefore is not suitable for routine production analytical applications. The IC method has not been sufficiently developed to allow full evaluation.

4.4.1.2 Automated Sample Preparation and Analysis

During FY 1995 through FY 1997, a heavy laboratory analysis load for HLW waste samples will be incurred to support DNFSB and TPA characterization commitments. Substantial analytical loads will be incurred for many years thereafter in support of disposal programs.

Most HLW samples must undergo preparation before analysis by such methods as gas chromatography-mass spectrometry (GC-MS) or ICP-MS. Preparation can include extraction, preconcentration, digestion, fusion, and preconcentration/predilution steps, which may be amenable to automation. Automation of HLW sample preparation and analysis could significantly reduce the amount of labor-intensive operations, providing cost and schedule advantages and reducing personnel exposure. In addition, automated systems can operate unattended for extended periods and potentially produce more reliable and reproducible results from repetitive operations.

A specific target area for HLW analytical automation is sample dissolution, which currently is required for all HLW solid samples. With automated monitoring of this process with light scattering or other methods, dissolution times could be minimized for easily dissolved solids or extended for more intractable residues. As a second example, the costs of metal/radionuclide analyses could be reduced by an estimated factor of four or more by full automation of ICP/MS coupled with advanced separations technology. Robotics and flow injection analysis (FIA) and sequential injection analysis (SIA) techniques have been developed for a wide variety of industrial applications and may be adaptable to TWRS laboratory and process analytical needs. Recent advances in Eichrome resin separations represent another analytical scheme that could be automated.

EM-50 supports laboratory automation through the Robotics Integrated Demonstration, but the focus has an environmental focus rather than HLW focus. In the past, EM-30 has provided some support for automation of HLW methods, such as ICP/MS.

Automated procedures must be consistent with performance requirements of applicable DQO and test plans.

4.4.1.3 Total Organic Carbon (TOC) Analysis

Reliable TOC analyses are required to determine whether or not fuel content in HLW tank wastes exceeds 3%, as per Organic Safety and Safety Screening DQO. TOC content also is needed by the Pretreatment Program because of concerns about fouling of ion exchange resins and the flowsheet behavior of organic-complexed strontium and TRU. These concerns could necessitate the use of organic destruction in the pretreatment process. In addition, the vitrification program may need to know TOC levels in vitrification feed material for proper melter design because of possible concerns with offgas treatment, noble metal reduction, and foaming.

Due to the complexity of the organic species present in the wastes, four TOC analytical methods currently are used to span the range of tank waste samples expected. These methods use different organic oxidizing agents and detection systems. During FY 1994, a comparative study of these methods concluded that the range of tank sample compositions requires that all four methods be retained. However, the possibility of developing improved (i.e., more universal) methods was suggested.

4.4.1.4 Laboratory Physical/Rheological Property Methods

Reliable characterization of tank waste physical and rheological properties is required to provide the data needed for formulation of the overall retrieval process, including design of retrieval equipment. Equipment issues dependent on waste physical properties include sizing, bearing material, seal design, etc. Draft retrieval DQO identify as key physical measurements abrasivity, particle settling velocity, particle density, adhesiveness, viscosity, porosity, and tensile, shear, and compression strengths. It is expected that the final DQO will bound the physical parameter range of interest, thereby substantially focusing method development.

Existing TWRS laboratory methods for some physical and rheological properties pertinent to retrieval have severe accuracy and precision limitations. While in situ measurement of physical properties would be preferable, neither a deployment platform nor suitable measurement devices are available. FY 1994 and 1995 laboratory methods work focused on that subset of physical properties that are less prone to sampling artifacts. This subset includes abrasivity, particle size, and settling rates. It is expected that further development work will be required in FY 1996.

4.4.1.5 Nickel 59/63 Analysis

This template is driven by the need to develop and implement a practical laboratory analytical procedure to quantify the amount of nickel-59 and nickel-63 isotopes, which arise from activation of stainless steel, for LLW performance assessment. The TWRS production analytical laboratories currently have no validated procedures for these isotopes. The need for nickel-59/63 analyses is driven by a regulatory requirement for quantifying all radionuclides that contribute more than 1% of the total activity in the final HLW form. Although the likelihood is low that the concentrations of nickel-59/63 actually will exceed this level, there currently is no way to confirm this expectation.

Classical methods are available for measurement of total nickel concentrations in various matrices by spectrophotometric methods. Typically, these methods use quantitative precipitation of nickel with dimethylglyoxime, filtration of the gelatinous product, redissolution, and quantitation by spectrophotometry. This sequence of operations is inefficient to perform on highly radioactive samples. In addition, sample preparation must be consistent with isotopic quantitation.

Nickel-63 decays by beta emission (67 KeV, half life 100 yr). Nickel-59 decays by electron capture (half life 76,000 yr, overall Q for decay of 1.07 MeV) with emission of very low energy characteristic

X-radiation (6 KeV). These emissions are difficult to use in identifying the isotopes and therefore quantitative separation must be completed before separation. Isobaric interferences complicate mass spectrometric approaches. For example, the presence of cobalt-59 interferes with nickel-59 in mass spectrometry unless a high mass resolution instrument is used or efficient nickel/cobalt separations are performed.

Radiochemical separation and quantitation is typically used for analyzing low activity samples. Inorganic and organic chemical and radiochemical interferences have not been evaluated fully and documented for this approach with Hanford HLW samples. The low energy X-ray emissions from nickel-59 may be difficult to detect at concentrations of interest to performance assessment. The beta emission from nickel-63 is readily detected but is hard to discriminate from other beta-emitters likely to be present.

Quantitation by ICP/MS may provide positive identification of the isotopes, but the low nickel detection levels required may be a concern. Documentation of instrument capabilities and interference potential must be provided, and the methodology must be accepted as meeting the defensibility needs of the program.

Both radiometric and mass spectrometric methods should be investigated.

4.4.1.6 Phosphorus, Sulfur, and Noble Metals Analytical Methods for Water-Washed Sludge

The concentration of noble metals in water-washed sludge is a concern in the design of melters because of the potential for electrode shorting. In addition, noble metals are potential catalysts for conversion of nitrate to ammonia, which could influence melter offgas system design. The concentrations of phosphorus and sulfur are needed because their allowable loading in vitrified waste is limited and therefore could strongly influence the amount of vitrified LLW that will be generated, as well as impact the retrieval sequence and blending strategy. There is also concern that undesired phosphate-salt precipitation reactions could occur during pretreatment if the phosphate level is too high.

Current IC methods suffice for phosphorus and sulfur determination for the water soluble fraction of HLW. The insoluble sludge fraction is fused with KOH and then dissolved in hydrochloric acid before IC, analysis. The resulting high ion concentration degrades the precision and accuracy of the IC method. Dilution to avoid this problem degrades precision and accuracy. Therefore, an improved procedure for phosphorus and sulfur determination in the insoluble sludge fraction is desirable.

Elsewhere in the DOE complex, noble metals are analyzed by ICP/MS. Acquisition of ICP/MS instrumentation is scheduled for FY 1995. Lithium borate fusion to facilitate dissolution, followed by IC, also has potential. A methods survey and implementation of procedures in FY 1996 should provide the needed phosphorus, sulfur, and noble metals analysis improvements.

4.4.2 Field Sampling Improvements

4.4.2.1 Sample Verification Instrumented Receiver

Push mode and rotary core sampling have been hampered by poor sample recovery, which currently can be ascertained only after samplers have been placed in casks, shipped across site, and examined in hot cell facilities elsewhere at Hanford. Several initiatives have been pursued to improve the sampling process, but the ability to assess sample recovery at the tank remains highly desirable. When a partially filled sampler is encountered, questions also arise about which location in the tank the recovered sample actually represents.

In 1994, design of an instrumented receiver to address these issues was completed. Delivery of a system for routine operational use is scheduled for March 1995. This system has capability for neutron and acoustic interrogation and load cell (weight) measurements. It is anticipated that ultimately two additional units, based on the design and performance of the initial unit, will be fabricated and implemented.

4.4.2.2 Multiple Location Sampler

The ability to sample waste volume at depth and laterally through existing risers, including tank bottom and hardpan materials, is needed to support retrieval planning and operations, pretreatment planning, tank safety issue resolution (e.g., criticality), provide confidence that spatial variability has been bounded, and verify models of tank contents based on historical data.

EM-50 is supporting the development of a utility arm that can support a number of sampler end effectors, but the limited payload of this device limits its ability to sample at depth. A solicitation of proposals to assess the current availability of applicable multiple location sampler technology has been issued by TDPO, and an award was made in January 1995. Sampler development and/or acquisition could result from this study if promising technology is identified. A report is expected by June 1995. Interactions with potential industrial sources of this technology have been established.

4.4.2.3 Core Bit Instrumentation

The DNFSB 93-5 Implementation Plan specifies that rotary core bits for in-tank sampling be equipped with instrumentation for real-time sensing of bit temperature and proximity to the tank bottom. Present practice relies on administrative controls to address temperature and proximity concerns. These controls include cooling of the drill bit head with a flow of cold nitrogen gas, maintenance of conservative stand-off distances from the tank bottoms, limitations on rotation speed, drill bits designed to disintegrate on contact with steel, and interlocks to stop operations when penetration forces become too high. The use of flowing gas raises concerns about the accuracy of moisture content measurements on recovered core samples.

Augmentation of the administrative controls with real-time temperature and proximity sensors offers the possibility of increased operational flexibility (e.g., faster drilling rates) while providing additional confidence that operations remain within the established safety envelope. In FY 1995, a core bit temperature engineering model has been developed and successfully developed. The interface requirements with the core sampler and the tangible benefits of deployment are being re-examined before completing design and fabrication of a unit for field use.

4.4.3 In Situ Methods

4.4.3.1 In Situ Chemical Sensor Development

This template encompasses in situ chemical sensors, which are being developed for deployment on a platform such as the cone penetrometer. In general, deployment into HLW tanks will follow successful hot cell demonstration on HLW samples.

Significant life-cycle schedule reduction, cost savings, secondary waste stream minimization, and reduction in personnel exposure may be realized with in situ chemical characterization. Safety concerns such as potential criticality and ferrocyanide reactivity drive the need for HLW moisture content and molecular speciation. In situ measurements also may avoid sample degradation problems, such as inadvertent drying when samples are removed from HLW tanks. In addition, in situ application may allow continuous vertical profiling, which provides much more information than is possible from discrete sampling.

The copper foil activation method for moisture is considered a mature technology and will be concluded in FY 1995 with calibration experiments and a final technical report. An active neutron fission chamber probe for moisture determination will be completed in FY 1995 and is described in the cone penetrometer platform template, which also addresses available force sensors for the cone penetrometer package.

Cone penetrometer-deployed fiber optic-based systems for in situ near infrared (NIR) moisture and Raman molecular speciation determination are under development with EM-30 support and provide the focus for this template. Other NIR and Raman development activities are described in templates 4.4.4.3 and 4.4.4.4 and are keyed primarily to safety screening DQO. EM-50 is expected to continue to support both the NIR moisture and Raman molecular speciation activities.

Electromagnetic induction methods for in situ moisture determination are being investigated by the TWRS Safety Program.

4.4.3.2 In Situ Monitoring, Surveillance, and Stratigraphy

The location of buried objects is of interest to the Retrieval Program because of their potential impact on overall mining strategy, including shadow effects on retrieval effectiveness and equipment damage. The detection of major depositional layers is of interest to the retrieval, safety, and characterization programs. Layering information also should be useful in verifying historical models of tank contents.

Several technology initiatives, primarily supported by EM-50, currently are addressing detection of discontinuities and obstructions at depth within the waste, surface mapping, and imaging through obscured head space gas. EM-50 is supporting the investigation of the feasibility of applying structured light and laser range-finding technology to detailed surface mapping of tank wastes. The structured light system may provide highly accurate detailed surface maps, but because the method assumes surface continuity, it does not effectively map anomalies such as pipes and deep holes. Laser range finder technology is a complementary surface mapping tool that lacks the accuracy of the surface light system, but is faster and able to map anomalies.

It is anticipated that EM-50 will continue to fund these studies which, if demonstrated through testing, would strengthen the inventory estimation and sampling activities by the TWRS Characterization Program, as well as support planning and operations of the Retrieval Program. EM-50 also is expected to continue to develop imaging technology that might be effective through head space obscured by in-tank fogs, information of value for surveillance and retrieval purposes.

In addition, there is a need by sampling crews to anticipate properties of the subsurface waste properties directly beneath risers. Advance information would facilitate the selection and operation of sampling devices. An industry survey will be carried out in FY 1995.

4.4.3.3 In Situ Physical and Rheological Properties Methods

Measurement of rheological and physical properties of HLW is needed for designing retrieval equipment (nozzle, pump, long-reach manipulator, scarifier, etc.), preparing accurate waste simulants, predicting effective cleaning radii, and establishing the overall retrieval strategy. In situ measurement is required to minimize artifacts caused by sampling and handling. Various strength parameters (shear, tensile, compression), viscosity, porosity, abrasivity, density, temperature and other pertinent physical/rheological properties are specified in draft Retrieval DQO documentation.

The Characterization Program currently also supports the development of a waveguide sensor for performing in situ viscosity, density, and temperature measurements. FY 1994 work on development, fabrication, and testing will continue in FY 1995 to extend the operating range to the extreme HLW tank conditions. Strength measurements will be conducted with currently available cone penetrometer sensors as described in template 4.4.3.4.

4.4.3.4 Cone Penetrometer Platform

Development of a truck-based in-tank cone penetrometer platform for deploying sensors for in situ measurement of selected HLW properties is supported by the TWRS Characterization Program Office. Sensor development is funded jointly by EM-50 and TWRS. The cone penetrometer system will be deployed through 10 cm "4-inch" risers and will perform continuous profiling measurements from the waste surface to the tank bottom.

Because of the special constraints associated with the HLW tanks, the cone penetrometer platform must be custom built with features not routinely available. For example, the standard center-chassis mount configuration is not practical because of access restrictions posed by risers. Therefore, an extended support structure must be added to the platform. As another example of the non-standard nature of the platform, the long unsupported reach between the platform and the surface of the waste must be supported by a vertical guide tube to prevent buckling of the penetrometer, and a special clamping arrangement must be provided to ensure that tools are not lost in the tanks. Such special features require development, thereby driving up cost and extending schedule for deployment.

The penetrometer tip will include an industry-standard instrumentation package for various force measurements, from which strength parameters relevant to retrieval (e.g., shear, compression, and tensile strengths) can be deduced after calibration against standards. An active neutron moisture probe with a fission chamber detector will be available by March 1995 for deployment inside the cone penetrometer tube for vertical moisture profiling. Other sensors either available or under development include Raman molecular speciation, near infrared moisture, pH, and viscosity sensors, as discussed in other templates.

4.4.4 Rapid Analytical Methods

4.4.4.1 Rapid Elemental Analytical Methods for Water-Washed Sludge

There is a continuing need for a laboratory elemental analytical procedure for TWRS water-washed sludge samples that is rapid, inexpensive, reliable, and does not require sample dissolution yet meets applicable DQO and test plan requirements. Existing elemental methods require substantial time and effort for sample preparation and subsequent analysis.

Methods such as energy- or wavelength-dispersive x-ray fluorescence (XRF) could provide substantial efficiency gains if interference from x- and gamma-radiation background can be overcome and appropriate calibration standards can be identified. The use of modern micro-characterization capabilities may allow the background problem to be defeated. Micro-characterization also could be used to efficiently establish sample homogeneity. The simple setup for and operation of XRF analyses, minimal secondary waste generation, and potential for process control applications offer additional advantages over other techniques.

In addition to radiation background problems, XRF drawbacks include limited interrogation depth, difficulty in measuring low atomic number elements (lighter than sodium), and concerns related to sample homogeneity and the small spot size of the XRF beam. These concerns form the focus of FY 1995 development work.

XRF could form part of a hot cell screening analysis package. Development activities will be tied to precision, sensitivity, and accuracy requirements of applicable safety and pretreatment DQO and test plans.

4.4.4.2 Rapid Elemental Analytical Methods

Elemental, molecular, moisture, and radiochemical analyses of existing HLW, process materials, and final waste forms are essential to the TWRS cleanup mission. Rapid analytical methods have the potential to meet these needs and to reduce reliance on slow turnaround, labor-intensive, and costly standard laboratory methods. In addition to reducing direct costs and personnel exposure, rapid methods would provide more immediate information for all decision makers who use analytical data and facilitate the selection of optimum subsamples for standard laboratory analyses. The availability of rapid analysis results will expedite initial waste characterization, routine operation, and the development and deployment of suitable technologies for remediation functions including retrieval, pretreatment, and LLW and HLW vitrification. Specific requirements for analysis to support end function technology developments will be found within the appropriate end function sections of the ITP.

One practical, early application for the rapid analysis methods would be to scan core samples. An example of how core scanning with rapid analysis technologies could reduce standard laboratory analytical requirements is afforded by the safety screening DQO, which specifies quarter subsegment analyses on each core taken from ferrocyanide tanks. If the cores were scanned and shown to be uniform within prescribed DQO limits, at most one subsegment (rather than four) would need to undergo standard laboratory analyses. If the scanning analysis results met DQO requirements in all aspects, standard laboratory analysis might not be required at all.

Rapid analysis technology development initially will focus on hot cell laboratory applications to support the current Characterization Program emphasis on analysis of wastes as they now exist in the HLW tanks. However, subsequent extension of rapid analysis methods to other TWRS applications may be possible. For example, it might be advantageous to extend some rapid analysis methods to in situ characterization, pretreatment process development support, and vitrification process monitoring. The potential pretreatment and vitrification applications are discussed in the respective program element sections elsewhere in this document.

An integrated suite of complementary elemental, molecular, moisture, and radiochemical data provide a more comprehensive understanding of the waste constituents than would be possible from any single data set. In addition, rapid sample analysis data can be analyzed to determine total analyte levels, equivalent to composite sample data. The use of a single, integrated analysis suite will yield the same information currently provided by multiple, independent methods with the potential benefit that data validation and reporting will be significantly streamlined. The integrated data sets will provide the basis for a more complete understanding of the waste material and can be archived in a form that is easily retrieved if subsequent data assessment is needed. The availability of a broader data suite will reduce the technical risk in decisions based on HLW composition, both in the short- and long-terms.

The overall technology development and implementation strategy is being coordinated in the TWRS Characterization Program through the Advanced Hot Cell Analytical Technologies Project.

Specific rapid elemental analytical technologies being developed at this time are discussed in this template. Template 4.4.4.3 describes rapid molecular analysis methods development, and template 4.4.4.4 describes moisture methods development. These three templates address technologies that can stand alone or be combined as an integrated package.

Elemental LA/MS is an isotopic measurement technique that can detect nearly all elements in the periodic table. A focused laser ablates a portion of the sample into a carrier-gas stream, which is then injected into an ICP/MS. The method measures the elements rapidly and simultaneously, and requires essentially no sample preparation. Components are commercially available. Sensitivity is excellent, in the ppm range for light elements (sodium, iron, nickel, etc.) and in the sub-ppm for heavy elements (plutonium, americium, etc.). Accuracy of 10-15% has been demonstrated on waste glass standards and 10-15% on HLW simulant. A laboratory system is in place for a demonstration on HLW early in FY 1995.

The initial applications will consist of rapid sample scanning in a HLW laboratory to determine the presence of analytes above preset threshold values set by DQO and other documented data requirements. In addition, spatial distributions of analytes, homogeneous or spatially concentrated, can be determined and unanticipated spatial layering can be characterized. This approach will focus on key analytes above thresholds of interest.

A workshop on HLW applicable scanning technologies will be conducted in FY 1995 to determine the status of development of laser ablation and related technologies globally. The tradeoff of new technology versus upgrade of existing methods in view of new projections of sample load also will be done.

4.4.4.3 Rapid Molecular Analytical Methods

The justification for rapid molecular analytical methods is as given in the narrative for template 4.4.4.2, "Rapid Elemental Analytical Methods." As described below, in FY 1995 and FY 1996, EM-30 intends to support two rapid molecular methods.

Molecular laser ablation/mass spectrometry operates by the same principle and can use the same laser ablation equipment as for elemental LA/MS (template 4.4.4.2). However, an ionization method milder than ICP is used for ablation.to allow the production of molecular ions with minimal modification to the molecular composition of the sample. The ion-trap mass spectrometer provides simultaneous detection of +/- ion species. This molecular method follows prior experience in aerosol analysis but is not as fully developed as the elemental LA/MS. Some work with HLW is planned for FY 1995.

Raman spectroscopy involves the inference of molecular structure from measured shifts in a laser beam scattered from the sample. The intensity of the scattered beam can be used to quantify the amount of each molecular species in the sample. Commercially available components are being integrated for application to Hanford HLW. Systems will first be implemented in a hot cell scanning mode and then be extended to in situ platforms such as the cone penetrometer.

4.4.4.4 Moisture Analytical Methods

Moisture analysis is a key analytical requirement for safety considerations. A multitude of sensing techniques have been developed for in situ and laboratory analysis. Each method has strengths and weaknesses, and no single method is optimum for all specific moisture questions.

Electromagnetic induction (EMI) specifically deals with moisture determination by NIR spectroscopy , a method which is being developed jointly by EM-30 and EM-50. The method uses absorption of NIR radiation by water O-H stretching overtones to determine water content. The NIR method is rapid and requires no sample preparation. The method is readily adaptable for remote applications by fiber optics, including hot cell core scanning, discrete "mash probe" measurements, and large waste surface area scanning using a long-range NIR camera. NIR technology is used widely in food processing, grain marketing, and other commercial applications. Precision and accuracy on HLW simulants have been demonstrated to be adequate for TWRS DQO purposes. A limitation of NIR is the relatively short depth interrogation range. FY 1995 activities will consist of continued development of the method, and hot cell application is planned for FY 1996.

EMI techniques have been supported in the past by EM-50 and now are being pursued by the Safety Program for in situ LOW logging and scanning waste surfaces in HLW tanks. The current EMI work shows that it is best suited for applications requiring significant penetration into the waste, but is restricted by calibration issues and its inability to function through metal (e.g., cone penetrometer). One of the calibration issues is the uncertainty of the EMI probes interrogation volume. The material volume within a probe field of view is a necessary factor to extract an absolute water concentration value (usually expressed as a weight percent). Trapped gases and ionic variations within the tank wastes are some of material issues affecting the concentration parameter.

A number of passive and active neutron-based in situ moisture detection systems have been developed under both EM-30 and EM-50 sponsorship. Neutron moisture methods have intermediate range of penetration, can function through metal, and are well established in borehole logging. However these oil industry tools have a scale that is much larger than the confines of a waste tank. In addition to conventional neutron systems currently being used in LOWs, fission counter and copper foil activation methods suitable for cone penetrometer deployment are being developed (see Templates 4.4.3.1 an 4.4.3.4). Neutron methods are subject to calibration and neutron poisoning uncertainties, and active systems require handling of a radioactive source. Small quantities of high neutron cross-section atoms can have a large impact on the neutron response of a material. Neutron methods have particular sensitivity to boron, a constituent of LOWs.

Time domain reflectometry (TDR) methods have been developed with EM50 support for in situ application. As with the preceding moisture methods, calibration is an issue with this method. TDR basically measures the permittivity of a volume of material within the field limits of the sensor. Although permittivity of other materials within the sensitive volume of a TDR probe requires calibration. Entrapped gas that impacts the apparent density of the material within the probe field is one of the factors that requires calibration. The TDR technology has been under development in the public sector and there are several commercial products being used in niche applications. One of these is a TDR-based soil moisture sensor. Another is a void fraction sensor for water/steam media.

Thermogravimetric methods currently are used for TWRS laboratory measurements. Although the method has adequate accuracy and precision, this method is slow and tedious because it requires acquisition of samples and transfer to hot cells for measurements. The method also is less desirable than in situ methods because of the penalty for sample collecting, opportunity for sample drying, and the discrete nature of the sampling versus continuous in situ scanning methods. Because the method requires sample drying at elevated temperatures, loss of organic volatiles can complicate the gravimetric data interpretation.

4.5 Integration of EM-30 and EM-50 Characterization Activities Relevant to TWRS

4.5.1 EM-50

The Office of Technology Development (OTD) (EM-50) conducts a national program of applied research and development to focus, manage, and accelerate the development and implementation of technologies to meet specific Environmental Restoration and Waste Management (ER/WM) requirements. The OTD efforts mainly concentrate on developing the most promising techniques for performing laboratory scanning analysis, remotely monitoring tank conditions, and analyzing tank waste in situ.

Over 100 EM-50 development activities have been identified that have directly supported TWRS. Detailed descriptions of FY 1994 activities, including title, performing organization, principal investigator, scope description, funding level, and major milestones, are available elsewhere.(a) Current EM-50 activities relating to the TWRS Characterization Program are summarized below.

The Characterization Monitoring and Sensor Technology Integrated Program (CMST-CP) currently supports development and demonstration of in-tank sensors to detect gases with safety implications, in situ acoustic methods for monitoring effective mixing radius and HLW physical density, and electromagnetic sensor for measurement of moisture in SSTs, a time-domain reflectrometry sensor for characterizing HLW bulk and layering characteristics, and techniques for in situ imaging of the HLW surface through obscured conditions during sluicing operations for waste retrieval. The development of a fission chamber neutron detector for moisture sensing for deployment with a cone penetrometer also is being supported by CMST-IP. As to the support of laboratory analysis, CMST-IP is developing a Fourier-transform infrared photoacoustic spectroscopic method to quantify nitrates and ferrocyanides in HLW sludges and solids.

UST-ID is supporting nondestructive rapid analytical techniques such as raman and NIR spectroscopy. These techniques demonstrated in a hot cell environment will be candidates for in situ deployment via cone penetrometer or other deployment platforms currently in development.

The Robotics Integrated Program (RIP) and UST-ID are supporting the developing of the Light Duty Utility Arm (LDUA). This device will provide a platform for deploying an array of sampling and characterization devices of value to TWRS.

(a) The document *Technology Development Activities Supporting Tank Waste Remediation* has been issued in draft form by the Technology Development Program Office.

4.5.2 EM-30

The Office of Waste Management (EM-30) works with OTD (EM-50) to develop innovative technologies for addressing safety and waste treatment, disposal and minimization issues. The broad range of EM-30 technology development activities supporting the Hanford TWRS is described in detail in this ITP and elsewhere.[a] The following paragraphs summarize activities relating to the TWRS Characterization Program.

In FY 1995, it is expected that EM-30, through the TWRS Characterization Program, will invest approximately $4.6M (6% of the total Characterization Program budget) on applied engineering and technology development to address HLW characterization issues. This expenditure is in addition to sharply focused characterization technology work supported by the TWRS Safety Program, as discussed in Chapter 3.0.

In FY 1995, sampling and analysis costs are expected to consume approximately 70% of the approximately $80M in the Characterization Program budget. As the Characterization Program increasingly addresses technology needs of disposal program elements and TWRS enters the FY 1995-FY 1997 period of intense sampling, characterization technology expenditures are expected to shift in focus and are projected to peak in FY 1996.

In FY 1995, characterization technology and applied engineering work is focused in four strategic areas:

- laboratory analysis
- field sampling
- in situ characterization
- rapid analysis

The primary drivers for these technology categories are timely resolution of waste tank safety and other programmatic issues, improved reliability of the characterization data, and minimization of the time and cost for sampling and analysis.

Laboratory analysis. Approximately $29M (36%) of the FY 1995 TWRS Characterization Program budget will be consumed by activities directly or indirectly related to laboratory analysis. The practical difficulties of working with HLW samples and the evolving nature of the analytical requirements (notably, DQO) causes current HLW laboratory analyses to be slow, expensive, and sometimes technically inadequate. All of these factors contribute to the high cost and slow turnaround of HLW analysis. In FY 1995, the Characterization Program expects to spend approximately $0.9M (13% of the applied engineering/technology development budget) on improving laboratory analysis. As discussed below, this investment is supplemented with development of rapid analysis methods, which can be used in either a scanning or non-scanning mode.

Specific laboratory analytical development activities planned for FY 1995 include methods development for total organic carbon (TOC) complexants, phosphorus and sulfur, noble metals, nickel isotopes, and physical properties. In addition, surveys are planned for technetium analytical methods and potential high-impact areas for laboratory automation.

(a) Tank Waste Remediation System: *FY 1994 Technology Development Plan*, TWRS Technology Development Program Office, January 5, 1994.

Field sampling. Approximately $26M (32%) of the FY 1995 TWRS Characterization Program budget will be consumed by activities directly related to field sampling. Severe operational constraints posed by the HLW tank environment, as well as properties of the HLW, causes sampling to be slow, expensive, and sometimes ineffective. In addition, the critical problem of ensuring that representative characterization of the HLW has been accomplished continues to be difficult. In FY 1995, the Characterization Program expects to support approximately $1.7M (37% of the applied engineering/technology development budget) of work to improve the effectiveness of the field sampling program. This work is supplemented by in situ characterization development, described below.

FY 1995 field sampling technology work includes an instrumented receiver for near real-time sensing of sample recovery, instrumentation to sense the temperature of the rotary core bit, and cross-borehole seismology to characterize waste physical properties and interfaces. In addition, an industry-wide survey will be conducted to identify near-term technology that will allow sampling at multiple locations in a tank from a single access point.

In situ characterization. If characterization could be performed in situ, dramatic reductions of cost, schedule, secondary waste generation, and personnel exposure could be realized because samples would not have to be removed from the tanks and analyzed in a laboratory. In addition, some physical and rheological properties important for retrieval must be performed in situ, because the physical disturbance caused by sampling can alter the properties that are to be measured.

The centerpiece of the FY 1995 in situ characterization technology work is the development of a cone penetrometer platform. This platform will be capable of sampling through 10 cm "4-inch" risers to the bottoms of the HLW tanks. The platform will allow the deployment of standard force sensors, which will provide data to allow the inference of various strength parameters important to retrieval. Standard sensors for temperature and pH are also available. FY 1995 development of other cone penetrometer sensors is being directed toward moisture (fission chamber neutron, copper foil neutron, and NIR detectors), molecular speciation (Raman spectroscopy), physical/rheological properties (wave guide sensor), and tank proximity sensing for the cone penetrometer tip.

Rapid analytical methods. Laboratory analytical methods are currently available with rapid turnaround time, little or no sample preparation, broad analyte capability, and utility in either scanning or discrete analysis modes. If such methods could be used for HLW analysis, dramatic efficiency gains would be realized. In FY 1995, $0.7M (1% of the total Characterization Program budget and 15% of the applied engineering/technology development budget) will be directed toward rapid analytical methods.

The rapid analysis development work focuses on hot-cell based systems with analytical components that can be operated either individually or in an integrated fashion. The systems can be operated either in scanning or non-scanning modes. Specific technologies include laser Raman spectroscopy for molecular speciation, NIR spectroscopy for moisture determination, LA/MS for both elemental and molecular analysis, and gamma energy/high energy beta methods for radiochemical analysis. The Raman, NIR, and LA/MS effort is strongly leveraged by EM-50 support. In parallel to development for hot cell use, the Raman and NIR methods also are being developed for in situ deployment by cone penetrometer.

4.6 Schedule and Budget

The schedule and budget for technology activities supporting the Waste Characterization Program are shown in Figure 4.2 and Table 4.3, respectively. Figure 4.2 identifies template activities, tasks within each template, deliverables, critical interfaces, and drivers (depicted to the right of each template activity bar). Table 4.3 presents two sets of budget estimates by program element and fiscal year. The first profile consists of activities currently included in the TWRS Multi-Year Work Plan (MYWP) and reflects the estimated budget available for technology. The second profile reflects the estimated budget required to perform all tasks shown in the ITP, including activities that are anticipated to be funded and those that are not (unfunded activities have been prioritized for inclusion in the MYWP at the first opportunity).

4.7 Prioritization (Results)

Table 4.2 presents the functions, technology packages, tasks, FY 1995 budgeted costs, estimated costs for FY 1996, and a brief statement regarding the benefit of funding these technology activities. For the Waste Characterization Program element, the planning basis indicates that sufficient funding is available for all technology work within the TWRS Baseline Program for FY 1996 and beyond. Consequently, formal prioritization of nonbaseline activities is not necessary at this time.

4.7.1 FY 1995 Impacts of Funding at Baseline Versus Recommended Program Level

The preliminary FY 1995 baseline budget for characterization technology development addresses health and safety issues associated with tank waste sampling and analysis. Initiatives focused on sampling improvements, minimum and required analytical methods development identified in support of disposal programs, and acceleration of tank waste analysis are also being pursued.

The proposed baseline budget is responsive to the constrained TWRS program baseline budget, but does not provide for delivery of technology to meet all DNFSB 93-5 implementation plan commitments on schedule. With current information and needs statements from TWRS program elements, FY 1995 TPA milestones are not impacted. Acceleration of some sampling technology development, analytical methods development, and in situ characterization in support of disposal programs is deferred until more definitive sampling and analysis requirements are established and the budget is less constrained. It is assumed that portions of the characterization technology program will be supported by EM-50 programs, with continued emphasis on in situ sampling, in situ surveillance, monitoring and stratigraphy, laboratory automation, and methodology to accelerate waste analysis.

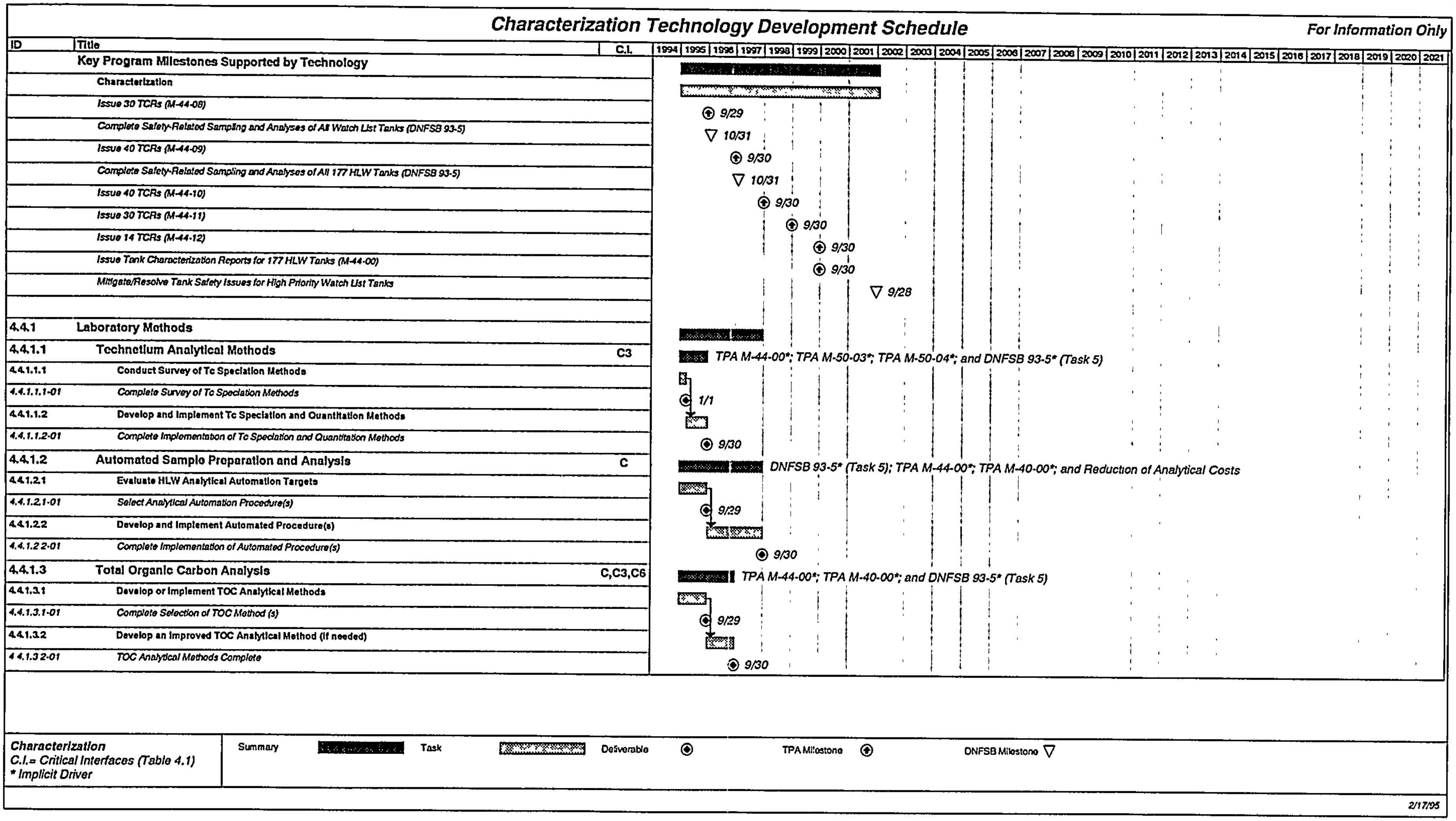
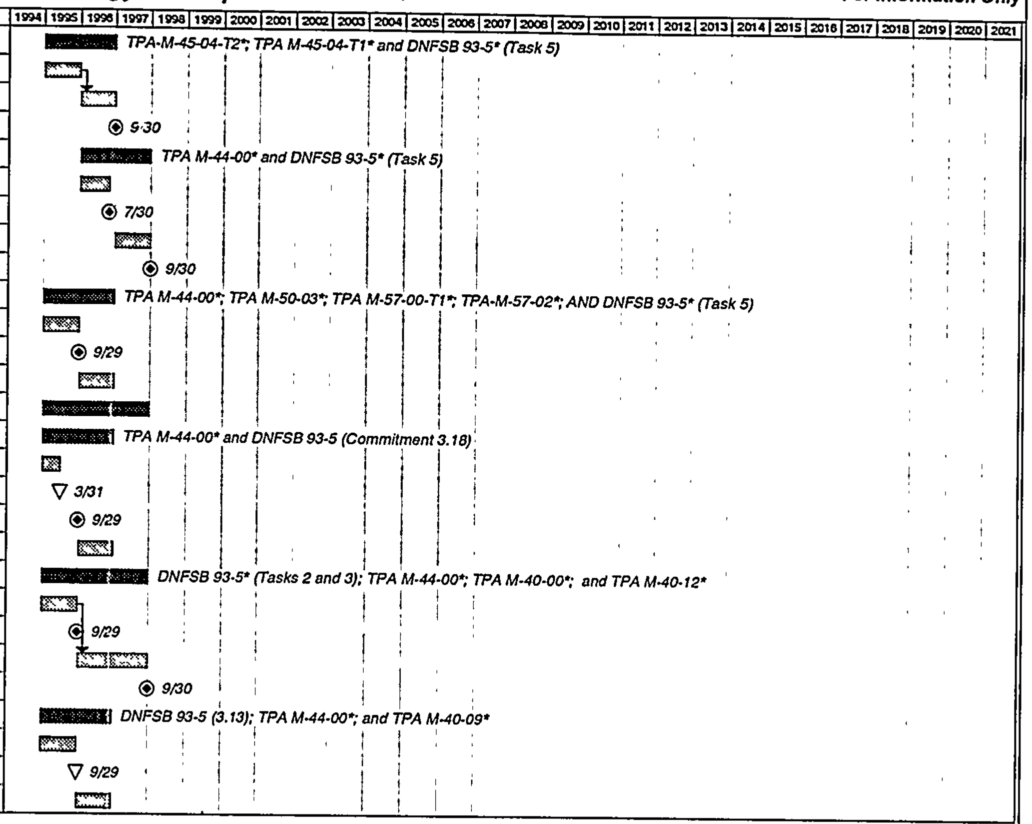


Figure 4.2. Schedule

Characterization Technology Development Schedule

For Information Only

ID	Title	C.I.
4.4.1.4	Laboratory Physical/Rheological Property Methods	C2
4.4.1.4.1	Develop Analytical Methods to Infer Pertinent In Situ HLW Properties	
4.4.1.4.2	Implement Analytical Methods	
4.4.1.4.2-01	*Complete Implementation of Laboratory Procedures*	
4.4.1.5	Nickel 59/63 Analysis	C3
4.4.1.5.1	Develop, Demonstrate, and Implement Radiochemical Method for Quantitation of Ni-59 and Ni-63	
4.4.1.5.1-01	*Radiochemical Method for Ni Implemented*	
4.4.1.5.2	Develop, Demonstrate , and Implement ICP/MS Method for Quantitation of Ni-59 and Ni-63	
4.4.1.5.2-01	*ICP/MS Method of Ni Implemented*	
4.4.1.6	Phosphorous, Sulfur, and Noble Metals Analytical Methods for Water Washed Sludge	C3
4.4.1.6.1	Acquire and Deploy ICP/MS Instrumentation and Implement Procedures for Noble Metal Determination	
4.4.1.6.1-01	*ICP/MS Instrumentation Procedures Complete*	
4.4.1.6.2	Identify Analytical Methods for Routine Analysis of Phosphorous and Sulfur in Water Washed Sludge	
4.4.2	Field Sampling Improvements	
4.4.2.1	Sample Verification Instrumented Receiver	C1
4.4.2.1.1	Delivery and Implementation of an Instrumented Receiver	
4.4.2.1.1-01	*Complete Delivery and Implementation of Instrumented Receiver*	
4.4.2.1.1-02	*Complete Decision to Enhance Instrumented Receiver*	
4.4.2.1.2	Enhanced Instrumented Receiver (if needed)	
4.4.2.2	Multiple Location Sampler	C3
4.4.2.2.1	Conduct Industry-Wide Survey of Available and Promising Technology	
4.4.2.2.1-01	*Complete Technology Survey*	
4.4.2.2.2	Develop Multiple Sampling Capability	
4.4.2.2.2-01	*Complete Development of Multiple Sampling Capability*	
4.4.2.3	Core Bit Instrumentation	C1
4.4.2.3.1	Develop Final Temperature Sensing Package	
4.4.2.3.1-01	*Complete Final Temperature Sensing Package*	
4.4.2.3.2	Develop Proximity Sensing Package	



Characterization
C.I.= Critical Interfaces (Table 4.1)
** Implicit Driver*

Summary ■ Task ▨ Deliverable ◉ TPA Milestone ⊕ DNFSB Milestone ▽

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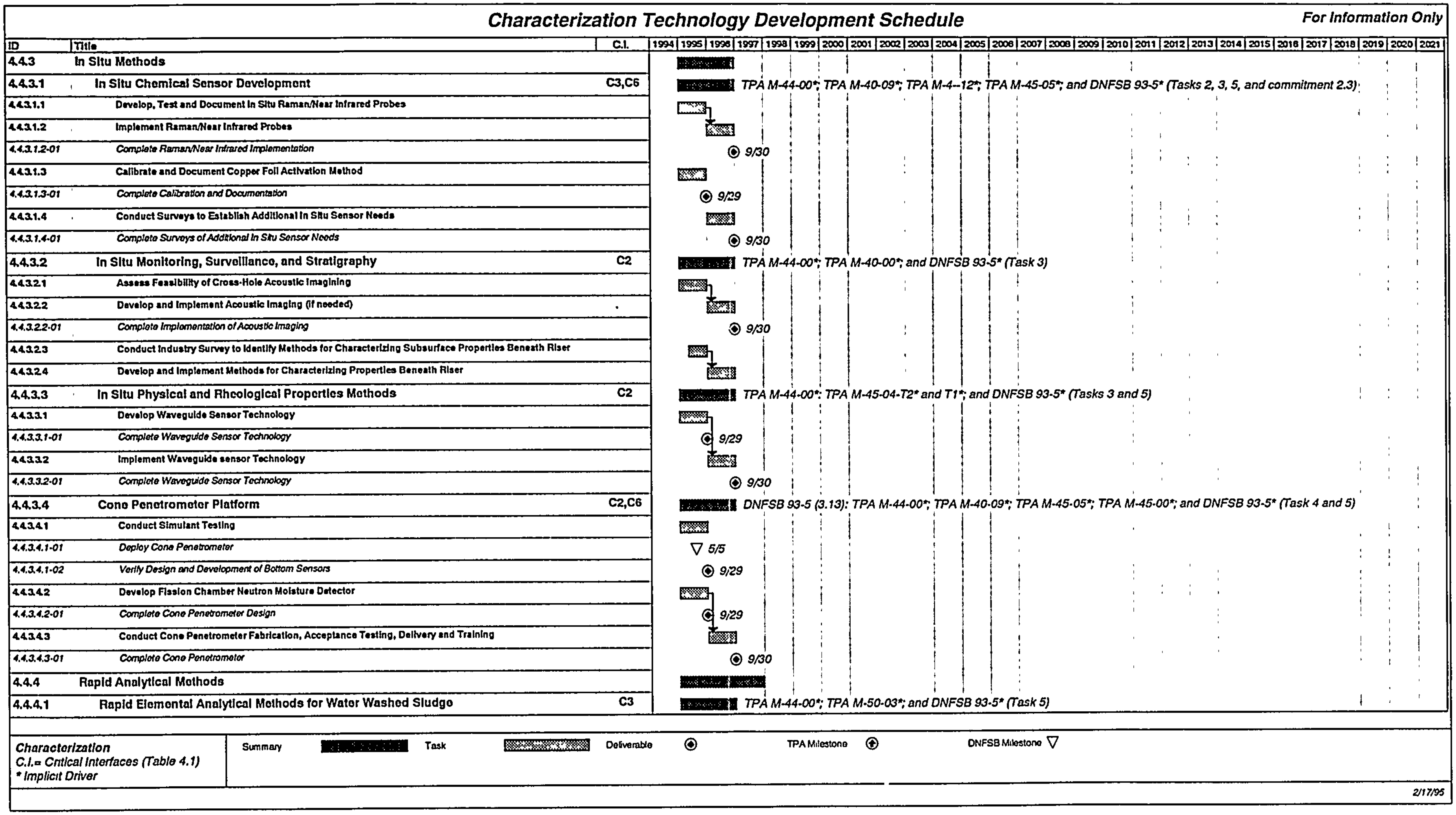
Figure 4.2. Schedule (cont.)



Characterization Technology Development Schedule

For Information Only

ID	Title	C.I.	
4.4.3	In Situ Methods		
4.4.3.1	In Situ Chemical Sensor Development	C3,C6	TPA M-44-00*; TPA M-40-09*; TPA M-4--12*; TPA M-45-05*; and DNFSB 93-5* (Tasks 2, 3, 5, and commitment 2.3)
4.4.3.1.1	Develop, Test and Document In Situ Raman/Near Infrared Probes		
4.4.3.1.2	Implement Raman/Near Infrared Probes		
4.4.3.1.2-01	*Complete Raman/Near Infrared Implementation*		9/30
4.4.3.1.3	Calibrate and Document Copper Foil Activation Method		
4.4.3.1.3-01	*Complete Calibration and Documentation*		9/29
4.4.3.1.4	Conduct Surveys to Establish Additional In Situ Sensor Needs		
4.4.3.1.4-01	*Complete Surveys of Additional In Situ Sensor Needs*		9/30
4.4.3.2	In Situ Monitoring, Surveillance, and Stratigraphy	C2	TPA M-44-00*; TPA M-40-00*; and DNFSB 93-5* (Task 3)
4.4.3.2.1	Assess Feasibility of Cross-Hole Acoustic Imagining		
4.4.3.2.2	Develop and Implement Acoustic Imaging (if needed)		
4.4.3.2.2-01	*Complete Implementation of Acoustic Imaging*		9/30
4.4.3.2.3	Conduct Industry Survey to Identify Methods for Characterizing Subsurface Properties Beneath Riser		
4.4.3.2.4	Develop and Implement Methods for Characterizing Properties Beneath Riser		
4.4.3.3	In Situ Physical and Rheological Properties Methods	C2	TPA M-44-00*: TPA M-45-04-T2* and T1*; and DNFSB 93-5* (Tasks 3 and 5)
4.4.3.3.1	Develop Waveguide Sensor Technology		
4.4.3.3.1-01	*Complete Waveguide Sensor Technology*		9/29
4.4.3.3.2	Implement Waveguide sensor Technology		
4.4.3.3.2-01	*Complete Waveguide Sensor Technology*		9/30
4.4.3.4	Cone Penetrometer Platform	C2,C6	DNFSB 93-5 (3.13): TPA M-44-00*; TPA M-40-09*; TPA M-45-05*; TPA M-45-00*; and DNFSB 93-5* (Task 4 and 5)
4.4.3.4.1	Conduct Simulant Testing		
4.4.3.4.1-01	*Deploy Cone Penetrometer*		5/5
4.4.3.4.1-02	*Verify Design and Development of Bottom Sensors*		9/29
4.4.3.4.2	Develop Fission Chamber Neutron Moisture Detector		
4.4.3.4.2-01	*Complete Cone Penetrometer Design*		9/29
4.4.3.4.3	Conduct Cone Penetrometer Fabrication, Acceptance Testing, Delivery and Training		
4.4.3.4.3-01	*Complete Cone Penetrometer*		9/30
4.4.4	Rapid Analytical Methods		
4.4.4.1	Rapid Elemental Analytical Methods for Water Washed Sludge	C3	TPA M-44-00*; TPA M-50-03*; and DNFSB 93-5* (Task 5)

Characterization
C.I.= Critical Interfaces (Table 4.1)
** Implicit Driver*

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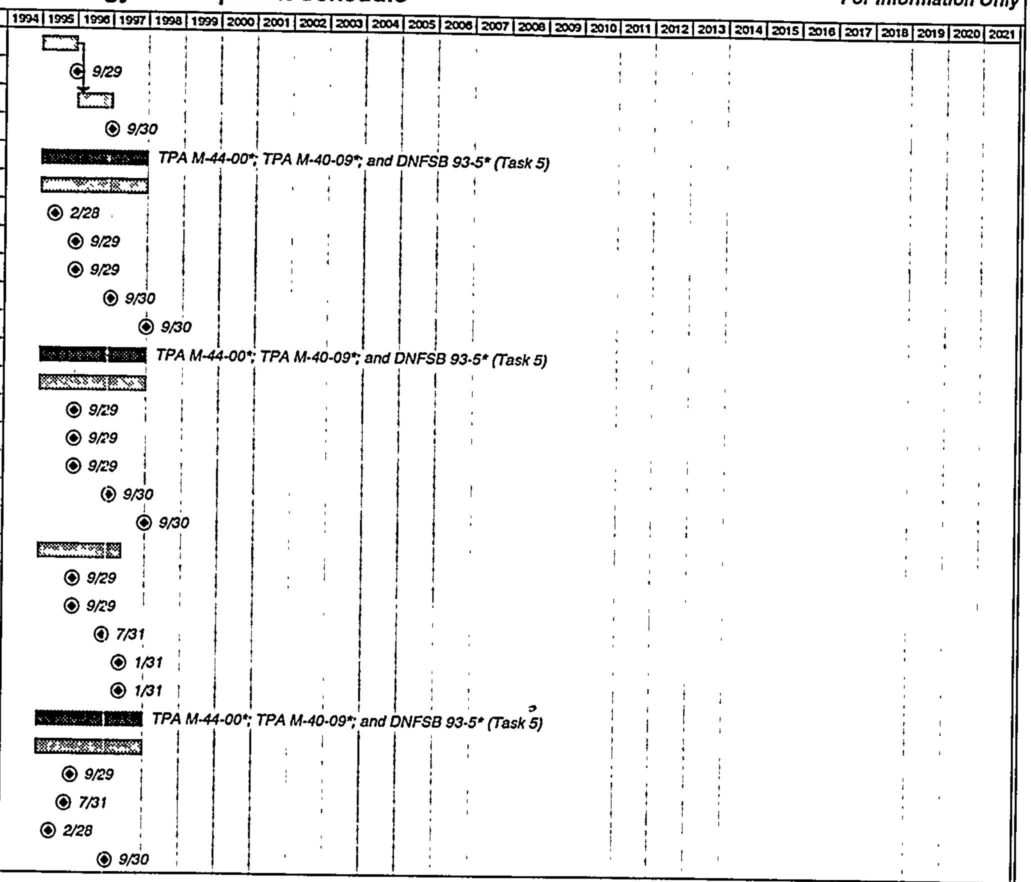
Figure 4.2. Schedule (cont.)

Characterization Technology Development Schedule

For Information Only

ID	Title	C.I.
4.4.4.1.1	**Develop XRF Microfluorescence Methodology**	
4.4.4.1.1-01	*Complete Development of XRF Microfluorescence Methodology*	
4.4.4.1.2	**Implement XRF Microfluorescence Method**	
4.4.4.1.2-01	*Complete Implementation of XRF Microfluorescence Method*	
4.4.4.2	**Rapid Elemental Analytical Methods**	
4.4.4.2.1	**Develop and Implement Elemental Laser Ablation/MS HLW Scanning Analysis**	C3
4.4.4.3.1-01	*Complete Initial Tests*	
4.4.4.3.1-02	*Establish Design Concept for Ablation Gas Sampling*	
4.4.4.3.1-03	*Revise System Conceptual Design*	
4.4.4.3.1-04	*Complete Modification of PNL Hot Cell*	
4.4.4.3.1-05	*Implement Complete System in PNL Hot Cell*	
4.4.4.3	**Rapid Molecular Analytical Methods**	
4.4.4.3.1	**Develop and Implement Laser Ablation/MS for Routine Molecular Analysis**	C3
4.4.4.3.1-01	*Establish CRADAs*	
4.4.4.3.1-02	*Complete Measurement Demonstration with Simulants*	
4.4.4.3.1-03	*Complete Integrated Elemental/Molecular System Conceptual Design*	
4.4.4.3.1-04	*Complete Fabrication of Hot Molecular System*	
4.4.4.3.1-05	*Implement Complete System in PNL Hot Cell*	
4.4.4.3.2	**Develop and Implement Raman Spectroscopy Scanning for HLW Molecular Analysis**	C3
4.4.4.3.2-01	*Complete Functions, Requirements, and Conceptual Design for Hot Cell System*	
4.4.4.3.2-02	*Determine Performance Using 780 nm Laser*	
4.4.4.3.2-03	*Revise Hot Cell Qualification Document*	
4.4.4.3 2-04	*Complete Install of Scanning System in Hot Cell*	
4.4.4.3.2-05	*Qualify Hot Cell System Performance on Simulants and HLW*	
4.4.4.4	**Moisture Analytical Methods**	
4.4.4.4.1	**Develop and Implement Near Infrared Spectroscopy Scanning for Routine HLW Moisture Analysis**	C3,C6
4.4.4.4.1-01	*Demonstrate HLW Moisture Analysis*	
4.4.4.4.1-02	*Establish Systems Requirements for Hot Cell Scanning System*	
4.4.4.4.1-03	*Assess In Situ and Hot Cell Uses*	
4.4.4.4.1-04	*Implement for Routine Use*	



Characterization
C.I.= Critical Interfaces (Table 4.1)
** Implicit Driver*

Summary ▆ Task ▨ Deliverable ◉ TPA Milestone ◉ DNFSB Milestone ▽

2/17/95

Figure 4.2. Schedule (cont.)

Table 4.3. Budget

CHARACTERIZATION
TWRS Technology Budget Estimates
(Unescalated Dollars in Thousands by Fiscal Year)

TECHNOLOGY PACKAGE NUMBER AND TITLE	1995	1996	1997	1998	1999	2000	2001 +	TOTAL
["Expected Budget Available for Technology" consists of activities in TWRS Multi-Year Work Plan]								
4.4.1.1--Technetium Analytical Methods								
Expected Budget Available for Technology	75	205	0	0	0	0	0	280
Total Estimated Budget for Technology Activities in ITP	75	205	0	0	0	0	0	280
4.4.1.2--Automated Sample Preparation and Analysis								
Expected Budget Available for Technology	100	200	200	0	0	0	0	500
Total Estimated Budget for Technology Activities in ITP	100	200	200	0	0	0	0	500
4.4.1.3--Total Organic Carbon Analysis								
Expected Budget Available for Technology	200	200	0	0	0	0	0	400
Total Estimated Budget for Technology Activities in ITP	200	200	0	0	0	0	0	400
4.4.1.4--Laboratory Physical/Rheological Property Methods								
Expected Budget Available for Technology	200	200	0	0	0	0	0	400
Total Estimated Budget for Technology Activities in ITP	200	200	0	0	0	0	0	400
4.4.1.5--Nickel 59/63 Analysis								
Expected Budget Available for Technology	0	140	165	0	0	0	0	305
Total Estimated Budget for Technology Activities in ITP	0	140	165	0	0	0	0	305
4.4.1.6--Phosphorous, Sulfur and Noble Metals Analytical Methods for Water Washed Sludge								
Expected Budget Available for Technology	150	100	0	0	0	0	0	250
Total Estimated Budget for Technology Activities in ITP	150	100	0	0	0	0	0	250
4.4.2.1--Sample Verification Instrumented Receiver								
Expected Budget Available for Technology	505	200	0	0	0	0	0	705
Total Estimated Budget for Technology Activities in ITP	505	200	0	0	0	0	0	705
4.4.2.2--Multiple Location Sampler								
Expected Budget Available for Technology	75	1,400	1,900	0	0	0	0	3,375
Total Estimated Budget for Technology Activities in ITP	75	1,400	1,900	0	0	0	0	3,375

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Table 4.3. Budget (cont.)

CHARACTERIZATION (Continued)
TWRS Technology Budget Estimates
(Unescalated Dollars in Thousands by Fiscal Year)

TECHNOLOGY PACKAGE NUMBER AND TITLE	1995	1996	1997	1998	1999	2000	2001 +	TOTAL
["Expected Budget Available for Technology" consists of activities in TWRS Multi-Year Work Plan]								
4.4.2.3--Core Bit Instrumentation								
Expected Budget Available for Technology	600	500	0	0	0	0	0	1,100
Total Estimated Budget for Technology Activities in ITP	600	500	0	0	0	0	0	1,100
4.4.3.1--In Situ Chemical Sensor Development								
Expected Budget Available for Technology	197	400	0	0	0	0	0	597
Total Estimated Budget for Technology Activities in ITP	197	400	0	0	0	0	0	597
4.4.3.2--In Situ Monitoring, Surveillance and Stratigraphy								
Expected Budget Available for Technology	131	600	0	0	0	0	0	731
Total Estimated Budget for Technology Activities in ITP	131	600	0	0	0	0	0	731
4.4.3.3--In Situ Physical and Rheological Properties Methods								
Expected Budget Available for Technology	200	200	0	0	0	0	0	400
Total Estimated Budget for Technology Activities in ITP	200	200	0	0	0	0	0	400
4.4.3.4--Cone Penetrometer Platform								
Expected Budget Available for Technology	1,104	1,200	0	0	0	0	0	2,304
Total Estimated Budget for Technology Activities in ITP	1,104	1,200	0	0	0	0	0	2,304
4.4.4.1--Rapid Elemental Analytical Methods for Water Washed Sludge								
[See Footnote (1)]								
4.4.4.2--Rapid Elemental Analytical Methods								
Expected Budget Available for Technology	340	2,200	1,200	0	0	0	0	3,740
Total Estimated Budget for Technology Activities in ITP	340	2,200	1,200	0	0	0	0	3,740
4.4.4.3--Rapid Molecular Analytical Methods [See Footnote (2)]								
Expected Budget Available for Technology	*	2,050	1,550	0	0	0	0	3,600
Total Estimated Budget for Technology Activities in ITP	*	2,050	1,550	0	0	0	0	3,600

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Table 4.3. Budget (cont.)

CHARACTERIZATION (Continued)
TWRS Technology Budget Estimates
(Unescalated Dollars in Thousands by Fiscal Year)

TECHNOLOGY PACKAGE NUMBER AND TITLE	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001 +**	**TOTAL**
["Expected Budget Available for Technology" consists of activities in TWRS Multi-Year Work Plan]								
4.4.4.4--Moisture Analytical Methods [See Footnote (2)]								
Expected Budget Available for Technology	*	1,000	400	0	0	0	0	1,400
Total Estimated Budget for Technology Activities in ITP	*	1,000	400	0	0	0	0	1,400
CHARACTERIZATION TOTALS:								
Expected Budget Available for Technology	3,877	10,795	5,415	0	0	0	0	20,087
Total Estimated Budget for Technology Activities in ITP	3,877	10,795	5,415	0	0	0	0	20,087

Footnotes:

(1) This template is being funded by the Pretreatment Program (Template 6.4.3, Task #5). Budget estimate is $180K in 1995.

(2) Templates 4.4.4.3 and 4.4.4.4 are to receive some EM50 funding in FY95 that is not included in these totals.

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5.0 Waste Retrieval

5.1 Purpose, Objectives, Scope, and Strategy

The **purpose** of the Waste Retrieval Program is to remove waste from the underground storage tanks (USTs) and transport it to various facilities. The primary focus of this program is to design, install, and operate the equipment when waste must be removed from the USTs. This includes upgrade and/or replacement of any tank farm infrastructures and transfer lines not performed by the Tank Farm Upgrades Program, when upgrades are required to support retrieval.

The overall **objective** of technology implementation for the Waste Retrieval Program is to support remediation of tank safety issues, transfer waste from aging single-shell tanks (SSTs) into double-shell tanks (DSTs), transfer waste between DSTs to facilitate tank space consolidation, and transfer waste to other facilities for treatment and disposal.

The **scope** of the Waste Retrieval Program includes defining, planning, and implementing waste retrieval activities consisting of program element management, retrieval technology development, systems engineering, project activities, and retrieval support activities. Project tasks include the following:

- Prepare the necessary documentation to formulate the Tank Waste Remediation System (TWRS) and waste retrieval programmatic baseline.
- Establish and administer projects to install retrieval systems in DSTs and SSTs.
- Perform startup testing and readiness reviews on completed projects.

The **strategy** for the Waste Retrieval Program is to implement the best demonstrated technology in a time frame that complies with the overall TWRS mission objectives and minimizes additional waste retrieval operations during the tank closeout process. The retrieval operations will be initiated with known, proven technologies to support rapid closeout of tank safety issues and statutory commitments. Additional technology will be developed and deployed as available to meet the TWRS mission requirements.

Early emphasis of the Waste Retrieval Program will be on the following:

- Demonstrate reference technologies.
- Verify design basis.
- Evaluate improvement/enhancements to the reference retrieval technologies.
- Identify and develop alternate retrieval technologies that promise to substantially reduce the overall cost of retrieval.

5.1.1 Key Assumptions

The key assumptions for the Waste Retrieval Program are as follows:

- The resolution of safety issues will require retrieval of waste from selected Watch List tanks.
- The retrieval technology program will meet the requirements of the negotiated Tri-Party Agreement (TPA).
- Waste retrieval will be required for all SSTs.

- In-tank hardware, such as piping, pumps, etc., are not considered waste.
- Discarded radioactive sources must be recovered for disposal.
- Two mixer pumps will successfully mobilize all sludge in each DST.
- Past-practice sluicing is the reference SST retrieval method; additional methods will be required to achieve the TPA objectives for waste removal in some tanks. Additionally, past-practice sluicing may not be allowed in excessively leaking tanks.
- The Hanford Defense Waste Environmental Impact Statement (EIS) and Record of Decision (ROD) provide sufficient National Environmental Policy Act (NEPA) documentation for retrieving DST waste.
- An environmental assessment is sufficient NEPA documentation for retrieving waste from the first SST (Tank 241-C-106). The TWRS EIS will need to be approved before retrieving waste from the remaining SSTs.
- The Waste Retrieval Program will perform all activities necessary to transfer DSTs, SSTs, and miscellaneous underground storage tanks (MUSTs) to the Environmental Restoration (ER) Program for closure.
- Subsurface barriers (SSBs) will be evaluated for use but will not be included in the baseline work scope.
- There is no requirement to provide retrieved tank waste samples for large-scale (>25 L samples) pretreatment and immobilization development.
- Evaluation of leak detection in support of closure planning is required.

5.1.2 Key Uncertainties

The key uncertainties that affect Waste Retrieval are 1) retrieval design parameters (includes to what extent waste must be retrieved to meet closeout requirements), 2) DST storage capability, and 3) maintenance and solid waste disposal capability, as described below.

- Key retrieval design parameters need to be determined. For example, to determine the rate of the overall retrieval process, the uncertainties associated with tank space availability, waste treatment flow rates, and the rate of production of HLW and LLW glass will need to be resolved. Further, possible restrictions placed on the use of high-water-volume retrieval systems, such as past-practice sluicing, may require more rapid development of enhancements to hydraulic retrieval systems (reduced water volume or improved confinement systems) or the remote-manipulator-based systems. The extent to which waste must be recovered to meet tank closeout requirements and the allowable leakage to the soil during retrieval remain open issues.
- The required DST storage capacity for receiving retrieved SST waste needs to be determined. The space available may impact dilution ratios of retrieved waste for various retrieval options, because “low-tech” alternatives tend to produce higher volumes of diluted waste for DST storage. Efficient evaporators to remove excess water are proven technology.
- The capabilities of maintenance and solid waste disposal need to be identified. Removal of in-tank hardware may be required to facilitate deployment of some retrieval systems and/or required to meet waste clean out goals. Hardware removed from the tanks will need to be cleaned and stored until the appropriate treatment facilities can be constructed. Further, retrieval system equipment should

be expected to require repair and maintenance. Therefore, the uncertainties associated with solid waste disposal requirements and repair and maintenance can significantly impact important design consideration for retrieval systems.

5.1.3 Critical Interfaces

A *critical interface* is an important system boundary/point of coordination between two TWRS program elements for one or both elements to successfully meet program objectives. The critical interfaces related to technology activities supporting all six program elements of the TWRS program are integrated in Table 5.1. These interfaces are generally technology-to-TWRS program element or TWRS program element-to-technology (not technology-to-technology or program element-to-program element).

Table 5.1 Critical Interfaces for Technology Activities Supporting Waste Retrieval

No.	From	To	Need By	Item Provided
R1	OPS,UPG	RT	9/96	Operation of pipelines, upgrading, and other tank farm infrastructure supporting waste retrieval
R2	RT	OPS	9/95	Input on infrastructure needs and requirements for tank farm upgrades to support retrieval
R3	RT	OPS	9/97	Design, installation, and operation of waste retrieval systems to resolve safety issues (Tank C-106, then sequential need)
R4	CH	RT	1/95	Physical and chemical properties of waste in SSTs and DSTs
R5	RT	CH	10/94+	Data requirements and DQOs
R6	RT	PT,HLW,ST	9/95	Identify potential chemical addition that may be used during retrieval
R7	SW	RT	9/95	Capability to handle retrieval solid waste
R8	RT	OPS	9/95	Need for maintenance facilities
R9	HLW,PT,ST	RT	9/97	Define chemical addition limitations

No.	From	To	Need By	Item Provided
R10	ER/WM	RT	9/95	Requirements for tank closeout

Note: + = More than one update or user.

LEGEND:
CH = Characterization Program Element.
ER/WM = Environmental Remediation/Waste Management.
ST = Waste Tank Safety Program Element.
RT = Waste Retrieval Program Element.
PT = Waste Pretreatment Program Element.
HLW = High-Level Waste Immobilization Program Element.
LLW = Low-Level Waste Immobilization Program Element.
OPS = Operations and Maintenance.
UPG = Upgrades.
SW = Solid Waste.

5.2 Functional Flow Diagram

Functions are simple statements that define what a system must do. Functions form the basis for identifying technology deliverables required to support TWRS program needs. A block diagram that maps the relationship between functions and technology packages for the Waste Retrieval Program is provided in Figure 5.1. The block diagram also indicates which technologies are reference, enhancements, or alternatives.

5.3 Functions and Associated Technology Packages for Waste Retrieval

Table 5.2 presents the program recommended by the technologists that prepared the Integrated Technology Plan (ITP) for Waste Retrieval. In addition to the Tank Waste Remediation System (TWRS) Baseline Program, other tasks presented in Table 5.2 represent nonbaseline activities. Each of these programs is defined in the Preface.

The TWRS Baseline Program is consistent with the most recent version of the Multi-Year Program Plan (MYPP). The nonbaseline activities shown are those that, while vital to overall TWRS mission, are not currently projected to be funded. These activities have been prioritized for inclusion in the Baseline at the first opportunity. The technology activities in both programs were identified and prioritized through a process described in Appendix A.

5.3.1 Key to Table

Program: Those technology packages and tasks that fall in the TWRS Baseline Program appear in normal font. Those that fall in the Nonbaseline Program appear in italics.

Function: The systems engineering function (as described in the TWRS Functional Requirements document (U.S. DOE/RL 1994b) associated with this technology package (followed by the number for the appropriate systems engineering level in parentheses).

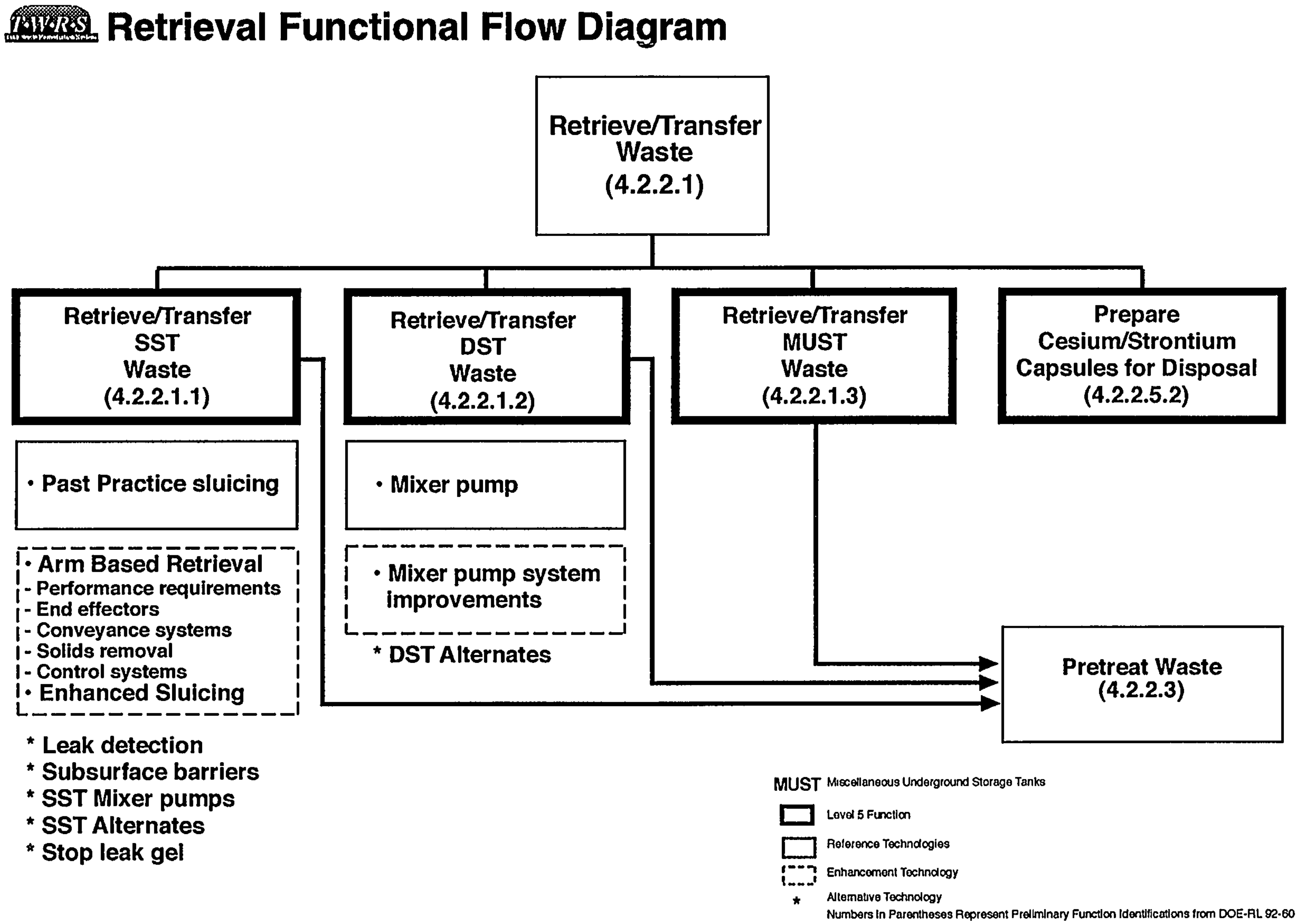
Technology Package: A set of technology activities that need to be completed to respond to a functional need. May include activities to address/support the reference case, or enhancements or alternatives to the reference case (followed by the program element chapter number in parenthesis).

Tasks: The tasks that need to be performed to resolve this technology need. Dates are unofficial; they are for planning purposes only.

FY 1996 Cost Estimate: An estimate of the funding that would be needed to conduct FY 1996 tasks. (Note: Tasks are listed for the entire TWRS life-cycle, but costs for outyear tasks are not shown on this table. See Appendix E for more information on each technology package.)

FY 1996 estimated costs are listed for each program. Dollar figures are unescalated, burdened FY 1995 dollars, in thousands. Costs are unofficial; they are for planning purposes only.

Benefit: The reasons these tasks are important to the program element.



Note: Reference, enhanced, and alternative retrieval systems have distinct characterization needs. Technologies listed here correspond to templates in E-5.

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Figure 5.1. Functional Flow Diagram

Table 5.2. Waste Retrieval: Recommended Technology Program

Function and Technology Package		Tasks		FY 1996 Cost Estimate ($K)		
Functional Need Level 4	Template Title (number)	No.	Title	Funded	Not Funded	Benefit
Retrieve/ Transfer Waste (4.2.2.1)	**Define Characterization Needs/Develop Simulants** **5.4.1.1** Reference	1.	Develop preliminary simulants	125		Commitments: Will affect all TPA productions requirements requirements; required for RCRA compliance for closure and solid waste acceptance criteria. Operations: Must know tank contents before a tank can be retrieved. Reduce Risk: Reduce cost; reduce operating and technical uncertainty. Safety: Must define characterization needs to prevent potential unknown hazards, e.g., flammability.
		2.	Determine critical physical properties for simulants for retrieval and develop catalog of actual waste properties. Develop DQO.	350		
		3.	Refine simulant properties to match actual waste	320		
		4.	Develop sensors for in situ measurement of physical properties	160		
Retrieve/ Transfer Waste (4.2.2.1)	**Enhanced SST Sluicing** **5.4.1.2** Enhancement	1.	Sluicing enhancements concept study, design, test, demo	2,000		Reduce Risk: Minimizes environmental risk; reduces cost; improves operations.

LEGEND: Baseline is normal font/*Non-baseline is italics.*
(a) Fund Immediately.
(b) Fund If Possible.

Table 5.2. Waste Retrieval: Recommended Technology Program (contd)

Function and Technology Package		Tasks		FY 1996 Cost Estimate ($K)		
Functional Need Level 4	Template Title (number)	No.	Title	Funded	Not Funded	Benefit
Retrieve/ Transfer Waste (4.2.2.1)	**Develop and Demonstrate SST Arm-Based Retrieval System** **5.4.1.3** Alternative	1.	Resolve vendor inquiries	2,000		Commitments: TPA M-45-03 for alternate retrieval demonstrations; RCRA during retrieval action; TPA M-45-04 and M-45-05 may require arm-based system in some tanks. Reduce Risk: Reduces waste volume; reduces environmental risk.
		2.	End effector testing	2,000		
		3.	Test bed feature testing	2,580		
Retrieve/ Transfer Waste (4.2.2.1)	**Develop Alternate SST Retrieval Technologies** **5.4.1.4** Alternative	1.	Industry concept engineering studies	520		Commitments: Improves potential of meeting retrieval milestones. Reduce Risk: Reduce environmental impact; minimize cost; reduce technical and operational risk and uncertainty; minimize waste volume.
		2.	*Evaluate contracts and award development contracts*		*200*	
		3.	*Proof-of-principle tests*		*600*	

LEGEND: Baseline is normal font/*Non-baseline is italics.*
(a) Fund Immediately.
(b) Fund If Possible.

Table 5.2. Waste Retrieval: Recommended Technology Program (contd)

Function and Technology Package		Tasks		FY 1996 Cost Estimate ($K)		
Functional Need Level 4	Template Title (number)	No.	Title	Funded	Not Funded	Benefit
Retrieve/ Transfer Waste (4.2.2.1)	**Evaluate Feasibility of Barriers** **5.4.1.5** Alternative	1.	SSB demonstration	4,600		Commitments: TPA M-45-07, evaluate barriers. Reduce Risk: Evaluate potential reduction of environmental insult; reduce technical and operational uncertainty.
Retrieve/ Transfer Waste (4.2.2.1)	**SST Leak Detection and Monitoring (LDM)** **5.4.1.6** Reference	1.	LDM Technology Development and Engineering Application (as needed)	1,000		Operations: Provides ability to quantify the waste leaking from SSTs during the retrieval process; may provide a means to determine subsurface barrier performance. Reduce Risk: Potential reduction to public and worker safety; potential reduction in environmental insult; potential reduction in waste volume.

LEGEND: Baseline is normal font/*Non-baseline is italics.*
(a) Fund Immediately.
(b) Fund If Possible.

Table 5.2. Waste Retrieval: Recommended Technology Program (contd)

Function and Technology Package		Tasks		FY 1996 Cost Estimate ($K)		
Functional Need Level 4	Template Title (number)	No.	Title	Funded	Not Funded	Benefit
Retrieval/ Transfer Waste (4.2.2.1)	**Test/Analyze Mixer Pump Performance** **5.4.2.1** Reference	1.	Mixer pump design and testing	3,500		Operations: Understanding critical performance parameters is key to designing a viable operational retrieval project. Without these parameters, DST retrieval with mixer pumps may not function sufficiently to retrieve the wastes. Reduce Risk: Reduce operations cost; greatly reduced operating and technical uncertainty.
		2.	Evaluate sonic probe	40		Operations: Assist mixer pumps by reducing yield stress and viscosity. Reduced Cost: Use of sonic probe may eliminate need for one or more mixer pumps in DST.

LEGEND: Baseline is normal font/*Non-baseline is italics.*
(a) Fund Immediately.
(b) Fund If Possible.

Table 5.2. Waste Retrieval: Recommended Technology Program (contd)

Function and Technology Package		Tasks		FY 1996 Cost Estimate ($K)		
Functional Need Level 4	Template Title (number)	No.	Title	Funded	Not Funded	Benefit
Retrieval/ Transfer Waste (4.2.2.1)	**Test/Analyze Mixer Pump Performance** **5.4.2.1** Reference	3.	Enhanced mixer pump performance testing	3,649		Operations: An advanced mixer pump design will reduce costs with higher reliability and improved hydrolic performance. Advanced pump could lead to greater waste recovery in DSTs with heels.
Retrieve/ Transfer Waste (4.2.2.1)	**Evaluate Alternative DST Retrieval Technologies** **5.4.2.2** Reference	1.	Evaluate alternative retrieval technologies for DST wastes	1,318		Reduce Risk: Reduce risk of retrieval of difficult DST wastes and heels. Reduce Cost: Reduce high cost of DST mixer pump retrieval.
Total						

LEGEND: Baseline is normal font/*Non-baseline is italics.*
(a) Fund Immediately.
(b) Fund If Possible.

5.4 Narrative on Technology Packages

The technology packages associated with each function of the Waste Retrieval Program are described in this section. The description provides a brief summary of

- the justification for this activity
- current status of the technology
- technical approach
- other issues that need to be highlighted.

More detailed information is found in the templates for the Waste Retrieval Program, located in Appendix E.

An asterisk (*) following the title of any technology package in this section indicates that the package is not funded at all in the TWRS Baseline Program. Refer to Section 5.7.1 for further discussion of the impacts of funding at the TWRS Baseline Program versus the Recommended Program level.

5.4.1 Retrieve SST Waste

5.4.1.1 Define Characterization Needs/Develop Simulants

Simulant development to define the waste behavior properties is necessary to verify the retrieval and transport technologies. Simulants have and will be developed to exhibit certain physical properties; however, work is needed to validate the fidelity of the choice or ranges of such properties with actual waste properties. Simulant wastes are necessary in developing and evaluating the various retrieval and transport processes.

Work is needed to establish the fundamental relationships between waste properties and physical performance parameters of waste retrieval equipment and solid waste. This understanding of waste behavior will also identify physical parameters that characterize performance requirements and develop methods to establish physical and/or chemical properties for retrieval demonstration.

Certain physical properties of DST and SST waste have a strong influence on the performance of retrieval systems. Some of the properties, such as shear strength, bearing strength, hardness, tensile strength, viscosity and stickiness, need to be measured to ensure measurable and "real time" measurement of the property. Success of the waste retrieval effort is directly dependent on proper equipment selection and design based on these waste properties.

5.4.1.2 Enhanced SST Sluicing

Past-practice sluicing is the reference technology used to recover soft sludge wastes from the SSTs. High-volume flow, low-pressure sluicing nozzles are used to erode/dissolve the sludge-type wastes and then move the material towards the transfer pump. The transfer pump removes the slurry to a settling tank. The sludge is allowed to settle to the bottom of the tank and the supernate is recycled to the sluicing nozzles.

Improvements to the sluicing technology are expected to extend the ability of the sluicing system to recover a majority of wastes other than soft sludges, or to improve the recovery limits of the sluicing technology. Closer placement of the sluicing nozzles, higher pressures, and other concepts will be examined to improve recovery efficiencies and reduce retrieval and waste treatment costs.

5.4.1.3 Develop and Demonstrate SST Arm-Based Retrieval System

The arm-based system will be deployed as a demonstration in the recovery of wastes from Tank C-106. In general, the tank wastes to be retrieved may require capabilities to recover multiple waste types in the presence of embedded vertical obstructions, such as piping, thermocouple trees, pump housings, and other in-tank hardware. The combination of multiple waste forms with in-tank hardware indicates the need for a retrieval system capable of deploying several end effectors to cut in-tank hardware, handle cut material, retrieve hard wastes, and retrieve soft wastes.

5.4.1.4 Develop Alternative SST Retrieval Technologies

The projected high cost of retrieval using the reference retrieval approaches dictates the search for more cost-effective retrieval options. The alternate SST retrieval systems program will identify systems capable of challenging the reference retrieval approaches from the standpoint of cost and performance. New and innovative alternate retrieval systems are being solicited from private industry and universities. This project may be funded by EM-50 or EM-30.

Promising new technologies will be developed using a five step process: 1) engineering study, 2) proof-of-principle testing, 3) scale testing and concept design report, 4) full-scale test and training unit, and 5) production unit(s). The alternate program will complete steps 1, 2, and 3. When an alternate retrieval system is selected for a SST retrieval project, the project will complete steps 4 and 5.

5.4.1.5 Evaluate Feasibility of Barriers

SSBs have been proposed as a method to mitigate leaks from SSTs during retrieval operations. They have been identified as a TWRS safety initiative and TPA Milestone, M-45-07, requires evaluation and demonstration testing of related technologies suitable for deployment of SSBs at Hanford. Demonstration testing of barriers will provide data to evaluate the feasibility of confining hazardous waste under SSTs to keep them from leaking into the environment. A feasibility study of tank leakage mitigation using SSBs was completed in FY 1994 to support a decision whether or not to proceed with the SSB Program. In addition, specific documents were completed in FY 1994 to establish a baseline for barriers to support the feasibility study.

The decision about the need to proceed with barrier demonstration testing will be made during the second quarter of FY 1995. If the decision is to proceed, industrial partners will be contracted to deploy and test SSB technologies in the arid soils at Hanford. Test data will be evaluated to determine barrier performance.

5.4.1.6 SST Leak Detection and Monitoring (LDM)

Leak detection and monitoring (LDM) technology may be required to locate and quantify tank leaks during SST retrieval operations, and may be needed to monitor the performance of SSBs. Functions and requirements (F&Rs) are needed to establish criteria for the selection and use of LDM technology and methods. F&Rs for leak detection to support SST waste retrieval and disposal do not currently exist. This activity includes the determination of LDM technology F&Rs, evaluation of current LDM technologies to fulfill F&Rs, and technology development/engineering application recommendations.

F&Rs will provide the basis for identification and evaluation of LDM technology that can support ongoing and future SST waste retrieval and disposal activities. F&Rs also provide the basis for assessing capabilities of currently used LDM methods and devices to support future operational and remediation activities. Without established F&Rs it is difficult, if not impossible, to defend currently used LDM devices and methods within the context of remediation discussions.

A general survey of available LDM technologies was conducted during FY 1994. Demonstration and testing of a typical, electrical resistance, leak detection technology was carried out at Hanford during FY

1994. A general purpose site was prepared within the Hanford 200E area for demonstration and testing of candidate leak detection techniques and technology deployment methods. Other technologies such as crosswell seismic imaging and electromagnetic imaging may also be tested at this site dependent upon need as described in the F&Rs. An activity to determine the F&Rs for SST external leak detection and monitoring to support waste retrieval and disposal is funded and underway for FY 1994. An evaluation of current, candidate LDM technologies, against established F&Rs is planned for FY 1995. Based upon findings within the F&R development process, a technical assessment will be performed for LDM. This will include preparation of a cost-benefit analysis and risk assessment for LDM development, deployment, and use to support remediation.

Leak detection and monitoring can potentially support SST tank farms routine/custodial operations, remediation and disposal activities, and long-term site monitoring. Data from leak detection systems will be used during remediation to make operational decisions during the planning phases to determine remediation strategy, and also during final site closure activities.

5.4.2 Retrieve DST Waste

5.4.2.1 Test/Analyze Mixer Pump Performance

The Waste Retrieval Program strategy for retrieving DST waste is to use two 300 hp jet mixer pumps per tank to mobilize the waste and a 75 hp transfer pump, which removes the waste from the tank. Identified design and implementation issues require an evaluation of mixer pump performance through analysis and scale testing (1/2 and 1/25th scale) to establish jet pump design parameters. The mixer pump performance testing includes the following:

- identifying parameters that affect cleaning radius
- identifying jet nozzle parameters that affect jet integrity
- identifying jet pump inlet mixer vanes parameters
- identifying parameters required to maintain sludge uniformity
- identifying variations of solids concentration slurry (uniformity)
- identifying instrumentation needs for DST retrieval systems.

Enhanced mixer pump performance is also being evaluated. The primary technology being considered is the Advanced Design Mixer Pump, which has a higher reliability and improved hydraulic performance over the referenced state-of-the-art design. The advanced mixer pump will reduce the heels remaining after waste is pumped out of a tank (i.e., greater percent recovery). A second technology being considered is the sonic probe, which reduces the yield stress and viscosity of the waste, allowing gravitational forces to feed the intake of the transfer pump. This option may eliminate or reduce the need for a mixer pump in some tanks that require more than one mixer pump.

5.4.2.2 Evaluate Alternative DST Retrieval Technologies

The projected high cost of retrieval using the reference retrieval approaches dictates the search for more cost-effective retrieval options. Mixer pump use at the Savannah River Site (SRS) has shown this technology to have high initial and life-cycle costs. The alternative DST retrieval systems program will identify systems capable of challenging the reference retrieval approach from the standpoint of cost and performance improvement.

Two technologies are being considered: 1) Remote manipulator arm-based retrieval system is the primary technology relied on to remove DST waste should mixer/transfer pumps fail, and 2) past-practice sluicing with a remote position hydro jet and transfer pump combination has successfully removed SST waste; however, adaptation to DST-type waste, which dissolves more slowly and has a higher yield strength, remains a technical challenge.

5.5 EM-50/30 Related Activities

5.5.1 EM-50

The Office of Technology Development (OTD) (EM-50) is tasked with carrying out a national program of applied research and development (R&D) to focus, manage, and accelerate the development and implementation of new and existing technologies to meet specific Environmental Restoration and Waste Management (ER/WM) requirements.

Over 100 EM-50 development activities have been identified that directly support the TWRS efforts. Detailed descriptions of each activity, including title, performing organization, principal investigator, scope description, FY 1994 funding, and major milestones, are available elsewhere.(a) The EM-50 activities relating to the Waste Retrieval Technology Program are summarized below.

The OTD has chosen to invest approximately $15M in FY 1995 developing technologies for retrieval of waste from USTs, as well as $9M for technologies to provide barriers that could be placed under tanks to prevent spread of liquids during retrieval. The Underground Storage Tank Integrated Demonstration (UST-ID), Robotics Technology Demonstration Program (RTDP), and to a lesser extent, the Buried Waste Integrated Demonstration (BW-ID) provide most of the retrieval technology, while the Volatile Organic Compound-Arid Integrated Demonstration (VOC-Arid ID), Mixed Waste Landfill Integrated Demonstration (MWL-ID), and In Situ Remediation Integrated Program (ISR-IP) provide the bulk of the barrier technologies.

The OTD retrieval technologies emphasize arm-based robotic techniques for removing waste from tanks. Industrial expertise is used and numerous partnerships have been formed. Methods for dislodging the waste and conveying it from the tank are being developed, along with methods and equipment for waste surveillance before and during operations. The full infrastructure of supporting technologies is being developed.

5.5.2 EM-30

The Office of Waste Management (EM-30) works with the OTD to develop innovative technologies for the treatment and disposal of present and future waste streams and for waste minimization. The broad range of EM-30 technology development activities supporting the Hanford TWRS is described in detail elsewhere.(b) The following paragraphs summarize the technical activities and associated costs by TWRS program element. EM-30 activities relating to the Waste Retrieval Program are summarized below.

Sluicing is the reference retrieval technology. Sluicing may not be adequate to achieve the 99% waste removal goal, and there are uncertainties relative to the potential of leakage during sluicing for some SSTs. The supporting technology development strategy for FY 1995 is to explore the potential of SSBs to limit or contain leakage and the development of robotics and associated end-effectors that could enable retrieval with minimal use of liquids. Supporting research with tank waste simulants is being conducted to define phenomena likely to be encountered during sluicing and transport operations. Some of the major activities include the following:

(a) The document *Technology Development Activities Supporting Tank Waste Remediation* has been issued in draft form by the Technology Development Program Office.

(b) Tank Waste Remediation System: *FY 94 Technology Development Plan*, TWRS Technology Development Program Office, January 5, 1994.

- leak detection and monitoring assessment and F&R development
- SSB assessment
- simulant development
- retrieval alternatives and enhancements such as arm-based retrieval, enhanced sluicing and others.

5.5.3 Cryobarrier Demonstration Project

A Cryobarrier Demonstration Project may be jointly funded and supported by the DOE-RL (EM-50 and EM-30 Programs) and a team from private industry. The project kickoff date was originally July 1994 to design, install, operate, and maintain a frozen soil SSB at Hanford for demonstration purposes. The primary test scenario will simulate a SST at one-third scale. Duration of testing operations is planned for 9 months, which will extend into FY 1996. Test results may satisfy in part or in whole the TPA Milestone M-45-07 for SSBs.

5.6 Schedule and Budget

The schedule and budget for technology activities supporting the Waste Retrieval Program are shown in Figure 5.2 and Table 5.3, respectively. Figure 5.2 identifies template activities, tasks within each template, deliverables, critical interfaces, and drivers (depicted to the right of each template activity bar). Table 5.3 presents two sets of budget estimates by program element and fiscal year. The first profile consists of activities currently included in the TWRS Multi-Year Work Plan (MYWP) and reflects the estimated budget available for technology. The second profile reflects the estimated budget required to perform all tasks shown in the ITP, including activities that are anticipated to be funded and those that are not (unfunded activities have been prioritized for inclusion in the MYWP at the first opportunity).

5.7 Prioritization (Results)

Table 5.2 presents the functions, technology packages, tasks, FY 1996 budgeted costs, and a brief statement regarding the benefit of funding these technology activities. For the Waste Retrieval Program element, the planning basis indicates that all technology work is funded within the TWRS Baseline Program for FY 1996 and beyond. Consequently, formal prioritization of nonbaseline activities was not necessary at this time. However, the Retrieval Prioritization Team expressed concern about adequate future funding for the future retrieval technology activities. They identified two activities they felt should be among the first retrieval activities considered for any future funding reductions. They were:

- Test/Analyze Mixer Pump Performance (5.4.2.1)
- Develop Alternate DST Retrieval Technologies (5.4.2.2)

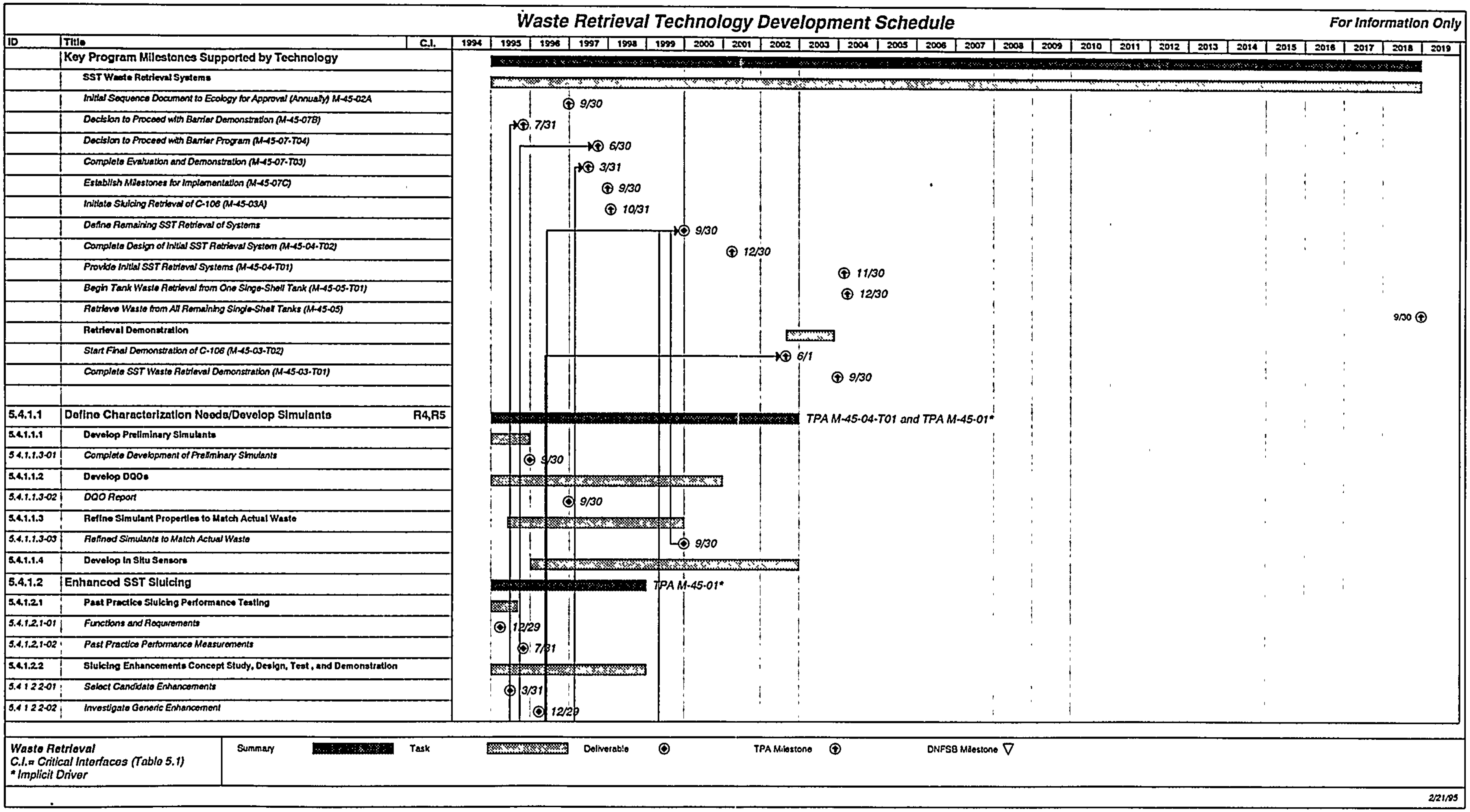
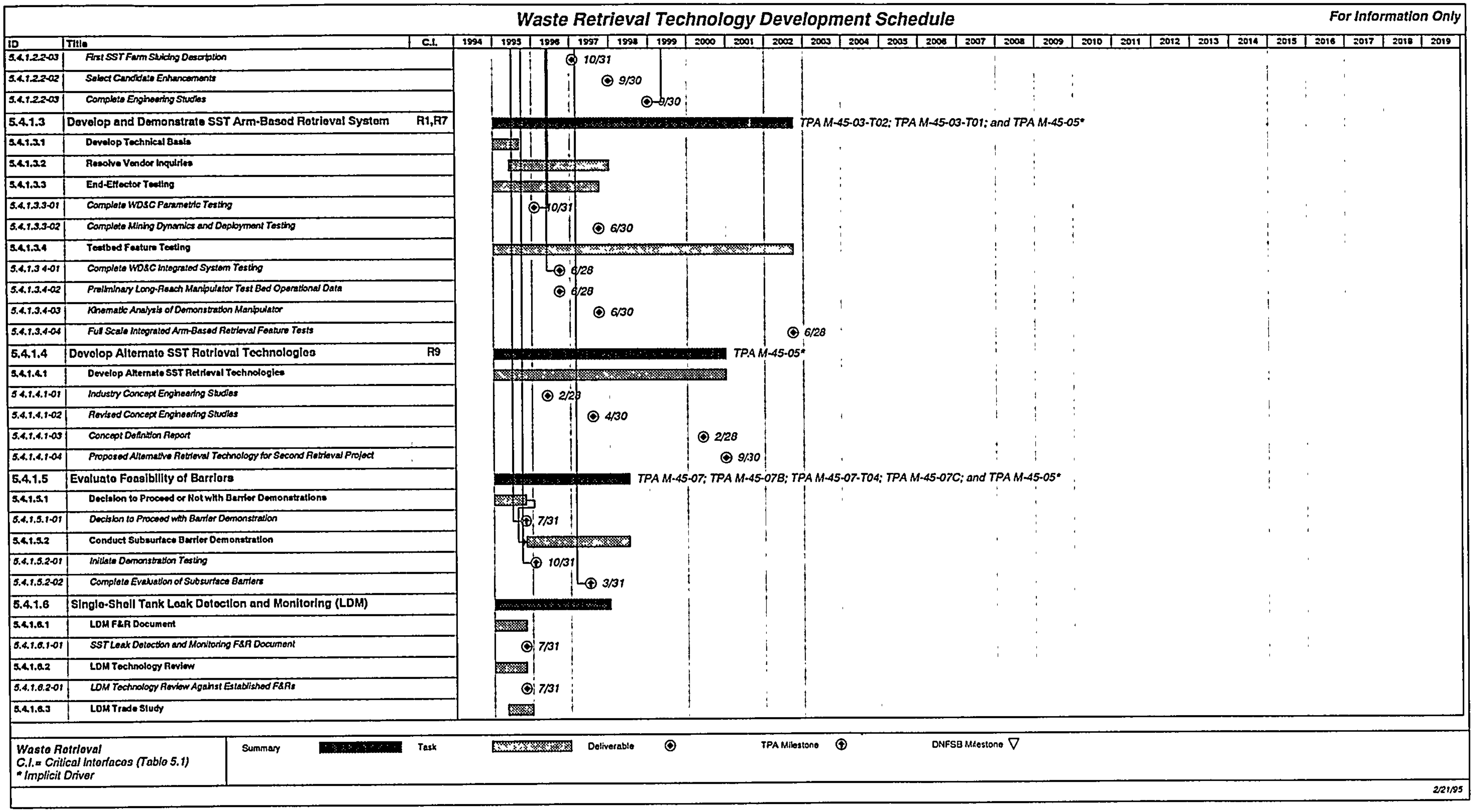


Figure 5.2. Schedule



ID	Title	C.I.
5.4.1.2.2-03	*First SST Farm Sluicing Description*	
5.4.1.2.2-02	*Select Candidate Enhancements*	
5.4.1.2.2-03	*Complete Engineering Studies*	
5.4.1.3	Develop and Demonstrate SST Arm-Based Retrieval System	R1,R7
5.4.1.3.1	**Develop Technical Basis**	
5.4.1.3.2	**Resolve Vendor Inquiries**	
5.4.1.3.3	**End-Effector Testing**	
5.4.1.3.3-01	*Complete WD&C Parametric Testing*	
5.4.1.3.3-02	*Complete Mining Dynamics and Deployment Testing*	
5.4.1.3.4	**Testbed Feature Testing**	
5.4.1.3 4-01	*Complete WD&C Integrated System Testing*	
5.4.1.3.4-02	*Preliminary Long-Reach Manipulator Test Bed Operational Data*	
5.4.1.3.4-03	*Kinematic Analysis of Demonstration Manipulator*	
5.4.1.3.4-04	*Full Scale Integrated Arm-Based Retrieval Feature Tests*	
5.4.1.4	Develop Alternate SST Retrieval Technologies	R9
5.4.1.4.1	**Develop Alternate SST Retrieval Technologies**	
5 4.1.4.1-01	*Industry Concept Engineering Studies*	
5.4.1.4.1-02	*Revised Concept Engineering Studies*	
5.4.1.4.1-03	*Concept Definition Report*	
5.4.1.4.1-04	*Proposed Alternative Retrieval Technology for Second Retrieval Project*	
5.4.1.5	Evaluate Feasibility of Barriers	
5.4.1.5.1	**Decision to Proceed or Not with Barrier Demonstrations**	
5.4.1.5.1-01	*Decision to Proceed with Barrier Demonstration*	
5.4.1.5.2	**Conduct Subsurface Barrier Demonstration**	
5.4.1.5.2-01	*Initiate Demonstration Testing*	
5.4.1.5.2-02	*Complete Evaluation of Subsurface Barriers*	
5.4.1.6	Single-Shell Tank Leak Detection and Monitoring (LDM)	
5.4.1.6.1	**LDM F&R Document**	
5.4.1.6.1-01	*SST Leak Detection and Monitoring F&R Document*	
5.4.1.6.2	**LDM Technology Review**	
5.4.1.6.2-01	*LDM Technology Review Against Established F&Rs*	
5.4.1.6.3	**LDM Trade Study**	

Waste Retrieval
C.I.= Critical Interfaces (Table 5.1)
** Implicit Driver*

Figure 5.2. Schedule (cont.)

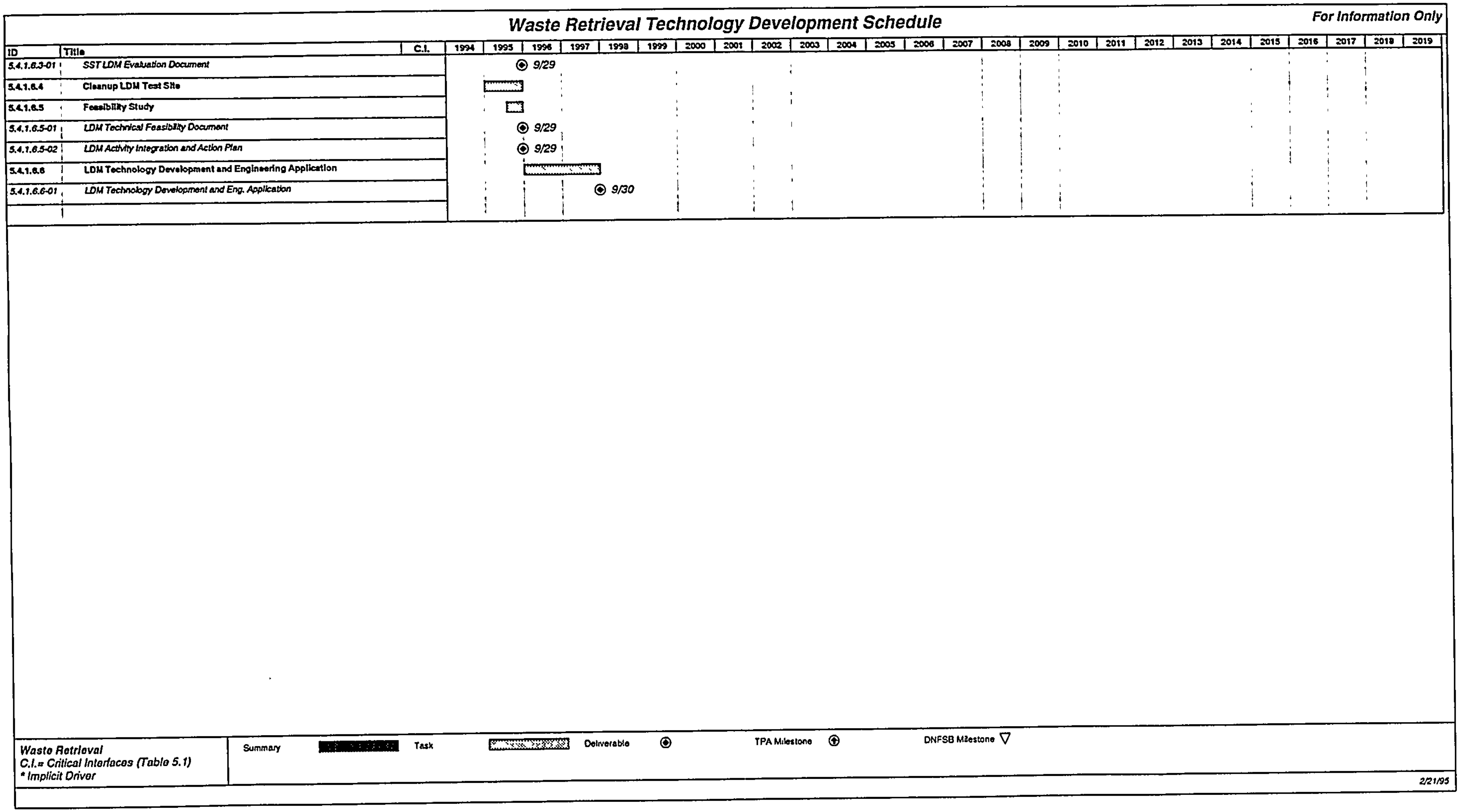
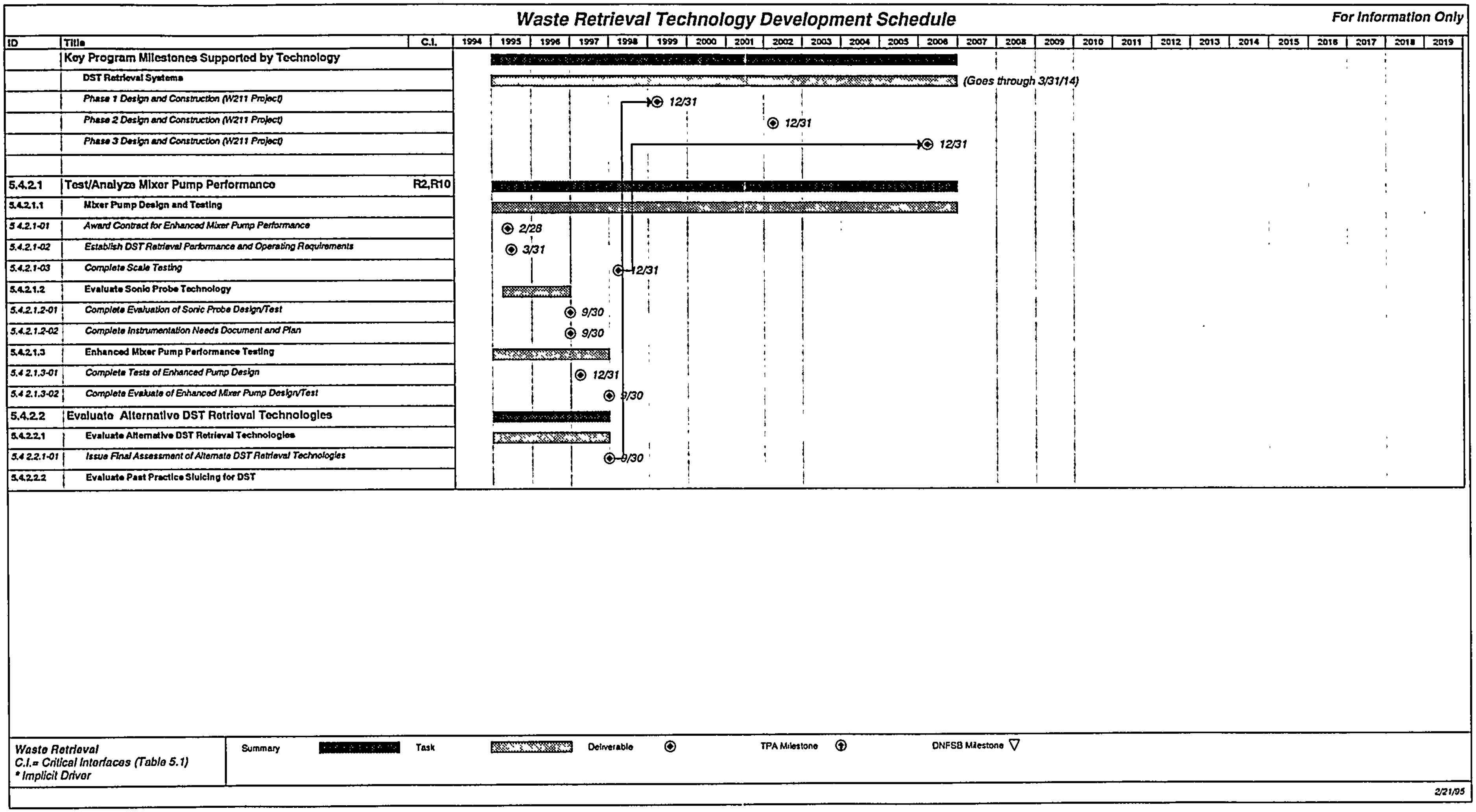


Figure 5.2. Schedule (cont.)

Waste Retrieval Technology Development Schedule

For Information Only



ID	Title	C.I.
	Key Program Milestones Supported by Technology	
	DST Retrieval Systems	
	Phase 1 Design and Construction (W211 Project)	
	Phase 2 Design and Construction (W211 Project)	
	Phase 3 Design and Construction (W211 Project)	
5.4.2.1	Test/Analyze Mixer Pump Performance	R2,R10
5.4.2.1.1	Mixer Pump Design and Testing	
5.4.2.1-01	*Award Contract for Enhanced Mixer Pump Performance*	
5.4.2.1-02	*Establish DST Retrieval Performance and Operating Requirements*	
5.4.2.1-03	*Complete Scale Testing*	
5.4.2.1.2	Evaluate Sonic Probe Technology	
5.4.2.1.2-01	*Complete Evaluation of Sonic Probe Design/Test*	
5.4.2.1.2-02	*Complete Instrumentation Needs Document and Plan*	
5.4.2.1.3	Enhanced Mixer Pump Performance Testing	
5.4.2.1.3-01	*Complete Tests of Enhanced Pump Design*	
5.4.2.1.3-02	*Complete Evaluate of Enhanced Mixer Pump Design/Test*	
5.4.2.2	Evaluate Alternative DST Retrieval Technologies	
5.4.2.2.1	Evaluate Alternative DST Retrieval Technologies	
5.4.2.2.1-01	*Issue Final Assessment of Alternate DST Retrieval Technologies*	
5.4.2.2.2	Evaluate Past Practice Sluicing for DST	

Waste Retrieval
C.I.= Critical Interfaces (Table 5.1)
** Implicit Driver*

Summary ■ Task ▨ Deliverable ◉ TPA Milestone ⊕ DNFSB Milestone ▽

2/21/95

Figure 5.2. Schedule (cont.)

Table 5.3. Budget

WASTE RETRIEVAL
TWRS Technology Budget Estimates
(Unescalated Dollars in Thousands by Fiscal Year)

TECHNOLOGY PACKAGE NUMBER AND TITLE	1995	1996	1997	1998	1999	2000	2001 +	TOTAL
["Expected Budget Available for Technology" consists of activities in TWRS Multi-Year Work Plan]								
5.4.1.1--Define Characterization Needs/Develop Simulants								
Expected Budget Available for Technology	447	830	830	825	820	820	1,635	6,207
Total Estimated Budget for Technology Activities in ITP	447	830	830	825	820	820	1,635	6,207
5.4.1.2--Enhanced SST Sluicing								
Expected Budget Available for Technology	185	2,000	1,000	500	0	0	0	3,685
Total Estimated Budget for Technology Activities in ITP	185	2,000	1,000	500	0	0	0	3,685
5.4.1.3--Develop and Demonstrate SST Arm-Based Retrieval System								
Expected Budget Available for Technology	14,000	6,580	6,580	6,580	6,580	6,580	13,160	60,060
Total Estimated Budget for Technology Activities in ITP	14,000	6,580	6,580	6,580	6,580	6,580	13,160	60,060
5.4.1.4--Develop Alternate SST Retrieval Technologies								
Expected Budget Available for Technology	150	520	0	0	0	0	0	670
Total Estimated Budget for Technology Activities in ITP	150	1,320	833	1,834	1,667	2,167	0	7,971
5.4.1.5--Evaluate Feasibility of Barriers								
Expected Budget Available for Technology	400	4,600	5,900	0	0	0	0	10,900
Total Estimated Budget for Technology Activities in ITP	400	4,600	5,900	0	0	0	0	10,900
5.4.1.6--Single-Shell Tank Leak Detection and Monitoring (LDM)								
Expected Budget Available for Technology	251	1,000	1,000	0	0	0	0	2,251
Total Estimated Budget for Technology Activities in ITP	251	1,000	1,000	0	0	0	0	2,251
5.4.2.1--Test/Analyze Mixer Pump Performance								
Expected Budget Available for Technology	1,050	7,189	6,579	3,200	0	0	0	18,018
Total Estimated Budget for Technology Activities in ITP	1,050	7,189	6,579	3,200	0	0	0	18,018
5.4.2.2--Evaluate Alternative DST Retrieval Technologies								
Expected Budget Available for Technology	0	1,318	250	0	0	0	0	1,568
Total Estimated Budget for Technology Activities in ITP	0	1,318	250	0	0	0	0	1,568
WASTE RETRIEVAL TOTALS:								
Expected Budget Available for Technology	16,483	24,037	22,139	11,105	7,400	7,400	14,795	103,359
Total Estimated Budget for Technology Activities in ITP	16,483	24,837	22,972	12,939	9,067	9,567	14,795	110,660

FOR PLANNING PURPOSES ONLY — NOT OFFICIAL COST INFORMATION

6.0 Waste Pretreatment

6.1 Purpose, Objectives, Scope, and Strategy

The **purpose** of waste pretreatment is to separate the tank waste into two streams: 1) a low-activity waste stream containing the bulk of the chemicals, and 2) a high-activity waste stream containing the bulk of the radionuclides.

The **objective** of waste pretreatment technology is to meet the technical and process design baselines for the low-level waste (LLW) pretreatment facility (Project W-236B, Initial Pretreatment Module), high-level waste (HLW) pretreatment facility, and in-tank processing to ensure the Waste Pretreatment Program element fulfills the Tank Waste Remediation System (TWRS) mission requirements. These baselines are established by TWRS engineering. The development objective includes ensuring processes to provide acceptable feeds in a timely and cost-effective manner to meet the following goals:

- Production of a LLW vitrified waste form meeting the requirements for disposal as a LLW.
- Production of a HLW vitrified waste form that meets the requirements for geologic disposal and reasonable volume.

The **scope** of waste pretreatment technology includes the following activities:

- Perform laboratory studies with waste simulants and actual waste to provide input to trade studies and to validate assumptions.
- Develop technologies to the point where the most promising can be selected for more advanced development.
- Perform bench-scale tests using simulated and actual waste for input to process design.
- Perform large-scale tests, i.e., in-tank sludge washing tests or pilot-scale tests.
- Support development of process flow sheets and equipment.
- Support evaluation of tank waste characterization data and flow sheet updates.
- Evaluate technology options for optimizing feeds to the LLW and HLW vitrification facilities.

The overall **strategy** for pretreating tank waste is to provide pretreatment capability by the following reference:

1. Separate the water soluble fraction from the insoluble fraction of the in-tank waste.
2. Pretreat the soluble fraction to provide a feed that does not exceed the comparable limits for commercial LLW (Class C per 10 CFR 61) and is in accordance with the U.S. Nuclear Regulatory Commission's (NRC) "incidental waste" classification for Hanford, DOE's as low as reasonably achievable (ALARA) policy, and the disposal system performance requirements.
3. Treat the insoluble fraction in-tank by enhanced, in-tank sludge washing (alkaline leaching and metathesis) followed by simple in-tank washing to provide feed to the HLW vitrification facility. Any additional pretreatment required will be performed in the proposed HLW pretreatment facility. Current trade studies indicate that out-of-tank sludge washing (alkaline leaching and metathesis) followed by water washing (with adequate caustic to inhibit corrosion and avoid gel/colloid formation)

may be a viable alternative to in-tank sludge washing. These investigations will assess/demonstrate the viability of sludge washing (alkaline leaching and metathesis) to produce a reasonable HLW volume.

The strategy includes continuing development of enhancements and alternatives to determine if they demonstrate potential for significant improvements (e.g., reductions in HLW volumes).

6.1.1 Key Assumptions for Reference Approach

This Section lists many of the key assumptions related to the set of specific technologies assumed for the Tri-Party Agreement (TPA) negotiations, which led to the recent agreement on a revised technical strategy for TWRS. The ITP identifies technology activities necessary to confirm these assumptions and to provide alternatives if the assumptions are erroneous. Engineering evaluations will also be required to confirm or deny these assumptions.

6.1.1.1 General Pretreatment Assumptions for Reference Approach

- Enhanced sludge washing (alkaline leaching and metathesis) will be implemented. Advanced sludge pretreatment capability (dissolution of sludge in acid plus acid-side separations processes) will be evaluated as an alternative (as funding restrictions allow).

Note: Safety issues no longer consider organic destruction as a potential resolution. Satisfactory alternatives exist.

6.1.1.2 Soluble Waste Feed Assumptions for Reference Approach

- Concentrations of transuranics (TRU) supernatants are sufficiently low that TRU removal will not be needed to reach <100 nCi/g in the LLW glass product [except in complexant concentrate (CC) waste].

- Destruction of organic supernatants will not be implemented (unless required for CC waste).

- If required, complexants in CC waste will be destroyed in-tank using a heat-and-digest process. Technology for destroying complexants will continue to be evaluated as an alternative until it or some more attractive process is chosen.

6.1.1.3 Radionuclide Removal Assumptions for Reference Approach

- Technology for cesium-137 reduction to 0.1 Ci/m^3 will be developed to meet specifications for LLW vitrification feed, ALARA and incidental waste concerns. This will be in the nominal range, 5.0 to 7.0 sodium molarity.

- TRU and strontium will be removed from CC waste if required to meet specifications for LLW vitrification feed.

- Technetium removal will not be required.

6.1.1.4 Solid-Liquid Separation, Sludge Washing, and Enhanced Sludge Washing (Alkaline Leaching/Metathesis) Assumptions for Pretreatment Reference

- Settle-decant, solids washing, and alkaline leaching and metathesis will be performed in-tank, although recent trade studies indicate high potential for out-of-tank processing.

- Waste will be blended to meet vitrification feed specifications.

- Removal of glass-limiting constituents, such as phosphate, sulfate, sodium, aluminum, and chromium, will be sufficiently high to produce an acceptable volume of vitrified HLW.

- Separate complexes will be constructed to accommodate enhanced sludge washing and radionuclide removal processes. A stand-alone replacement for the 242-A Evaporator will not be required, as evaporators in the pretreatment facilities will fulfill that need. These complexes could be stand-alone facilities, a set of distributed facilities, or part of a central processing complex.

6.1.2 Key Uncertainties

The key uncertainties identified for pretreatment in general and for the reference processes and alternative processes are as follows:

6.1.2.1 General Uncertainties

- The extent of pretreatment for particular constituents (e.g., radionuclides, nitrates, heavy metals, organic materials) is not fully defined. TWRS has not negotiated the definition of "incidental waste" with the NRC – ALARA considerations are a major factor. Technetium, neptunium, and uranium all require defined performance assessments for LLW glass. In addition, changes in other program elements (i.e., selection of different LLW forms) can impact the specific pretreatment processes that are needed and their performance requirements. As requirements and processes are developed and defined, the need for removal capabilities will be assessed. Meanwhile, development of removal capabilities will continue until not needed.

- Substantial waste tank sampling capability will be required to support development needs for pretreatment technology.

- Timely feedback of analysis results for pretreatment technology development will require substantial analytical services.

- The need for only two waste forms for the pretreatment product streams is uncertain.

6.1.2.2 Uncertainties Associated with the Reference Approach

- The effectiveness of alkaline leaching and metathesis in removing sufficient amounts of phosphate, chromium, aluminum, and other components to produce an acceptable volume of HLW glass is uncertain.

- The compatibility of tank storage construction materials with pretreated waste is unknown.

- The flexibility of the blending/pretreatment system processes and equipment needs to be determined.

- The technical basis for solid/liquid separation assumes an adequate solids-settling rate, solids compaction, and adequate filtration. These are uncertain.

6.1.2.3 Uncertainties Associated with Alternatives to the Reference Approach

- If acid-dissolution is required, the amount of sludge that will dissolve under candidate operating conditions is difficult to predict.

- If acid-dissolution is required, it is not known if cesium and strontium can be removed efficiently from the acid solution.

- If selected, the advanced separations approach is vulnerable because of the complex technologies likely required to perform the needed separations. Most of these technologies have not been developed beyond the laboratory- and/or bench-scale, and will require a considerable investment in research, development, and demonstration.

6.1.3 Critical Interfaces

A *critical interface* is an important system boundary/point of coordination between two TWRS program elements for one or both elements to successfully meet program objectives. The critical interfaces related to technology activities supporting all six program elements of the TWRS program are identified in Table 6.1. These interfaces are generally technology-to-TWRS program element or TWRS program element-to-technology (not technology-to-technology or program element-to-program element).

Table 6.1 Critical External Interfaces for Technology Activities Supporting Waste Pretreatment

No.	From	To	Need By	Item Provided
P1	CH	PT	10/94-9/99	Supernate/salt cake samples of tank wastes
P2	PT	CH	10/94+	Sampling needs through requirements documents using DQO process and through test plans
P3	CH	PT	10/94-9/99	Sludge samples of tank waste
P4	CH	PT	10/94-9/99	Sludge samples for settling tests
P5	CH	PT	10/94+	Waste characteristic data
P6	LLW	PT	10/94+	LLW feed specifications
P7	HLW	PT	10/94+	HLW feed specifications, alternate disposal
P8	ER/WM/ NRC+	PT	10/94+	Requirements for decontamination and decommissioning
P9	PT	LLW	10/94+	Projected feed composition
P10	PT	HLW	10/94+	Projected feed composition
P11	ST	PT	9/95	Notification that mitigation measures for resolving waste tank safety issues have been validated
P12	ST	PT	10/94+	Identify potential chemical additions that may be used for safety issue resolution
P13	PT	LLW,HLW	3/98	Impact of pretreatment decision on enhanced sludge washing of low-level feeds

No.	From	To	Need By	Item Provided
P14	PT	IPM	10/94+	Test results
P15	PT	NRC	10/95+	Technical performance/decontamination factors

Note: + = More than one update or user.
LEGEND:
CH = Characterization Program Element.
ST = Waste Tank Safety Program Element.
RT = Waste Retrieval Program Element.
PT = Waste Pretreatment Program Element.
HLW = High-Level Waste Immobilization Program Element.
LLW = Low-Level Waste Immobilization Program Element.
OPS = Operations and Maintenance.
ER/WM/NRC = Environmental Restoration and Waste Management, Nuclear Regulatory Commission.
IPM = Initial Pretreatment Module (within Pretreatment Program Element but a key transferee of results).

Critical interfaces for each program element are also listed in Chapters 3.0, 4.0, 5.0, 6.0, 7.0, and 8.0. Critical interfaces specific to individual functions and their associated technology packages are listed on the templates in Appendix E.

6.2 Functional Flow Diagram

Functions are simple statements that define what a system must do. Functions form the basis for identifying technology deliverables required to support TWRS program needs. Figure 6.1 shows a simplified process flow diagram that illustrates how the different technologies might be grouped together to form a process. A block diagram that maps the relationship between functions and technology needs for the Waste Pretreatment Program is provided in Figure 6.2.

6.3 Functions and Associated Technology Packages for Waste Pretreatment

Table 6.2 presents the program recommended by the technologists that prepared the Integrated Technology Plan (ITP) for Waste Pretreatment. In addition to the Tank Waste Remediation System (TWRS) Baseline Program, one other program is presented in Table 6.2: Non-Baseline activities. Each of these programs is defined in the Preface.

The TWRS Baseline Program is consistent with the most recent version of the Multi-Year Program Plan (MYPP). The Non-Baseline activities shown are those that, while vital to overall TWRS mission, are not currently projected to be funded. These activities have been prioritized for inclusion in the Baseline at the first opportunity. The technology activities in both programs were identified and prioritized through a process described in Appendix A.

6.3.1 Key to Table

Program: Those technology packages and tasks that fall in the TWRS Baseline Program appear in normal font. Those that fall in the Non-Baseline Program appear in *italics*.

Function: The systems engineering function (as described in the TWRS Functional Requirements document (U.S. DOE/RL 1994b) associated with this technology package (followed by the number for the appropriate systems engineering level in parenthesis).

Technology Package: A set of technology activities that need to be completed to respond to a functional need. May include activities to address/support the reference case, or enhancements or alternatives to the reference case (followed by the program element chapter number in parenthesis).

Tasks: The tasks that need to be performed to resolve this technology need. Dates are unofficial; they are for planning purposes only.

FY 1996 Cost Estimate: An estimate of the funding that would be needed to conduct FY 1996 tasks. (Note: Tasks are listed for the entire TWRS life cycle, but costs for outyear tasks are not shown on this table. See Appendix E for more information on each technology package.)

FY 1996 estimated costs are listed for each program. Dollar figures are unescalated, burdened FY 1995 dollars, in thousands. Costs are unofficial; they are for planning purposes only.

Benefit: The reasons these tasks are important to the program element.

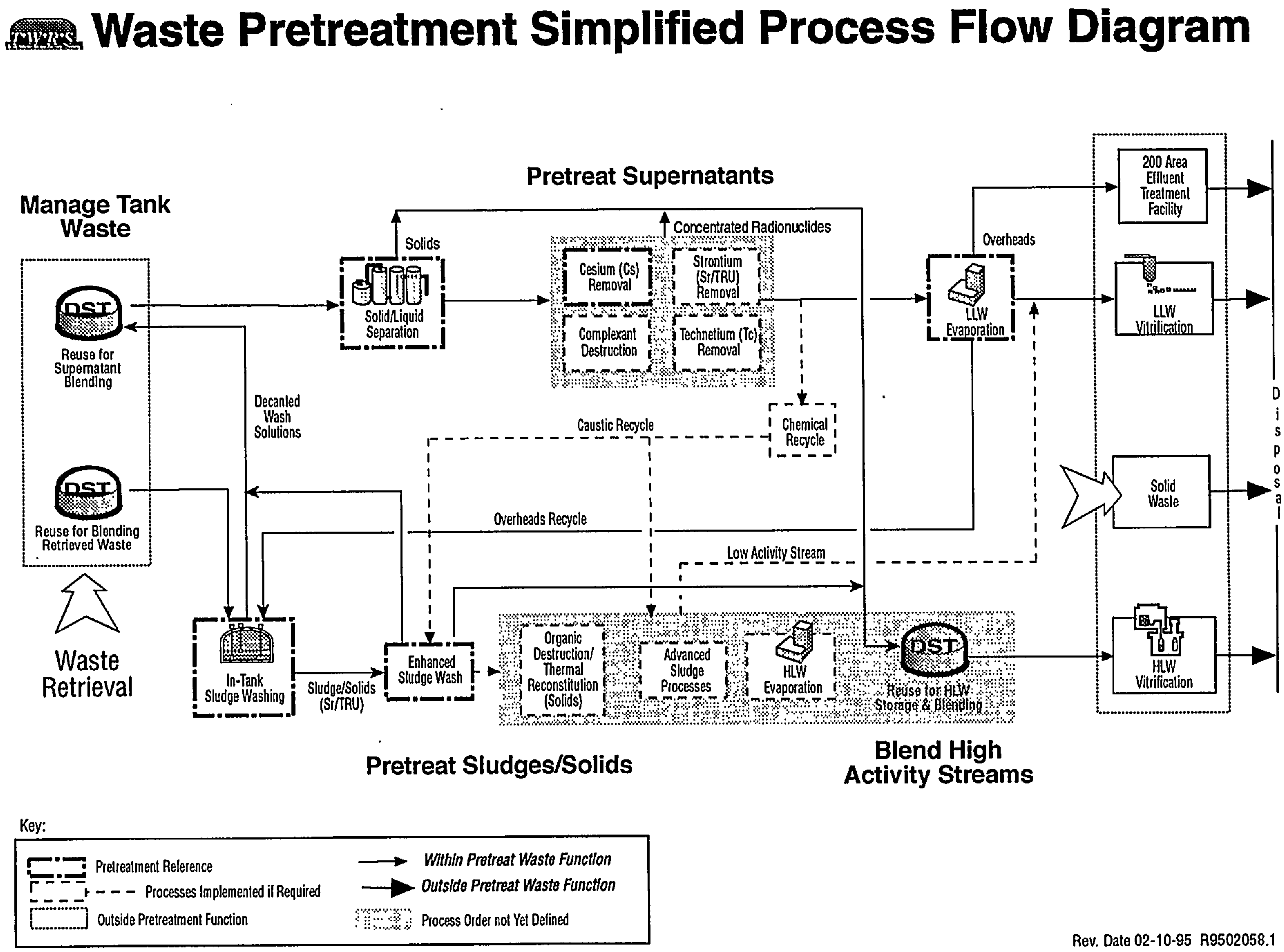


Figure 6.1. Functional Flow Diagram

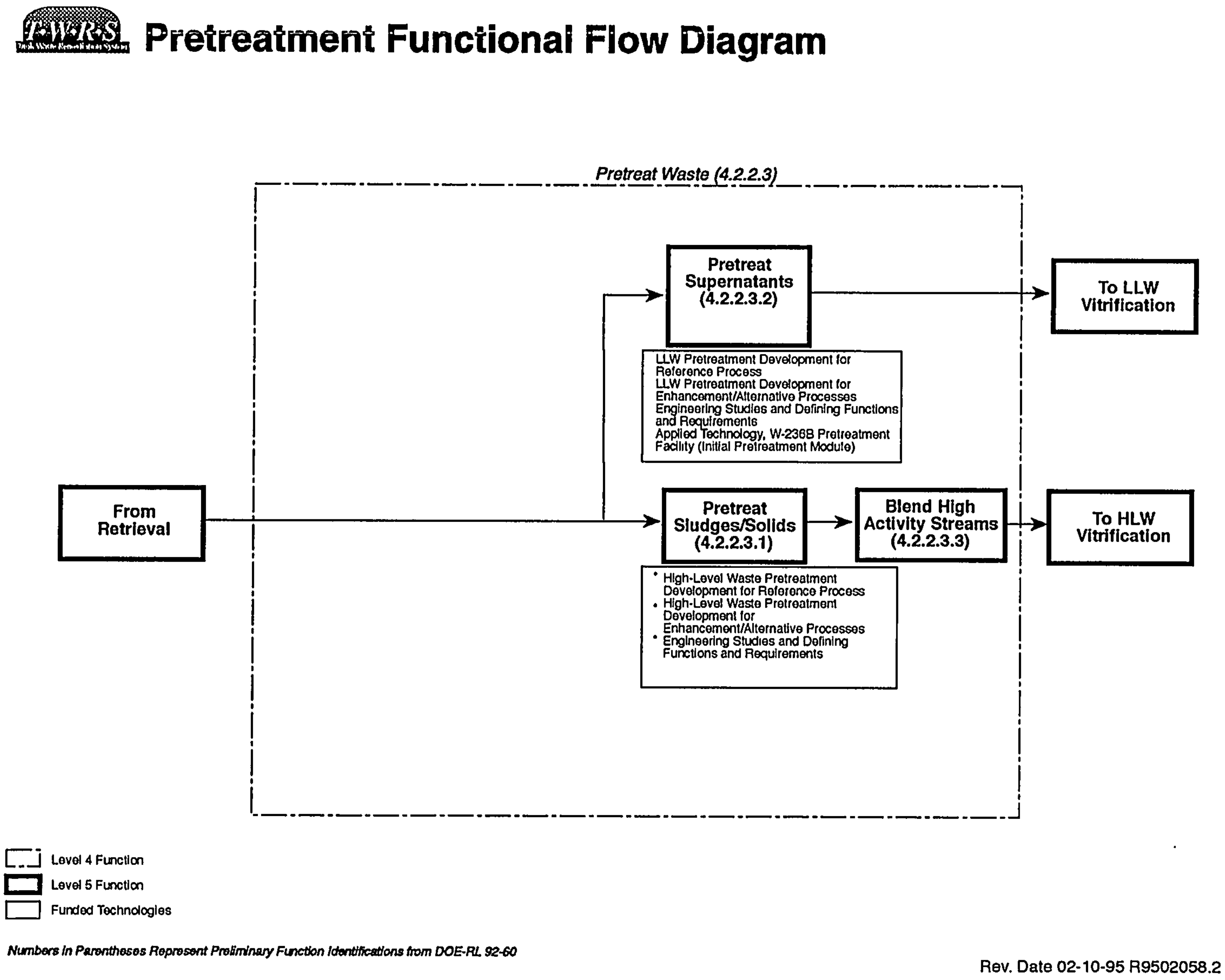


Figure 6.2. Waste Pretreatment: Recommended Technology Program

Table 6.2. Waste Pretreatment: Recommended Technology Program

Function and Technology Package		Tasks		FY 1996 Cost Estimate ($K)		
Functional Need Level 4	Template Title (number)	No.	Title	Funded	Not Funded	Benefit
Pretreat Waste (4.2.2.3)	**LLW Pretreatment Development for Reference Process** **6.4.1** Reference	1.	CST optimization for supernatant	400		Remove cesium from LLW Commitment: TPA reference technology supporting TPA M-50-01-T02.
		2.	Conduct electrochemical elution techniques with waste simulants using RF and CS-100 resin (PNL)	489		
Pretreat Waste (4.2.2.3)	**LLW Pretreatment Development for Enhancements and Alternatives** **6.4.2** Enhancement/Alternatives	1.	Conduct batch and column IX tests for Strontium removal from actual CC waste that has had the Cesium removed	694		Commitment: TPA reference technology supporting TPA M-50-01 and M-50-01-T02. Technical Base For: ALARA, "incidental waste" classification, and PA.
		2.	Conduct batch and column solid sorbent tests with actual DSS/DSSF and CC waste to remove Strontium	400		
		3.	Conduct batch carrier precipitation tests and sodium Titanate adsorption tests to remove TRU from actual DSSF and CC wastes	810		

LEGEND: Baseline is normal font/*nonbaseline is italics.*
(a) Fund Immediately.
(b) Not considered reasonable to fund and to estimate costs at this point.
* Not expected to remain in MYWP FY 1996 and beyond - Not included in totals.

Table 6.2. Waste Pretreatment: Recommended Technology Program (contd)

Function and Technology Package		Tasks		FY 1996 Cost Estimate ($K)		
Functional Need Level 4	Template Title (number)	No.	Title	Funded	Not Funded	Benefit
		4.	Conduct column IX tests for Technetium removal using actual DSSF waste	600		

LEGEND: Baseline is normal font/*nonbaseline is italics.*
(a) Fund Immediately.
(b) Not considered reasonable to fund and to estimate costs at this point.
* Not expected to remain in MYWP FY 1996 and beyond - Not included in totals.

Table 6.2. Waste Pretreatment: Recommended Technology Program (contd)

Function and Technology Package		Tasks		FY 1996 Cost Estimate ($K)		
Functional Need Level 4	Template Title (number)	No.	Title	Funded	Not Funded	Benefit
Pretreat Waste (4.2.2.3)	**HLW Pretreatment Development for Reference Process**	1.	Conduct sludge wash/alkaline leach tests of actual tank waste for 1995-outyears cores—PNL	2,200		Commitment: TPA M-50-03, required for evaluating enhanced sludge washing (3/98).
	6.4.3 Reference	2.	Conduct sludge wash/alkaline leach tests of actual tank waste for 1995-outyears cores—LANL	2,300		Reduce Risk: May reduce HLW volume; may reduce cost.
		3.	Evaluate sludge processing science for actual sludge, 1995-outyears	2,178		
		4.	Conduct selective leaching experiments of actual sludges 1995 - outyears	282		
		5.	Conduct sludge settling tests of actual waste, 1995 - outyears cores	1,200		
		6.	Conduct radioactive colloid tests (FY 1996, 1997)	605		
		7.	Program management 1996	1,600		
		8.	Infrastructure support 1996-1997	1,200		

LEGEND: Baseline is normal font/*nonbaseline is italics.*
(a) Fund Immediately.
(b) Not considered reasonable to fund and to estimate costs at this point.
* Not expected to remain in MYWP FY 1996 and beyond - Not included in totals.

Table 6.2. Waste Pretreatment: Recommended Technology Program (contd)

Function and Technology Package		Tasks		FY 1996 Cost Estimate ($K)		
Functional Need Level 4	Template Title (number)	No.	Title	Funded	Not Funded	Benefit
		9.	Solid-liquid separation	505		
Pretreat Waste (4.2.2.3)	**HLW Pretreatment Development for Enhancements and Alternatives** **6.4.4** Enhancements/Alternatives	1.	Conduct non-thermal reconstitution tests, FY 1996 - outyears cores	500		Commitment: TPA M-50-03, required for evaluating enhanced sludge washing (3/98); TPA M-50-04-T02 (11/98), definitive design of HLW facility. Reduce Risk: May reduce HLW volume; may reduce cost; reduces technical risk by providing a backup to alkaline leach of sludge.

LEGEND: Baseline is normal font/*nonbaseline is italics.*
(a) Fund Immediately.
(b) Not considered reasonable to fund and to estimate costs at this point.
* Not expected to remain in MYWP FY 1996 and beyond - Not included in totals.

Table 6.2. Waste Pretreatment: Recommended Technology Program (contd)

Function and Technology Package		Tasks		FY 1996 Cost Estimate ($K)		
Functional Need Level 4	Template Title (number)	No.	Title	Funded	Not Funded	Benefit
Pretreat Waste (4.2.2.3)	**Engineering Studies and Functions and Requirements (F&R)** **6.4.5** Reference	1.	Retrieval Sequence and Blending Strategy	703		Commitment: TPA reference technology support TPA M-50-T02 and TPA M-50-03; M-50-02 and M-50-04. Reduce Risk: My reduce technical and operating risk; may reduce cost of operating HLW and LLW plants. NOTE: These are engineering tasks related to technology development. Provided for information.
		2.	In-Tank Sludge Washing Technical Support	500		
		3.	Determine Waste Processing Strategy	1,081		
		4.	In-tank Sludge Washing Process Text	536		
		5.	Evaluate Process Alternatives	495		

LEGEND: Baseline is normal font/*nonbaseline is italics.*
(a) Fund Immediately.
(b) Not considered reasonable to fund and to estimate costs at this point.
* Not expected to remain in MYWP FY 1996 and beyond - Not included in totals.

Table 6.2. Waste Pretreatment: Recommended Technology Program (contd)

Function and Technology Package		Tasks		FY 1996 Cost Estimate ($K)		
Functional Need Level 4	Template Title (number)	No.	Title	Funded	Not Funded	Benefit
Pretreat Waste (4.2.2.3)	**Applied Technology, W-236B Pretreatment Facility (Initial Pretreatment Module)** **6.4.6** Reference	1.	Equipment Testing	12,342		Commitment: DOE Order 5820.2A required to meet TRU limitations for LLW; TPA M-50-01, M-50-02. Operations: Needed for LLW performance assessment requirements. Reduce Risk: May reduce technical and operating risk; may reduce cost of operating LLW plant. NOTE: These are tasks related to technology development in the initial pretreatment module. Provided for information.
		2.	Sludge Sampling Truck	360		
		3.	Process Testing	5,901		

LEGEND: Baseline is normal font/*nonbaseline is italics.*
(a) Fund Immediately.
(b) Not considered reasonable to fund and to estimate costs at this point.
* Not expected to remain in MYWP FY 1996 and beyond - Not included in totals.

Table 6.2. Waste Pretreatment: Recommended Technology Program (contd)

Function and Technology Package		Tasks		FY 1996 Cost Estimate ($K)		
Functional Need Level 4	Template Title (number)	No.	Title	Funded	Not Funded	Benefit
Pretreat Waste (4.2.2.3)	**LLW Pretreatment Development for Reference Process (Unfunded Tasks)** **6.4.7** Reference	*1.*	*LEVEL 1: Competing Ion Effect Studies*$^{(a)}$		*750*	Commitment: TPA reference technology supporting M-50-01-T02.. Operations: Required to remove cesium and to support a minimally shielded LLW vitrification plant. Reduce Risk: Reduces cost of disposal; may reduce long-term public health risk by providing safer waste form.
		2.	*LEVEL 2: -REQUIRING ENGINEERING TRADE STUDY EVALUATION* *- Cesium Elution and Resin Disposal Alternatives*		*(b)*	
		3.	*LEVEL 2: -REQUIRING ENGINEERING TRADE STUDY EVALUATION - Evaporation/ Concentration of Process Streams*		*(b)*	

LEGEND: Baseline is normal font/*nonbaseline is italics.*
(a) Fund Immediately.
(b) Not considered reasonable to fund and to estimate costs at this point.
* Not expected to remain in MYWP FY 1996 and beyond - Not included in totals.

Table 6.2. Waste Pretreatment: Recommended Technology Program (contd)

Function and Technology Package		Tasks		FY 1996 Cost Estimate ($K)		
Functional Need Level 4	Template Title (number)	No.	Title	Funded	Not Funded	Benefit
Pretreat Waste (4.2.2.3)	**LLW Pretreatment Development for Enhancements and Alternatives (Unfunded Tasks)** **6.4.8** Enhancement/Alternatives	*1.*	*LEVEL 1: - Determine the Effectiveness of Competition Reactions to Overcome Effects of Organic Complexants on Strontium and TRU Removal*[(a)]		*200*	Commitment: TPA reference technology supporting TPA M-50-01, M-50-01-T02. Technical Base For: ALARA, "incidental waste" classification, and PA.
		2.	*LEVEL 1: - Uranium Removal from Supernatant (Add to Existing TRU studies)*[(a)]		*250*	
		3.	*LEVEL 2: - Competing Ion Studies for Technetium Removal*		*(b)*	
		4.	*LEVEL 2/3: - Removal of Cesium and Technetium by Volatilization during Calcination*		*(b)*	
		5.	*LEVEL 2/3: - Study Additional Technetium Ion Exchange Materials*		*(b)*	
		6.	*LEVEL 2/3: - Study Precipitations/Reduction Methods for Removal of Technetium*		*(b)*	

LEGEND: Baseline is normal font/*nonbaseline is italics.*
(a) Fund Immediately.
(b) Not considered reasonable to fund and to estimate costs at this point.
* Not expected to remain in MYWP FY 1996 and beyond - Not included in totals.

Table 6.2. Waste Pretreatment: Recommended Technology Program (contd)

Function and Technology Package		Tasks		FY 1996 Cost Estimate ($K)		
Functional Need Level 4	Template Title (number)	No.	Title	Funded	Not Funded	Benefit
Pretreat Waste (4.2.2.3)	**HLW Pretreatment Development for Reference Process (Unfunded Tasks)** **6.4.9** Reference	*1.*	*LEVEL 1: - Retrieval Chemistry Impacts on HLW Glass Volume(a)*		*300*	Commitment: TPA M-50-03, required for evaluating inhanced sludge washing supporting TPA M-50-04-T02, design of HLW facility (11/98). Reduce Risk: Reduce HLW volume; reduce cost.
		2.	*Glass Frit Filters Lifetime Studies*		*(b)*	
Pretreat Waste (4.2.2.3)	**HLW Pretreatment Development for Enhancements and Alternatives (Unfunded Tasks)** **6.4.10** Enhancements/Alternatives	1.	*Conduct acid dissolution tests with actual sludges(a)*		*500*	Commitment: TPA M-50-03, required for evaluating enhanced sludge wash (3/98). Reduce Risk: May reduce HLW volume; may reduce cost; reduces technical risk by providing a backup to alkaline leach of sludge.
		2.	*Level 3. Conduct bench scale solvent extraction system, design hot system, FY 1995*		*(b)*	
		3.	*Level 3. Conduct bench scale solvent extraction system, construct hot system, FY 1995-1997 (PNL)*		*(b)*	
		4.	*Level 3. Conduct bench scale solvent extraction system, hot system, FY 1997*		*(b)*	

LEGEND: Baseline is normal font/*nonbaseline is italics.*
(a) Fund Immediately.
(b) Not considered reasonable to fund and to estimate costs at this point.
* Not expected to remain in MYWP FY 1996 and beyond - Not included in totals.

Table 6.2. Waste Pretreatment: Recommended Technology Program (contd)

Function and Technology Package		Tasks		FY 1996 Cost Estimate ($K)		
Functional Need Level 4	Template Title (number)	No.	Title	Funded	Not Funded	Benefit
		5.	*Level 3. Treatment of Residue from Acid Dissolutions*		*(b)*	Commitment: TPA M-50-03, required for evaluating enhanced sludge wash (3/98).
		6.	*Level 3. Treatment of Residue from Acid Dissolutions*		*(b)*	Reduce Risk: May reduce HLW volume; may reduce cost; reduces technical risk by providing a backup to alkaline leach of sludge.
		7.	*Level 3. Deferred for Engineering Study Evaporation/Concentration of Separated Radionuclide Product Streams*		*(b)*	
Total						

LEGEND: Baseline is normal font/*nonbaseline is italics.*
(a) Fund Immediately.
(b) Not considered reasonable to fund and to estimate costs at this point.
* Not expected to remain in MYWP FY 1996 and beyond - Not included in totals.

6.4 Narrative on Technology Packages

The technology packages associated with each function of the Waste Pretreatment Program are described in this section. The description provides a brief summary of

- the justification for this activity
- current status of the technology
- technical approach
- other issues that need to be highlighted.

More detailed information is found in the templates for the Waste Pretreatment Program, located in Appendix E.

The interface requirements for pretreatment have not yet been defined fully. Pretreatment development, characterization development, LLW development, HLW development, and engineering analysis, as well as regulatory review and public acceptance, are prerequisites to the interface requirements. To initiate planning for pretreatment development, a set of interface requirements has been assumed. An attempt has been made to make those requirements used in development more stringent, or at least bounding values, as compared to the expected final values used for implementation. Using more stringent values will ensure that development work covers a range of values so that adequate data will be available for trade studies. The pertinent interface requirements are identified in the appropriate section.

Technology activities for pretreatment have been divided among ten different packages, depending on whether they support reference or enhancement/alternative processes, whether they are planned to be funded in FY 1995, and whether they are funded under projects, engineering, or technology development.

The reference pretreatment flowsheet divides the waste components into HLW and LLW streams to be vitrified separately for storage and disposal. The waste liquids and dissolved saltcakes are separated from the sludges and treated by an ion exchange process to remove cesium before becoming the feed to the LLW vitrification process. The sludges are treated with hot caustic solution to leach/dissolve portions of some of the elements (e.g., aluminum, chromium, phosphorus, sodium, and sulfur) that can have large impacts on the volume of HLW glass required to be produced. The leached sludges are then washed to remove the residual dissolved materials and mixed with the cesium removed from the LLW liquids to form feed to the HLW vitrification process.

The first six technology packages (Templates 6.4.1 through 6.4.6) represent tasks/efforts included in the current Multi-Year Work Plan (MYWP). Although many tasks contained in the MYWP are funded at levels recommended by the Pretreatment Program Office and by the Technology Development Program Office (TDPO) (including the Pretreatment Subgroup of the Waste Processing Architecture Group), some tasks are not funded or are not funded at recommended levels. Other tasks have been identified for funding/support. All unfunded tasks or tasks that are recommended for increased funding are included in the last four technology packages (Templates 6.4.7 through 6.4.10). It should also be noted that some tasks were unfunded in FY 1995 but are still currently under consideration for FY 1996 initiation. Electrochemical elution is an example of such an activity. Acid-side processing tasks in the HLW Pretreatment Development for Enhancements and Alternatives technology package (see para 6.4.4.7 below) are not funded in FY 1995 and will most likely not be funded in FY 1996 or in FY 1997. Change to this approach would probably occur only if 1) the reference technology for the HLW pretreatment process proves to be ineffective, or 2) engineering assessment/trade study assumptions demonstrate total life-cycle costs for storage/disposal of the target HLW depend primarily on total volume/number of logs of the HLW that exceed the "reasonable" volume allowed (versus total radionuclide heat of the waste and its management).

6.4.1 LLW Pretreatment Development for Reference Process

The primary goal of this activity is to develop the reference LLW pretreatment process. The primary function of the reference process is cesium removal using an ion exchange process. The specific objectives are to develop a third, higher capacity non-regenerable ion exchange (IX) media [crystalline silicotitanates (CSTs)], to develop preliminary engineering data for this new IX material, and to provide engineering data on the electrochemical elution of the two regenerable organic IX resins (phenol-formaldehyde [CS-100] and resorcinol-formaldehyde [R-F]). Small-scale batch testing and column testing on simulants and actual waste will provide engineering data. Early focus will be on testing with actual DSSF, which is the first supernate that will be processed through the LLW pretreatment facility.

Tasks contained in the MYWP that pertain to development of the reference process are briefly described in Section 6.4.1.2. Section 6.4.7 describes tasks which are not currently in the MYWP. Refer also to Template 6.4.1 in Appendix E (Chapter 6.0).

6.4.1.1 Remove Cesium from Alkaline Solutions

The solutions containing the tank waste supernates and dissolved saltcakes, plus materials removed from the sludge during washing and leaching/metathesis operations, must be treated to separate cesium from the bulk chemical components before those components are immobilized in a LLW form for storage/disposal. The degrees of separation required will depend not only on established general criteria for the disposal of LLW, but also on factors such as ALARA and the NRC's "incidental waste" classification for Hanford wastes. In addition, the required degree of separation may be governed by the concentrations of those radionuclides as allowed by shielding requirements in the LLW vitrification facility. The radionuclide of principal concern regarding shielding is cesium-137. A maximum cesium decontamination factor of 10,000 is being assumed for development purposes.

Ion exchange with CS-100 or R-F resins is the reference technology for removing cesium from alkaline solutions. With this technology, the cesium is removed from solution onto the resin and is then eluted off the resin and routed for vitrification. The eluted resin is then used in another removal cycle. Both resins have been tested at the laboratory scale using simulated feeds in both batch and column modes. An electrochemical method to improve the elution step has shown promise in initial tests. An alternative approach is not to elute the CS-100 or RF if trade studies show that a net HLW volume decrease occurs by only handling exchanger waste with no elutent waste.

Several other technologies exist for removing cesium from alkaline solutions. Ion exchange using zeolite columns was used at the West Valley plant. This approach suffers from poor zeolite stability at the high pH values of Hanford Site wastes and a relatively low capacity for cesium. Additionally, cesium cannot be eluted, which requires the cesium-contaminated zeolites be vitrified (or produce an additional waste form). New materials consisting of cesium complexants and absorbers that are bound to, or sorbed onto, solid supports are under development. With these materials, the cesium can be eluted and the materials reused.

Other cesium sorbents that show promise are CSTs, pillared clays, and transition metal ferrocyanides. These sorbents cannot be eluted for reuse and are not yet available in forms suitable for column operation, meaning that batch operations involving relatively large quantities of sorbents would be required to achieve the required cesium removal factors. Whether such sorbent quantities would impact the volume of HLW glass is yet to be determined. Currently only the CSTs appear to have a sufficiently mature development to potentially impact the TWRS selection for a cesium exchanger material. An engineered form of CST, which is suitable for column operations, is being jointly developed by Sandia National Laboratory (SNL) and UOP, Inc. Batch cesium-removal tests with this engineered-form using actual wastes are scheduled for Summer 1995 at PNL. Cold column tests are also planned at SNL in 1995. If these tests are successful, column tests with actual wastes will be conducted in FY 1996.

Co-precipitation of cesium with potassium tetraphenylborate is planned for use at the Savannah River Site (SRS). This approach does not appear to be suitable for use at the Hanford Site because of the technical and safety problems encountered at the SRS and because much larger amounts of potassium are present in the Hanford Site wastes.

Solvent extraction methods for removing cesium from alkaline solutions are also being investigated. It is not likely that they will be developed in time for application to the Hanford Site waste problem.

An important factor in all of these candidate processes is their selectivity for cesium over competing ions, especially sodium and potassium. High selectivity is important to the minimization of HLW glass volume, especially for nonelutable adsorbents/exchangers where the matrix as well as the adsorbed ions are vitrified.

Data on the alternate technologies are needed to show whether they promise to be clearly superior to IX by CS-100 or R-FO. This work can be done with simulant solutions over a range of compositions that are likely to be present in actual waste. Demonstration with actual waste stream samples should be performed at laboratory scale (and pilot scale where shown to be needed) to verify simulant testing. Appropriate engineering-scale testing should follow to provide scaleup factors for plant design. Data should be collected to predict long-term stability of reagents, and environment, safety, and health (ES&H) and economic factors should be analyzed.

6.4.1.2 Tasks within the LLW Pretreatment Development for Reference Process include:

Develop engineered form of CST (SNL). CST has shown promise at having some advantages over existing resins for cesium removal; however, it is available only in a powder form, which is unacceptable for column operation. This task continues FY 94 work to develop an engineered form at UOP Inc., this form should be suitable for single-loading, non-eluting column operation for removal of cesium from alkaline solutions. Pilot size quantities (nominally 10 kg) of engineered form will be produced at UOP, Inc. After verification of performance by SNL, samples will be provided to PNL for radioactive testing. SNL will independently conduct cold-simulant column testing.

Conduct batch tests of engineered form of CST using DSS/DSSF feed (PNL). PNL will conduct batch tests of the engineered form using actual waste. The first waste to be tested is double-shell slurry/double-shell slurry feed (DSS/DSSF). These tests will verify the cesium capacity and selectivity of the exchanger.

CST optimization for supernatant (SNL). Optimization of the application of the engineered form of the CSTs will be investigated/developed for TWRS-specific needs in the high alkaline waste supernatants.

Conduct electrochemical elution techniques with waste simulants using R-F and CS-100 resin (PNL). The electrochemical mode of cesium elution will continue in its evaluation by AEA Technology under subcontract to PNL. A transfer to and demonstration by PNL will occur at the completion of this effort.

Construct and test electrochemical elution IX System using actual wastes (PNL). Demonstration of the electrochemical mode of elution for cesium will occur. This will provide performance data for necessary trade studies.

6.4.2 LLW Pretreatment Development for Enhancements and Alternatives

The primary goal of this activity is to develop enhancements and alternatives to the reference LLW pretreatment process. The specific objective is to select the most promising technologies and develop engineering data for those processes that will remove strontium, TRU and technetium from supernate, dissolved saltcake, and sludge wash and leach solutions. The removal of technetium from the supernatant and the solutions from sludge leaching/metathesis and washing may be required to meet performance assessment (PA) problems for the LLW glass because of migration of technetium. Technetium has a long half life (210,000 years) and is mobile in the environment. Removal of TRUs may be required to meet both LLW definition and performance assessment criteria. Removal of strontium may be required to meet ALARA requirements and to allow the classification of incidental wastes by the NRC.

Background information on destruction of organic complexants to aid in these radionuclide removal processes is presented in Section 6.4.2.1. The next three sections contain information on removal of strontium, transuranic elements, and technetium. Tasks planned in the MYWP are listed in Section 6.4.2.5. More detailed task information is contained in Template 6.4.2 in Appendix E (Chapter 6.0). Section 6.4.8 and Template 6.4.8 in Appendix E (Chapter 6.0) describe tasks in this technical area that are not currently in the MYWP.

6.4.2.1 Destroy Organic Complexants for LLW Processing

The CC tanks contain large quantities of complexants that could interfere with pretreatment processes to remove TRUs and strontium from LLW. If complexant destruction is required, in-tank processes are preferred to minimize costs, but out-of-tank processes such as electrochemical and thermal might prove to be preferable.

A combination of heat-and-digest within the waste tanks has been suggested as one technology for destroying complexants. Testing of this technology started in FY 1994. Note that conversion of organics to the point of producing CO_2 and water may not be necessary here; conversion only to acetate or oxalate could have the effect desired for this LLW processing application.

The potential for oxidizing the complexants with permanganate needs to be studied because not only should the complexants be destroyed in the tanks, but the MnO_2 product should adsorb strontium and TRUs, thus reducing the DFs needed in subsequent radionuclide removal processes. Additional technologies that should be studied include adding iron or other complexable metal ions, or simply blending with other wastes, to decrease the free complexant concentration and thus allow more efficient removal of strontium and TRUs. Such decreases could perhaps also be accomplished by extracting the organic complexants from the waste, either alone or along with the complexed radionuclides, by supercritical fluid (or conventional) extraction. Also, the effects of the complexants may be decreased in some cases simply by increasing the hydroxide concentration of the waste.

6.4.2.2 Remove Strontium from Alkaline Solutions

Removing strontium from the alkaline wastes and sludge leaching/metathesis and washing solutions may be required if the LLW vitrification facility is going to be a lightly shielded, possibly contact-maintained, facility and may be required for ALARA considerations. Most of the strontium-90 is present in the sludge, but the fraction that is present in solution, especially in complexed wastes, may still present problems. The fraction of radioactive strontium that is in solution in complexed wastes should be decreased by the addition of nonradioactive strontium, of calcium, or another complexable metal ion. This approach should be tested with a variety of complexed wastes. Preliminary results (Herting, WHC) indicate that isotopic dilution (adding excess nonradioactive strontium) works well to reduce the amount (fraction) of strontium-90 in solution.

The methods available for removing uncomplexed strontium are largely the same as those discussed for cesium in Section 6.4.3.1, although different materials may be required. Chelating IX resins, which allow elution of the strontium-90 and reuse of the resin, have shown considerable promise in laboratory tests. Newer column materials, which consist of strontium complexants that are bound to, or sorbed onto, solid supports, are under development. Batch addition of monosodium titanate is being used at the SRS to remove strontium from alkaline waste solutions. CSTs, if used for cesium removal, should also remove strontium.

A solvent extraction process (SREX) using a crown ether extractant has been developed for extracting strontium from both acidic and basic solutions. The developmental work has focused on acidic solutions, but batch contacts with simulated waste have shown the process can be used to remove strontium-90 from the basic tank supernatants. This process may also be useful for removing technetium and plutonium from high-nitrate, alkaline solutions. Development still needs to go from batch to countercurrent testing and from simulants to real waste.

Data on the alternate technologies are needed to see if the performance of the technology promises to be clearly superior to IX. This work can be done using simulant solutions over a range of compositions that are likely to be present during processing actual Hanford Site waste. Demonstration using actual waste stream samples should be performed at the laboratory scale to verify simulant testing. Appropriate engineering-scale testing must follow to provide scaleup factors for plant design. Data must be collected to predict long-term stability of reagents, and ES&H and economic factors must be analyzed.

6.4.2.3 Remove Transuranic Radionuclides from Alkaline Solutions

Removing TRU radionuclides from the supernatant and sludge leaching/metathesis and washing solutions may be required to meet the LLW criterion of 100 nCi/g; removing neptunium may also be required to alleviate PA problems for the LLW glass stemming from NpO_2^+ migration in the environment. The concentration of americium in the supernatant is dependent on the complexants present and the effectiveness of the solid/liquid separation (americium is likely to be sorbed on fine materials suspended in these solutions). The presence of plutonium and neptunium in these solutions could also be due to their presence as higher oxidation states. Depending on the degree of sludge washing and the initial amounts found in tank supernatants already in place, a DF ranging from less than 1 to greater than 100 may be needed.

Destruction of organic complexants (Section 6.4.2.1) would probably ensure that TRU concentrations in the alkaline solutions would be low enough to meet the LLW criterion for the LLW glass, presuming that solid/liquid separations processes are sufficiently efficient. However, it also might be necessary to add a reducing agent to minimize the concentrations of higher oxidation states of plutonium and neptunium, especially because of the potential PA implications of neptunium(V).

The method generally used to remove traces of TRU radionuclides from alkaline solutions is carrier precipitation, generally with ferric hydroxide. A mixture of ferrous and ferric hydroxide might be desirable for removing neptunium(V) along with other TRUs. TRUs are also removed, along with strontium, by sorption on monosodium titanate. At West Valley, they were removed by the titanate-impregnated zeolite used for cesium removal. CSTs also show promise for removing TRU elements, as well as cesium and strontium. IX and solvent extraction processes for this application are not well developed. Data must be collected to analyze the effect of waste stream composition (especially the presence of complexants and colloids) on TRU removal for the most developed technology (carrier precipitation) and for the alternative technologies, which are little more than conceptual at this stage. Specific high-TRU streams must be characterized to learn to what extent plutonium, americium, and neptunium are in solution or suspension.

Data on alternative technologies are needed to see if they perform better than carrier precipitation. This work can be done using simulant solutions over a range of compositions that are likely to be present during processing actual Hanford Site waste. Demonstration using actual waste stream samples should be performed at the laboratory scale to verify simulant testing.

6.4.2.4 Remove Technetium from Alkaline Solutions

Because of the long half life (2.1×10^5 y) of technetium-99 and its mobility in the environment, removing technetium from the LLW glass feed may be required to meet the PA criteria for the final waste form.

Technetium is expected to be found in the supernatant and sludge leaching/metathesis and wash solutions as the soluble technetiumO_4^- ion. For the purposes of technology development, decreasing the technetium content of the LLW form by a factor of 10 is currently assumed to be required to meet the constraint of the PA for the final LLW waste form; a PA-defendable technetium-99 removal requirement must be supplied to pretreatment process planners.

Anion exchange was used in the past to recover kilogram amounts of technetium from Hanford Site waste supernate. Laboratory studies, both batch and column experiments, have been performed on simulated waste streams for newer resins. Some column chromatography has also been done with extractants sorbed on solid supports. A few batch experiments have been done on SREX processing. Removing technetium by precipitation may also have promise. Based on the extent of development, anion exchange would be considered the strongest possibility, especially if a simple, process-compatible method of elution were available. Technetium can also be removed by chemical or eletrochemical reduction, with the latter having been demonstrated on actual SRS waste during FY 1994 as part of the ESPIP (EM-50) program.

Data on alternative technologies are needed to see if the performance of the technology promises to be clearly superior to anion exchange. This work can be done using simulant solutions over a range of compositions that are likely to be present when processing actual Hanford Site waste. Demonstration using actual waste stream samples should be performed at the laboratory scale to verify simulant testing. Appropriate engineering-scale testing should follow to provide scaleup factors for plant design. Data should be collected to predict long-term stability of reagents, and ES&H and economic factors should be analyzed.

6.4.2.5 Tasks within the LLW Pretreatment Development for Enhancements and Alternatives include:

Conduct batch and column IX tests for strontium removal from synthetic CC waste (LANL). In a continuation of work, experimental investigations in FY 1995 will address the feasibility/utility of using promising exchangers (identified in the FY 1994 work) for ion exchange removal of strontium from waste solutions. Complexed wastes will be the focus of this activity, because they present the greatest challenge. Column tests with synthetic waste will be done to verify the process.

Conduct batch and column IX tests for strontium removal from actual CC waste that has had the cesium removed (LANL). In a continuation of work at the end of FY 1995, experimental investigations will address the feasibility/utility of using promising exchangers (identified in the FY 1994 work) for ion exchange removal of strontium from waste solutions. Batch and column tests will be conducted on actual supernatant waste, most probably DSSF and CC wastes, that have had the cesium removed in previous IX tests at PNL.

Conduct batch solid sorbent tests with synthetic DSS/DSSF and CC waste to remove strontium. Experimental investigations in FY 1995 will address the feasibility/utility of developing and testing new solid sorbents. Batch testing will be conducted with sodium titanate, pillared clays, or complexants bound on solid supports. DSSF and CC waste simulants will be used for these cold tests.

Conduct batch and column solid sorbent tests with actual DSS/DSSF and CC waste to remove strontium. Experimental investigations FY 1995 will address the feasibility/utility of developing and testing new solid sorbents. This task will test promising sorbents identified in the previous task. Batch and column sorbent tests for strontium removal will be conducted on actual supernatant waste, most probably DSSF and CC wastes that have had the cesium removed at PNL. This will probably not occur until the second half of the year when samples are expected to be available. Quantities of solution required for these tests are in the range of hundreds of milliliters.

Conduct batch carrier precipitation tests and sodium titanate adsorption tests to remove TRU from actual DSSF and CC wastes (LANL). Precipitation tests for removal of neptunium and other TRUs will be conducted on diluted actual DSS/DSSF that has had the cesium removed at PNL. This task will test promising materials/methods identified in task .10. These tests will occur during the second half of FY 95 when actual waste samples in quantities of several hundred milliliters or more should be available from PNL.

Conduct column IX tests for technetium removal using synthetic DSSF waste. Column tests for technetium removal will be conducted FY 1995 on diluted DSS/DSSF simulant waste. These removal tests will be conducted during the first half of the year with Reillex$_{TM}$ resin. As in 1994, the work will involve both loading and eluting the IX column, emphasizing the development of elution techniques that are compatible with downstream processing.

Conduct column IX tests for technetium removal using actual DSSF waste. Column tests for technetium removal will be conducted on diluted actual DSS/DSSF that has had the cesium removed at PNL. These tests will occur during the second half of the year when actual waste samples in the quantities of several hundred milliliters should be available. This work will include testing of the most promising elution procedures developed in the previous task.

Conduct batch tests on alternate techniques for technetium removal using synthetic DSSF waste. Alternative techniques suitable for technetium removal will be investigated in FY 1995. These limited batch tests will be conducted on diluted DSS/DSSF simulant. This work will be done during the first half of the year with candidate materials and will merge with other technetium removal efforts in FY 1996.

Conduct batch tests on alternative techniques for technetium removal using actual DSSF waste. The best techniques identified in Task .08 will be investigated in batch tests with diluted actual DSS/DSSF that has had the cesium removed at PNL. This will occur during the second half of the year when actual waste samples in quantities of several hundred milliliters should be available. This work will merge with other technetium removal efforts in FY 1996.

Conduct batch carrier precipitation tests and sodium titanate adsorption tests to remove TRU from synthetic DSSF and CC wastes (LANL). Precipitation tests for removal of neptunium and other TRUs will be conducted on diluted DSS/DSSF simulant. Currently, concern is only for neon but behavior of other TRUs will be observed as experiments allow. These tests will occur during the first half of the year. Testing should include ferrous/ferric hydroxide as a carrier precipitant. Sodium titanate should also be tested to determine its effectiveness at adsorbing TRU.

Batch test of complexant destruction with actual CC waste (PNL). Conduct batch tests with actual CC waste of heat and digest process and permanganate oxidation. Experimental investigations will address the feasibility/utility of destroying complexants using heat-and-digest and permanganate oxidation. Emphasis should be placed on using actual CC tank waste in small batch modes.

6.4.3 HLW Pretreatment Development for Reference Process

Washing of sludge with water is necessary to dissolve salts and remove the interstitial liquid, containing dissolved salts, from the water-insoluble sludge components. In this manner these dissolved salt components do not contribute to the volume of the HLW glass produced on vitrification of the sludge. Leaching and metathesis steps to remove some water-insoluble sludge components may be performed either before or after initial washing of the sludge. Effectiveness and efficiency of removing sludge components must be determined to allow estimation of resulting HLW glass volumes. Reagent concentrations, operating conditions, and equipment must also be determined.

The separation of HLW tank liquid supernates, sludge leaching/metathesis solutions, and washing solutions from sludge is necessary for subsequent processing of these liquids to a LLW glass. The solid/liquid separations are required not only to achieve adequate decontamination of the liquid phase from transuranics (TRUs) and strontium, which are concentrated in the solid phase, but also to provide a solids-free feed stream to cesium and possibly strontium separation processes, most probably solid sorbents, so that those processes can operate properly. The primary solid/liquid separation will be made in-tank by settling solids and decanting the liquid phase. This will provide a gross separation of phases; however, the liquid phase will still contain some suspended solids and require additional solids removal. This second "polishing" phase separation will probably use filtration technology to remove these solids before the IX unit.

Background information on the major technologies involved in this reference process is contained in Sections 6.4.3.1 through 6.4.3.4, and the tasks planned in the MYWP are listed in Section 6.4.3.5. More detailed information is contained in Template 6.4.3 in Appendix E (Chapter 6.0). Section 6.4.9 and Template 6.4.9 Appendix E (Chapter 6.0) describe tasks in this technical area that are not currently in the MYWP.

6.4.3.1 Separate Sludge from Solution

The separation of HLW tank liquid supernates and wash/leach solutions from sludge is necessary for subsequent processing of these liquids to produce a LLW glass. The solid/liquid separation is required not only to adequately decontaminate the liquid phase from TRUs and strontium, which are concentrated in the solid phase, but also to provide a solids-free feed stream to cesium/strontium separation processes, most probably solid sorbents, so those processes can operate properly. The primary solid/liquid separation will be made in-tank by settling solids and decanting the liquid phase. This technique will provide a gross separation of phases; however, the liquid phase may still contain some suspended solids and may require further removal of the solids. This second "polishing" phase separation will be completed in a separate facility using either filtration or centrifugation technology.

A fundamental need in this area is the collection of pertinent data with a wide variety of actual tank waste sludges. Pertinent data include solids settling rates, settled solids volumes, and particle sizes. The effectiveness of settling agents such as flocculents to decrease settling times and improve solids compaction should also be investigated. If successful, flocculents could reduce the volume of wash/leach solutions to be treated by radionuclide removal processes and by concentration steps preceding LLW vitrification.

The particle size data can be obtained in work with very small samples (<1 g). For meaningful settling rate and settled solids volume measurements, experiments with sludge volumes nominally 1.0 liter and total solution volumes nominally 3.0 to 6.0 liters have been determined on the basis of guidelines in the literature.

For particles as small as 0.01 microns in diameter, as have been found in significant quantities in Hanford Site tank waste, filtration appears to be more appropriate for separation than is centrifugation. If separations of these small particles are necessary, the use of coagulation or precoats should be examined and ultrafiltration and other techniques as appropriate should be evaluated.

The effectiveness of separation of solids and liquids in the settle/decant step depends on how close to the top of the settled solids layer the liquids can be removed without also removing some of the solid. Thus, if the liquid/sludge interface can be detected relatively accurately, liquid decanting can be maximized. This could mean fewer washing steps and, again, less liquid to be processed and concentrated before LLW vitrification. One serious general concern with separation of solids and liquids is formation of a colloid or gel where extremely fine solids remain suspended in the liquid phase. The fine solids can foul the IX and also may potentially contain high levels of radionuclides that are not treated by the exchanger. Both possibilities can result in a LLW stream not meeting regulatory requirements for disposal.

6.4.3.2 Wash Sludge

Washing the sludge with water is necessary to separate water-soluble salts, and the interstitial liquid containing the dissolved salts, from the insoluble sludge components. This prevents the dissolved salt components from contributing to the volume of the HLW glass produced when vitrifying the sludge. Washing steps may be performed both 1) following the initial separation of the sludge from the liquid portion of the retrieved tank waste, and 2) following enhanced sludge-washing operations that convert certain insoluble sludge materials to other, more readily soluble materials. The first stage of washing can actually be a retrieval step if water sluicing is used. The water retrieving the sludge is also performing a first stage washing.

The separation factor for dissolved components in such washing operations is known to be equal to the separation factor for the liquid itself, which simply depends on the fractions of the liquid that are removed from, or that remain with, the sludge. For a settle-and-decant or centrifugation approach to separating the solids and liquids, these fractions depend on the quantity of solution added and the quantity of solution that is not removed from the sludge, which depends primarily on the volume of the sludge phase after separation from the bulk of the liquid.

The key parameter to be measured in this study is, therefore, the volume of the sludge phase per unit mass of sludge in washing and settling tests with actual tank waste sludges. These measurements can be made in conjunction with enhanced sludge-washing tests, and should be made with as wide a variety of tank waste sludges as is practicable. Additional measurements should be made to compare the volumes of the sludge phases after simple gravity settling with the volumes after centrifugation, in the event that centrifuging is incorporated in the process flowsheet.

6.4.3.3 Leaching and Metathesis of Sludge with Basic Solutions (Enhanced Sludge Washing)

The current DOE planning basis for TWRS assumes that enhanced sludge washing (leaching and/or metathesis) can be done sufficiently well that a reasonable volume of HLW glass will be produced from vitrifying the treated sludges. Leaching and/or metathesis steps are necessary because some HLW glass volume-limiting components of the sludge will not be efficiently removed by simple sludge washing because they are present in chemical forms not sufficiently soluble in typical wash solutions. Enhanced sludge-washing steps, which may involve relatively long contact times, high temperatures, and high solution concentrations, can assist in removing such components by converting them to more soluble forms. Typical examples include 1) the metathesis of insoluble phosphates to insoluble hydroxides (or carbonates) so the phosphate can be washed out of the sludge, 2) the conversion of insoluble aluminum hydroxide to soluble sodium aluminate by reaction with caustic, and 3) the use of oxidant-containing caustic solutions to convert relatively insoluble chromium (III) hydroxide to soluble chromium (VI) species. Limited data are available with actual tank waste sludges to indicate the potential feasibility of this approach.

The technical approach to be used here should involve testing a wide variety of tank waste sludges. These sludges may vary not only in chemical composition, but also in mineral form; thus, it is imperative to study a wide variety of sludges. Parameters to be investigated in such tests include 1) solution composition, 2) reaction temperature, 3) reaction time, 4) degree of mixing, and 5) solution-to-sludge ratio. The initial and the leached solid phases should be characterized and the experimental results compared with results of thermodynamic modeling calculations.

The solutions resulting from such leaching operations will be combined with the soluble components separated from the sludge to be processed for radionuclide removal before going to LLW vitrification. The radionuclide contents (and species) of the leach solutions need to be determined in the experimental tests to address the question of whether additional radionuclide removal processes will be needed to meet the criteria for the LLW vitrification feed. This is of special concern for TRU elements because of the potential for formation of more soluble complexes and/or oxidation states in some of the potential leach solutions.

6.4.3.4 Leaching of Sludge with Dilute Acidic Solutions (Acid Leach of Sludge)

Some minerals that contain HLW glass volume-limiting components may be more amenable to leaching by dilute acids than by bases. An example of such behavior would be a phosphate mineral that would be more soluble in acidic solution than in neutral or basic solution because the concentration of free phosphate is much lower than the concentration of phosphoric acid in acidic solutions.

Little is known about the dilute acid leaching approach. This approach should be addressed in an experimental effort done in parallel with the leach/metathesis study employing basic solutions. Depending on the results of these tests, it may be necessary to develop methods for treating the acidic leach solutions. Such treatment might involve simple reneutralization, or perhaps acidic separations processes would be required.

6.4.3.5 Tasks within the HLW Pretreatment Development for Reference Process include:

Conduct sludge wash/alkaline leach tests of actual tank waste for 94-95 sample cores-PNL (available cores split between PNL & LANL). This FY 1995 activity will consist of conducting laboratory tests on small samples (approximately 5 grams) of actual waste from a variety of sludges to determine the extent of removal of components when washed with inhibited (for corrosion) water and when leached with hot caustic solutions. Leach conditions may include a range of caustic concentrations, times of reaction, and temperatures. Distribution of key components (e.g., sulfate, phosphate, aluminum, chromium, and radionuclides) among the wash and leach solutions and the leached residue will be determined.

Conduct sludge wash/alkaline leach tests of actual tank waste for 94-95 sample cores-LANL (available cores split between PNL & LANL). This FY 1995 activity will consist of conducting laboratory tests on small samples (approximately 5 grams) of actual waste from a variety of sludges to determine the extent of removal of components when washed with inhibited (for corrosion) water and when leached with hot caustic solutions. Leach conditions may include a range of caustic concentrations, times of reaction, and temperatures. Distribution of key components (e.g., sulfate, phosphate, aluminum, chromium, and radionuclides) among the wash and leach solutions and the leached residue will be determined.

Conduct sludge wash/alkaline leach tests of actual tank waste for 95-outyears cores-PNL (available cores split between PNL & LANL). This FY 1996-1997 activity will consist of conducting laboratory tests on small samples (approximately 5 grams) of actual waste from a variety of sludges to determine the extent of removal of components when washed with inhibited (for corrosion) water and when leached with hot caustic solutions. Leach conditions may include a range of caustic concentrations, times of reaction, and temperatures. Distribution of key components (e.g., sulfate, phosphate, aluminum, chromium, and radionuclides) among the wash and leach solutions and the leached residue will be determined.

Conduct sludge wash/alkaline leach tests of actual tank waste for 95-outyears cores-LANL (available cores split between PNL & LANL). This FY 1996-1997 activity will consist of conducting laboratory tests on small samples (approximately 5 grams) of actual waste from a variety of sludges to determine the extent of removal of components when washed with inhibited (for corrosion) water and when leached with hot caustic solutions. Leach conditions may include a range of caustic concentrations, times of reaction, and temperatures. Distribution of key components (e.g., sulfate, phosphate, aluminum, chromium, and radionuclides) among the wash and leach solutions and the leached residue will be determined.

Evaluate sludge processing science for actual sludge, 94-95. Basic understanding of the chemical and physical properties that govern the leaching and metathesis of Hanford Site tank waste sludges is critical to evaluation and optimization of the technique. Processes ranging from chemical kinetics to ion interactions in solutions and on surfaces to transport processes governing kinetic solubility rates are only some of the considerations that must be made. Both experimental test and theoretical modeling efforts will be involved in this FY 1995 activity.

Evaluate sludge processing science for actual sludge, 95-outyears. Basic understanding of the chemical and physical properties that govern the leaching and metathesis of Hanford Site tank waste sludges is critical to evaluation and optimization of the technique. Processes ranging from chemical kinetics to ion interactions in solutions and on surfaces to transport processes governing kinetic solubility mechanism are only some of the considerations that must be made. Both experimental test and theoretical modeling efforts will be involved in this FY 1995 activity.

Conduct selective leaching experiments of actual sludges, 94-95. FY 1995 laboratory testing (approximately 5 grams scale) on a variety of sludges will be necessary over a wide range of experimental conditions. Investigations will include use of specific reagents, varying the periods of time for reaction, and varying temperature. Studies will determine the effects on solubilizing key components such as sulfates, phosphates, aluminum and chromium (as well as radionuclides). Reagents may include dilute acid mixes, alkaline oxidants such as potassium permanganate, carbonate/hydroxide mixes, complexants, etc. Determination of the effects of processing conditions on the leaching of key sludge components will be a major goal. Larger scale experiments will be necessary to the later phases (definitely in 1997). Distribution of key components between the leach solutions and the leached residue will be determined.

Conduct selective leaching experiments of actual sludges 95 - outyears. FY 1996 and FY 1997 laboratory testing (approximately 5 grams scale) on a variety of sludges will be necessary over a wide range of experimental conditions. Investigations will include use of specific reagents, varying the periods of time for reaction, and varying temperature. Studies will determine the effects on solubilizing key components such as sulfates, phosphates, aluminum, and chromium (as well as radionuclides). Reagents may include dilute acid mixes, alkaline oxidants such as potassium permanganate, carbonate/hydroxide mixes, complexants, etc. Determination of the effects of processing conditions on the leaching of key sludge components will be a major goal. Larger scale experiments will be necessary to the later phases (definitely in 1997). Distribution of key components between the leach solutions and the leached residue will be determined.

Conduct sludge settling tests of actual waste, 94-95. Focus in FY 1996 and FY 1997 will be on the measurement of settling times, compaction, and particle-size density/distribution measurement will occur before and after real sludges are washed, alkaline leached, and rewashed. Sample size has nominally been established as 1.0 liter sludge to ensure proper scaling behavior. Effectiveness of settling agents will also be assessed to determine effects on settling times and compaction, if settling times are less than 1 to 2 inches per day. Characterization of the particles in the supernate is necessary to evaluate/test techniques to remove the suspended particulate matter.

Conduct sludge settling tests of actual waste, 95 - outyears cores. Focus in FY 1995 laboratory tests will be on the measurement of settling times, compaction, and particle-size density/distribution. Measurement will occur before and after when real sludges are washed, alkaline leached, and rewashed. Sample size has nominally been established as 1.0 liter sludge to ensure proper scaling behavior. Effectiveness of settling agents will also be assessed to determine effects on settling times and compaction, if settling times are less than 1 to 2 inches per day. Characterization of the particles in the supernate is necessary to evaluate/test techniques to remove the suspended particulate matter.

Establish a radioactive colloid laboratory capability (FY 1995). A laboratory capability for colloid studies will be established in FY 1995 for investigations of colloid formation/behavior in the supernatant. The goal is to determine the significance of sludge components going into or being in colloids that can not be readily separated because of their extremely small size. Additionally, colloids and radionuclides often attach to each other, making the separation/isolation/extraction of radionuclides more difficult.

Conduct radioactive colloid tests (FY96, 97). A laboratory capability for colloid studies will be established for investigations of colloid formation/behavior in the supernatant, and tests will be performed in FY 1996 and FY 1997. The goal is to determine the significance of sludge components going into or being in colloids that can not be readily separated because of their extremely small size. Additionally colloids and radionuclides often attach to each other, making the separation/isolation/extraction of radionuclides more difficult.

Program management 95. This account specifically provides for oversight program management by the performing organization.

Program management 96-97. This account specifically provides for oversight program management by the performing organization.

Infrastructure support. This account provides the support for special shipping of radioactive materials on and off the Hanford Site, support for specific pretreatment development sampling and handling, purchase of shipping containers both Type A and Type B as necessary, etc.

6.4.4 HLW Pretreatment Development for Enhancements and Alternatives

The primary goal of this activity is to develop enhancements and alternatives to the reference HLW pretreatment process. The specific objective of this activity is to select the most promising technologies and develop engineering data for these processes that will decrease the quantity of the nonradioactive waste components that must be disposed in the HLW. Potential alternatives being investigated include reconstitution of the sludge by acid dissolution, reneutralization and subsequent alkaline leaching, and acid dissolution followed by separation of radionuclides by solvent extraction or IX.

The current U.S. Department of Energy (DOE) planning basis for TWRS assumes that alkaline leaching and metathesis of sludges can be done effectively. The plan assumes that a reasonable volume of HLW glass will result from the vitrification of the treated sludges. This, however, may not be what really happens. Some important HLW-glass-volume-limiting components of the sludge may not be sufficiently removed by simple sludge washing and alkaline leaching and metathesis. These components are present in chemical forms that may not be sufficiently dissolved in typical wash/alkaline solutions. These components are expected to be dissolved in acid media, leading to the thesis that removal of these components by alkaline leaching and metathesis can be enhanced by acid dissolution followed by reneutralization (reconstitution of sludge). This could destroy "aged" crystals that are much less easy to dissolve by alkaline leaching and metathesis.

A much greater decrease in the quantity of nonradioactive waste components to be disposed in the HLW glass can be achieved by removing key radionuclides (e.g., TRU, strontium, cesium) from the acid-dissolved sludge solution so that the bulk sludge components (e.g., iron, aluminum, zirconium, bismuth, etc.) can go to LLW vitrification rather than to HLW vitrification. Such radionuclide removal processes would likely involve solvent extraction or IX.

Background information on acid dissolution of sludge is given in Section 6.4.4.1. The concept of reneutralization of the acid-dissolved sludge solution to give materials that can be caustic-leached more effectively is described in Section 6.4.4.2. Sections 6.4.4.3 through 6.4.4.6 provide background information on processes to separate radionuclides from the bulk components in the acid-dissolved sludge solutions. The tasks in the MYWP are listed in Section 6.4.4.7. More detailed task information is contained in Template 6.4.4 in Appendix E (Chapter 6.0). Section 6.4.10 and Template 6.4.10 Appendix E (Chapter 6.0) describe tasks that are not currently in the MYWP.

Another possibility to reduce the HLW volume is the use of high-temperature calcination. This process can destroy organics and nitrates and can convert insoluble aluminum, chromium, and phosphate salts in soluble sodium salts. Thermal efficiencies, erosion, corrosion, and component wear are all important design considerations. Calcination requires a strong engineering development program at various bench-top and pilot-scaling sizes to demonstrate system feasibility and reliability. The potential advantages make the process attractive for further consideration.

6.4.4.1 Dissolve Sludge in Acid

Dissolution of the sludge in nitric acid solutions could be a major step in decreasing the volume of HLW glass to a quantity that is more reasonable than the minimum that is achievable by the reference caustic leach (enhanced sludge wash) approach. A dissolution step could serve as the first step in a non-thermal sludge reconstitution process aimed at achieving a more efficient caustic leach step or it could provide an acid-dissolved sludge solution to be treated to separate key radionuclides from the bulk sludge components so that the bulk components can go to LLW vitrification rather than to HLW vitrification.

To approach the goal of complete sludge dissolution, it is likely that complexants (e.g., fluoride, oxalate) will have to be added to the nitric acid dissolvent. It is also likely that, for some sludge types, less undissolved sludge residue will remain after acidic dissolution if a caustic leach step precedes acidic dissolution.

Dissolution data are now available for sludges from three types of double-shell tank (DST) waste and from five different single-shell tanks (SSTs). High percentages of dissolution were observed in most cases, especially when a primary nitric acid-only step was followed by a mixed nitric/hydrofluoric acid step. Even in the cases where the percentage of total sludge dissolution was low, the percentage of radionuclide dissolution was high. Thus, depending on yet-to-be-defined LLW vitrification feed criteria, the residual sludge remaining after dissolution might go to LLW glass rather than to HLW glass; this could substantially reduce the HLW glass volume.

The work in this area needs to be expanded to include a wider variety of tank sludge samples and a wider variety of dissolution conditions (e.g., solution composition and volume, reaction temperature and times). Key measurements to be made include determining the fractions of both major sludge elements and key radionuclides that do not dissolve under different conditions. These measurements can be made in experiments using several-gram samples of the sludges.

Other key measurements in this area are those related to the need for clarifying the acidic dissolver solution before its use in radionuclide/inert chemical separations processes. This includes measurements of particle sizes and densities, settling rates, and settled solids volume on the residue remaining after dissolution. These measurements are very similar to those that will need to be done in the study addressing the initial separation of tank waste sludge from solution.

6.4.4.2 Reconstitute Sludge

The effectiveness of removing some important HLW glass-limiting components from the sludge during washing and leaching/metathesis operations might be improved if the sludge were reconstituted (i.e., converted to different chemical compounds and/or solids of different particle sizes). Little work has been done in this area with tank wastes, but experience in related areas suggests the approach could be beneficial. It has long been known that freshly formed precipitates tend to be less crystalline (thus, easier to dissolve) than are aged precipitates. Thus, dissolution of the sludge in acid followed by reprecipitate of the sludge components by adding caustic could be expected to lead to increased removals of caustic-leachable sludge components.

This approach should be tested with actual tank waste sludges, especially those that exhibit poor leachability of glass-limiting components (e.g., phosphate, chromium, aluminum) in the existing condition. The quantities of such components remaining in the reconstituted and leached sludges would allow estimation of the HLW glass volume resulting from such a combined treatment. Comparing the quantities of such components in the leached sludge with and without a reconstitution step would provide a measure of the effectiveness of the reconstitution step.

A second approach for reconstitution is the thermal calcination of sludges. If the sludges are calcined along with sodium/nitrite/nitrate/hydroxide, the effective result would be a caustic fusion step that also serves to reconstitute the sludge. Caustic fusion has been used for years as a tool in analytical chemistry to convert minerals to forms that are easily dissolved. Technical development for treatment of offgases generated would also be required. This would involve removal of volatized radioactive and hazardous materials.

6.4.4.3 Remove Transuranics from Acidic Solutions

Removal of TRU elements from acidic solutions resulting from sludge dissolution produces a low-volume, TRU-bearing stream that will be processed to form HLW glass. The resulting non-TRU stream would be further processed to remove strontium and other radionuclides, if necessary, to meet as-yet-unspecified criteria for the LLW vitrification feed.

Many technologies are available to remove TRUs from acidic waste, including solvent extraction, extraction chromatography, solid sorbents, and precipitation. Of these technologies, the most promising appears to be solvent extraction using the TRU-extraction (TRUEX) process. This process has been extensively demonstrated on simulated solutions, and to a limited extent on actual wastes. A computer program has been prepared for modeling performance of the TRUEX process for many key elements. Another extractant, abbreviated DHDECMP or CMP, could also be used to meet the required TRU DFs. Equipment for solvent extraction processes is highly developed, but significant testing with actual wastes would be required to support this process.

Such solvent extraction processes involve selectively extracting the TRU elements into a solvent phase, while leaving most of the inert chemical components in the aqueous phase (lanthanide elements also extract, however). The solvent phase can be scrubbed to enhance removal of undesired components, and is then stripped with another solution to return the TRUs to an aqueous solution. The solvent phase is washed and then reused. The solvent wash solution is routed for LLW vitrification and the extraction raffinate, which contains nearly all of the inert chemical components, is treated to remove other radionuclides before also being routed for LLW vitrification. The strip solution, which contains essentially all of the TRU and lanthanide elements, is routed for HLW vitrification.

Key development issues to be determined for a solvent extraction process are distribution coefficients for americium, plutonium, and neptunium from various dissolved sludges. Other important information, such as phase disengagement, third-phase formation, and interfacial crud, should be observed during testing. Valence adjustment of neptunium (V) will need to be studied to move neptunium into an extractable state. These tests and observations should be made with as many different actual tank wastes as practical, because significant differences have been observed with the dissolved sludge solutions tested so far.

A combined TRU precipitation and IX concept that also removes strontium from the dissolved sludge solution also appears to be worthy of experimental testing. This concept uses oxalate precipitation to remove the bulk of the TRUs and strontium from solution; the oxalate precipitates could then be calcined before the TRU and strontium are sent for HLW vitrification. Lanthanide elements plus calcium and barium would also be sent to the HLW fraction. The supernatant solution would be treated by IX to lower the TRUs and strontium to the levels required for LLW vitrification; oxalate complexing of inert elements such as iron, zirconium, and aluminum would minimize their sorption by the IX resin and they would be treated as LLW. The IX elements would be eluted from the resin with nitric acid and recycled to the dissolution step. The TRU removal aspects of this concept were examined ~20 years ago at Oak Ridge National Laboratory (ORNL); the high concentrations of calcium (and barium) in Hanford Site tank wastes suggests that strontium removal could also be effected by carrier precipitation with calcium oxalate.

6.4.4.4 Remove Strontium from Acidic Solutions

The removal of strontium from the acidic, dissolved sludge solution may be required to 1) allow the LLW melter to be contact maintained and 2) to meet LLW disposal criteria, as well as ALARA considerations. Several technologies are available to remove strontium from dissolved sludge solutions. Solvent extraction using crown ethers (the SREX process), either alone or as mixed TRUEX/SREX or mixed PUREX/SREX solvents, shows promise in laboratory tests with simulated wastes. These approaches would be tested as described for TRU removal. Solvent extraction using a cobalt-dicarbollide-based solvent is used in Russia; whether or not this solvent is suitable for use in the United States is being addressed in an Office of Technology Development (OTD) program.

These and other candidate extractants, either sorbed or bound to solid substances, could also be used in packed column operations. A combined precipitation and IX concept for removing strontium as well as TRUs was described in Section 6.3.4.3. Solid sorbents such as CSTs may also be useful, especially if they can be used in a column mode.

Data for each of these technologies are needed to compare their potential application in actual processing. This work can be done using simulant solutions over a range of compositions likely to be present when processing Hanford Site waste. Demonstration using actual waste samples should be performed at the laboratory scale to verify simulant testing. Appropriate engineering-scale testing should follow to provide scale-up factors for plant design. Data should be collected to predict long-term stability of reagents, and ES&H and economic factors should be analyzed.

6.4.4.5 Remove Technetium from Acidic Solutions

Depending on the results of PA analyses to determine what fraction of the technetium can be present in the LLW, and on characterization results for the fraction of technetium present in the sludge, it also may be necessary to remove technetium from dissolved sludge solutions. The technetium can be removed using many of the solvent extraction processes that might be used for removing TRUs and strontium, as well as other extraction processes (e.g., quaternary ammonium salts). Removal can be achieved either in the liquid/liquid mode or the liquid/solid mode with the extractant sorbed onto or bound to a solid support. Anion exchange processes could also be used. If the dissolved sludge solution is neutralized after removing most radionuclides of concern, it is likely that technetium would remain in the liquid phase and could be removed by alkaline-side processes, as discussed previously.

Data for each of these technologies are needed to compare their potential application in actual processing. This work can be done using simulant solutions over a range of compositions likely to be present when processing Hanford Site waste. Demonstration using actual waste samples should be performed at the laboratory scale to verify simulant testing. Appropriate engineering-scale testing should follow to provide scale-up factors for plant design. Data should be collected to predict long-term stability of reagents, and ES&H and economic factors should be analyzed.

6.4.4.6 Remove Cesium from Acidic Solutions

Removing cesium from acidic solutions produced during sludge dissolution may be required to meet as-yet-unspecified criteria for LLW feed vitrification. The amount of cesium remaining in the sludge following washing and enhanced sludge washing steps is unknown, but is expected to be higher than the limit for LLW vitrification. While relatively well-developed technologies exist for removing cesium from alkaline solutions, only less developed technologies are available for its removal from acidic solutions. Technologies available include precipitation (phosphotungstic acid and metal ferrocyanides), IX [ammonium molybdophosphate (AMP) and CST], and solvent extraction using crown ethers or cobalt dicarbollide. Of these technologies, only precipitation has been used on a large scale. Precipitation processes have inherent disadvantages, such as batch operation and the need for using solid/liquid separation techniques. Ion exchange sorbents such as AMP and CST have a high affinity for cesium, but cannot be eluted and presently are not available for column operation. Removal of cesium by solvent extraction with crown ethers has been studied recently on simulated wastes, but has not been demonstrated on actual wastes. Removal of cesium (and strontium) by solvent extraction with a cobalt dicarbollide-based solvent is being practiced in Russia; whether this solvent is suitable for use in the United States is being addressed in an OTD program.

Key development issues for precipitation processes involve determining DFs for specific precipitants on actual waste samples and developing solids/liquid separation equipment. IX processes require development of engineering supports for CST and/or AMP, determination of distribution coefficients for each sorbent, and establishment of breakthrough curves for each sorbent in a column. Both CST and AMP contain elements with limited solubility in glass, and use of either must be carefully considered. Cesium solvent extraction processes would require determination of distribution coefficients and observation of important operations aspects such as phase disengagement, third-phase formation, and interfacial crud formation. Tests for all separations technologies should be done using as many different tank wastes as practical, because significant differences exist between tanks.

6.4.4.7 Tasks within the HLW Pretreatment Development for Enhancements and Alternatives include:

Conduct non-thermal reconstitution tests, FY 1994-95 cores (PNL). Small-scale (approximately 5 grams) testing on a variety of sludges will be necessary over a wide range of experimental conditions. Investigations will include various acid dissolution conditions to dissolve sludge; the dissolved sludge components will then be reprecipated by addition of caustic; and the reprecipated materials will be subjected to leach tests as in task 1.1.1.3.01.02.03.1 (sludge wash/caustic leach).

Conduct non-thermal reconstitution tests, FY 1995 - outyears cores (PNL). Small scale (approximately 5 grams) testing on a variety of sludges will be necessary over a wide range of experimental conditions. Investigations will include various acid dissolution conditions to dissolve sludge; the dissolved sludge components will then be reprecipated by addition of caustic; and the reprecipated materials will be subjected to leach tests as in task 1.1.1.3.01·.02.03.1 (sludge wash/caustic leach).

6.4.5 Engineering Studies and Functions and Requirements (F&R)

The focus of the effort in this activity centers on the definition of functions and requirements (F&Rs) and on trade studies and evaluations. Consequently, the focus of the effort is not on technology and technology development. **The entire scope and range of tasks in this activity are presented for informational background purposes. Tasks that are considered directly related to technology and technology development are presented at the end of the narrative.**

All engineering studies and F&Rs will provide additional assurance that processes are developed in a timely and cost effective manner to support the following Program goals:

- design, construction, and operation of a LLW pretreatment facility and production of acceptable feed for treatment in a LLW vitrified waste form that will meet all requirements for disposal as a LLW form
- design, construction, and operation of a HLW pretreatment facility to treat the HLW form that will meet the requirements for geologic disposal
- evaluation of enhanced sludge washing.

This activity includes performance of the necessary engineering evaluations to support:

1. Preparation of a LLW pretreatment Design Requirement Document (DRD) in support of a conceptual design report (CDR) completion in FY 1996. The milestones are based on the logic that development of good F&R documents is an iterative process requiring intensive engineering support.
2. Preparation of a HLW pretreatment F&R in support of a FY 1998 completion of the HLW pretreatment facility CDR as well as the performance of a process test of sludge washing in-tank 101-AZ using the mixer pumps installed under project W-151. The milestones for the engineering evaluations are based on the logic that development of good F&R documents is an iterative process requiring intensive engineering support. The in-tank sludge washing tests are expected to be completed in FY 1997. Based upon the results of these tests and overall systems response modeling done in Block 00, the F&R for in-tank processing would be prepared. It is expected that further process tests will be developed for enhanced sludge washing (caustic leach) in other tanks.

The scope of this activity also includes the following:

- Conduct Systems Engineering & Trade Studies
    - Identify alternative facility configuration options for LLW and HLW pretreatment and vitrification processes, identify advantages and disadvantages of the various options, and recommend preferred options. These activities are performed by identifying facility functions and requirements, identifying and reviewing alternative options, and preparing preliminary cost estimates for each option. Engineering studies will be performed to comply with the criteria for the option selection process. In addition, assessments of specific systems, subsystems, and component implementations will be conducted to optimize plant performance and adapt to changing operating conditions and/or requirements.
- Define DRD for LLW Pretreatment Facility
    - Develop LLW pretreatment process and facility requirements, identify necessary engineering studies, and identify the technology development needs for pretreatment.
- Define F&R for In-Tank Processes
    - Provide all necessary engineering support to evaluate and implement in-tank washing. Included are trade activities, including program element management, planning, studies, technical evaluations, process tests, and other necessary activities.
- Define F&R for the HLW Pretreatment Facility
    - Develop HLW pretreatment process and facility functions and requirements, identify and perform necessary engineering studies, prepare process and facility design criteria, and identify technology development needs for HLW pretreatment. Provide engineering support during the conceptual design and advanced conceptual design phases of the HLW pretreatment facility(ies).

<u>Technologies to be assessed:</u>

- Applied engineering for technologies to be assessed as they are identified. Specific technology development activities are addressed in WBS 1.1.1.3.01.02 (Level V).

<u>Options to be considered:</u>

- Waste pretreatment facility options include:
    - centralized LLW and HLW pretreatment facility
    - stand alone LLW and HLW pretreatment facilities
    - dispersed pretreatment module
    - colocated with the LLW and HLW vitrification facilities
    - colocated with either the LLW or the HLW vitrification facility.

<u>Technology and Technology Development-Related Tasks:</u>

- Retrieval Sequence and Blending Strategy

- In-Tank Sludge Washing Technical Support
- Thermal Reconstitution Process Chemistry Development
- Determine Waste Processing Strategy
- In-Tank Sludge Washing Process Test
- Thermal Reconstitution of Tank Waste Sludge
- Evaluate Process Alternatives

6.4.6 Applied Technology, W-236B Pretreatment Facility (Initial Pretreatment Module)

The focus of this activity is on the testing and the evaluation that will provide the necessary data to make recommendations to be incorporated in the design of the LLW pretreatment facility. Consequently, the focus of effort is not on technology and technology development. **The entire scope and range of tasks in this activity are presented for informational background purposes. Tasks that are considered directly related to technology and technology development are presented at the end of the narrative.**

Process Testing: The primary goal of LLW pretreatment is the removal of cesium (and potentially technetium, strontium, and transuranics [TRUs]) from the tank waste supernatant, the liquid from the solids/ liquid separations, and the liquids produced from the HLW pretreatment process. The processes needed for LLW pretreatment must be tested to determine the design specifications and to validate proper operation of the processes selected. The process testing requirements are influenced by the feed specifications for the LLW vitrification facility. The testing and evaluation of the processes will provide the necessary data to make recommendations concerning process selection, exchanger selection, process operating conditions, and process operating efficiency to support project design activities.

Equipment Testing: The primary goal of LLW pretreatment is the removal of cesium (and potentially technetium, strontium, and TRUs) from the tank waste supernatant, the liquid from the solids/liquid separations and the liquids produced from the HLW pretreatment process. The equipment needed for LLW pretreatment must be tested and evaluated to ensure proper performance and execution of task. The equipment requirements are influenced by the design and feed specifications for the LLW vitrification facility. The testing and evaluation will provide the necessary data to make recommendations to be incorporated in the design of the LLW pretreatment facility.

Equipment-truck: The primary goal of this cost account is to purchase a sludge sampler truck for use in the operation of a 25-liter sludge and supernatant sampler. The need exists for larger samples of actual waste to support bench-scale and pilot plant testing. Currently, there is no existing vehicle to fulfill this need. The sampling device is being prepared by the retrieval organization.

This task will also purchase sample casks and liners for transporting the sampled waste material across the Hanford Site for delivery to the testing facilities. The cask design is being prepared by WHC Transportation during FY 1994.

TRU Monitor: During the pretreatment of tank liquids, the level of TRUs must be monitored to determine the levels of TRU in the material being fed to the LLW Vitrification facility. The TRU monitor is a device to measure concentration levels of TRU in a process stream. The TRU monitor will ultimately be used as an on-line process control instrument to verify levels of TRU going to the LLW vitrification facility. This device will allow close coupling of the LLW pretreatment facility with the LLW vitrification facility. In addition, the confidence that non-TRU LLW glass will be made is much greater than can be achieved with random sampling or batch tank sampling. The advantages of using this device to measure TRU content include:

- rapid turnaround of analyses
- large number of sample points per million gallons of product at less cost. (over 3,000 data points per 1,000,000 gallons of liquid versus 10 samples per 1,000,000 tank)
- can be integrated into process control for rapid segregation of off-specification material
- less operator exposure (samples only need to be taken to calibrate instruments periodically)

Technologies to be assessed in this technology package are listed below.

- Solid/liquid separations and polishing filtration
  - in-tank settling
  - centrifuge
  - inclined pipe
  - hydropulse filter
  - cross-flow filters
  - effect of flocculants and filter precoats.
- Cesium ion exchange
  - cesium-100 resin-based process (conceptual design reference)
  - R-F resin (Savannah River Technology Center-developed)
  - CST exchanger [Sandia National Laboratory, Texas A&M University, and UOP, Inc., developed and sponsored, in part by Efficient Separations Integrated Program (ESPIP) (EM-50) and TWRS]
  - super Lig exchangers [IBC/3M Company-developed, Efficient Separations Processes Integrated Program (ESPIP) (EM-50) sponsored]
  - other developed exchangers available at selection time.
- Technetium separations
  - Process(es) as developed by the Technology Development Program Office (TDPO) for the Pretreatment Program (ADS 1220)
- Strontium separations
  - Process(es) as developed by the TDPO for the Pretreatment Program (ADS 1220)
- TRU separations
  - Process(es) as developed by the TDPO for the Pretreatment Program (ADS 1220)

6.4.6.1 Tasks within the Applied Technology, W-236B Pretreatment Facility include:

Equipment Testing

- **Equipment Testing Evaluation and Oversight**. The equipment necessary to perform the pretreatment of supernatant requires testing to ensure that all needs of the supernatant pretreatment are met. This activity will also be involved with the development of equipment test plans and analysis of test data. Tank waste material for testing purposes will be identified and obtained. This activity will also provide F&Rs for project required test facilities and design review support for test facilities.

- **Gross Solids\Liquid Separations**. The solids\liquid separations equipment must be tested and recommended to ensure the removal of gross entrained particulates. The equipment to be tested are settling, centrifuge, incline pipe, and hydro-pulse filter. The test data will be evaluated and recommendations based on the test data will be presented. The characterization data relating to the solids characteristics will also be evaluated and validated.

- **Supernatant Colloid Evaluation and Polishing Filtration**. The solids\liquid separations equipment must be tested for the removal of fine colloidal particles.

- **IX Column Equipment Testing**. Perform equipment testing of cesium IX to determine resin characteristics in test bed with respect to repeated cycling. Test various components of process (i.e., valves) to determine leakage characteristics of equipment.

- **Instrumentation and Process Control Testing**. Testing of process system to verify process control system operations during all phases of operation including startup and abnormal conditions. Process control equipment (i.e., TRU monitor) must be tested to determine instrument sensitivity and reproducibility under process conditions.

- **Operations Support Testing and Training**. Full-scale systems must be provided for development of operating procedures, development of maintenance procedures, and training of operations staff.

Sludge Sampler Truck (CENRTC). plutoniumrchase a 25 liter sludge sampler truck with CENRTC funds.

Transportation Casks and Liners (CENRTC). plutoniumrchase 2 sample casks and liners based on recommendation of WHC Transportation.

TRU Monitor (CENRTC). Design and procure TRU monitor for hot testing in conjunction with in-tank washing tests.

Applied Process Testing. Support process testing of candidate processes to develop criteria for selection of preferred processes, including exchanger selection if applicable. In addition, this task will interface with other DOE-funded technology development activities to help support refinement of their testing programs to provide appropriate data for inclusion into process and/or exchanger selection. Upon selection of process and/or exchanger perform testing to develop all A/E identified design data. In addition, this WBS activity will support process validation.

- Several cesium ion exchangers will be tested over the conceptual design period. The exchangers identified include CS-100 (reference), R-F resin, and the engineered form of CST.

- Initial testing of processes to separate technetium, strontium, and TRU radionuclides is being provided by ADS 1220. Once the processes are selected, this WBS activity will develop the needed design information.

6.4.7 LLW Pretreatment Development for Reference Process (Unfunded Tasks)

The primary goal of this activity is to develop the reference LLW pretreatment process. The primary function of the reference process is cesium removal using an IX process. This section describes work that is not currently funded at levels recommended by the TDPO Review. Specific tasks may or may not be identified in the current MYWP. This activity currently only identifies tasks not included in the current MYWP. These tasks are presented for the first time in this section and also in an Template 6.4.7 in Appendix E (Chapter 6.0).

Section 6.4.1 presents background information for this set of tasks.

6.4.7.1 Tasks within the LLW Pretreatment Development for Reference Process (Unfunded Tasks) include:

Competing Ion Effect Studies. Conduct competing ion studies with standard exchangers. Extensive and systematic batch tests should be run with viable cesium IX materials to determine the effects of minor component ions anticipated to be present in supernatant, dissolved saltcake solutions, and sludge leach and wash solutions on cesium loading capacity and selectivity. Among the components of concern are potassium, calcium, and magnesium ions for supernatant and dissolved saltcake and chromium and permanganate ions for sludge leach and wash solutions. These tests should employ synthetic waste solutions at several sodium concentrations.

Evaporation/Concentration of Process Streams. Studies are needed for the evaporation/concentration processes planned for supernate, dissolved saltcake solutions, and sludge leach and wash solutions to determine the extent of scaling and precipitation during processing. Initial work should include development of a needs document and experimental plan for the reference flow sheet. Subsequently, experimental studies with synthetic waste solutions with concentrations spanning the expected range to determine potential for fouling crud and precipitation. A predictive model should be developed based on the experimental studies. Pilot demonstrations first with synthetic and then with real wastes should be done to validate the model and synthetic studies.

6.4.8 LLW Pretreatment Development for Enhancements and Alternatives (Unfunded Tasks)

The primary goal of this activity is to develop enhancements and alternatives to the reference LLW pretreatment process. The specific objective is to select the most promising technologies and develop engineering data for these processes that will remove strontium, TRU, and technetium from supernate, dissolved saltcake, and sludge wash and leach solutions. The removal of technetium from the supernatant and the solutions from sludge leaching/metathesis and washing may be required to meet performance assessment problems for the LLW glass due to migration of technetium. Technetium has a long half life (210,000 years) and is mobile in the environment. Removal of TRUs may be required from the standpoint of both LLW definition and performance assessment criteria. Removal of strontium may be required to meet ALARA requirements and to allow for the feasibility of a lightly shielded, possibly contact-maintained, LLW vitrification plant.

This section describes work that is not currently funded at levels recommended by the TDPO Review. Specific tasks may or may not be identified in the current MYWP. This activity currently identifies tasks not included in the current MYWP: they are presented for the first time in this section and also in Template 6.4.8 in Appendix E (Chapter 6.0).

Section 6.4.2 presents background information for this set of tasks.

6.4.8.1 Tasks within the LLW Pretreatment Development for Enhancements and Alternatives (Unfunded Tasks) include:

Determine the Effectiveness of Competition Reactions to Overcome Effects of Organic Complexants on Strontium and TRU Removal. Determine whether it is feasible to use other complexable cations to replace strontium cations. Organic compounds increase the solubility of strontium and/or TRU elements by forming complexes with the metal ions. Other metal ions, e.g., calcium, iron, nickel, or natural strontium can be added, which can replace the radioisotopes from the complexes allowing them to be separated from the solutions. Adjustment of the pH of the solution could change the complexation equilibrium sufficiently to allow precipitation of strontium and TRU elements. Blending and dilution with other waste solutions should be studied as a source of competitive ions or to provide the pH adjustment needed to allow removal of strontium and TRU elements for the solutions.

Uranium Removal from Supernatant. Add this emphasis to existing TRU removal studies.

Study Removal of Cesium and Technetium by Volatilization during Calcination. Conduct tests to determine the feasibility of achieving efficient volatilization of cesium and technetium during calcination of supernatant, dissolved saltcake, and leach and wash solutions before vitrification.

Competing Ion Studies for Technetium IX. Perform batch and column tests with synthetic waste solutions to evaluate the effects of competing ions on technetium loading capacity and selectivity. Among the components of concern are nitrate, nitrite, carbonate, sulfate, phosphate, silicate, chromate, and permanganate ions. These tests should employ solution compositions covering those of several typical waste solutions.

Study Additional Technetium IX Materials. Alternative IX materials should be studied to determine if viable, more efficient/more readily elutable materials are available.

Study Precipitation/Reduction Methods for Removal of Technetium. Alternative approaches for the removal of technetium that involve the reduction of the pertechnetate ion and ultimate precipitation into a stable, nonvolatile form should be investigated. Possible precipitants and reductants need to be evaluated for suitability in decontaminating supernatant, dissolved saltcake, and sludge wash and leach solutions from technetium. Reduction methods should include chemical (e.g., zinc) and eletrochemical. The studies should not neglect the possibility of redissolution of the precipitate or metal. The two-three best approaches should be selected for further study with synthetic wastes spiked with technetium and with real waste.

6.4.9 HLW Pretreatment Development for Reference Process (Unfunded Tasks)

Washing of sludge with water is necessary to dissolve salts and remove the interstitial liquid, containing dissolved salts, from the water-insoluble sludge components. In this manner these dissolved salt components do not contribute to the volume of the HLW glass produced on vitrification of the sludge. Leaching and metathesis steps to remove some water-insoluble sludge components may be performed either before or after initial washing of the sludge. Effectiveness and efficiency of removing sludge components must be determined to allow estimation of resulting HLW volumes. Reagent concentrations, operating conditions, and equipment must also be determined.

This section describes work that is not currently funded at levels recommended by the TDPO Review. Specific tasks may or may not be identified in the current MYWP. This activity currently only identifies tasks not included in the current MYWP. These tasks are presented for the first time in this section and also in Template 6.4.9 in Appendix E (Chapter 6.0).

Section 6.4.3 presents background information for this set of tasks.

6.4.9.1 Tasks within the HLW Pretreatment Development for Reference Process (Unfunded Tasks) include:

Retrieval Chemistry Impacts on HLW Glass Volume. The mixing of different types of wastes during retrieval (or storage before pretreatment) can have bad as well as good impacts on the HLW glass volume.

One potential example is the formation of additional calcium phosphate, which would increase the quantity of phosphate remaining after caustic leaching. The potential for other adverse reactions should be examined and candidate mixes should be evaluated experimentally, first with synthetic wastes and then with actual wastes. Another aspect of this study should be the chemistry of chemicals that may be proposed to be added to aid waste retrieval and transfer operations, relative to their behavior in pretreatment operations and their impacts on HLW glass volume.

Evaporation/Concentration of Eluted Cesium Product. Studies are needed of the evaporation of the cesium solution eluted from IX in LLW pretreatment to determine whether or not fouling and precipitation are a problem.

Glass Frit Filters Lifetime Studies. The present reference flowsheet includes filtration of fine solids from liquids with glass frit that is then sent to the HLW vitrifier. These highly caustic liquids will dissolve the glass from the filter over a period of time. Studies are needed of the rate of dissolution of the glass frit so the lifetime of the filter can be determined if this type of filter is selected. Initial work will be with simulant solutions followed by work with actual waste solutions and solids.

6.4.10 HLW Pretreatment Development for Enhancements and Alternatives (Unfunded Tasks)

The primary goal of this activity is to develop enhancements and alternatives to the reference HLW pretreatment process. The specific objective of this activity is to select the most promising technologies and develop engineering data for these processes that will decrease the quantity of the nonradioactive waste components that must be disposed in the HLW. Potential alternatives being investigated include reconstitution of the sludge by acid dissolution, reneutralization and subsequent alkaline leaching; and acid dissolution followed by separation of radionuclides by solvent extraction or IX.

The current U.S. Department of Energy (DOE) planning basis for TWRS assumes that alkaline leaching and metathesis of sludges can be done effectively. The plan assumes that a reasonable volume of HLW glass will result from the vitrification of the treated sludges. This, however, may not be what really happens. Some important HLW-glass-volume-limiting components of the sludge may not be sufficiently removed by simple sludge washing and alkaline leaching and metathesis. These components are present in chemical forms that may not be sufficiently dissolved in typical wash/alkaline solutions. The components are expected to be dissolved in acid media, leading to the thesis that dissolution can be enhanced by acid dissolution followed by reneutralization (reconstitution of sludge). This could destroy "aged" crystals that are much less easy to dissolve.

At the TWRS Baseline Program funding level, no funding was provided for the acid dissolution of sludge. The acid dissolution of sludge is a potential enhancement for sludge washing and alkaline leaching (enhanced washing). Because only limited data are available on alkaline leaching of actual sludges, the effectiveness of alkaline leaching is not well known. If alkaline leaching is not effective, significant quantities of HLW glass would be produced. This could have a negative impact on the overall disposal cost. Thus, the impact of limited funding for acid dissolution is a higher risk that acceptable quantities of HLW glass will be produced. Also, with limited funding between now and the 3/98 decision on advanced sludge processing, the quality of the 3/98 decision will be reduced because the assumptions will need to be made with limited data on acid dissolution. TDPO and the Pretreatment Subgroup of the Waste Processing Architecture Group (WPAG) recommend funding acid dissolution studies at approximately 500K for FY 1995, FY 1996, and FY 1997 to provide an experimental determination/evaluation of the upper limit potential for acid-side separations processes.

This section describes work that is not currently funded at levels recommended by the TDPO Review. Specific tasks may or may not be identified in the current MYWP. As such, two types of tasks are included: 1) those initially contained in the MYWP but whose funding was eliminated and 2) those never included in the current MYWP. These tasks are presented for the first time in this section and also in Template 6.4.10 in Appendix E (Chapter 6.0).

Section 6.4.4 presents the background information (for this set of tasks).

6.4.10.1 Tasks within the HLW Pretreatment Development for Enhancements and Alternatives (Unfunded Tasks) include:

Conduct acid dissolution tests with actual sludges, FY 1994-95 cores (PNL). Laboratory batch testing on a variety of sludges will be necessary over a wide range of experimental conditions. Investigation will include use of specified reagents, varying the periods of time for reaction, and varying temperature. Reagents will include nitric acid, nitric/oxalic acid mixes, and nitric/hydrofluoric acid mixes. Distribution of key components between the solutions and the residue solids will be determined. Results of these tests will allow the necessary optimizations/tradeoffs necessary to determine operating conditions for sludge dissolutions and will allow accurate projection of HLW volume. Test-tube level experiments will be the major focus of this activity. These studies could provide feed material for batch solvent extraction and IX tests.

Conduct acid dissolution tests with actual sludges, FY 1995 - outyears cores (PNL). Laboratory batch testing on a variety of sludges will be necessary over a wide range of experimental conditions. Investigation will include use of specified reagents, varying the periods of time for reaction, and varying temperature. Reagents will include nitric acid, nitric/oxalic acid mixes, and nitric/hydrofluoric acid mixes. Distribution of key components between the solutions and the residue solids will be determined. Results of these tests will allow the optimizations/tradeoffs to determine operating conditions for sludge dissolutions and will allow accurate projection of HLW volume. Test-tube level experiments will be the major focus of this activity. These studies could provide feed material for batch solvent extraction and IX tests.

Conduct batch solvent extraction tests for strontium and TRU removal, FY 1994-95 cores (PNL). Laboratory batch testing on a variety of acid-dissolved sludges will be necessary over a wide range of experimental conditions. Investigations will include use of specific immiscible (second liquid phase) chemical and chemical mixtures for extracting strontium and TRUs from acidic solutions. Separation/partitioning coefficients will be determined and the potential for interfacial crud and/or third phase formation will be assessed. Results of these tests will allow accurate projection of HLW volume. Test-tube level experiments will be the major focus of this activity.

Conduct batch solvent extraction tests for strontium and TRU removal, FY 1995-outyears cores (PNL). Laboratory batch testing on a variety of acid-dissolved sludges will be necessary over a wide range of experimental conditions. Investigations will include use of specific immiscible (second liquid phase) chemical and chemical mixtures for extracting strontium and TRUs from acidic solutions. Separation/partitioning coefficients will be determined and the potential for interfacial crud and/or third phase formation will be assessed. Results of these tests will allow accurate projection of HLW volume. Test-tube level experiments will be the major focus of this activity.

Conduct tests on alternatives to acid side solvent extraction (PNL). Laboratory batch testing on acid-dissolved sludges will be necessary over a range of experimental conditions. Emphasis will be on alternative methods to solvent extraction techniques for removal of cesium, strontium, technetium and/or TRUs. Test-tube level experiments will be the major focus of this activity over the next year.

Conduct bench-scale solvent extraction study, cold systems, FY 1995 tests (PNL). Laboratory bench-scale testing on a variety of acid-dissolved sludges could be necessary over a wide range of experimental conditions. A facility to conduct tests using simulated waste was constructed in 1994. Cold testing in that facility could start in FY 1995. Hot testing should start in FY 1997.

Conduct bench-scale solvent extraction studies, cold systems, FY 1996 - outyears tests (PNL). Laboratory bench scale testing on a variety of acid-dissolved sludges could be necessary over a wide range of experimental conditions. A facility to conduct tests using simulated waste was constructed in 1994 and will be available for such testing.

Conduct bench-scale solvent extraction system, design hot system, FY 1995 (PNL). Laboratory bench scale testing on a variety of acid-dissolved sludges could be necessary over a wide range of experimental conditions. A facility to conduct tests using actual wastes could be designed in 1996, building on the experience gained in building a cold testing facility in 1994.

Conduct bench-scale solvent extraction system, construct hot system, FY 1995-97 (PNL). Laboratory bench-scale testing on a variety of acid-dissolved sludges could be necessary over a wide range of experimental conditions. A facility to conduct tests using actual wastes could be constructed in 1996 and 1997 following design completion in 1996.

Conduct bench-scale solvent extraction system, hot system, FY 1998 (PNL). Laboratory bench-scale testing on a variety of acid-dissolved sludges could be necessary over a wide range of experimental conditions. A facility to conduct tests using actual wastes could be constructed in 1996 and 1997 following design completion in 1995. Hot testing should start in FY 1998. **Note:** The previous three tasks (xx.10, xx.11, xx.12) are all part of an integrated project. All or none of these tasks must be funded.

Develop acid-side cesium solvent extraction system (ANL). A new solvent extraction process for extraction cesium from solutions whose compositions are similar to acid-dissolved Hanford sludges shall be developed.

Conduct tests using actual waste with an acid-side cesium extraction system (PNL). Test the solvent extraction process system developed at ANL for extracting cesium from solutions whose compositions are similar to acid-dissolved Hanford Site sludges. Tests will be conducted using simulants for checkout followed by actual waste.

Conduct acid-side cesium removal test using CST and actual waste for batch (PNL). Laboratory batch testing on a variety of acid dissolved sludges will be necessary. Investigations will determine the effectiveness of CSTs in removing cesium from acid-dissolved sludge solutions. Effectiveness in removing strontium and transuranic elements will also be assessed. Separation/partitioning coefficients (Kds) will be determined. Results of these tests will allow the necessary optimizations/tradeoffs necessary to determine operating conditions for sludge dissolution and will allow accurate projection of HLW volumes. Test-tube level experiments will be the major focus of this activity.

Conduct acid-side cesium removal test using CST and actual waste for column (PNL). Laboratory batch testing on a variety of acid-dissolved sludges will be necessary. Investigations will determine the effectiveness of CSTs in removing cesium from acid-dissolved sludge solutions. Effectiveness in removing strontium and TRU elements will also be assessed. Separation/partitioning coefficients (Kds) will be determined. Results of these tests will allow the necessary optimizations/tradeoffs necessary to determine operating conditions for sludge dissolution and will allow accurate projection of HLW volumes. Small columns, large enough for determining scaling parameters, will be the major focus of these tests.

Update generic TRUEX model (ANL). The generic TRUEX model must be updated to accommodate technical revisions/updates to properly consider the case of Hanford Site tank waste sludges that are dissolved in acid and subsequently extracted. Emphasis should be placed on TRUEX, SREX, and CSEX. This effort will permit accurate modeling and thus allows accurate tradeoffs in basic design/approach for pretreating sludge wastes. Results of this effort will allow the necessary optimizations/tradeoffs necessary to determine operating conditions for solvent extraction and will facilitate projections of HLW volume.

Improved Solid/Liquid Separation through Addition of Co-precipitants. Studies of addition of various metal ions (for example, ferric ion) to waste slurries to form precipitates, which adsorb or carry fine solids, thus improving solution clarification.

Treatment of Residue from Acidic Dissolutions. Tests of acid dissolution of sludge may result in residues that are not readily soluble, but retain radionuclides. Such residues should be studied further to determine how to remove radionuclides or completely dissolve for further processing to reduce HLW glass volume. Studies should include electrochemical treatment to dissolve TRUs and caustic fusion to obtain complete dissolution.

Evaporation/Concentration of Separated Radionuclide Product Streams. If strontium and technetium removal from the LLW liquid stream is required by the PA, the removals will result in product streams that require evaporation before vitrification. Studies are needed to determine the composition of such streams, and the potential for mixing these streams with the cesium stream prior to evaporation. Depending on the impurities present experimental studies may be required to determine the potential for scale and precipitate formation during evaporation. Predictive models are needed for the concentrating process as well as pilot demonstrations with real waste.

Thermal reconstitution to improve caustic leaching. Studies of calcination/fusion of caustic waste sludges followed by treatment with water to reconstitute the sludge should be continued to define conditions for improving the caustic leaching process. Previous work has shown that fusion converts all the mineral phases in some sludges to soluble forms. Addition of water may either dissolve such components or form a fresh sludge from which components with low glass solubility such as aluminum, chromium, phosphate, and sulfate are more easily dissolved during caustic leaching.

6.5 EM-50/30 Related Activities

6.5.1 EM-50

The Office of Technology Development (OTD) (EM-50) is tasked with carrying out a national program of applied research and development to focus, manage, and accelerate the development and implementation of new and existing technologies to meet specific Environmental Restoration and Waste Management (ER/WM) requirements.

OTD activities have been identified that support pretreatment of Hanford Site waste retrieved from tanks before vitrification or other final treatment. These activities are coordinated primarily by the Underground Storage Tank Integrated Demonstration (UST-ID), Efficient Separations and Processing Integrated Program (ESP-IP), Mixed Waste Integrated Program (MW-IP), and the Supercritical Water Oxidation Program (SCWO).

Additionally, Characterization efforts in the area of real-time and near real-time analytical techniques hold potentially high payoff in direct cost savings in analyses and in processing flexibility; these effects should receive high priority support.

6.5.2 EM-30

The Office of Waste Management (EM-30) works with the OTD to develop innovative technologies for the treatment and disposal of present and future waste streams and for waste minimization. The broad range of EM-30 technology development activities supporting the Hanford TWRS is described in detail elsewhere.(a) The following paragraphs summarize the technical activities and associated costs by TWRS program element. EM-30 activities relating to the Waste Pretreatment Program are summarized below.

The technology development strategy for the Waste Pretreatment Program in FY 1995 is to continue studies of the effectiveness of sludge washing and leaching in reducing the volume of HLW glass, alternative sludge treatment processes, and the basic chemistry of sludges, and to maintain an aggressive technology

(a). Tank Waste Remediation System: *FY 94 Technology Development Plan*, TWRS Technology Development Program Office, January 5, 1994.

development program in the area of radionuclide removal from basic solutions (including TRUs, technetium, cesium, and strontium, and an assessment of the need for organic destruction to decomplex various radionuclides). EM-30 will invest approximately $15 million in FY 1995 developing these technologies. The LLW reference process technology package (cesium removal from supernatant, dissolved saltcake, and wash/leach solutions) has budgeted $2,004K. The HLW reference process technology package (enhanced sludge washing, sludge science, selective leaching, colloid studies, management/infrastructure) has budgeted $9,730K. The LLW enhancement/alternative processes technology package (strontium, TRU, technetium removal studies) has budgeted $4,059K. The HLW enhancement/alternative processes technology package has budgeted $1,005K.

6.6 Schedule and Budget

The schedule and budget for technology activities supporting the Waste Pretreatment Program are shown in Figure 6.3 and Table 6.3, respectively. Figure 6.3 identifies template activities, tasks within each template, deliverables, critical interfaces, and drivers (depicted to the right of each template activity bar). Table 6.3 presents two sets of budget estimates by program element and fiscal year. The first profile consists of activities currently included in the TWRS Multi-Year Work Plan (MYWP) and reflects the estimated budget available for technology. The second profile reflects the estimated budget required to perform all tasks shown in the ITP, including activities that are anticipated to be funded and those that are not (unfunded activities have been prioritized for inclusion in the MYWP at the first opportunity.)

6.7 Prioritization (Results)

Table 6.2 presented the functions, technology packages, tasks, FY 1996 budget costs and a brief statement regarding the benefit of funding these technology activities. For the Waste Pretreatment Program element, not all future technology work is funded within the scope of the TWRS Baseline Program for FY 1996 and beyond. This circumstance has forced the Pretreatment technology managers to prioritize the technology work into several categories to emphasize its relative importance to the Pretreatment program.

The Pretreatment templates contained twenty-five technology issues outside the scope of the Baseline Program. Five engineering studies were screened from the list and placed on their own template (these studies are unfunded and unprioritized). The remaining issues were pre-sorted by the Pretreatment Prioritization group into categories of critical program needs, important program needs, and issues that would not impact the design of processes or facilities. The six issues in the critical program needs were selected for prioritization using the process described in Appendix A.

The Pretreatment Prioritization team determined their relative attribute importance weights and then scored the six critical program issues. After discussion of multiple points of view within the context of the scoring exercise, the following prioritized list was agreed upon:

1. Determine the effectiveness of competition to overcome effects of organic complexants on strontium and TRU removal

2. Uranium Removal (supernatant)

3. Competing Ion Effect Studies

4/5. Retrieval Chemistry Impacts on HLW Glass Volume

4/5. Laboratory Tests of Blended Fraction to reflect flowsheet scenarios.

The sixth issue, Disposition of Spent or Loaded Cesium Sorbents, was thought to belong to High-Level Waste Immobilization and it was the determination of the Pretreatment Prioritization team that this task be handled by HLW.

The Pretreatment Prioritization team did not prioritize the remaining fourteen issues. While these issues are important, budget realities indicate that there is little hope that funding will extend to these issues. The Waste Processing Architecture Group (WPAG) and Pretreatment technology managers will advise the Pretreatment Program Office of the increased levels of risk inherent in not funding these issues. Risk mitigation plans can then be determined by the program office.

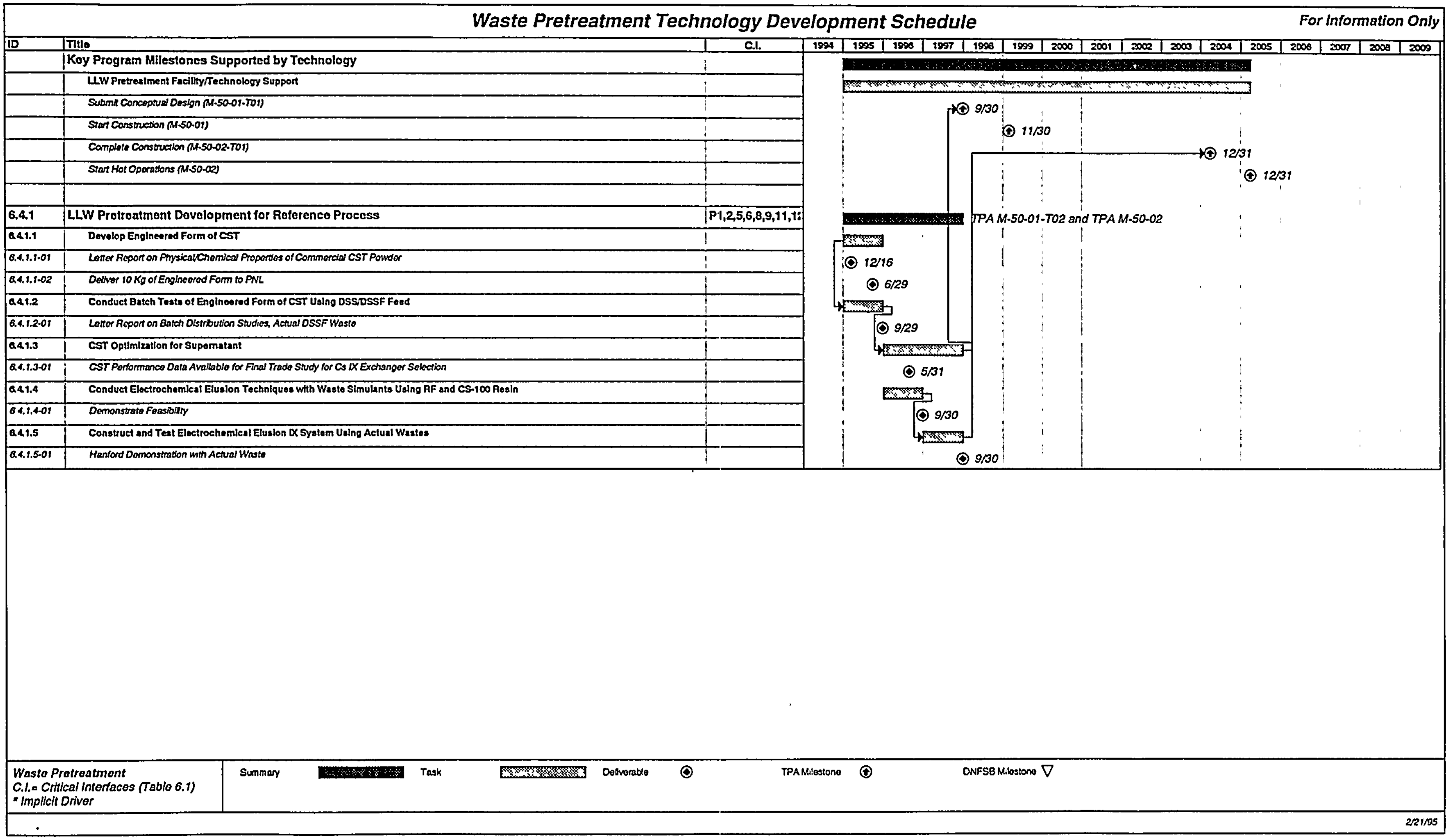
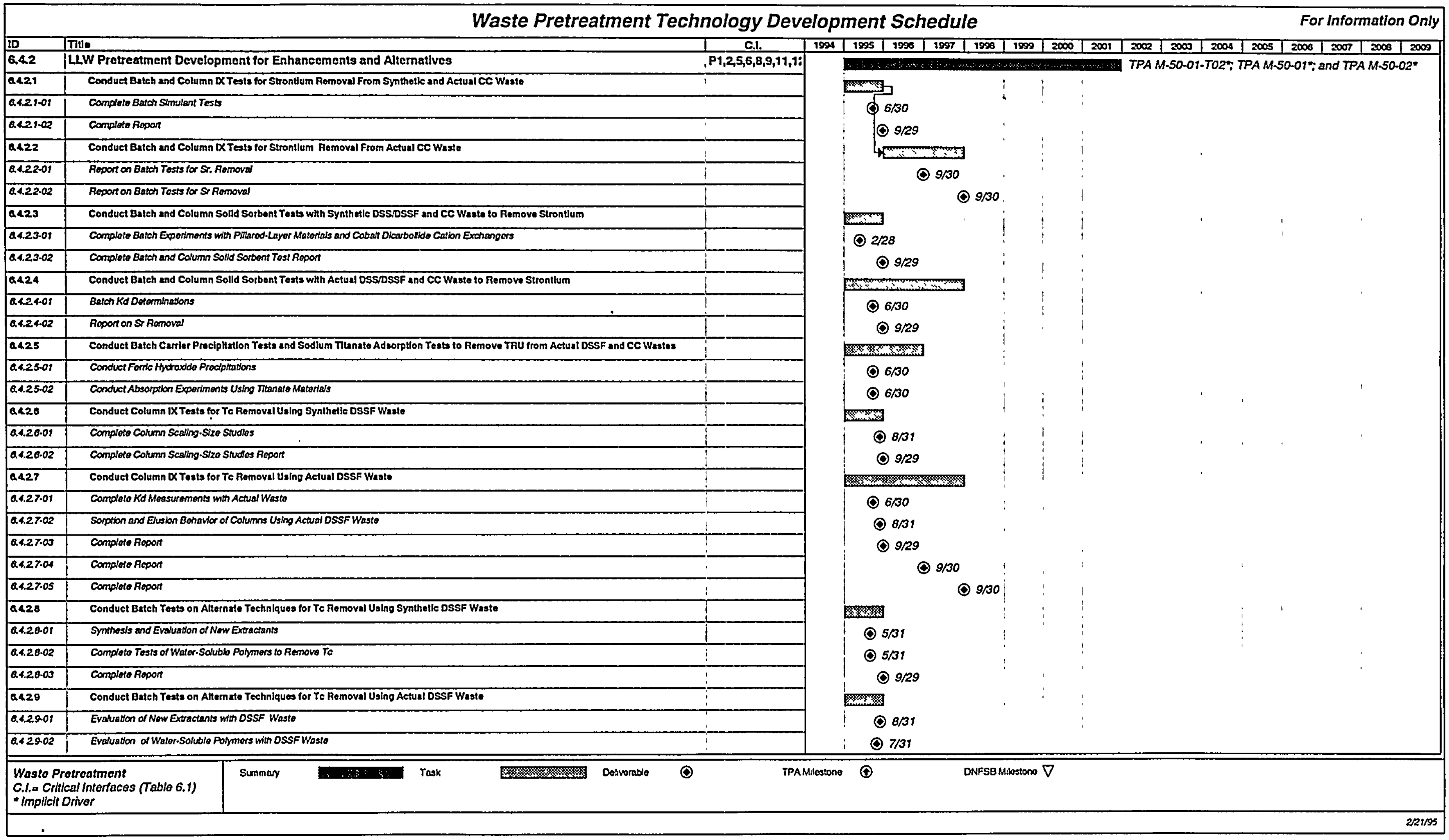


Figure 6.3. Schedule



Waste Pretreatment Technology Development Schedule

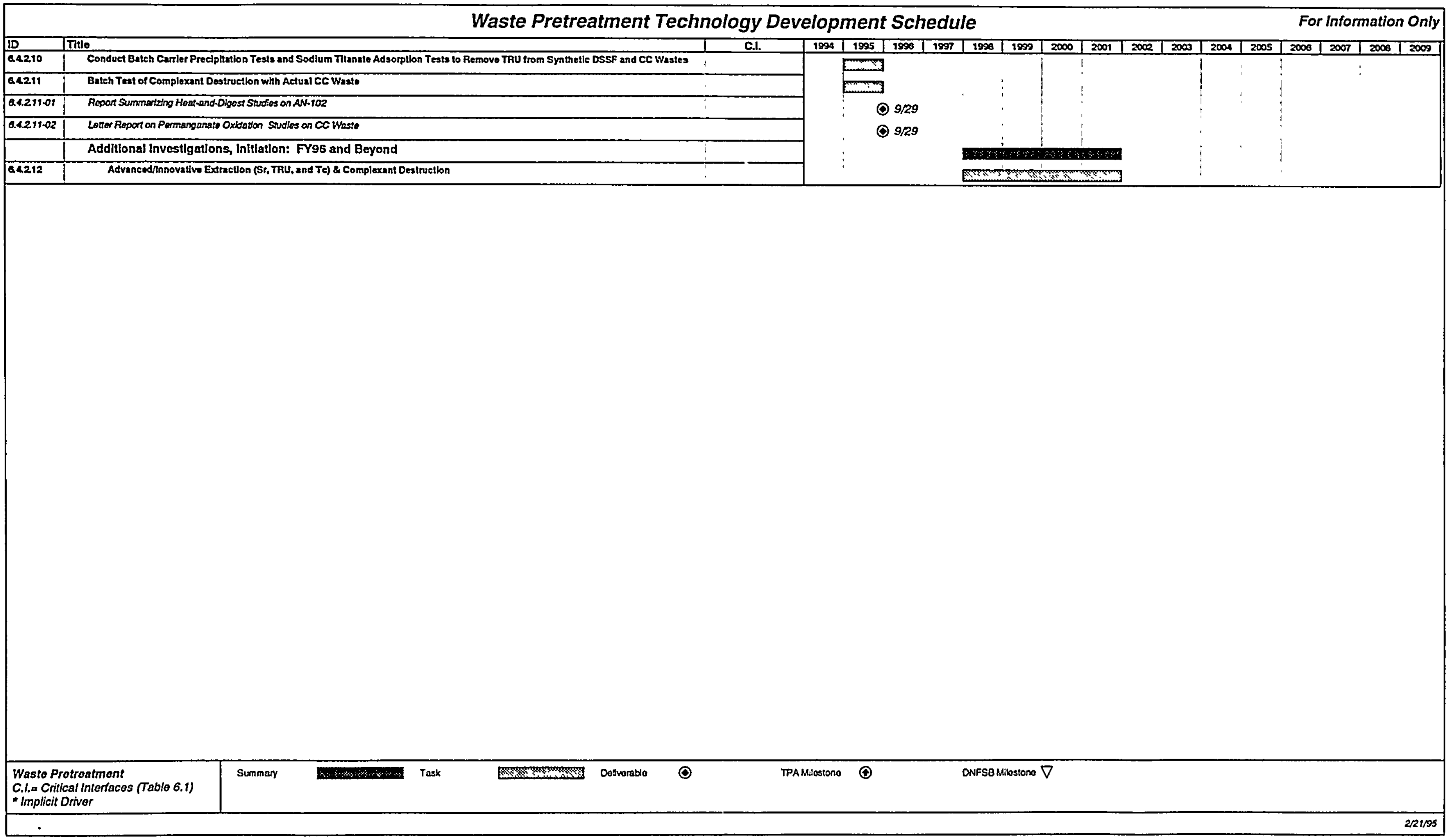
For Information Only

ID	Title	C.I.
6.4.2	LLW Pretreatment Development for Enhancements and Alternatives	P1,2,5,6,8,9,11,1
6.4.2.1	Conduct Batch and Column IX Tests for Strontium Removal From Synthetic and Actual CC Waste	
6.4.2.1-01	Complete Batch Simulant Tests	
6.4.2.1-02	Complete Report	
6.4.2.2	Conduct Batch and Column IX Tests for Strontium Removal From Actual CC Waste	
6.4.2.2-01	Report on Batch Tests for Sr. Removal	
6.4.2.2-02	Report on Batch Tests for Sr Removal	
6.4.2.3	Conduct Batch and Column Solid Sorbent Tests with Synthetic DSS/DSSF and CC Waste to Remove Strontium	
6.4.2.3-01	Complete Batch Experiments with Pillared-Layer Materials and Cobalt Dicarbollide Cation Exchangers	
6.4.2.3-02	Complete Batch and Column Solid Sorbent Test Report	
6.4.2.4	Conduct Batch and Column Solid Sorbent Tests with Actual DSS/DSSF and CC Waste to Remove Strontium	
6.4.2.4-01	Batch Kd Determinations	
6.4.2.4-02	Report on Sr Removal	
6.4.2.5	Conduct Batch Carrier Precipitation Tests and Sodium Titanate Adsorption Tests to Remove TRU from Actual DSSF and CC Wastes	
6.4.2.5-01	Conduct Ferric Hydroxide Precipitations	
6.4.2.5-02	Conduct Absorption Experiments Using Titanate Materials	
6.4.2.6	Conduct Column IX Tests for Tc Removal Using Synthetic DSSF Waste	
6.4.2.6-01	Complete Column Scaling-Size Studies	
6.4.2.6-02	Complete Column Scaling-Size Studies Report	
6.4.2.7	Conduct Column IX Tests for Tc Removal Using Actual DSSF Waste	
6.4.2.7-01	Complete Kd Measurements with Actual Waste	
6.4.2.7-02	Sorption and Elusion Behavior of Columns Using Actual DSSF Waste	
6.4.2.7-03	Complete Report	
6.4.2.7-04	Complete Report	
6.4.2.7-05	Complete Report	
6.4.2.8	Conduct Batch Tests on Alternate Techniques for Tc Removal Using Synthetic DSSF Waste	
6.4.2.8-01	Synthesis and Evaluation of New Extractants	
6.4.2.8-02	Complete Tests of Water-Soluble Polymers to Remove Tc	
6.4.2.8-03	Complete Report	
6.4.2.9	Conduct Batch Tests on Alternate Techniques for Tc Removal Using Actual DSSF Waste	
6.4.2.9-01	Evaluation of New Extractants with DSSF Waste	
6.4.2.9-02	Evaluation of Water-Soluble Polymers with DSSF Waste	

Waste Pretreatment
C.I.= Critical Interfaces (Table 6.1)
* Implicit Driver

2/21/95

Figure 6.3. Schedule (cont.)



Waste Pretreatment Technology Development Schedule

For Information Only

ID	Title	C.I.
6.4.2.10	Conduct Batch Carrier Precipitation Tests and Sodium Titanate Adsorption Tests to Remove TRU from Synthetic DSSF and CC Wastes	
6.4.2.11	Batch Test of Complexant Destruction with Actual CC Waste	
6.4.2.11-01	*Report Summarizing Heat-and-Digest Studies on AN-102*	
6.4.2.11-02	*Letter Report on Permanganate Oxidation Studies on CC Waste*	
	Additional Investigations, Initiation: FY96 and Beyond	
6.4.2.12	Advanced/Innovative Extraction (Sr, TRU, and Tc) & Complexant Destruction	

Waste Pretreatment
C.I.= Critical Interfaces (Table 6.1)
** Implicit Driver*

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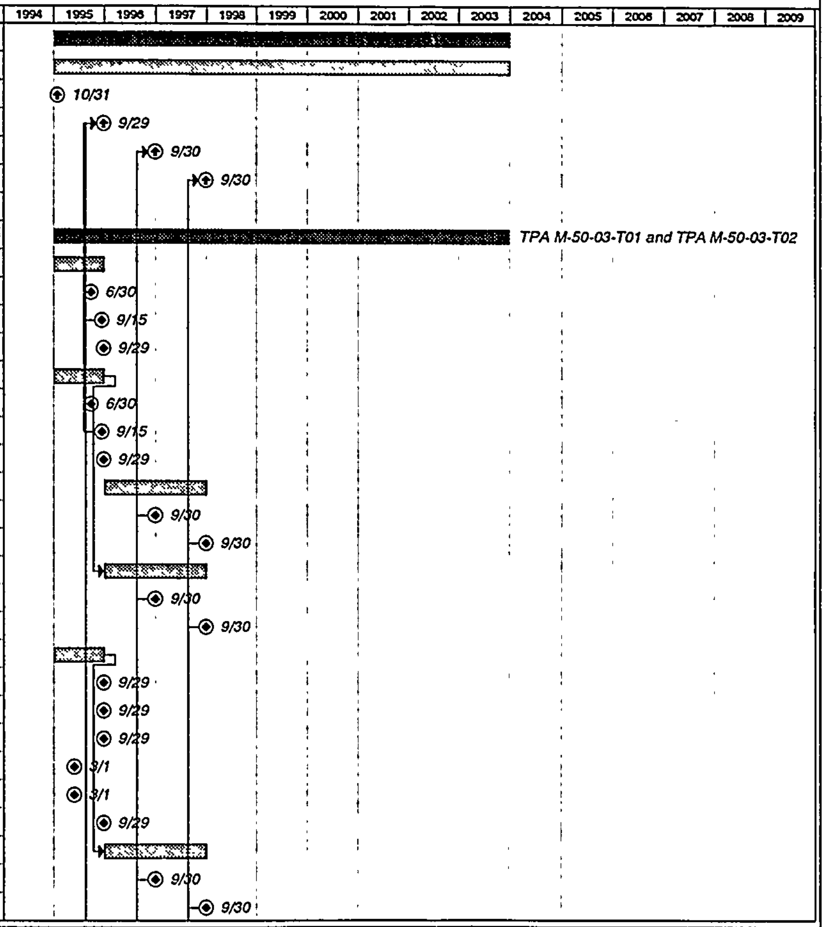
Figure 6.3. Schedule (cont.)

Waste Pretreatment Technology Development Schedule

For Information Only

ID	Title	C.I.
	Key Program Milestones Supported by Technology	
	HLW Pretreatment Facility/Technology Support	
	Issue Report on Current Status of Sludge Washing (M-50-03-T01)	
	Submit Enhance Sludge Washing Report (M-50-03-T02A)	
	Submit Enhance Sludge Washing Report (M-50-03-T02B)	
	Submit Enhance Sludge Washing Report (M-50-03-T02C)	
6.4.3	**HLW Pretreatment for Development for Reference Process**	P2,3,4,5,6,7,10,1
6.4.3.1	**Conduct Sludge Wash/Alkaline Leach Tests of Actual Tank Waste for 94-95 Sample Cores-PNL**	
6.4.3.1-01	*Interim Report from PNL on 5 Samples, Including T-104 and S-104*	
6.4.3.1-02	*Interim Report Public Release*	
6.4.3.1-03	*Complete Letter Report for Lab Studies on 8 Sludges*	
6.4.3.2	**Conduct Sludge Wash/Alkaline Leach Tests of Actual Tank Waste for 94-95 Sample Cores-LANL**	
6.4.3.2-01	*Interim Report from LANL on 7 Sludges, Including T-104 and S-104*	
6.4.3.2-02	*Interim Report Public Release*	
6.4.3.2-03	*Complete Letter Report for Lab Studies on 10 Sludges*	
6.4.3.3	**Conduct Sludge Wash/Alkaline Leach Tests of Actual Tank Waste For 95-Outyears Cores-PNL**	
6.4.3.3-01	*Lab Studies on 10 Sludges*	
6.4.3.3-02	*Lab Studies on 10 Sludges*	
6.4.3.4	**Conduct Sludge Wash/Alkaline Leach Tests of Actual Tank Waste For 95-Outyears Cores-LANL**	
6.4.3.4-01	*Lab Studies on 10 Sludges*	
6.4.3.4-02	*Lab Studies on 10 Sludges*	
6.4.3.5	**Evaluate Sludge Processing Science for Actual Sludge, 94-95**	
6.4.3.5-01	*Sludge Model Updates: Ca & Mg Phosphate, Sr, Cr*	
6.4.3.5-02	*Letter Report on Sludge Analytical/Characterization Results*	
6.4.3.5-03	*Letter Report on Speciation Studies*	
6.4.3.5-04	*DOE-Cleared Report on Sludge Wash Factors and Impact of Sludge Washing on Sludges*	
6.4.3.5-05	*DOE-Cleared Report on Sort on Radioactive Waste Model with Statistical Verifications of Method*	
6.4.3.5-06	*Review of all Pretreatment Chemistry Evaluations*	
6.4.3.6	**Evaluate Sludge Processing Science for Actual Sludge, 95-Outyears**	
6.4.3.6-01	*Sludge Model Update, Task Letter Report*	
6.4.3.6-02	*Sludge Model Update, Task Letter Report*	



Waste Pretreatment
C.I.= Critical Interfaces (Table 6.1)
** Implicit Driver*

Summary ■ Task ▨ Deliverable ◉ TPA Milestone ◉ DNFSB Milestone ▽

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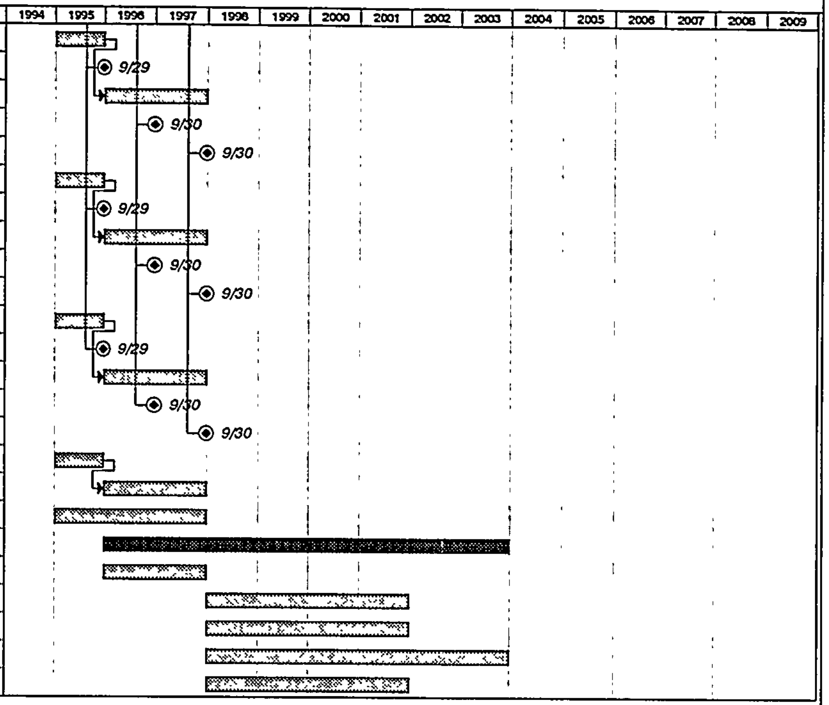
Figure 6.3. Schedule (cont.)

Waste Pretreatment Technology Development Schedule

For Information Only

ID	Title	C.I.
6.4.3.7	**Conduct Selective Leaching Experiments of Actual Sludges, 94-95**	
6.4.3.7-01	*Complete Studies on 3 Sludges, Letter Report*	
6.4.3.8	**Conduct Selective Leaching Experiments of Actual Sludges, 95-Outyears**	
6.4.3.8-01	*Complete Studies on 3 Sludges, Letter Report*	
6.4.3.8-02	*Complete Studies on 3 Sludges, Letter Report*	
6.4.3.9	**Conduct Sludge Settling Tests of Actual Wastes, 94-95**	
6.4.3.9-01	*Complete Report on First 1.0 Liter C-107 Sample*	
6.4.3.10	**Conduct Sludge Settling Tests of Actual Wastes, 95-Outyears**	
6.4.3.10-01	*Complete Report on Both C-107 Samples Plus 2 Other Sludges*	
6.4.3.10-02	*Complete Report on Three Additional Sludges*	
6.4.3.11	**Establish a Radioactive Colloid Lab Capability**	
6.4.3.11-01	*Complete Letter Report on Equipment Design, Fabrication and Checkout Tests*	
6.4.3.12	**Conduct Radioactive Colloid Tests**	
6.4.2.12-01	*Letter Report on Colloid Tests*	
6.4.3.12-02	*Letter Report on Colloid Tests*	
6.4.3.13	**Program Management 95**	
6.4.3.14	**Program Management 96-97**	
6.4.3.15	**Infrastructure Support**	
	Additional Investigations, Initiation: FY 96 and Beyond	
6.4.3.16	**Sludge Processing Science/Solid-Liquid Separation**	
6.4.3.17	**Program Management, FY 1998-2001**	
6.4.3.18	**Advanced Sludge Reduction**	
6.4.3.19	**Sludge Processing Science/Solid-Liquid Separation, FY1998-2003**	
6.4.3.16.4	**Infrastructure Support**	



Waste Pretreatment
C.I.= Critical Interfaces (Table 6.1)
** Implicit Driver*

Summary ▇ Task ▨ Deliverable ◉ TPA Milestone ⊕ DNFSB Milestone ▽

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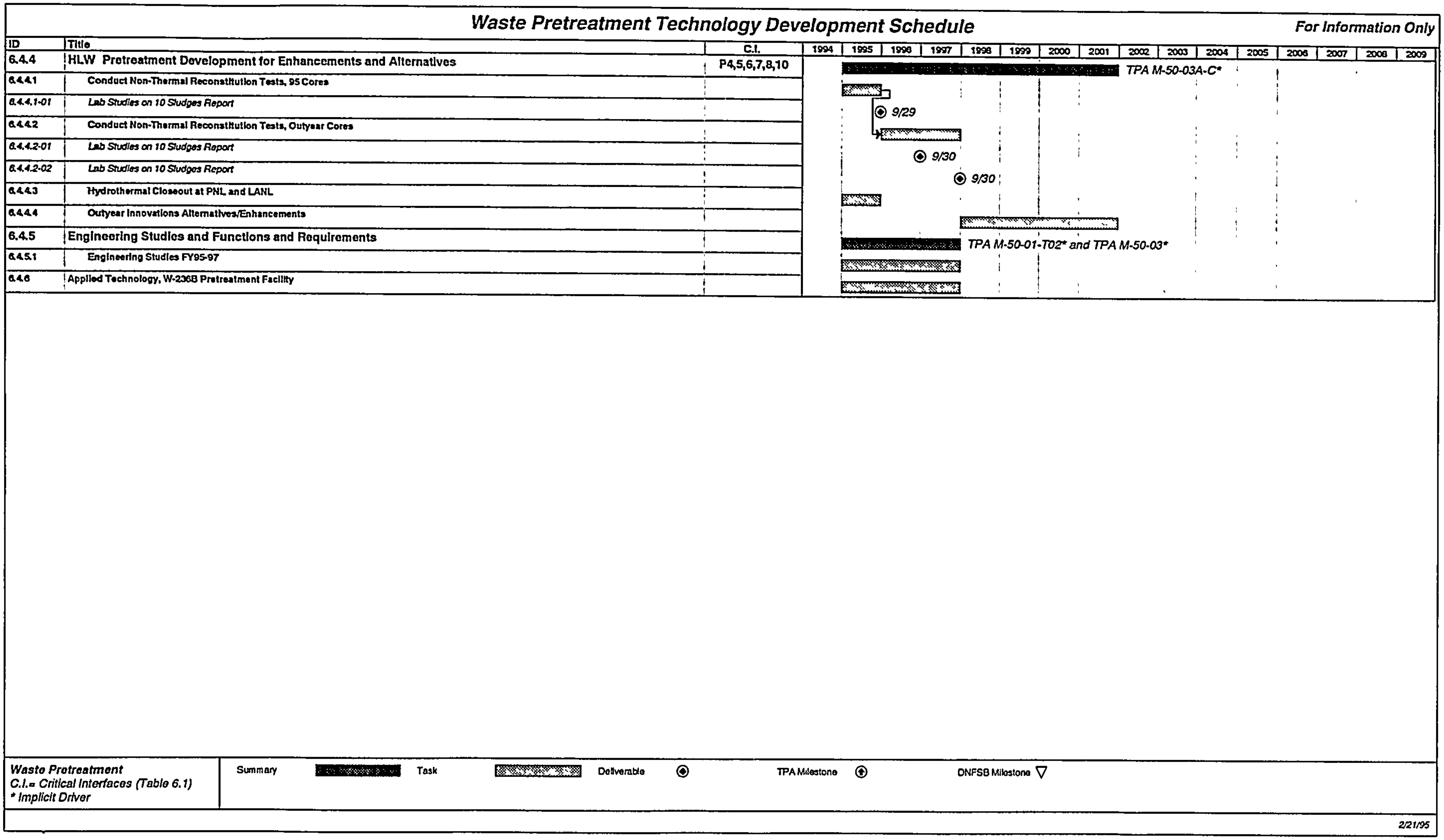
Figure 6.3. Schedule (cont.)



Waste Pretreatment Technology Development Schedule

For Information Only

ID	Title	C.I.
6.4.4	HLW Pretreatment Development for Enhancements and Alternatives	P4,5,6,7,8,10
6.4.4.1	Conduct Non-Thermal Reconstitution Tests, 95 Cores	
6.4.4.1-01	*Lab Studies on 10 Sludges Report*	
6.4.4.2	Conduct Non-Thermal Reconstitution Tests, Outyear Cores	
6.4.4.2-01	*Lab Studies on 10 Sludges Report*	
6.4.4.2-02	*Lab Studies on 10 Sludges Report*	
6.4.4.3	Hydrothermal Closeout at PNL and LANL	
6.4.4.4	Outyear Innovations Alternatives/Enhancements	
6.4.5	Engineering Studies and Functions and Requirements	
6.4.5.1	Engineering Studies FY95-97	
6.4.6	Applied Technology, W-236B Pretreatment Facility	

Waste Pretreatment
C.I.= Critical Interfaces (Table 6.1)
** Implicit Driver*

Figure 6.3. Schedule (cont.)

Table 6.3. Budget

WASTE PRETREATMENT
TWRS Technology Budget Estimates
(Unescalated Dollars in Thousands by Fiscal Year)

TECHNOLOGY PACKAGE NUMBER AND TITLE	1995	1996	1997	1998	1999	2000	2001 +	TOTAL
["Expected Budget Available for Technology" consists of activities in TWRS Multi-Year Work Plan]								
6.4.1--LLW Pretreatment Development for Reference Process								
Expected Budget Available for Technology	2,004	889	1,080	0	0	0	0	3,973
Total Estimated Budget for Technology Activities in ITP	2,004	889	1,080	0	0	0	0	3,973
Activities Include:								
Develop Engineered Form of CST	*1,750*	*0*	*0*	*0*	*0*	*0*	*0*	*1,750*
Conduct Batch Tests of Engineered Form of CST Using DSS/DSSF Feed	*254*	*0*	*0*	*0*	*0*	*0*	*0*	*254*
CST Optimization for Supernatant	*0*	*400*	*400*	*0*	*0*	*0*	*0*	*800*
Conduct Electrochemical Elution Tech. w/ Waste Simulants Using RF and CS-100 Resin (PNL)	*0*	*489*	*0*	*0*	*0*	*0*	*0*	*489*
Construct and Test Electrochemical Elution IX System Using Actual Wastes (PNL)	*0*	*0*	*680*	*0*	*0*	*0*	*0*	*680*
6.4.2--LLW Pretreatment Development for Enhancements and Alternatives								
Expected Budget Available for Technology	4,059	2,504	1,560	1,000	1,000	1,000	1,000	12,123
Total Estimated Budget for Technology Activities in ITP	4,059	2,504	1,560	1,000	1,000	1,000	1,000	12,123
Activities Include:								
Conduct Batch & Column IX Tests for Sr Removal from Synthetic CC Waste That Has Cs Removed	*944*	*0*	*0*	*0*	*0*	*0*	*0*	*944*
Conduct Batch & Column IX Tests for Sr Removal from Actual CC Waste That Has Cs Removed	*0*	*694*	*560*	*0*	*0*	*0*	*0*	*1,254*
Conduct Batch & Column Solid Sorbent Tests w/ Synthetic DSS/DSSF & CC Waste to Remove Sr	*200*	*0*	*0*	*0*	*0*	*0*	*0*	*200*
Conduct Batch & Column Solid Sorbent Tests w/ Actual DSS/DSSF & CC Waste to Remove Sr	*200*	*400*	*400*	*0*	*0*	*0*	*0*	*1,000*
Conduct Batch Carrier Precipitation Tests and Sodium Titanate Adsorption Tests to Remove TRU from Actual DSSF and CC Wastes	*405*	*810*	*0*	*0*	*0*	*0*	*0*	*1,215*
Conduct Column IX Tests for Technetium Removal Using Synthetic DSSF Waste	*685*	*0*	*0*	*0*	*0*	*0*	*0*	*685*
Conduct Column IX Tests for Technetium Removal Using Actual DSSF Waste--EXPENSE	*485*	*507*	*507*	*0*	*0*	*0*	*0*	*1,499*
Conduct Column IX Tests for Technetium Removal Using Actual DSSF Waste--CENRTC	*75*	*93*	*93*	*0*	*0*	*0*	*0*	*261*
Conduct Batch Tests on Alternate Tech. for Technetium Removal Using Synthetic DSSF Waste	*105*	*0*	*0*	*0*	*0*	*0*	*0*	*105*
Conduct Batch Tests on Alternate Tech. for Technetium Removal Using Actual DSSF Waste	*105*	*0*	*0*	*0*	*0*	*0*	*0*	*105*
Conduct Batch Carrier Precipitation Tests and Sodium Titanate Adsorption Tests to Remove TRU from Synthetic DSSF and CC Wastes	*405*	*0*	*0*	*0*	*0*	*0*	*0*	*405*
Batch Test of Complex Destruction with Actual CC Waste	*450*	*0*	*0*	*0*	*0*	*0*	*0*	*450*
Additional Investigations, Initiation: (FY1996 and beyond)								
Advanced/Innovative Extraction (Sr, TRU, Tc) & Complexant Destruction	*0*	*0*	*0*	*1,000*	*1,000*	*1,000*	*1,000*	*4,000*

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Table 6.3 Budget (cont.)

WASTE PRETREATMENT (Continued)
TWRS Technology Budget Estimates
(Unescalated Dollars in Thousands by Fiscal Year)

TECHNOLOGY PACKAGE NUMBER AND TITLE	1995	1996	1997	1998	1999	2000	2001 +	TOTAL
["Expected Budget Available for Technology" consists of activities in TWRS Multi-Year Work Plan]								
6.4.3--HLW Pretreatment Development for Reference Process								
Expected Budget Available for Technology	9,730	12,070	12,991	9,700	10,144	4,695	6,254	65,584
Total Estimated Budget for Technology Activities in ITP	9,730	12,070	12,991	9,700	10,144	4,695	6,254	65,584
Activities Include:								
Conduct Sludge Wash/Alkaline Leach Tests of Actual Tank Waste for 94-95 Sample Cores--PNL	*941*	*0*	*0*	*0*	*0*	*0*	*0*	*941*
Conduct Sludge Wash/Alkaline Leach Tests of Actual Tank Waste for 94-95 Sample Cores--LANL	*1,508*	*0*	*0*	*0*	*0*	*0*	*0*	*1,508*
Conduct Sludge Wash/Alkaline Leach Tests of Actual Tank Waste for 95-outyears cores--PNL	*0*	*2,200*	*2,200*	*0*	*0*	*0*	*0*	*4,400*
Conduct Sludge Wash/Alkaline Leach Tests of Actual Tank Waste for 95-outyears cores--LANL	*0*	*2,300*	*2,300*	*0*	*0*	*0*	*0*	*4,600*
Evaluate Sludge Processing Science for Actual Sludge, 94-95--EXPENSE	*2,231*	*0*	*0*	*0*	*0*	*0*	*0*	*2,231*
Evaluate Sludge Processing Science for Actual Sludge, 94-96--CENRTC	*60*	*0*	*0*	*0*	*0*	*0*	*0*	*60*
Evaluate Sludge Processing Science for Actual Sludge, 95-outyears	*0*	*2,178*	*2,178*	*0*	*0*	*0*	*0*	*4,356*
Conduct Selective Leaching Experiments of Actual Sludges 94-95	*275*	*0*	*0*	*0*	*0*	*0*	*0*	*275*
Conduct Selective Leaching Experiments of Actual Sludges 95 - outyears	*0*	*282*	*290*	*0*	*0*	*0*	*0*	*572*
Conduct Sludge Settling Tests of Actual Waste, 94-95	*1,300*	*0*	*0*	*0*	*0*	*0*	*0*	*1,300*
Conduct Sludge Settling Tests of Actual Waste, 95 - Outyears Cores	*0*	*1,200*	*1,200*	*0*	*0*	*0*	*0*	*2,400*
Construct a Colloid Lab (FY95)--EXPENSE	*716*	*0*	*0*	*0*	*0*	*0*	*0*	*716*
Construct a Colloid Lab (FY95)--CENRTC	*450*	*0*	*0*	*0*	*0*	*0*	*0*	*450*
Conduct Radioactive Colloid Tests (FY96, 97)	*0*	*605*	*605*	*0*	*0*	*0*	*0*	*1,210*
Program Management 95	*1,700*	*1,600*	*1,600*	*0*	*0*	*0*	*0*	*4,900*
Infrastructure Support	*549*	*1,200*	*1,618*	*0*	*0*	*0*	*0*	*3,367*
Additional Investigations, Initiation: (FY1996 and beyond)								
Advanced Sludge Reduction	*0*	*0*	*0*	*4,800*	*5,100*	*2,195*	*2,195*	*14,290*
Sludge Processing Science\SOLID-LIQUID SEPARATION	*0*	*505*	*1,000*	*2,000*	*2,000*	*1,000*	*2,559*	*9,064*
Infrastructure Support (Sampling\Sample Handling & Preparation)	*0*	*0*	*0*	*1,700*	*1,844*	*1,000*	*1,000*	*5,544*
Program Management, FY1998-FY2001	*0*	*0*	*0*	*1,200*	*1,200*	*500*	*500*	*3,400*
6.4.4--HLW Pretreatment Development for Enhancements and Alternatives								
Expected Budget Available for Technology	1,005	500	500	800	800	0	0	3,605
Total Estimated Budget for Technology Activities in ITP	1,005	500	500	800	800	0	0	3,605
Activities Include:								
Conduct Non-Thermal Reconstitution Tests, FY94-95 Cores	*500*	*0*	*0*	*0*	*0*	*0*	*0*	*500*
Conduct Non-Thermal Reconstitution Tests, FY95-Outyears Cores	*0*	*500*	*500*	*0*	*0*	*0*	*0*	*1,000*
Additional Investigations, Initiation: FY 1996 and beyond	*0*	*0*	*0*	*800*	*800*	*0*	*0*	*1,600*
FY94 Carryover Tasks	*505*	*0*	*0*	*0*	*0*	*0*	*0*	*505*

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Table 6.3 Budget (cont.)

WASTE PRETREATMENT (Continued)
TWRS Technology Budget Estimates
(Unescalated Dollars in Thousands by Fiscal Year)

TECHNOLOGY PACKAGE NUMBER AND TITLE	1995	1996	1997	1998	1999	2000	2001 +	TOTAL
["Expected Budget Available for Technology" consists of activities in TWRS Multi-Year Work Plan]								
6.4.5--Engineering Studies and Functions and Requirements (F&R) [SEE FOOTNOTE (1)]								
Expected Budget Available for Technology	4,379	4,382	8,954	0	0	0	0	17,715
Total Estimated Budget for Technology Activities in ITP	4,379	4,382	8,954	0	0	0	0	17,715
6.4.6--Applied Technology, W-236B Pretreatment Facility (IPM) [SEE FOOTNOTE (1)]								
Expected Budget Available for Technology	17,190	17,643	18,702	0	0	0	0	53,535
Total Estimated Budget for Technology Activities in ITP	17,190	17,643	18,702	0	0	0	0	53,535
6.4.7--LLW Pretreatment Development for Reference Process(Unfunded)								
Expected Budget Available for Technology	0	0	0	0	0	0	0	0
Total Estimated Budget for Technology Activities in ITP	0	750	375	0	0	0	0	1,125
Activities Include:								
Level 1: Competing Ion Effect Studies	*0*	*750*	*375*	*0*	*0*	*0*	*0*	*1,125*
Level 2: Requiring Engineering Trade Study/Evaluation--Cesium Elution and Resin Disposal Alternatives	*NR*	*NR*	*NR*	*NR*	*NR*	*NR*	*NR*	*NR*
Level 2: Requiring Engineering Trade Study/Evaluation--Evaporation/Concentration of Process Streams	*NR*	*NR*	*NR*	*NR*	*NR*	*NR*	*NR*	*NR*
6.4.8--LLW Pretreatment Development for Enhancements and Alternatives (Unfunded)								
Expected Budget Available for Technology	0	0	0	0	0	0	0	0
Total Estimated Budget for Technology Activities in ITP	0	450	450	0	0	0	0	900
Activities Include:								
Level 1: Determine the Effectiveness of Competition to Overcome Effects of Organic Complexants on Sr and TRU Removal	*0*	*200*	*200*	*0*	*0*	*0*	*0*	*400*
Level 1: Uranium Removal from Supernatant (Add to Existing TRU studies)	*0*	*250*	*250*	*0*	*0*	*0*	*0*	*500*
Level 2: Competing Ion Studies for Technetium Removal	*NR*	*NR*	*NR*	*NR*	*NR*	*NR*	*NR*	*NR*
Level 2/3: Removal Of Cesium and Technetium by Volatilization during Calcination	*NR*	*NR*	*NR*	*NR*	*NR*	*NR*	*NR*	*NR*
Level 2/3: Study Additional Technetium Ion Exchange Materials	*NR*	*NR*	*NR*	*NR*	*NR*	*NR*	*NR*	*NR*
Level 2/3: Study Precipitations/Reduction Methods for Removal of Technetium	*NR*	*NR*	*NR*	*NR*	*NR*	*NR*	*NR*	*NR*
6.4.9--HLW Pretreatment Development for Reference Process(Unfunded)								
Expected Budget Available for Technology	0	0	0	0	0	0	0	0
Total Estimated Budget for Technology Activities in ITP	0	300	150	150	0	0	0	600
Activities Include:								

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Table 6.3 Budget (cont.)

WASTE PRETREATMENT (Continued)
TWRS Technology Budget Estimates
(Unescalated Dollars in Thousands by Fiscal Year)

TECHNOLOGY PACKAGE NUMBER AND TITLE	1995	1996	1997	1998	1999	2000	2001 +	TOTAL
["Expected Budget Available for Technology" consists of activities in TWRS Multi-Year Work Plan]								
Level 1: Retrieval Chemistry on HLW Volume	*0*	*300*	*150*	*150*	*0*	*0*	*0*	*600*
Level 2: Requiring Engineering Trade Study/Evaluation--Evap./Conc. of Eluted Cs Product	*NR*	*NR*	*NR*	*NR*	*NR*	*NR*	*NR*	*NR*
Level 2: DEFERRED PENDING DEVELOPMENT OF SOLID/LIQUID SEPARATION STRATEGY--Glass Frit Filters Lifetime Studies	*NR*	*NR*	*NR*	*NR*	*NR*	*NR*	*NR*	*NR*
<u>6.4.10--HLW Pretreatment Development for Enhancements and Alternatives (Unfunded)</u>								
Expected Budget Available for Technology	0	0	0	0	0	0	0	0
Total Estimated Budget for Technology Activities in ITP	500	500	500	0	0	0	0	1,500
<u>Activities Include:</u>								
Acid Dissolution with Actual Sludges	*500*	*500*	*500*	*NR*	*NR*	*NR*	*NR*	*1,500*
Level 2: Requiring Engineering Trade Study/Evaluation--Thermal Reconstitution to Improve Enhanced Sludge Washing Process	*NR*	*NR*	*NR*	*NR*	*NR*	*NR*	*NR*	*NR*
Level 2: Requiring Eng. Trade Study/Evaluation--Evap./Conc. of Separated Radionuclide Streams	*NR*	*NR*	*NR*	*NR*	*NR*	*NR*	*NR*	*NR*
Level 2: DEFERRED PENDING DEVELOPMENT OF SOLID/LIQUID SEPARATION STRATEGY--Improved Solid/Liquid Separation through Addition of Precipitates	*NR*	*NR*	*NR*	*NR*	*NR*	*NR*	*NR*	*NR*
Level 3: Treatment of Residue from Acid Dissolutions	*NR*	*NR*	*NR*	*NR*	*NR*	*NR*	*NR*	*NR*
Level 3: Acid-side Enhancements/Alternatives	*NR*	*NR*	*NR*	*NR*	*NR*	*NR*	*NR*	*NR*
WASTE PRETREATMENT TOTALS:								
Expected Budget Available for Technology	38,367	37,988	43,787	11,500	11,944	5,695	7,254	156,535
Total Estimated Budget for Technology Activities in ITP	38,867	39,988	45,262	11,650	11,944	5,695	7,254	160,660

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7.0 Low-Level Waste Immobilization

7.1 Purpose, Objectives, Scope, and Strategy

The **purpose** of the low-level waste (LLW) immobilization function is to convert the low-level portion of the wastes currently stored in the Hanford Site tanks into a solid, retrievable vitrified waste form suitable for disposal at an onsite facility.

The **objective** of LLW immobilization technology is to assist in developing the scientific and engineering bases needed for a vitrification and disposal capability that fulfills the Tank Waste Remediation System (TWRS) program mission. This includes ensuring, through technology development, data collection, and analysis, the production of an acceptable vitrified waste form for storage and disposal, and the design and construction of a suitable facility for the storage and disposal of the vitrified waste form.

Technology activities needed to achieve an acceptable waste form quality, and the vitrification rate (estimated at 91 t to 181 t [100 to 200 tons/day]) required to vitrify LLW according to the TPA-established schedule, have been incorporated into the LLW Immobilization Program element at a relatively high level. These activities encompass all aspects of the vitrification and disposal process, including equipment development, vitrified waste form product development, and development of the engineered storage and disposal facility.

The **scope** of the LLW Immobilization Program includes both the conversion of LLW tank wastes to a vitrified waste form and the storage and disposal of those vitrified wastes on the Hanford Site. To meet the program objectives requires the design, construction, and operation of a LLW vitrification facility and a LLW disposal facility. The following technology activities are necessary to support the program objectives:

- Develop acceptable glass waste forms with acceptable waste loading, long-term durability, processing characteristics, and adequate flexibility to respond to waste variations.
- Develop any packaging and/or matrices for transporting and storing the glass waste form.
- Develop the vitrification plant flowsheet, from receipt of the waste from tank farms/pretreatment through release of the vitrified waste form product to the disposal facility.
- Evaluate, select, and adapt, as necessary, a glass melter technology to be used for vitrifying the LLW.
- Develop the necessary process chemistry for preparing received wastes to be fed to the glass melter.
- Develop or adapt the equipment necessary to prepare the wastes for feeding to the glass melter.
- Develop or adapt suitable system for treating gaseous effluents from the glass melter, including methods for handling recycle streams, and possible non-vitrified waste forms for problem chemicals.
- Develop or adapt suitable system to form and package the glass emerging from the glass melter.
- Develop the strategy, instrumentation, and analytical tools to monitor and control the vitrification process and the resulting waste form product.
- Develop data to support design, permitting, and construction of the LLW vitrification system.
- Develop chemical, hydraulic, and physical barriers as required for disposal facility.

- Develop tools, as necessary, to conduct performance assessment (PA) analyses to provide guidance to waste form and disposal system design and to demonstrate compliance with environmental protection requirements.
- Develop data on disposal system including long-term durability of components and characteristics of disposal site to support design, permitting including PA, and construction of the disposal facility.
- Develop strategy, instrumentation, and analytical tools to monitor product quality and performance of LLW disposal facility.

This list of activities is necessarily general because the specific baseline and alternative technologies and data needs have not been completely identified at this time. In future revisions of this document, it is anticipated that more specific technologies and technology development will be identified as part of the baseline.

The TWRS **strategy** for vitrifying LLW specifies use of industrial, high-throughput melter technology to the maximum extent possible. Verification of this strategy requires evaluation and performance testing of alternative commercial melters and associated plant subsystems. The LLW vitrification facility design will be based on laboratory-, small-, and pilot-scale testing with simulants; laboratory- and small-scale testing with radioactive waste samples; and cold testing of facility components. A radioactive pilot plant is not currently planned for verification of the design concept.

The TWRS strategy, as outlined in the Tri-Party Agreement, includes operation of the LLW vitrification facility using pretreated double-shell slurry feed as the earliest feed to the plant.

The LLW disposal facility will be designed and operated to ensure protection of the public health and the environment. The TWRS strategy includes conducting PA analyses in order to provide guidance to the disposal system design and to provide waste inventory and waste form product performance specifications.

The initial emphasis of the LLW Immobilization Program is being placed on the following technical activities:

- Evaluate industrial melter technologies, including feasibility and operability testing at melter vendor facilities using simulants, in order to select a reference melter(s) to comply with TPA milestone M-60-02.
- As part of the melter vendor testing, evaluate the performance of auxiliary components of the vitrification system including melter feed preparation and offgas treatment.
- Develop and characterize, including long-term durability, glass formulations in order to establish a reference LLW glass formulation to comply with TPA milestone M-60-02.
- Evaluate sulfur polymer cement as a potential matrix material for encapsulating the glass waste form and initiate development of alternative matrix materials. Matrix materials with chemical gettering properties for technetium and other radionuclides will be emphasized.
- Develop preliminary performance requirements for the disposal facility and the waste form; use the performance assessment methodology to establish the amount of pretreatment required, the needed glass and waste form properties (durability, type, shape, and waste loading), and storage/disposal facility performance requirements. Develop the necessary hydraulic and chemical property data for the site geology to support the PA analyses.
- Develop instrumentation for monitoring the vitrification process and waste form quality.

- Conduct laboratory studies to support flowsheet development and vitrification facility design. These activities include determining the extent of cesium migration into refractories, determining melter refractory and electrode material corrosion rates, and determining technetium volatilization rates.

- In glass formulation studies, emphasize maximum waste loading, a robust glass composition to provide tolerance for waste variability, and identify means for dealing with troublesome minor components.

7.1.1 Key Assumptions

The key assumptions for the LLW Immobilization Program are as follows:

- Other program element activities (pretreatment, retrieval, etc.) will proceed on a schedule that supports the needs and inputs of the LLW vitrification program.

- Commercial melter and other subsystem technologies can be adapted to meet the requirements for vitrification for LLW.

- The LLW vitrification plant will begin operations in 2005.

- The LLW vitrification facility will have an operating life of 15 years.

- Melter throughput capacity will average100 to 200 tons/day (glass). The maximum rate would be achieved by using at least two melters.

- The LLW vitrification process will be designed based upon vendor testing of simulants, laboratory- and small-scale testing of radioactive waste samples, cold testing on a pilot scale of critical components and processes, and cold testing of facility components. A hot pilot plant will not be required for verification of the design concept.

- An acceptable method can be developed to treat offgas from the melter.

- Blending and pretreatment of tank wastes can provide feed that meets the specifications required for vitrification, resulting in a product that meets specifications for disposal. All of the LLW can be incorporated into a vitrified waste form.

- The vitrified LLW will be disposed of on the Hanford Site in a retrievable form.

- Glass will be shown to be an acceptable waste form for near-surface disposal of LLW on the Hanford site.

- A disposal system can be developed that, in conjunction with the glass waste form, meets requirements for environment, health, and safety protection.

7.1.2 Key Uncertainties

The key uncertainties include: 1) waste feed composition, 2) vitrification system performance, and 3) requirements regarding the disposal system and waste immobilization product, as described below.

- Information is currently lacking on pretreatment discharge compositions and composition ranges, as well as on well-defined property-composition relationships compatible with melter operating ranges and waste acceptance criteria.

- Many types of industrial glass melters exist that have potential for use in vitrifying Hanford's LLW. Vitrifying wastes of the composition represented by Hanford tank LLW is an unusual application of these melters. These melter types must be evaluated to select a reference type for design. Supporting subsystems, however, may not be sufficiently developed to allow effective use of the commercial vitrification technology without substantial modification.

- The approach for processing and disposing of contaminated components (melter, offgas treatment system, etc.) has not been determined.
- Performance requirements for the disposal facility and waste immobilization product, including the glass waste form, have yet to be formulated.

7.1.3 Critical Interfaces

A *critical interface* is an important system boundary/point of coordination between two TWRS program elements for one or both elements to successfully meet program objectives. The critical interfaces related to technology activities supporting all six program elements of the TWRS program are integrated in Table 7.1. These interfaces are generally technology-to-TWRS program element or TWRS program element-to-technology (not technology-to-technology or program element-to-program element).

Critical interfaces for each program element are also listed in Chapters 3.0, 4.0, 5.0, 6.0, 7.0, and 8.0.

Table 7.1. Critical Interfaces Technology Activities Supporting LLW Immobilization

No.	From	To	Need By	Item Provided
L1	HLW	LLW	9/96	Characteristics and volume of HLW plant-generated LLW streams
L2	PT,OPS, RT	LLW	10/94-9/98	Pretreatment product composition envelope
L3	PT	LLW	3/98	Impact of pretreatment decision on enhanced sludge washing of low-level feed
L4	LLW	DSP	6/99	Waste form system configuration
L5	LLW	DSP	6/99	Performance assessment data
L6	LLW	DSP	6/96	Reference Glass Formulation
L7	LLW	LPD	10/94+	Support systems: recycle streams, offgas, feed, and other subsystems
L8	DSP	LLW	9/98	Waste packaging performance requirements
L9	LLW	CH	10/94+	LLW DQO and test plans

Note: + = More than one update or user.

LEGEND:
DSP = Disposal
PT = Pretreatment Program Element
RT = Retrieval Program Element
HLW = High-Level Waste Program Element
LLW = Low-Level Waste Program Element
LPD = Low-Level Plant Design
OPS = Operations
ER/WM = Environmental Restoration and Waste Management
SW = Solid Waste

7.2 Functional Flow Diagram

Functions form the basis for identifying technology deliverables required to support TWRS program needs. A block diagram that maps the relationship between functions and technology packages for the LLW Immobilization Program is provided in Figure 7.1.

7.3 Functions and Associated Technology Packages for LLW Immobilization

Table 7.2 presents the technology activities identified by the TWRS program staff responsible for LLW immobilization. In addition to the Tank Waste Remediation System (TWRS) Baseline Program, other tasks presented in Table 7.2 represent nonbaseline activities. Each of these programs is discussed in Appendix E.

The TWRS Baseline Program is consistent with the most recent version of the Multi-Year Program Plan (MYPP). The nonbaseline activities shown are those that, while important to the overall TWRS mission, are not currently funded. These activities have been tentatively prioritized for inclusion in the Baseline at the first opportunity. The technology activities in both programs were identified and prioritized through a process described in Appendix E.

7.3.1 Key to Table

Program: In Table 7.2, those technology packages and tasks that fall in the TWRS Baseline Program appear in normal font. Those that fall in the Nonbaseline Program appear in italics.

Function: The systems engineering function (as described in the TWRS Functional Requirements document, U.S. DOE/RL 1994b) that this technology package supports (followed by the number for the appropriate systems engineering level in parenthesis).

Technology Package: A set of technology activities that need to be completed to respond to a functional need. May include activities to address/support the reference case, or enhancements or alternatives to the reference case (followed by the program element chapter number in parenthesis).

Tasks: The tasks that need to be performed to resolve this technology need. Dates are unofficial; they are for planning purposes only.

FY 1996 Cost Estimate: An estimate of the funding that would be needed to conduct FY 1996 tasks. (Note: Tasks are listed for the entire TWRS life-cycle, but costs for outyear tasks are not shown on this table. See Appendix E for more information on each technology package.)

FY 1996 estimated cost are listed for each program. Dollar figures are unescalated, burdened FY 1995 dollars, in thousands. Costs are unofficial, for planning purposes only.

Benefit: The reasons these tasks are important to the program element.

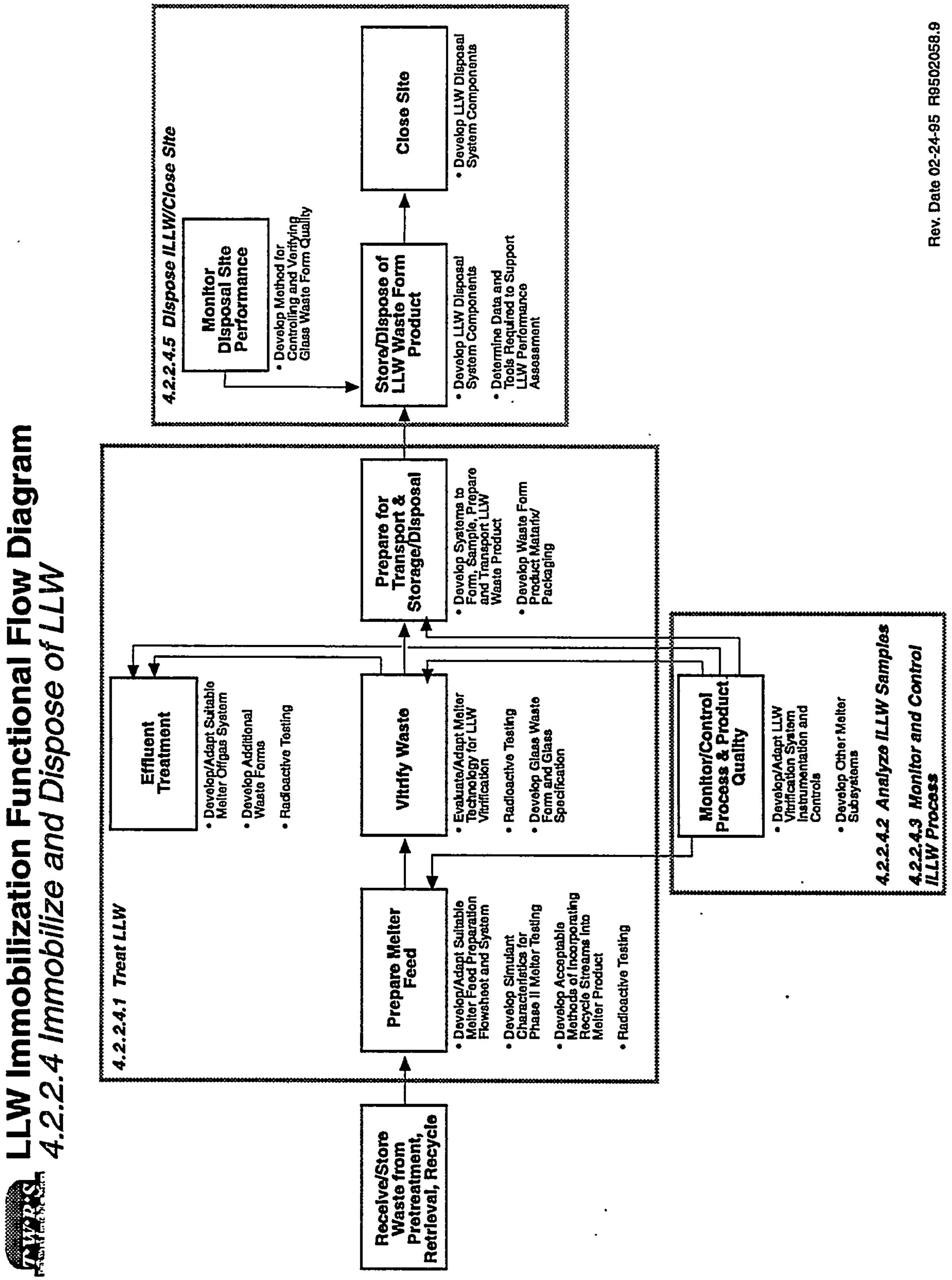


Figure 7.1. Functional Flow Diagram

Table 7.2. Low-Level Waste Immobilization: Recommended Technology Program

Function and Technology Package		Tasks		FY 1996 Cost Estimate ($K)		
Functional Need Level 4	Template Title (number)	No.	Title	Funded	Not Funded	Benefit
Immobilize & Dispose LLW (4.2.2.4)	**Develop/Adapt Suitable Melter Feed Preparation Flowsheet and System** **7.4.1** Reference	1.	Evaluate melter feed prep techniques	700		Operations/Interface: Required for melter selection and process design; required for acceptable disposal product; required to define pretreatment requirements. Reduce Risk: Optimize operations.
		2.	Process recycle streams	550		
Immobilize & Dispose LLW (4.2.2.4)	**Develop Simulant Characteristics for Phase II Melter Testing** **7.4.2** Reference	1.	Develop and supply Phase II simulant	430		Commitments: Required for TPA milestones M-60-01 and M-60-02, selection of LLW melter.

LEGEND: Baseline/*Non-baseline*.
(a) Fund Immediately.
(b) Fund If Possible.

Table 7.2. Low-Level Waste Immobilization: Recommended Technology Program (contd)

Function and Technology Package		Tasks		FY 1996 Cost Estimate ($K)		Benefit
Functional Need Level 4	Template Title (number)	No.	Title	Funded	Not Funded	
Immobilize & Dispose LLW (4.2.2.4)	**Develop Acceptable Methods of Incorporating Recycle Streams into Melter Product** **7.4.3** Reference	1.	Determine and verify product quality impacts	150		Operations: Required to size melter; determine and qualify acceptable waste form. Reduce Risk: Minimizes waste volume; potentially reduces size of disposal.
		2.	Evaluate and develop alternatives to recycle including alternative waste forms	340		
		3.	*Perform trade studies to evaluate alternate recycle concepts including recycle versus disposal*		*200*	
		4.	*Perform additional melter and product effects studies*		*100*	
		5.	*Materials erosion/corrosion evaluation*		*200*	
Immobilize & Dispose LLW (4.2.2.4)	**Radioactive Testing** **7.4.4** Reference	*1.*	*Design non-rad system*		*200*	Commitments: TPA milestone M-60-03, definitive design of LLW vitrification plant.

LEGEND: Baseline/*Non-baseline*.
(a) Fund Immediately.
(b) Fund If Possible.

Table 7.2. Low-Level Waste Immobilization: Recommended Technology Program (contd)

Function and Technology Package		Tasks		FY 1996 Cost Estimate ($K)		
Functional Need Level 4	Template Title (number)	No.	Title	Funded	Not Funded	Benefit
Immobilize & Dispose LLW (4.2.2.4)	**Evaluate/Adapt Melter Technology for LLW Vitrification** **7.4.5** Reference	1.	Phase II melter testing	5,000		Commitments: Required for TPA milestones M-60-01, M-60-02, selection of LLW melter.
		2.	Phase III melter testing for A&E	2,000		
Immobilize & Dispose LLW (4.2.2.4)	**Develop Glass Waste Form and Glass Specification** **7.4.6** Reference	1.	Reference glass composition	1,000		Commitments: Required to meet TPA milestone M-60-01-A, M-60-01-02. Operations: Required for initial concept design. Operations/Interface: Required to meet all disposal system specifications; required to specify pretreatment specification, required for melter selection and process design; required for acceptable disposal product. Reduce Risk: Optimize operations.
		2.	Glass optimization	200		
		3.	[High] waste loading	160		
		4.	Troublesome components	350		
		5.	Durability testing	1,450		
		6.	Glass modeling	300		
		7.	Improved glass durability (glass surface treatments)	500		

LEGEND: Baseline/*Non-baseline.*
(a) Fund Immediately.
(b) Fund If Possible.

Table 7.2. Low-Level Waste Immobilization: Recommended Technology Program (contd)

Function and Technology Package		Tasks		FY 1996 Cost Estimate ($K)		
Functional Need Level 4	Template Title (number)	No.	Title	Funded	Not Funded	Benefit
Immobilize & Dispose LLW (4.2.2.4)	**Develop/Adapt Suitable Melter Offgas System** **7.4.7** Reference	1.	Determine likely offgas products and quantities for melter type, operating conditions, waste composition and recycle streams	400		Commitments: Required for NEPA documentation, operating permits. Operations: Required for melter selection and initial concept design. Operations/Interface: Defines feed requirements to pretreatment; minimizes potential increase of offgas waste stream to HLW. Reduces Risk: Reduce public health risk by reducing offsite release.
		2.	Final BARCT/BACT/T-BACT	250		
		3.	Melter offgas treatment evaluation	300		
Immobilize & Dispose LLW (4.2.2.4)	**Develop Additional Waste Forms** **7.4.8** Reference	1.	Final waste form validation	490		Operations: Required to size melter, determine and qualify acceptable waste form. Reduce Risk: Minimizes waste volume; potentially reduces size of disposal.

LEGEND: Baseline/*Non-baseline*.
(a) Fund Immediately.
(b) Fund If Possible.

Table 7.2. Low-Level Waste Immobilization: Recommended Technology Program (contd)

Function and Technology Package		Tasks		FY 1996 Cost Estimate ($K)		
Functional Need Level 4	Template Title (number)	No.	Title	Funded	Not Funded	Benefit
Immobilize & Dispose LLW (4.2.2.4)	**Develop/Adapt LLW Vitrification System Instrumentation and Controls** **7.4.9** Reference	*1.*	*Melter operational models evaluate and recommend*		*100*	Commitments: TPA milestone M-60-03, definitive design of LLW vitrification plant.
		2.	*Develop melter head end control methods*		*150*	
		3.	*Develop operational analysis techniques*		*300*	
		4.	*Evaluate process and disposal data requirements*		*150*	
		5.	*Process and disposal control and monitoring approach*		*200*	
		6.	*Evaluate commercial instrumentation availability*		*200*	
Immobilize & Dispose LLW (4.2.2.4)	**Develop Systems to Form, Sample, and Prepare/Transport LLW Product** **7.4.10** Reference	1.	*Obtain melter discharge recording system data*		*200*	Commitments: TPA milestone M-60-03, definitive design of LLW vitrification plant.
		2.	Engineering disposal/packaging system concepts	30		
		3.	Engineering disposal/packaging system evaluation	30		
		4.	Field test disposal systems	200		

LEGEND: Baseline/*Non-baseline*.
(a) Fund Immediately.
(b) Fund If Possible.

Table 7.2. Low-Level Waste Immobilization: Recommended Technology Program (contd)

Function and Technology Package		Tasks		FY 1996 Cost Estimate ($K)		
Functional Need Level 4	Template Title (number)	No.	Title	Funded	Not Funded	Benefit
Immobilize & Dispose LLW (4.2.2.4)	**Develop Other Melter Subsystems** **7.4.11** Reference	1.	*Develop concepts design for material conveying and loading and retrieval subsystems*		*300*	Commitments: TPA milestone M-60-03, definitive design of LLW vitrification plant.
		2.	*Develop product rework/recycle concepts for out-of-specification product*		*500*	
		3.	Material compatibility	200		
		4.	*Develop system for handling frit*		*200*	
		5.	*Develop methods for treating liquid effluents*		*300*	
Immobilize & Dispose LLW (4.2.2.4)	**Develop Waste Form Product Matrix/Packaging** **7.4.12** Reference	1.	Identify and develop matrix/container materials	200		Commitments: Required for performance assessment of disposal actions (DOE order 5820.2A). Operations/Interface: Required to ensure physical systems compatibility with disposal facility.
		2.	Characterize sulfur polymer cement as matrix material	700		
		3.	Characterize alternative matrix material	300		
		4.	Characterize container material	200		

LEGEND: Baseline/*Non-baseline*.
(a) Fund Immediately.
(b) Fund If Possible.

Table 7.2. Low-Level Waste Immobilization: Recommended Technology Program (contd)

Function and Technology Package		Tasks		FY 1996 Cost Estimate ($K)		
Functional Need Level 4	Template Title (number)	No.	Title	Funded	Not Funded	Benefit
Immobilize & Dispose LLW (4.2.2.4)	**Develop Method for Controlling and Verifying Glass Waste Form Quality** **7.4.13** Reference	1.	Conduct laboratory development on optical electrical and spectroscopic monitoring	500		Operations: Required to verify product, operations, disposal facility specifications; will ensure the vitrified product meets specifications.
Functional Need Level 4: Immobilize & Dispose LLW (4.2.2.4)	**Develop LLW Disposal System Components** **7.4.14** Reference	1.	Identify candidate physical, chemical, hydraulic barriers	200		Commitments: Required for performance assessment of disposal actions (DOE order 5820.2A). Operations/Interface: Required to ensure physical systems compatibility with disposal facility.

LEGEND: Baseline/*Non-baseline*.
(a) Fund Immediately.
(b) Fund If Possible.

Table 7.2. Low-Level Waste Immobilization: Recommended Technology Program (contd)

Function and Technology Package		Tasks		FY 1996 Cost Estimate ($K)		
Functional Need Level 4	Template Title (number)	No.	Title	Funded	Not Funded	Benefit
Immobilize & Dispose LLW (4.2.2.4)	**Determine Data and Tools Required to Support LLW Performance Assessment** **7.4.15** Reference	1.	Inventory of Radionuclides	200		Commitments: Required to determine final site selection (DOE order 5820.2A).
		2.	Vadose transport parameters	2,000		Operations: Absolute driver for final glass quality form.,
		3.	Ground water transport parameters	200		Operations/Interface: Drives all pretreatment and LLW performance specifications; required for ongoing dialogue with public on acceptable waste form.
		4.	Dosimetry parameters	100		Reduce Risk: Lessons learned from public unacceptability of grout, do performance assessments first.
Total						

LEGEND: Baseline/*Non-baseline*.
(a) Fund Immediately.
(b) Fund If Possible.

7.4 Narrative on Technology Packages

Testing Strategy

Within the LLW immobilization program, the technology strategy requires development, adaptation, and testing of materials, processes, and equipment. Particularly for process and equipment development activities, a specific testing strategy will be followed to ensure that data is available for the LLW plant design and operation needs. Specifically, for each process/equipment development technology package, the following general tasks should be covered:

1. Identify, test, and evaluate technical feasibility of equipment/process
2. Adapt or develop equipment/process as necessary
3. Conduct testing to support design/construction
4. Conduct testing to support permitting/regulatory compliance
5. Conduct testing to support plant startup and operations.

The testing strategy for the LLW Immobilization program includes radioactive and nonradioactive testing at small- and laboratory-scales, nonradioactive testing at a pilot-scale, and final nonradioactive testing in the plant before hot operations. The intent is to maximize the information gained from the testing to support the needs of flowsheet and process development, product development, design, and operations while minimizing the costs.

Process development, equipment adaptation/development, design data generation, integrated system testing, and product quality verification testing will be conducted at small and pilot-scales. The actual sizes of these small- and pilot-scale facilities will be determined after the melter vendor competition has provided sufficient insights to select the technologies to be used. To minimize cost and provide the needed flexibility, most of the testing will be nonradioactive. The pilot-scale facility will be used to provide the scale-up information needed for the vitrification facility design. Because of the limited availability of wastes and the high costs of operation, the radioactive testing with actual wastes will be conducted on a small scale. Radioactive testing is needed for simulant validation, to determine impacts of minor waste components, and to determine the behavior of specific radionuclides in the processing equipment. A similar size/design nonradioactive melter system is then needed to provide validation of the simulants. The melter vendor testing represents the first steps in the nonradioactive testing. The nonradioactive small- and pilot-scale facilities will follow immediately from the vendor testing and may include the selected vendor's facilities. The radioactive small-scale facility will be used later in the program to validate the simulants being used in testing. These small- and pilot-scale facilities will be needed at least through the startup and initial production campaigns of the vitrification plant. They will be used for assessing the processability of wastes and glass formulations as they may vary according to tank retrieval and pretreatment strategies and for process optimization and problem resolution.

The final piece of the recommended testing strategy is the nonradioactive checkout of the vitrification plant. This may include water testing to check plant hydraulics and nonradioactive testing with simulants for final process and equipment verification before starting hot operations.

Technology Packages

The technology packages associated with each function of the LLW Immobilization Program are described below. The description provides a brief summary of

- the justification for this activity

- current status of the technology
- technical approach
- other issues that need to be highlighted.

More detailed information is found in the templates for the LLW Immobilization Program (in Appendix E).

7.4.1 Develop/Adapt Suitable Melter Feed Preparation Flowsheet and System

Before being vitrified, pretreated waste would be mixed with glass additives and prepared for the melter. Melter operation is affected by the feed form, especially the water content, rheology, pH, and redox. These characteristics need to be investigated and specified in relation to feed mixing, transportation, charging to the melter, and conversion to glass in the melter.

The feed form, whether solution/suspension, slurry, or calcine, will depend on the melter type. Glass additives may be fully or partially heat pretreated and fully or partially blended with the waste, or charged separately. Glass forming additions in the form of frit have the advantage of ease of control, while additions of raw chemicals will allow for added flexibility in composition. Precalcination of the feed offers many advantages for offgas management and is being studied in melter testing. In the case of calcination, a full or partial blending of glass additives with the waste may be necessary because the high sodium content of the waste could otherwise produce a corrosive, sticky, and hygroscopic alkaline calcine. If waste solution/suspension or slurry is used, glass additives may or may not be blended with the waste before charging to the melter.

- Feed Rheology: Rheology is important for feed transport and charging to the melter. There are three basic options for feed transportation/charging:
    - Waste solution/suspension and solid additives charged separately. This option virtually eliminates rheology problems; however, it creates excessive demand on the melter's energy supply. The melting rate can be slow in melters with a cold cap (batch blanket). Also, melt homogeneity may be compromised in melters with a short residence time and volume of melter offgas could be magnified.
    - Waste slurry blended or fed separately with glass additives. With this option, slurry rheology must be adjusted by optimizing water content and pH. Separately feeding the waste will eliminate the problem of suspending coarse-grained additives with fine-grained waste; however, this may lead to segregation in the feed tank, which may be detrimental to glass quality. Separate charging would require a melter with a good homogenizing capacity.
    - Waste dried or calcined with a total or fraction of glass additives. This option would allow good control of feed homogeneity and a high melting rate, and potentially better incorporation of volatiles into the melt. A detailed laboratory study of calcination reactions would be needed.
- Feed Redox and Volatility
    - Feed redox potential has an impact on incorporating troublesome components, such as technetium, into glass. Feed redox potential can be adjusted by adding reduction/oxidation agents that can be destroyed in the melter and removed by the offgas system. Proper redox potential will maximize incorporation of troublesome components to the glass without excessive recycling of these components through the offgas system. Care must be taken in

reduction of the melt to avoid decreasing the solubility of multivalent components and decreasing the glass durability.

- The rate of volatilization of sodium, cesium, boron, technetium, etc. would be experimentally determined as a function of melt composition, temperature, and melter atmosphere. Melter type will have an impact on volatilization: Cold cap melters will minimize it, melters with fluidized feed (combustion, plasma torch) will increase it by orders of magnitude. Humidity is also an important factor. Thus, a slurry-fed melter will exhibit a different volatilization rate than a calcine-fed melter; a gas-heated melter will behave differently than an electric-heated melter, etc. Gas flow rate, humidity, surface area exposed, temperature, redox, melt accelerants, and other factors should be investigated to provide criteria for melter selection, high waste loading, and reduction of volatilization.

7.4.2 Develop Simulant Characteristics for Phase II Melter Testing

The goal of this activity is to develop and specify a simulant to support Phase II testing and down selection of LLW melter technologies. The objective is to determine the ability of a melter system to feed the waste, perform any preprocessing of the feed, vitrify the waste under conditions of sustained operation, and to be able to address offgas issues. The simulant will be based on the best available characterization data, pretreatment assumptions, and specification for the waste feed, as well as knowledge of melter systems.

7.4.3 Develop Acceptable Methods of Incorporating Recycle Streams into Melter Product

Radioactive and/or hazardous streams (solid, liquid, and gas) other than the main LLW stream will be generated during pretreatment and HLW and LLW vitrification. The incorporation of these waste streams into glass, (via recycle), or into other waste forms has not been demonstrated. Some of these streams may best be recycled into the LLW melter or the head-end feed preparation. This will minimize waste streams in conformance with the Resource Conservation and Recovery Act (RCRA), but can have significant impacts on head-end process chemistry, melter operation, and LLW vitrification product quality. The effects become important when high-temperature, high-throughput melters are considered because of the release of semivolatiles into the offgas systems and the need to recycle such volatiles. In some cases, it may be cost effective to develop additional waste forms for constituents not readily incorporated in the glass waste form. The potential benefits derived from recycle will be compared to those of developing alternative waste forms to minimize disposal system costs and optimize system performance

Flow sheet development to identify potential recycle streams is under way. Other needed activities are the determination and verification of melter system impacts and needed system modifications, the steady-state equilibrium product concentrations of recycle components, the effect of recycle on product quality, and any necessary changes in melter operation to control the amount of materials to be recycled.

7.4.4 Radioactive Testing

Radioactive testing is required 1) to ensure that the simulants used in product and process development provide results representative of the actual wastes, 2) to provide process and product data on radioactive species that cannot be obtained from nonradioactive simulants, and 3) to validate the process and product models developed using simulants. If the simulants used in the product and process development are not validated, the vitrification plant or the glass product may not function as designed because the chemistry of the waste feed to the plant could be different because of process history, chemical history, and/or minor differences in composition.

Selected actual waste samples from the waste tanks will be processed through the vitrification process on a laboratory scale to validate process stream properties, process behavior, and glass product properties. It is highly unlikely that any of the tank samples will have the same composition as actual feeds to the plant. The key is to select a range of tank waste compositions that reasonably represent the envelope of waste feed concentrations to the plant so that the generic process chemistry can be validated early in the process development. It may be appropriate to run the wastes through a simulated pretreatment process before running them through the vitrification process. This validation is performed in a timely manner to make early modifications to plant, process, and/or product design, if needed. Additional validation on a laboratory scale would be prudent just before feeding a particular waste to validate glass formulation performance and product/process performance.

Selected tests would also be performed with actual pretreated radioactive wastes on a small scale. These scaling tests would process the waste through key small-scale plant equipment. Similar size/design nonradioactive equipment is then needed to provide validation of the simulants and to provide a tie from the radioactive bench-scale testing through to a nonradioactive pilot-scale facility to the actual operating plant.

7.4.5 Evaluate/Adapt Melter Technology for LLW Vitrification

The TWRS strategy for complying with the TPA calls for testing commercially available melter systems. This path has involved advertisement of interest, preparation of an RFP, and evaluation and selection of vendors. The testing is planned to be carried out in two phases. Phase I consists of seven vendors using joule heated, combustion, carbon arc, and plasma torch melters. Phase I vendors have prepared test plans, prepared their facilities, run tests with simulants, and prepared reports on the tests and the melter. Melter technologies will be down-selected to Phase II, where 3 to 5 additional LLW simulants will be run based on single tank inventory and remaining inventories of Hanford Site waste.

In order to evaluate the performance capability of vendor systems, glass and process stream samples will be taken at various intervals during the test. The melter systems will be evaluated for processing capability, technical maturity, operability, maintainability, flowsheet features, and system cost implications. Additional key performance characteristics are anticipated service life and reliability under continuous operating conditions.

Areas to be assessed are the ability to use a commercial melter in a radioactive environment, identification of commercial technology that can produce the needed quantity and quality of glass, ability to replace a melter or portion of the melter (e.g., refractory lined chambers), and flexibility of a melter system to process various waste feeds. These issues will be evaluated using results from the melter testing, and by conducting engineering studies for the various system components, which will be needed to carry out the LLW vitrification objectives.

7.4.6 Develop Glass Waste Form and Glass Specification

The glass composition and waste form specification cannot be based only on the performance requirements of the waste storage/disposal system. Processing requirements and other requirements imposed on the waste glass formulation by the melter and its subsystems must also be considered. The overall objectives of the glass formulation effort are 1) to develop glass formulations with maximum waste loading while maintaining satisfactory long-term durability, acceptable processing characteristics, and flexibility to handle waste variations, and 2) to develop the methodology and tools for modifying the glass formulation in response to large waste variations. Several of these considerations are described in the following subsections.

Reference Glass Formulation

- Because of the high sodium content in the Hanford LLW, the glass formulation will have a crucial impact on waste glass volume, processability, and durability. The waste loading in the glass is expected to be limited by sodium content—the higher the sodium content in the glass, the lower the total volume of glass waste product. Unfortunately, high-sodium glass tends to have relatively low durability. Careful glass formulation will allow waste loading to be maximized without compromising the product performance.

- Glass formulation development will begin by determining the specific glass type(s) to be selected for LLW immobilization. Literature will be reviewed and scoping tests performed to specify major glass components.
- The preliminary component choices for glass form are SiO_2, Al_2O_3, CaO, and B_2O_3, of which SiO_2 and Al_2O_3 will form the basic glass matrix and CaO and B_2O_3 are additives or modifiers that are incorporated, among other reasons, to inhibit the release of Na_2O and other constituents. Al_2O_3 is also added to suppress dealkalization.
- To optimize LLW glass properties and performance, major components of the reference glass will be varied and a series of simulant glasses will be prepared and tested. Thus, properties of the glass will be determined as functions of the glass composition. Correlation functions between properties and composition will be developed. The properties of interest are glass durability, melt viscosity, liquidus temperature, glass morphology, and, depending on the type of melter selected, melt electrical conductivity.

Waste Loading

- Special attention should be given to the relationship between the waste loading and glass durability. Nondurable glasses with a low sodium content (low LLW loading) exist, whereas durable glasses have been prepared with more than 30 wt% Na_2O. However, extremely high-sodium glasses may be sensitive to composition fluctuations, and their performance over the long term may not be reliable. Therefore, development of glasses with high sodium content would require a significant characterization effort to substantiate acceptable performance.

Troublesome Components

- Some minor components, such as phosphorus, sulfur, fluorides, chlorides, iodine, and technetium, may cause problems in melter operation (liquid-segregation, volatilization, corrosion of walls and electrodes, offgas problems), or even limit waste loading. The maximum allowable content of these components in glass would be determined. The effect of major glass components on the maximum allowable content of troublesome components and interactions between individual troublesome components would be studied. Studies would include both laboratory crucible testing and scaled melter tests. Radioactive testing will likely be necessary to verify non-radioactive work and determine impacts of components that cannot be adequately simulated.

Glass Durability

- Glass formulation work is guided by standard and modified durability tests based on glass dissolution over a range of temperatures in an aqueous medium. An increased test temperature may be used to accelerate the process provided that the dissolution mechanism does not change—this point must be checked. An additional method to accelerate glass dissolution testing is to powder the glass for testing. Additional approaches will involve varying the ratio glass surface area to water volume, use of both static and flow-through tests, and conducting vapor tests to provide information on surface phases. Dissolution would be measured as a function of time to determine the rate. Glass composition will be selected using the results of these durability tests.
- As part of the glass composition determination for reference formulation and back-ups, more detailed studies will be performed to determine the glass dissolution rate as a function of ground water

composition, saturation of the ground water with glass components, pH, redox, etc. This investigation will have two goals: 1) possible further modifications of glass composition to enhance glass performance, and 2) input for performance assessment models.

Glass Composition Computer Model

- The glass composition used in LLW vitrification will need to be selected for its waste loading, melter operation, and durability considerations. Because of the variety of waste streams in the TWRS program, a strong need exists for the ability to predict, quickly and accurately, the glass compositions and processing characteristics to optimize glass performance under these constraints. Ultimately, such a capability in the form of a computer code is envisioned to be an integral part of the control system for the vitrification facility.
- A computer-based, predictive model is needed that can take as input waste composition, durability requirements, and melter operating characteristics and whose output will be a prediction of optimum glass composition and process conditions. This model will require extensive experimental verification and refinements. Computer models have been developed at PNL and SRS for application to the HLW program. Their applicability to LLW will be assessed as data becomes available and the needs of the codes to guide glass formulation and process control are better defined.

7.4.7 Develop/Adapt Suitable Melter Offgas System

Extensive design and development has been performed for treating offgases from low-volume HLW melters at Savannah River, Hanford, and West Valley. Additional radioactive offgas experience has been gained from acid HLW melters operating in Britain, France, and Germany. However, the much larger size of the LLW melter and the volume of gases that must be processed at Hanford requires re-examination of the offgas treatment system for LLW. Melter type also impacts the offgas system. Combustion-fired melters typically produce much larger volumes of offgases than equivalent-capacity electric melters. The larger volume of offgas requires a larger offgas system for treatment, increases the entrainment of solids that must be removed, and dilutes the volatile and semivolatile radionuclides. Techniques for real time offgas monitoring will need to be adapted or developed.

The need for organic emissions control from the melter (i.e., would the melter be used and licensed as an incinerator?) and organics pathways through the plant must be resolved.

The need for sulfurous oxides control from the melter must also be addressed. Although sulfurous oxides are easily scrubbed from the melter offgas, an option is to release it from the plant stack if the concentration is low enough. With this option of a dry melter offgas system, the water in the melter would also be released from the stack to reduce plant wastes. If the sulfurous oxides are scrubbed, they may need to be recycled to the vitrification system, released with process wastes, or included in a "third waste form."

Release of semivolatile materials such as technetium-99, cesium-137, alkali metals, fluoride, chlorine, ruthenium-106, phosphorus, tin, and iodine-129 as offgas components need to be addressed. These semivolatile components may be released from the melter as a gas in amounts from several percent up to nearly complete volatization, depending on melter, redox, temperature, and other issues. These species may condense or be reduced to a solid and deposited in the offgas system. Options exist to develop glass formulations to suppress material volatilization, to collect and recycle the material to the melter (which results in a recycle buildup and may lead to accelerated materials corrosion), or to incorporate the material into a third waste form.

Solid, nonvolatile aerosols also will be generated by the melter. Technology generally exists to manage the solids in the offgases; however, some additional demonstration of melter offgas capture could be needed.

Conventional separation technologies that can be considered include scrubbing, condensation, filtration, electrostatic precipitation, and catalytic oxidation or reduction. Two alternative technologies are plasma torch/centrifugal separations and membrane separations.

Various design alternatives would be evaluated and individual components tested using nonradioactive materials at laboratory, small, or pilot scales. Limited testing with actual radioactive wastes is needed to confirm that the less expensive test results using nonradioactive simulants are valid.

7.4.8 Develop Additional Waste Forms

A means of disposal must be identified for materials and chemical components that are not amenable or not appropriate for immobilization in the LLW glass. These could be structural components, such as melters and piping, or volatile chemicals, such as technetium or iodine. A number of the volatile elements, even if recycling of the offgas system is prescribed, will return to the melter.

Development of additional waste forms must have as objectives 1) identifying compositions with maximum waste loading while maintaining satisfactory long-term durability, acceptable processing characteristics, and flexibility to handle waste variations, and 2) to develop the ability to modify the waste form in response to waste variations.

This activity will develop and analyze solutions for waste constituents that are not readily incorporated into a vitrified waste form. Process flowsheets and candidate waste streams will be examined and options chosen for treatment, recycle, and disposal of nonvitrifiable waste streams. Results will be provided to LLW permitting and design activities to help define the technical scope of the LLW effluent treatment facility and solid waste form disposal planning.

7.4.9 Develop/Adapt LLW Vitrification System Instrumentation and Controls

The processing and disposal of LLW will require the facility to provide control systems and data for product quality, process control, regulatory reporting, and other supporting requirements. It is necessary to control the quality of the vitrified LLW form from the melter to ensure a high-quality product that meets disposal criteria. Effluent liquids and gases must be measured and controlled to be suitable for treatment, recycle, release, or reporting. The disposal facility must monitor the ground water, soil column, leachate collection system, and waste form for extended periods of time to verify compliance with RCRA and DOE regulations. These objectives can be achieved if suitable instrumentation and controls, analysis methods, and supporting data acquisition methods are available.

A process and product control system *approach* must be established for the plant designers and must include considerations for economy, simplicity, reliability, and maintainability and only modest (if any) development. Ensuing designs and technical studies would be performed to assess process and product control approaches and to assess instrumentation and control equipment available to meet each control approach.

The LLW vitrification process provides several unique challenges attributable to the combination of radiation, heat, and salts in the critical process steps. Process variables in need of monitoring or control are melter feed flow rates, melter feed slurry density (solids composition if slurry processing will be used), melt temperature, melt redox potential, melt liquid level, melt composition, and gas composition. Also of concern are melt foaming and melt glass phase separation. Process monitoring instruments and control systems are available in the glass-making industry or can be adapted from plants in use at DOE processing facilities for HLW vitrification. Gaps in instrumentation/control technology need to be determined. Instrumentation development should be instituted *as necessary*, to account for specific differences in the LLW feed stream rheology, expected melt composition ranges, and offgas composition and properties.

The LLW vitrification plant would use existing analytical techniques to the maximum extent practical as developed commercially and at Hanford, Savannah River, and West Valley. Modest analytical method verification and any needed development work would be conducted to ensure the techniques work in their intended application. Examination of the expected analytical load and available techniques makes it apparent that rapid, simple, reliable, and accurate analytical techniques for cation and anion analyses would be highly desirable and cost effective. Laser ablation inductively coupled plasma/mass spectrometer (ICP/MS) for solids/slurry analyses and online ion chromatography (IC) with ICP/MS for important specific radionuclides are under development. Demonstration of these techniques with and without radionuclides is planned.

The sampling schedule for the LLW vitrification plant needs to be developed. It is currently anticipated that the speed of the planned analytical techniques will not change to the same extent as the sampling rate, as currently anticipated. The analytical techniques need to be tested using simulant materials and actual radioactive materials to develop methods as necessary, ensure that specific sample matrices do not cause problems with analysis results, and resolve any competing problems with element interference. The technique results need to be compared to those of different techniques and the same techniques performed at different sites. Finally, existing validated procedures need to be collated for use, and new or modified procedures need to be provided for any new or modified techniques.

7.4.10 Develop Systems to Form, Sample, and Prepare/Transport LLW Product

The TPA implementation strategy assumes that the vitrified LLW disposed of on the Hanford Site is in retrievable form. Systems need to be developed to receive the vitrified product from the LLW melter, verify that this product meets quality requirements of the product specification, and prepare and transport the vitrified product to the disposal site and load it into the facility.

Development needs include subsystems to receive the vitrified product from the melter; verify (rapidly and accurately) its acceptability against specifications; and develop methods to effectively load, transport, and unload the product for its placement in the storage/disposal facility.

7.4.11 Develop Other Melter Subsystems

Evaluation of vitrification plant subsystems is critical for a successful waste vitrification plant. These systems include those required to recycle the glass product, as well as product handling and packaging. Subsystem design input information will be developed and evaluated. These include:

- materials handling and loading subsystems
- a waste container, melter interface design concept, and product packaging
- liquid waste pretreatment
- glass handling and rework/recycle concepts to deal with out-of-specification product.

7.4.12 Develop Waste Form Product Matrix/Packaging

The glass discharged from the melter will be placed in a package for transport to the LLW storage/disposal facility. The current baseline concept is that glass in the form of a cullet or marbles will be placed in a molten sulfur-polymer-cement matrix and will be pumped to the storage/disposal facility. Alternative concepts include placing the glass/matrix into a container for transport/storage or pouring the molten glass directly into a container, which would be transported to the storage/disposal facility after cooling.

The use of a matrix presents the opportunity to improve the performance of the waste form in the disposal facility by controlling the chemistry in the immediate disposal environment and/or by controlling the flow of water around the glass.

Implementation of matrix/container concepts requires that matrix or container materials first be identified and evaluated. Sulfur-polymer cement has been identified as a potential matrix material for LLW and steel canisters have been selected for containers for HLW. Identification and development of alternative matrix materials is required, particularly those that could have a chemical gettering or retardation effect on radionuclides such as technetium.

Selected matrix and/or container materials must be characterized to support processing, performance assessment, and disposal system design. The characterization would include determining any deleterious interactions between the glass and the matrix or container, verifying any enhanced chemical, mechanical or hydraulic properties, determining the source term for the glass/matrix or glass/container, and determining the thermodynamic stability and kinetics of degradation of the matrix/container material, including radiation stability and biodegradation. Processing considerations for the glass/matrix/container are discussed in the section describing subsystems to form, sample, and prepare/transport the LLW product.

7.4.13 Develop Method for Controlling and Verifying Glass Waste Form Quality

To meet RCRA requirements for a Part B permit for disposal of LLW, a means of determining the quality of the waste form and monitoring the performance of the disposal system must be identified. It is highly desirable that this monitoring be done by nondestructive techniques.

Work is currently proceeding to deliver a prototype sensor for the measurement of electrochemical properties of the LLW waste form. This work also includes the measurement of the electrochemical potential in the melt. This will allow for measurements indicating glass quality during the melt process, after solidification, and in the disposal system.

7.4.14 Develop LLW Disposal System Components

The LLW form, including vitrified waste and any matrices and containers will be disposed in an engineered, near-surface disposal facility, most likely on the 200 Area plateau of the Hanford Site. This engineered disposal system will include physical, chemical, and hydraulic barriers as necessary to deter intrusion into the disposal site and to further control the release and migration of contaminants beyond what may be achievable with the LLW waste form to meet safety and environmental protection requirements.

Concepts for the disposal facility are currently being developed. The ability of these conceptual facilities to meet requirements for the long-term protection of the environment will be evaluated through PA analyses. These analyses may indicate that the performance of the vitrified waste form must be improved and/or that features must be added to the disposal system to meet the performance objectives. Through an iterative process, the design of the engineered disposal system, including the waste form, will evolve to one that can be shown with reasonable assurance to provide the long-term protection of the environment.

It has long been recognized that a protective cover will be placed over the disposal site to minimize water infiltration into the disposal area and to deter human, plant, and animal intrusion into the waste disposal area. This Hanford protective barrier is being developed by another program and a prototype is currently being tested on the Hanford Site.

7.4.15 Determine Data and Tools Required to Support LLW Performance Assessment

The TPA implementation strategy is to vitrify and store the low-level fraction of the Hanford Site tank waste and dispose of the vitrified waste onsite, near-surface, in a retrievable form. DOE Order 5820.2A requires a site-specific radiological PA for disposed waste to demonstrate compliance with performance objectives for protection of human health and the environment.

The official DOE PA system recognizes only the terms "preliminary" and "final" PAs. The Final is required prior to emplacement of waste in the disposal facility, according to present rules. That rule is about to change, however, and it will most likely change such that DOE approval of the Final is required prior to start of construction of the disposal (not processing) facility for a situation like TWRS. The "preliminary" is simply the first time the DOE Peer Review Panel (PRP) sees the PA, and receives feedback.

TWRS planned that DOE could not approve final design of the processing complex until they had some assurance that the product would be disposable at Hanford. Hence the "Interim" PA. TWRS plans to issue an interim PA in time to support a decision to authorize final design of the processing complex.

The PA includes an evaluation of the disposal system, environmental conditions, and human exposure scenarios. Because the location and design of the LLW disposal facility have direct effects on the facility's performance, a PA can be used as a tool in selecting a site and developing design criteria for the disposal facility. The PA can be especially useful to assess the sensitivity of the overall disposal system's performance to specific site, facility, and waste form design parameters.

This technology package deals with the data needs and tools for carrying out the PA. The work herein is closely compiled with work in the Glass Formulation, Matrix/Packaging, and Disposal System technology packages.

Currently, the location of the LLW disposal facility has not been selected, facility design criteria have not been established, and specification of waste forms and types of engineered barriers have not been determined. The PA methodology used will include all aspects of the release, transport, and exposure of radionuclides. Models should include waste form degradation, transport through engineered barriers, transport through unsaturated and saturated soils, transport through air, and human exposures. The PA should also address uncertainty and sensitivity analysis. Products of the performance assessment analyses include performance guidelines for disposal system design, inventory limits, and waste form performance requirements. A formal PA document is required to meet DOE orders.

Develop Transport Data for Performance Assessment of LLW Disposal

During the site selection process and the final performance evaluation of the LLW disposal system, a considerable amount of far-field transport data will be needed including geological/hydrological, recharge, geochemical, saturated flow, and air transport data. An important issue for the disposal of the Hanford LLW tank waste is to select a site that will not be impacted by future contamination plumes from existing and potential contamination. Understanding the transport behavior of contaminants is crucial to the disposal site selection, and can potentially involve extensive data collection.

Technology needs include the following

- Develop a strategy for data collection during the site selection process that will establish the types of data needed, the level of data collection needed, and how the data collection efforts can be prioritized based on preliminary PA actions.
- Collect and document far field transport data, and radionuclide retardation factors.

Determine LLW Constituent Inventories

Developing accurate inventories for critical constituents in the tank waste and hence in the LLW feed material received from pretreatment is an important part of developing an accurate and defensible PA. The inventory of a few key long-lived constituents, generally present in low concentrations in the tank waste, is expected to dominate and control the design and environmental impact of the LLW disposal system. The inventories of these constituents, such as technetium-99, iodine-129, and neptunium-237, must be accurately determined to ensure that the overall storage/disposal system will meet performance requirements. Presently, the inventories of many of the key constituents are not well known, and the techniques needed to make such measurements in many cases need to be developed.

The development needs include an accurate accounting of the tank waste inventories and their disposition, including the following:

- identify the key constituents of concern
- determine the accuracy and detection limits for these key constituents using existing laboratory facilities (from Characterization end function)
- determine the key constituent inventories in the tank waste (from Characterization end function)
- establish the pretreatment flow sheets and the partitioning of key constituents that emerge during pretreatment.

As a part of the Characterization function, the existing inventory of the tank waste will be evaluated and key constituents identified, along with their uncertainties and the effects of these uncertainties on the disposal system's long-term performance. If required, additional data will be obtained, and the techniques developed to collect those data and reduce inventory uncertainties to acceptable levels. Pretreatment flow sheets and laboratory tests will be used to determine the degree of partitioning that will occur in various pretreatment and vitrification operations to determine the actual inventory of the key constituents expected to be in the waste glass.

Develop LLW Immobilized Product Specifications

Performance-based specifications for the LLW glass and the other immobilization components (currently considered as a matrix material and possibly a waste package) will be developed based on onsite disposal of the LLW tank inventory. The performance-based product specification will be developed through the interaction of the disposal system performance analysis, testing of candidate waste glass formulations and matrix compositions, and waste inventory assessments to ensure the disposal system performance is achievable.

A preliminary performance-based specification for the immobilized waste product will be developed based on application of the PA methodology and simplifying conservative assumptions regarding the waste inventories and the site-specific characterization data.

These specifications will be compared with test data from candidate glass formulations and matrix concepts in the disposal system conceptual designs.

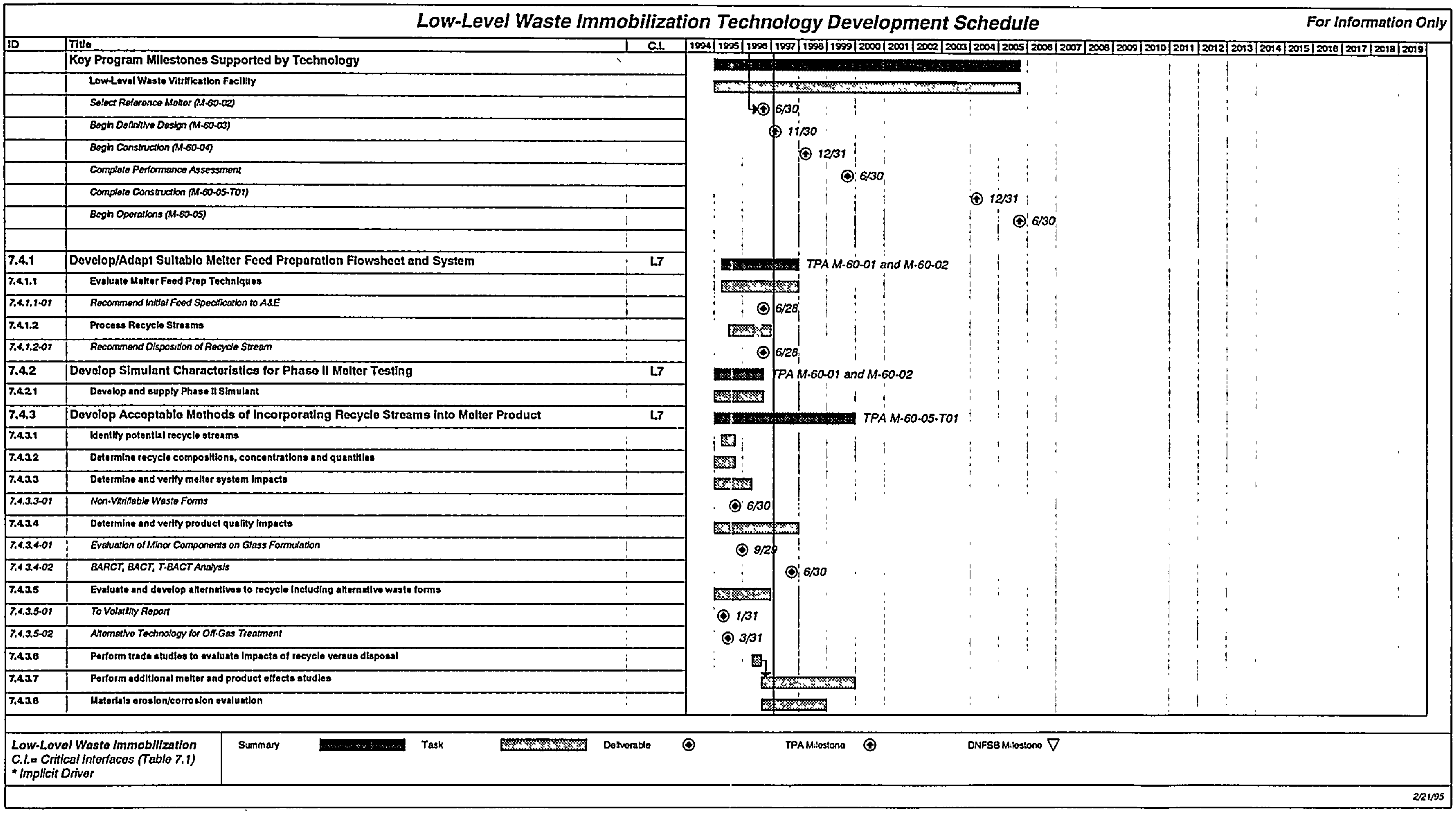
7.5 Schedule and Budget

The schedule and budget for technology activities supporting the LLW Immobilization Program are shown in Figure 7.2 and Table 7.3., respectively. Figure 7.2 identifies template activities, tasks within each template, deliverables, critical interfaces, and drivers (depicted to the right of each template activity bar). Table 7.3. presents two sets of budget estimates by program element and fiscal year. The first profile consists of activities currently included in the TWRS Multi-Year Work Plan (MYWP) and reflects the estimated budget available for technology. The second profile reflects the estimated budget required to perform all tasks shown in the ITP, including activities that are anticipated to be funded and those that are not (unfunded activities have been prioritized for inclusion in the MYWP at the first opportunity).

7.6 Prioritization (Results)

- Table 7.2 presents the functions, technology packages, tasks, FY 1996 budgeted costs, estimated FY 1996, and a brief statement regarding the benefit of funding these technology activities.
- The LLW technology development issues are some of the first to be addressed under the Tri-Party Agreement (TPA), and as such, there is little time to substantially alter them. The LLW planning

team felt that any changes in LLW issues would entail a change in task scope of existing technology packages rather than an addition or deletion of entire technology packages. The LLW group felt that some issues might need mid-course correction, primarily depending on selection of a specific melter technology.



Low-Level Waste Immobilization Technology Development Schedule

For Information Only

ID	Title	C.I.
	Key Program Milestones Supported by Technology	
	Low-Level Waste Vitrification Facility	
	Select Reference Melter (M-60-02)	
	Begin Definitive Design (M-60-03)	
	Begin Construction (M-60-04)	
	Complete Performance Assessment	
	Complete Construction (M-60-05-T01)	
	Begin Operations (M-60-05)	
7.4.1	Develop/Adapt Suitable Melter Feed Preparation Flowsheet and System	L7
7.4.1.1	Evaluate Melter Feed Prep Techniques	
7.4.1.1-01	*Recommend Initial Feed Specification to A&E*	
7.4.1.2	Process Recycle Streams	
7.4.1.2-01	*Recommend Disposition of Recycle Stream*	
7.4.2	Develop Simulant Characteristics for Phase II Melter Testing	L7
7.4.2.1	Develop and supply Phase II Simulant	
7.4.3	Develop Acceptable Methods of Incorporating Recycle Streams into Melter Product	L7
7.4.3.1	Identify potential recycle streams	
7.4.3.2	Determine recycle compositions, concentrations and quantities	
7.4.3.3	Determine and verify melter system impacts	
7.4.3.3-01	*Non-Vitrifiable Waste Forms*	
7.4.3.4	Determine and verify product quality impacts	
7.4.3.4-01	*Evaluation of Minor Components on Glass Formulation*	
7.4.3.4-02	*BARCT, BACT, T-BACT Analysis*	
7.4.3.5	Evaluate and develop alternatives to recycle including alternative waste forms	
7.4.3.5-01	*Tc Volatility Report*	
7.4.3.5-02	*Alternative Technology for Off-Gas Treatment*	
7.4.3.6	Perform trade studies to evaluate impacts of recycle versus disposal	
7.4.3.7	Perform additional melter and product effects studies	
7.4.3.8	Materials erosion/corrosion evaluation	

Low-Level Waste Immobilization
C.I.= Critical Interfaces (Table 7.1)
** Implicit Driver*

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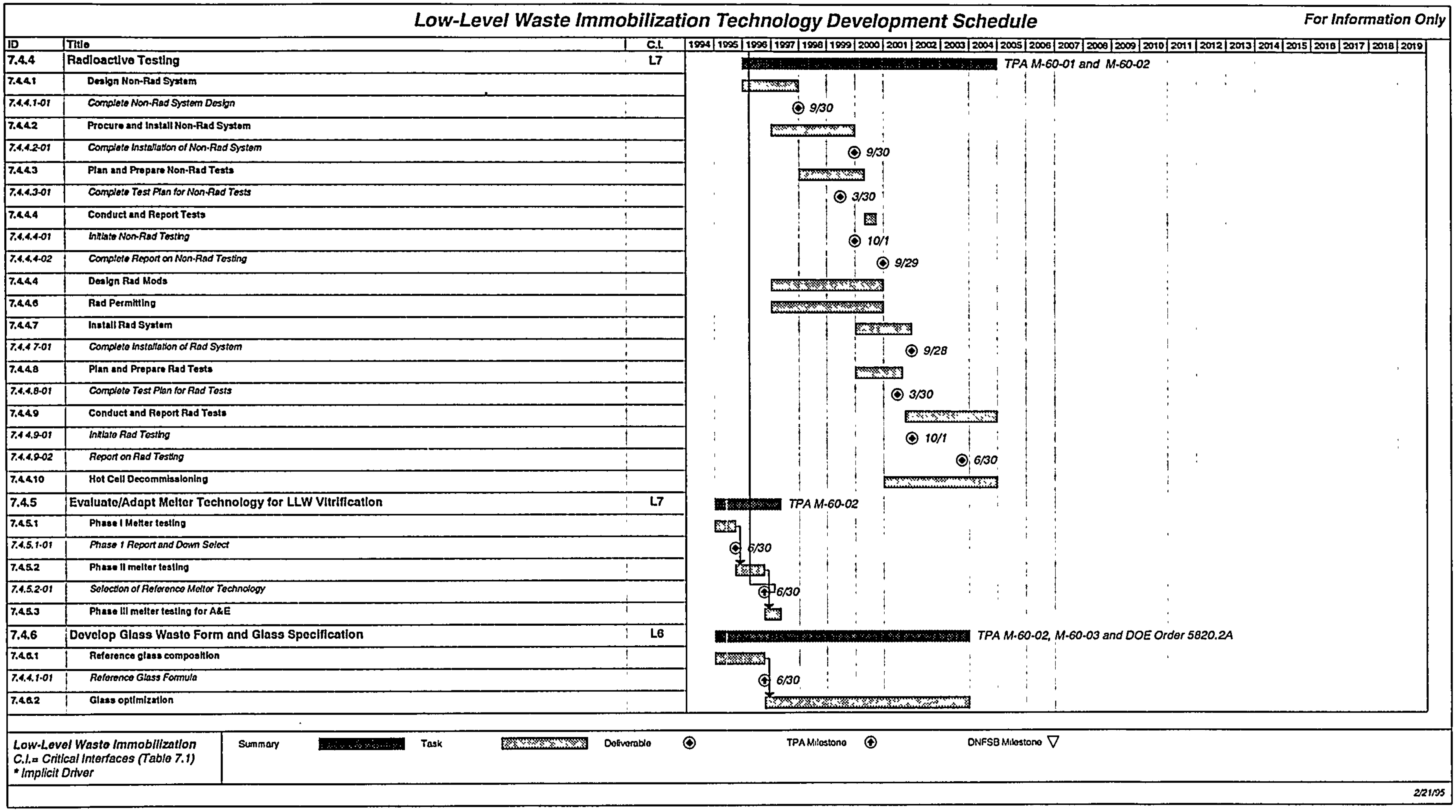
Figure 7.2. Schedule



Low-Level Waste Immobilization Technology Development Schedule

For Information Only

ID	Title	C.I.	
7.4.4	Radioactive Testing	L7	TPA M-60-01 and M-60-02
7.4.4.1	Design Non-Rad System		
7.4.4.1-01	*Complete Non-Rad System Design*		9/30
7.4.4.2	Procure and Install Non-Rad System		
7.4.4.2-01	*Complete Installation of Non-Rad System*		9/30
7.4.4.3	Plan and Prepare Non-Rad Tests		
7.4.4.3-01	*Complete Test Plan for Non-Rad Tests*		3/30
7.4.4.4	Conduct and Report Tests		
7.4.4.4-01	*Initiate Non-Rad Testing*		10/1
7.4.4.4-02	*Complete Report on Non-Rad Testing*		9/29
7.4.4.4	Design Rad Mods		
7.4.4.6	Rad Permitting		
7.4.4.7	Install Rad System		
7.4.4 7-01	*Complete Installation of Rad System*		9/28
7.4.4.8	Plan and Prepare Rad Tests		
7.4.4.8-01	*Complete Test Plan for Rad Tests*		3/30
7.4.4.9	Conduct and Report Rad Tests		
7.4 4.9-01	*Initiate Rad Testing*		10/1
7.4.4.9-02	*Report on Rad Testing*		6/30
7.4.4.10	Hot Cell Decommissioning		
7.4.5	Evaluate/Adapt Melter Technology for LLW Vitrification	L7	TPA M-60-02
7.4.5.1	Phase I Melter testing		
7.4.5.1-01	*Phase 1 Report and Down Select*		6/30
7.4.5.2	Phase II melter testing		
7.4.5.2-01	*Selection of Reference Melter Technology*		6/30
7.4.5.3	Phase III melter testing for A&E		
7.4.6	Develop Glass Waste Form and Glass Specification	L6	TPA M-60-02, M-60-03 and DOE Order 5820.2A
7.4.6.1	Reference glass composition		
7.4.4.1-01	*Reference Glass Formula*		6/30
7.4.6.2	Glass optimization		

Low-Level Waste Immobilization
C.I.= Critical Interfaces (Table 7.1)
** Implicit Driver*

Summary ▬ Task ▨ Deliverable ◉ TPA Milestone ◉ DNFSB Milestone ▽

2/21/95

Figure 7.2. Schedule (cont)

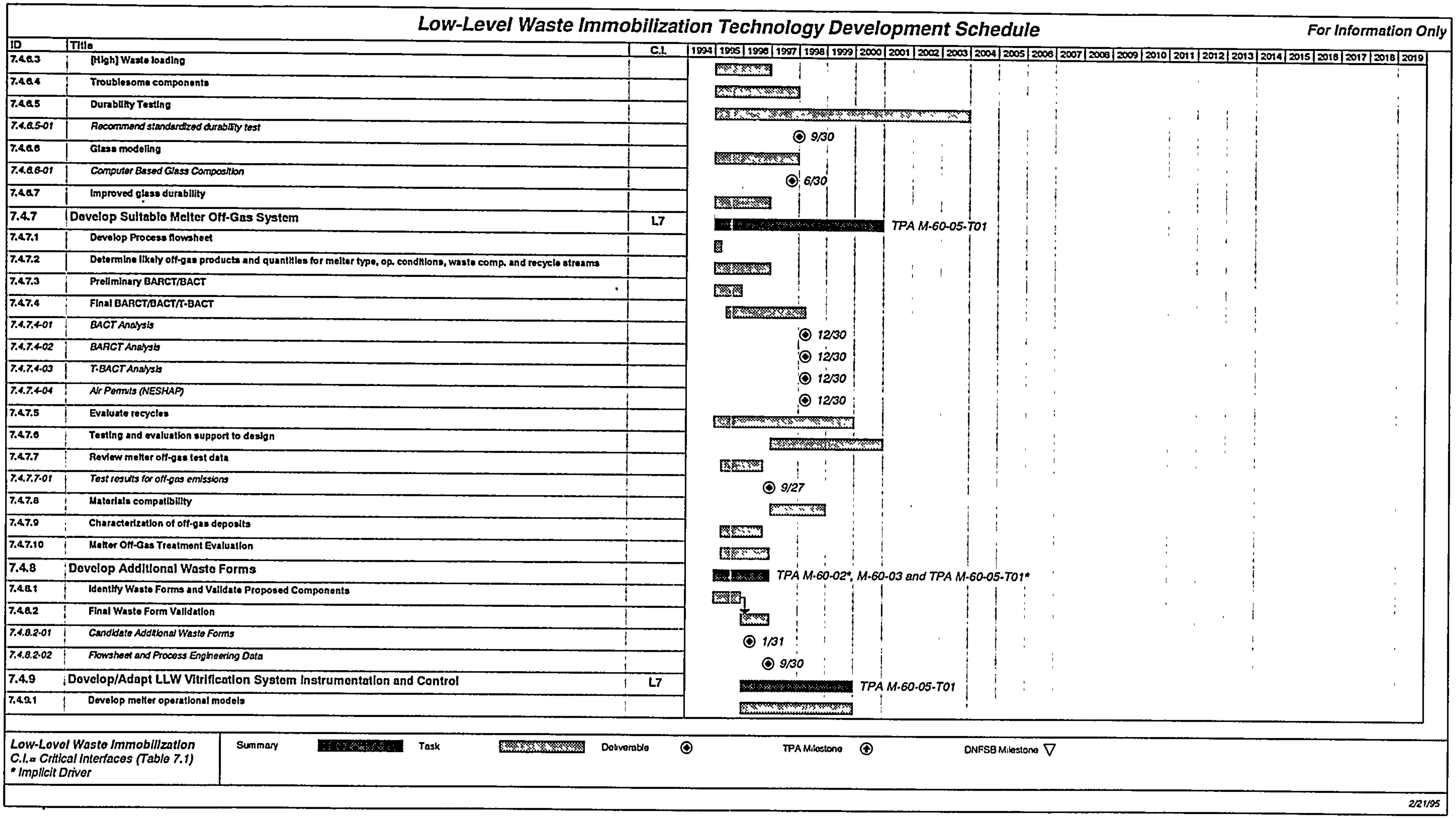
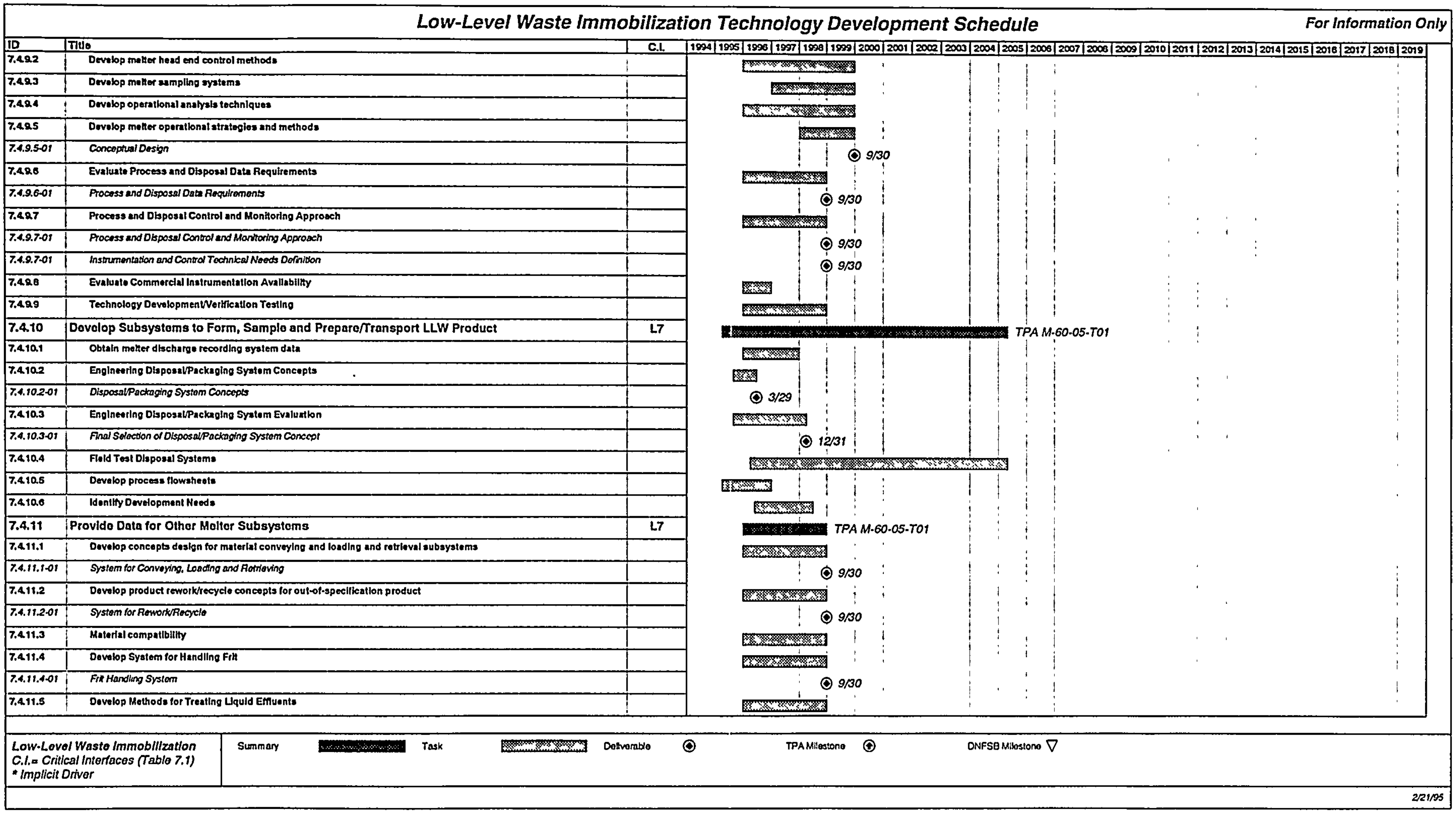


Figure 7.2. Schedule (cont)



Low-Level Waste Immobilization Technology Development Schedule

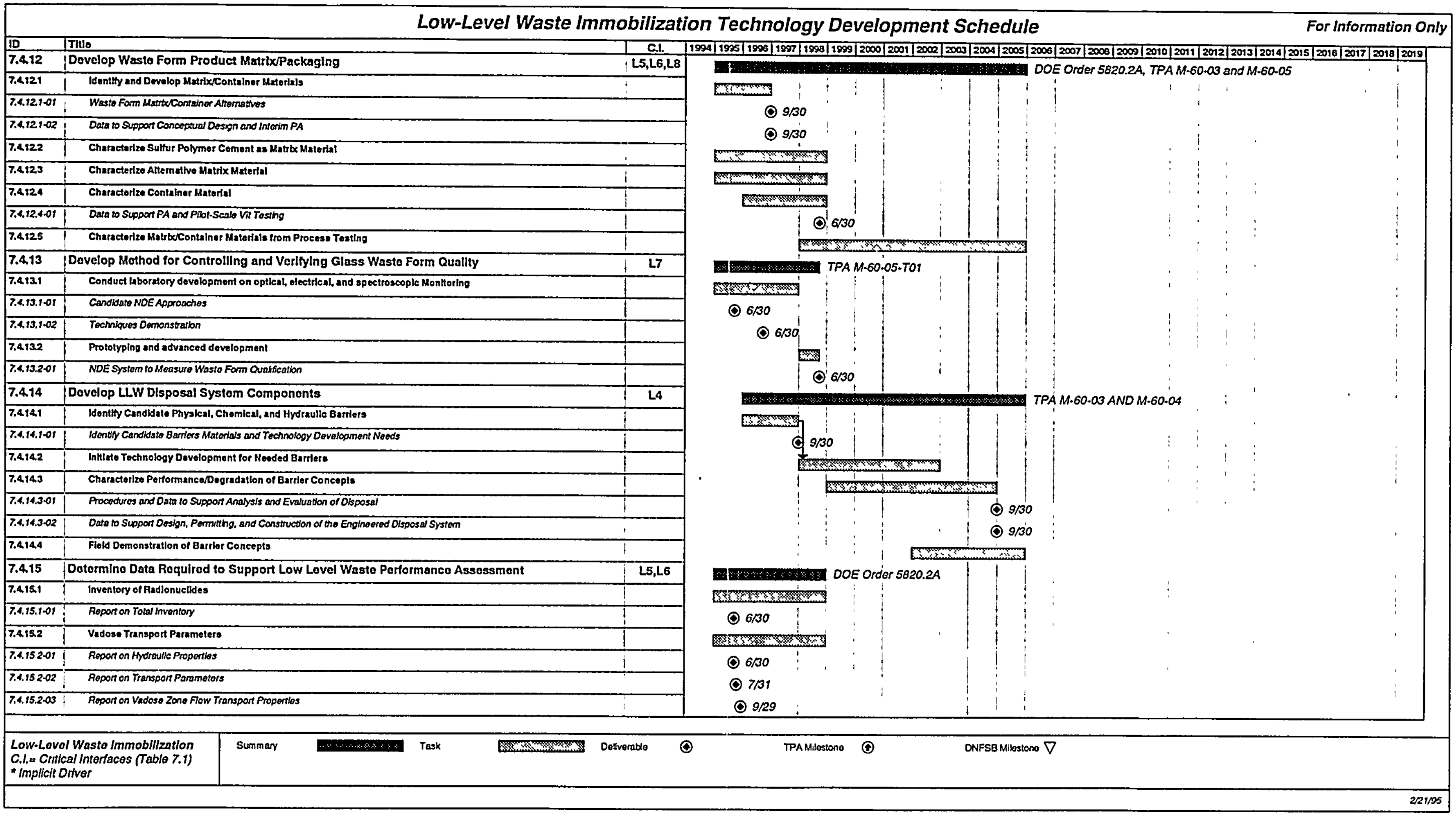
For Information Only

ID	Title	C.I.
7.4.9.2	Develop melter head end control methods	
7.4.9.3	Develop melter sampling systems	
7.4.9.4	Develop operational analysis techniques	
7.4.9.5	Develop melter operational strategies and methods	
7.4.9.5-01	*Conceptual Design*	
7.4.9.6	Evaluate Process and Disposal Data Requirements	
7.4.9.6-01	*Process and Disposal Data Requirements*	
7.4.9.7	Process and Disposal Control and Monitoring Approach	
7.4.9.7-01	*Process and Disposal Control and Monitoring Approach*	
7.4.9.7-01	*Instrumentation and Control Technical Needs Definition*	
7.4.9.8	Evaluate Commercial Instrumentation Availability	
7.4.9.9	Technology Development/Verification Testing	
7.4.10	Develop Subsystems to Form, Sample and Prepare/Transport LLW Product	L7
7.4.10.1	Obtain melter discharge recording system data	
7.4.10.2	Engineering Disposal/Packaging System Concepts	
7.4.10.2-01	*Disposal/Packaging System Concepts*	
7.4.10.3	Engineering Disposal/Packaging System Evaluation	
7.4.10.3-01	*Final Selection of Disposal/Packaging System Concept*	
7.4.10.4	Field Test Disposal Systems	
7.4.10.5	Develop process flowsheets	
7.4.10.6	Identify Development Needs	
7.4.11	Provide Data for Other Melter Subsystems	L7
7.4.11.1	Develop concepts design for material conveying and loading and retrieval subsystems	
7.4.11.1-01	*System for Conveying, Loading and Retrieving*	
7.4.11.2	Develop product rework/recycle concepts for out-of-specification product	
7.4.11.2-01	*System for Rework/Recycle*	
7.4.11.3	Material compatibility	
7.4.11.4	Develop System for Handling Frit	
7.4.11.4-01	*Frit Handling System*	
7.4.11.5	Develop Methods for Treating Liquid Effluents	

Low-Level Waste Immobilization
C.I.= Critical Interfaces (Table 7.1)
** Implicit Driver*

2/21/95

Figure 7.2. Schedule (cont)



Low-Level Waste Immobilization Technology Development Schedule

For Information Only

ID	Title	C.I.
7.4.12	Develop Waste Form Product Matrix/Packaging	L5,L6,L8
7.4.12.1	Identify and Develop Matrix/Container Materials	
7.4.12.1-01	*Waste Form Matrix/Container Alternatives*	
7.4.12.1-02	*Data to Support Conceptual Design and Interim PA*	
7.4.12.2	Characterize Sulfur Polymer Cement as Matrix Material	
7.4.12.3	Characterize Alternative Matrix Material	
7.4.12.4	Characterize Container Material	
7.4.12.4-01	*Data to Support PA and Pilot-Scale Vit Testing*	
7.4.12.5	Characterize Matrix/Container Materials from Process Testing	
7.4.13	Develop Method for Controlling and Verifying Glass Waste Form Quality	L7
7.4.13.1	Conduct laboratory development on optical, electrical, and spectroscopic Monitoring	
7.4.13.1-01	*Candidate NDE Approaches*	
7.4.13.1-02	*Techniques Demonstration*	
7.4.13.2	Prototyping and advanced development	
7.4.13.2-01	*NDE System to Measure Waste Form Qualification*	
7.4.14	Develop LLW Disposal System Components	L4
7.4.14.1	Identify Candidate Physical, Chemical, and Hydraulic Barriers	
7.4.14.1-01	*Identify Candidate Barriers Materials and Technology Development Needs*	
7.4.14.2	Initiate Technology Development for Needed Barriers	
7.4.14.3	Characterize Performance/Degradation of Barrier Concepts	
7.4.14.3-01	*Procedures and Data to Support Analysis and Evaluation of Disposal*	
7.4.14.3-02	*Data to Support Design, Permitting, and Construction of the Engineered Disposal System*	
7.4.14.4	Field Demonstration of Barrier Concepts	
7.4.15	Determine Data Required to Support Low Level Waste Performance Assessment	L5,L6
7.4.15.1	Inventory of Radionuclides	
7.4.15.1-01	*Report on Total Inventory*	
7.4.15.2	Vadose Transport Parameters	
7.4.15 2-01	*Report on Hydraulic Properties*	
7.4.15 2-02	*Report on Transport Parameters*	
7.4.15.2-03	*Report on Vadose Zone Flow Transport Properties*	

Low-Level Waste Immobilization
C.I.= Critical Interfaces (Table 7.1)
** Implicit Driver*

Summary ▬ Task ▨ Deliverable ◉ TPA Milestone ◉ DNFSB Milestone ▽

2/21/95

Figure 7.2. Schedule (cont)

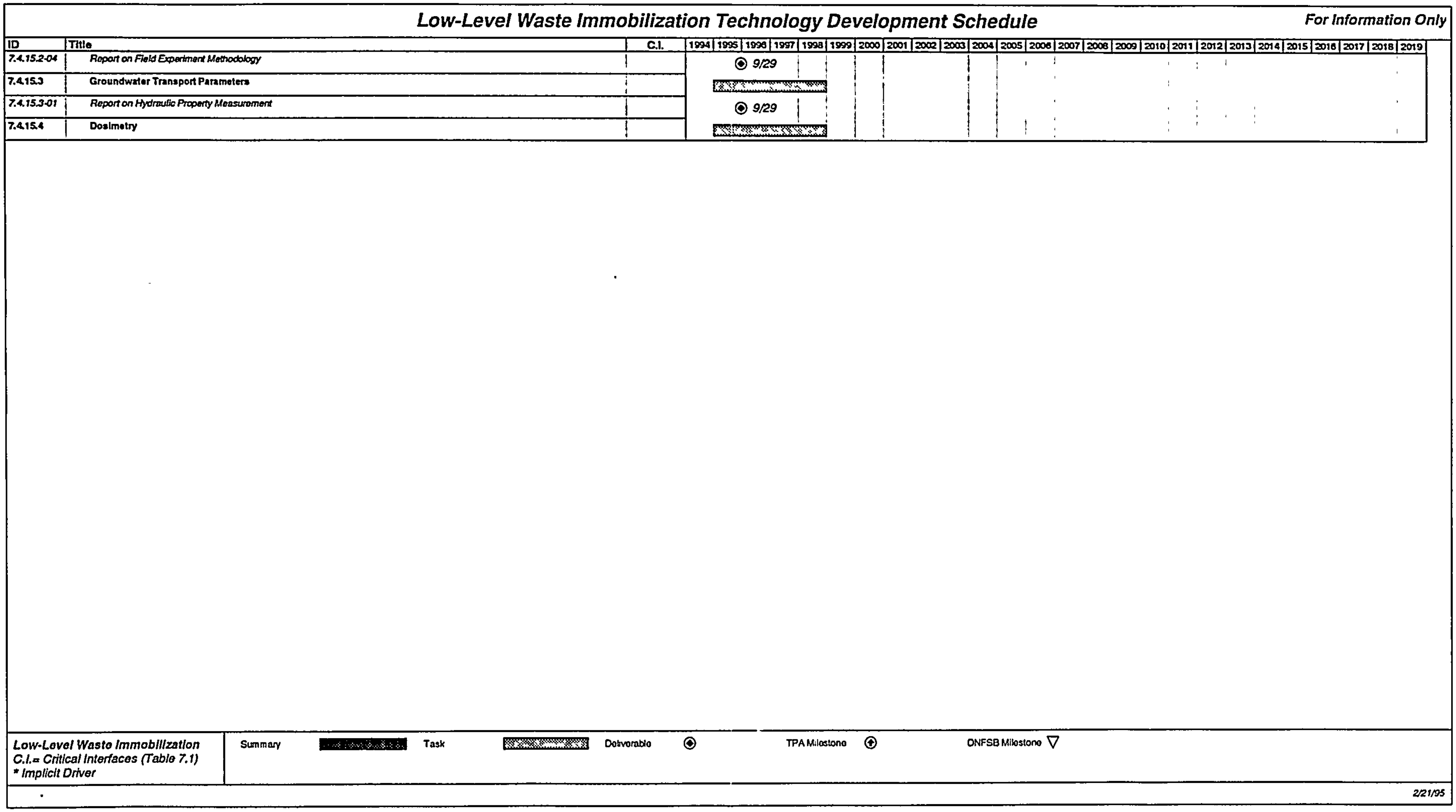


Figure 7.2. Schedule (cont)

Table 7.3. Budget

LOW-LEVEL WASTE IMMOBILIZATION
TWRS Technology Budget Estimates
(Unescalated Dollars in Thousands by Fiscal Year)

TECHNOLOGY PACKAGE NUMBER AND TITLE	1995	1996	1997	1998	1999	2000	2001 +	TOTAL
["Expected Budget Available for Technology" consists of activities in TWRS Multi-Year Work Plan]								
7.4.1--Develop/Adapt Suitable Melter Feed Preparation Flowsheet and System								
Expected Budget Available for Technology	490	1,250	90	0	0	0	0	1,830
Total Estimated Budget for Technology Activities in ITP	490	1,250	90	0	0	0	0	1,830
7.4.2--Define Simulant Characteristics for Phase II Melter Testing								
Expected Budget Available for Technology	500	430	0	0	0	0	0	930
Total Estimated Budget for Technology Activities in ITP	500	430	0	0	0	0	0	930
7.4.3--Develop Acceptable Methods of Incorporating Recycle Streams into Melter Product								
Expected Budget Available for Technology	690	490	150	0	0	0	0	1,330
Total Estimated Budget for Technology Activities in ITP	1,040	990	850	900	400	0	0	4,180
7.4.4--Radioactive Testing								
Expected Budget Available for Technology	0	0	0	0	0	0	0	0
Total Estimated Budget for Technology Activities in ITP	0	200	1,225	3,550	1,750	2,125	17,500	26,350
7.4.5--Evaluate/Adapt Melter for LLW Vitrification								
Expected Budget Available for Technology	11,000	7,000	500	0	0	0	0	18,500
Total Estimated Budget for Technology Activities in ITP	11,000	7,000	500	0	0	0	0	18,500
7.4.6--Develop Glass Waste Form and Glass Speciation								
Expected Budget Available for Technology	3,405	3,960	2,710	1,100	1,100	1,100	3,300	16,675
Total Estimated Budget for Technology Activities in ITP	3,405	3,960	2,710	1,100	1,100	1,100	3,300	16,675
7.4.7--Develop/Adapt Suitable Melter Offgas System								
Expected Budget Available for Technology	520	950	500	100	0	0	0	2,070
Total Estimated Budget for Technology Activities in ITP	520	950	1,100	700	200	200	0	3,670
7.4.8--Develop Additional Waste Forms								
Expected Budget Available for Technology	500	490	0	0	0	0	0	990
Total Estimated Budget for Technology Activities in ITP	500	490	0	0	0	0	0	990

FOR PLANNING PURPOSES ONLY — NOT OFFICIAL COST INFORMATION

Table 7.3. Budget (cont.)

LOW-LEVEL WASTE IMMOBILIZATION (Continued)
TWRS Technology Budget Estimates
(Unescalated Dollars in Thousands by Fiscal Year)

TECHNOLOGY PACKAGE NUMBER AND TITLE	1995	1996	1997	1998	1999	2000	2001 +	TOTAL
["Expected Budget Available for Technology" consists of activities in TWRS Multi-Year Work Plan]								
7.4.9--Develop/Adapt LLW Vitrification System Instrumentation and Controls								
Expected Budget Available for Technology	0	0	0	0	0	0	0	0
Total Estimated Budget for Technology Activities in ITP	0	1,100	1,650	2,050	1,700	0	0	6,500
7.4.10--Develop Systems to Form, Sample and Prepare/Transport LLW Product								
Expected Budget Available for Technology	50	260	400	TBD	TBD	TBD	TBD	710
Total Estimated Budget for Technology Activities in ITP	50	460	600	TBD	TBD	TBD	TBD	1,110
7.4.11--Develop Other Melter Subsystems								
Expected Budget Available for Technology	0	200	200	300	0	0	0	700
Total Estimated Budget for Technology Activities in ITP	0	1,500	1,900	2,000	0	0	0	5,400
7.4.12--Develop Waste Form Product Matrix/Packaging								
Expected Budget Available for Technology	1,400	1,400	1,200	1,300	500	300	700	6,800
Total Estimated Budget for Technology Activities in ITP	1,400	1,400	1,200	1,300	500	300	700	6,800
7.4.13--Develop Method for Controlling and Verifying Glass Waste Form Quality								
Expected Budget Available for Technology	400	400	400	1,000	0	0	0	2,200
Total Estimated Budget for Technology Activities in ITP	400	400	400	1,000	0	0	0	2,200
7.4.14--Develop LLW Disposal System Components								
Expected Budget Available for Technology	0	100	100	550	1,500	1,500	9,000	12,750
Total Estimated Budget for Technology Activities in ITP	0	100	100	550	1,500	1,500	9,000	12,750
7.4.15--Determine Data and Tools Required to Support Low Level Waste Performance Assessment								
Expected Budget Available for Technology	2,600	2,600	2,450	2,450	0	0	0	10,100
Total Estimated Budget for Technology Activities in ITP	2,600	2,600	2,450	2,450	0	0	0	10,100
LOW-LEVEL WASTE IMMOBILIZATION TOTALS:								
Expected Budget Available for Technology	21,555	19,530	8,700	6,800	3,100	2,900	13,000	75,585
Total Estimated Budget for Technology Activities in ITP	21,905	22,830	14,775	15,600	7,150	5,225	30,500	117,985

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8.0 High-Level Waste Immobilization

8.1 Purpose, Objectives, Scope, and Strategy

The **purpose** of high-level waste (HLW) immobilization is to convert the radioactive portion of the pretreated waste from Hanford Site tanks into a solid form suitable for interim storage at Hanford and final disposal at an offsite geologic repository.

The **objective** of technology for HLW immobilization is to develop the technical and design basis for a vitrification capability adequate to fulfill the Tank Waste Remediation System (TWRS) program mission. This includes ensuring production of an acceptable waste form for disposal of all HLW in double-shell tanks (DSTs) and single-shell tanks (SSTs).

Technology activities for the HLW high-capacity vitrification have been incorporated into the HLW Immobilization Program element. These activities include all aspects of the vitrification process, including equipment development, glass formulation, and waste acceptance technology support.

The **scope** of the HLW Immobilization Program includes the following activities:

- Test and evaluate candidate melters with the goal of selecting a single system for implementation.
- Test vitrification system performance to ensure throughput waste capacities, operating conditions, glass product quality, and compliance with regulatory requirements.
- Determine glass compositions and property relationships needed to meet vitrification processing and disposal requirements.
- Determine a waste feed specification.
- Evaluate and test process flow sheets, equipment, and systems for incorporation into vitrification plant design.
- Develop and evaluate process control methods.
- Evaluate alternative waste package approaches for transuranic (TRU) and cesium/strontium capsules.
- Develop glass waste form compositions and waste melter feed and glass property/composition relationships.

The **strategy** for HLW vitrification technology implementation involves testing, analyzing, and evaluating candidate melters and associated supporting systems to select the melter concept to complete the vitrification facility design.

Early emphasis of the HLW Immobilization Program element will be on the following:

- Evaluate candidate melter systems using nonradioactive simulant waste representing waste expected from the proposed minimum pretreatment strategy, with the goal of selecting a single melter system for implementation.
- Develop flow sheets and evaluate vitrification plant systems for candidate melters leading to definition of an integrated HLW vitrification plant for design.
- Develop glass formulation(s) for candidate melter testing and evaluation and for waste streams that envelop the range of waste compositions from the pretreated tank waste.

- Determine disposition of tank TRU and cesium/strontium capsules.

8.1.1 Key Assumptions

The key assumptions for the HLW Immobilization Program element are as follows:

- All of the HLW can be incorporated into a vitrified waste form.
- The throughput capacity of the vitrification facility will be adequate to complete HLW vitrification in 20 years.
- The HLW vitrification plant will begin operating in 2009.
- The HLW fraction from all tanks (SSTs and DSTs) will be vitrified.
- The estimated volume of vitrified HLW ranges from 10,000 to 28,000 m^3 (the lower value corresponds to 10,000 Mg of waste oxides and a 45% waste oxide loading, the higher value corresponds to 15,000 Mg of waste oxides and a 25% waste oxide loading). These volumes are considered to be acceptable to the Geologic Repository Program. Studies will be conducted to determine if waste oxide loading can be increased above 45%.
- The product will be disposed of offsite after interim storage at Hanford.
- The production and onsite storage of HLW glass in canisters is independent of geologic repository availability.
- HLW pretreatment operations can provide feed that meets HLW vitrification feed specifications.
- Adequate evaluation and testing of HLW melters and associated systems will be completed in time to support the facility design.
- The cesium and strontium capsules are packaged and accepted for disposal as an alternative HLW form; the packaged capsules will not require vitrification.
- TRU waste in the tanks will become part of the HLW stream and will be made part of the HLW glass product.

8.1.2 Key Uncertainties

The key uncertainties for the HLW Immobilization Program are the following:

- The compositions and ranges of pretreated vitrification feed have not yet been adequately defined.
- Waste, melter feed, and glass property/composition relationships for various melter types and operating conditions have not been defined.
- The optimum type of melter system for vitrifying Hanford HLW has not been determined.
- The capability to incorporate all HLW and recycle stream material into a single waste form, thus eliminating the need for multiple waste forms, has not been verified.
- Acceptance by the geologic repository of larger HLW canisters, or of overpacked cesium and strontium capsules, has not yet been determined; nor has acceptance by the Waste Isolation Pilot Plant (WIPP) of vitrified tank TRU waste been determined.

8.1.3 Critical Interfaces

A *critical interface* is an important system boundary/point of coordination between two TWRS program elements for one or both elements to successfully meet program objectives. The critical interfaces related to technology activities supporting all six program elements of the TWRS program are integrated in Table 8.1. These interfaces are generally technology-to-TWRS program element or TWRS program element-to-technology (not technology-to-technology or program element-to-program element). Critical interfaces to and from HLW Immobilization are listed in Table 8.1.

Critical interfaces for each program element are also listed in Chapters 3.0, 4.0, 5.0, 6.0, 7.0, and 8.0.

8.2 Functional Flow Diagram

Functions are simple activity statements that define what a system must do. Functions form the framework for identifying technology required to respond to TWRS program needs. A block diagram that maps the relationship between functions and technology needs for the HLW Immobilization Program is provided in Figure 8.1. The technology needs templates are shown in more than one function when appropriate.

8.3 Functions and Associated Technology Packages for HLW Immobilization

Table 8.2 presents the program recommended by the TWRS staff that prepared the Integrated Technology Plan (ITP) for HLW Immobilization. In addition to the TWRS Baseline Program, one other program can be presented in Table 8.2: Non Baseline Activities. Each of these programs is defined in the Preface.

The TWRS Baseline Program is consistent with the most recent version of the Multi-Year Work Plan (MYWP). There are no nonbaseline activities shown that are vital to overall TWRS mission and are not currently projected to be funded. The technology activities included in the various programs were identified through a process described in Section A.6.

8.3.1 Key to Table 8.2

Program: Those technology packages and tasks that fall in the TWRS Baseline Program appear in normal font. Those that fall in the Nonbaseline Program appear in italics.

Function: The systems engineering function (as described in the TWRS Functional Requirements document, U.S. DOE/RL 1994b) associated with this technology package (followed by the number for the appropriate systems engineering level in parenthesis).

Technology Package: A set of technology activities that need to be completed to respond to a functional need. May include activities to address/support the reference case, or enhancements or alternatives to the reference case (followed by the program element chapter number in parenthesis).

Tasks: The tasks that need to be performed to resolve this technology need. Dates are unofficial; they are for planning purposes only.

FY 1996 Cost Estimate: An estimate of the funding that would be needed to conduct FY 1996 tasks. (Note: Tasks are listed for the entire TWRS life-cycle, but costs for outyear tasks are not shown on this table. See Appendix E for more information on each technology package.)

Table 8.1. Critical Interfaces Technology Activities Supporting HLW Immobilization

No.	From	To	Need By	Item Provided
H1	PT	HLW	9/99	Pretreated feed for hot bench-scale testing (100's liters)
H2	TWRS	HLW+	6/95	TWRS integration site selection study
H3	PT	HLW	1/95+	Updated pretreated feed characteristics
H4	PT,S,R	HLW	3/98	Final pretreated feed characteristics for detailed design
H5	HLW	PT,R	10/94+	Updated HLW Feed Specification and bench test feed requirements
H6	HLW	PT	9/96	Feed concentration requirements
H7	HLW	CH	10/94+	Characterization data requirements for HLW process development (coordinated with PT, LLW, and RT)
H8	PT	HLW	9/95	Corrosion effects of washed sludge
H9	CH	HLW+	10/94+	Characterization data when published
H10	CH	HLW+	10/94+	Quantities of core sample material for PT and HLW process development tests
H11	TWRS	HLW	10/94+	TWRS site flow sheet
H12	HLW	ER/WM/ NRC	12/96	Decision for processing cesium and strontium capsules
H13	TWRS	HLW+	12/98	Approved TWRS EIS

Note: + = More than one update or user.

LEGEND:
CH = Characterization Program Element.
ST = Waste Tank Safety Program Element.
RT = Waste Retrieval Program Element.
PT = Waste Pretreatment Program Element.
HLW = High-Level Waste Immobilization Program Element.
LLW = Low-Level Waste Immobilization Program Element.
OPS = Operations and Maintenance.

FY 1996 estimated cost are listed for each program. Dollar figures are unescalated, burdened FY 1995 dollars, in thousands. Costs are unofficial; they are for planning purposes only.

Benefit: The reasons these tasks are important to the program element.

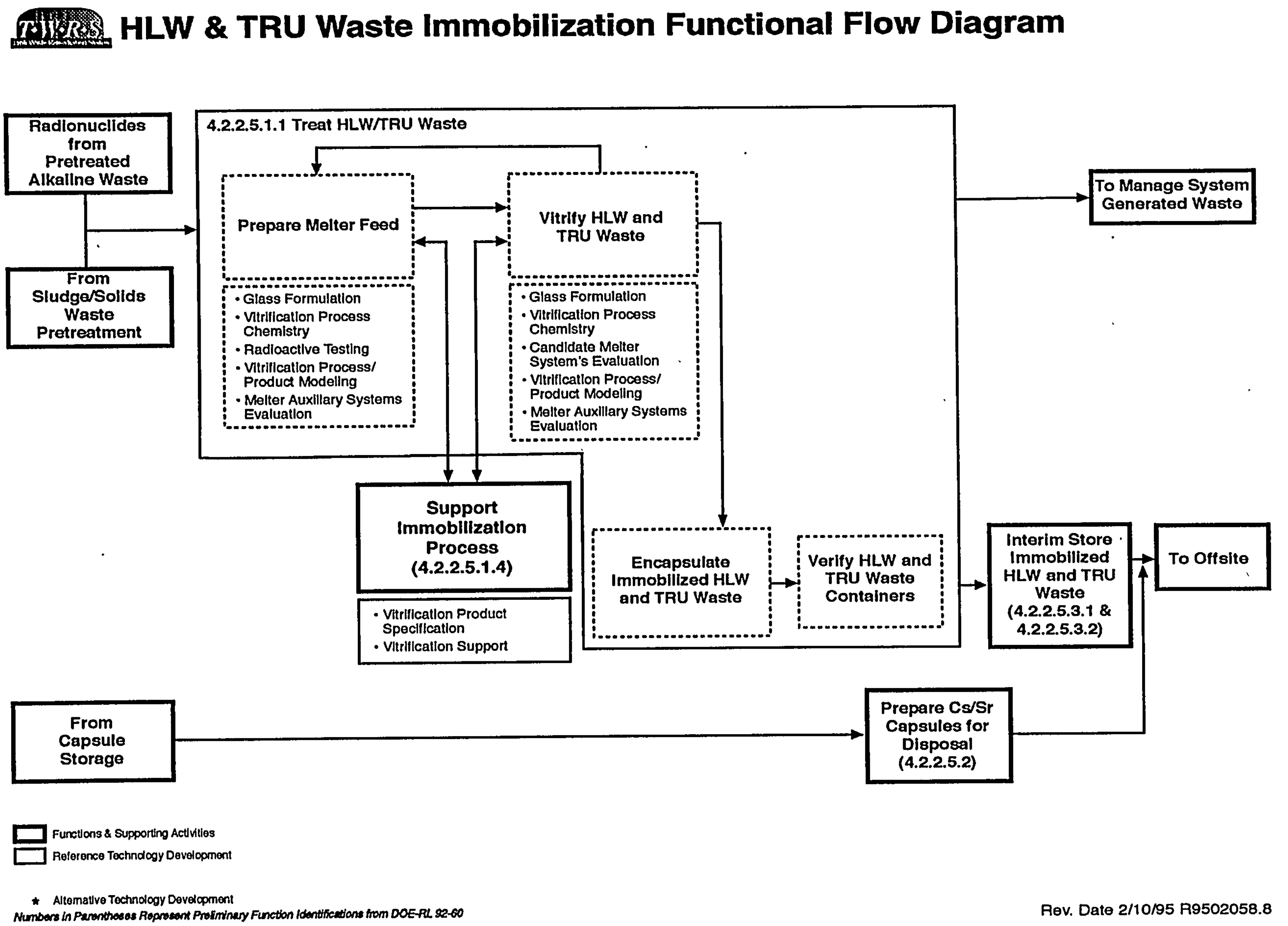


Figure 8.1. Functional Flow Diagram

Table 8.2 High–Level Waste Immobilization: Recommended Technology Program

Function and Technology Package		Tasks		FY 1996 Cost Estimate ($K)		
Functional Need Level 4	Template Title (number)	No.	Title	Funded	Not Funded	Benefit
Immobilize HLW/TRU Waste (4.2.2.2)	**HLW Glass Formulation** **8.4.1.1** Reference	1.	Low temperature glass development	0		Commitments: Supports TPA M–51–02, melter selection: Operations: Supports conceptual design, definitive design and plant startup. Reduce Risk: Provides information for potential reduction of program cost and risk.
		2.	Glass formulation studies supporting melter testing	323		
		3.	HTM glass formulation scoping studies documentation	109		
		4.	Formulate/characterize glass for reference conceptual design	273		
		5.	Glass property/ composition/ temperature relationships update	218		
		6.	Glass liquidus temperature/crystallinity relationships update	218		
		7.	Glass composition limits for critical components update	327		
		8.	HLW feed processability assessment support	109		
		9.	Base case glass formulation	599		

Table 8.2 High–Level Waste Immobilization: Recommended Technology Program

Function and Technology Package		Tasks		FY 1996 Cost Estimate ($K)		
Functional Need Level 4	Template Title (number)	No.	Title	Funded	Not Funded	Benefit
Immobilize HLW/TRU Waste (4.2.2.2)	**HLW Vitrification Process Chemistry** **8.4.1.2** Reference	1.	Melter system selection testing support	164		
		2.	Feed preparation process laboratory tests	490		
		3.	Conceptual design performance characteristics development	323		
		4.	Documentation of FY 1995 work on effects of major components	109		
		5.	Effects of major waste components on process chemistry	273		
Immobilize HLW/TRU Waste (4.2.2.2)	**HLW Radioactive Testing** **8.4.1.3** Reference	1.	Series 2 core sample testing	540		Reduce Risk: Data required to support Waste Form Qualification to verify process.
		2.	Series 2 core sample testing (SST core sample)	109		
Immobilize HLW/TRU Waste (4.2.2.2)	**Initial Design Feed Specification** **8.4.1.4** Reference	1.	Define Design Feed Specification	220		Operations: Provides for identification of technology development needs.

Table 8.2 High–Level Waste Immobilization: Recommended Technology Program

Function and Technology Package		Tasks		FY 1996 Cost Estimate ($K)		
Functional Need Level 4	Template Title (number)	No.	Title	Funded	Not Funded	Benefit
Immobilize HLW/TRU Waste (4.2.2.2)	**Feed/Process Evaluation** **8.4.1.5** Reference	1.	Glass Formulation Evaluation	200		Operations: Provides for identification of technology development needs.
		2.	Process Feed/Chemistry Evaluation	275		
		3.	Feed Process Operational Assessment	200		
Immobilize HLW/TRU Waste (4.2.2.2)	**Candidate Melter Systems Evaluations** **8.4.2.1** Reference	1.	Plan tests (Pilot-scale melters)	142		
		2.	Perform tests (Pilot-scale melters)	5,065		
		3.	Document tests (Pilot-scale melters)	164		
		4.	Plan tests (Small-scale melters)	327		
		5.	Perform tests (Small-scale melters)	1,090		
		6.	Small-scale melter data packages	164		
		7.	Small-scale melters testing final reports	55		
		8.	Melter concepts FY 1995 testing reports	164		
		9.	Document small-scale system testing on melters	55		

Table 8.2 High–Level Waste Immobilization: Recommended Technology Program

Function and Technology Package		Tasks		FY 1996 Cost Estimate ($K)		Benefit
Functional Need Level 4	Template Title (number)	No.	Title	Funded	Not Funded	
		10.	Plan tests (Laboratory support of melters)	490		
		11.	Perform tests (Laboratory support of melters)	349		
		12.	Laboratory support for melters test data package preparation	436		
		13.	Laboratory support of melters test reporting	218		
Immobilize HLW/TRU Waste (4.2.2.2)	**Vitrification Process/ Product Modeling** **8.4.2.2** Reference	1.	Process control strategy	55		
		2.	Glass formulation code development	251		
Immobilize HLW/TRU Waste (4.2.2.2)	**Melter Auxiliary Systems Evaluation** **8.4.2.3** Reference	1.	Technical support activities	27		

Table 8.2 High–Level Waste Immobilization: Recommended Technology Program

Function and Technology Package		Tasks		FY 1996 Cost Estimate ($K)		
Functional Need Level 4	Template Title (number)	No.	Title	Funded	Not Funded	Benefit
Immobilize HLW/TRU Waste (4.2.2.2)	**HLW Vitrification Process/Equipment Evaluation** **8.4.2.4** Reference	1.	Develop technical basis			Commitment: All tasks required to support TPA milestones.
		2.	Melter Testing Oversite (HL02005)	295		
		3.	Reference Melter Selection (HL02006)	250		
		4.	Testbed feature testing	250		
Immobilize HLW/TRU Waste (4.2.2.2)	**HLW Vitrification Process System Requirements and Concepts** **8.4.2.5** Reference	1.	Process flowsheet development	1,000		Operations: Provides data on reference melter system for design, startup, and operations.
		2.	Facility concepts and configuration	1,000		
		3.	Functions and Requirements Development	200		
		4.	Technology Transfer	565		
Total						

LEGEND: Baseline/*Nonbaseline*.
(a) Fund Immediately.
(b) Fund If Possible.

8.4 Narrative on Technology Packages

The technology packages associated with each function of the HLW Immobilization Program are described in this section. The description provides a brief summary of

- the justification for this activity
- current status of the technology
- technical approach
- other issues that need to be highlighted.

More detailed information is found in the templates for the HLW Immobilization Program, located in Appendix E.

8.4.1 Prepare Melter Feed

8.4.1.1 HLW Glass Formulation

Glass formulation involves combining the incoming waste stream with glass formers and adjusting feed preparation chemistry to obtain satisfactory glass waste loading, melter operation, and vitrified product. To formulate an appropriate glass product, the relationships between waste loading in the product, product forming additives, and processing conditions (time at temperature history) must be determined and controlled.

The waste feed composition(s) to the HLW vitrification plant need to be characterized to formulate a glass with acceptable properties and performance.

In formulating glass, several major items are considered. To minimize program costs for plant operation, product handling, storage, transportation, and disposal, maximizing the waste loading in the product will minimize glass volume for disposal. Maximizing waste loading is achieved by waste pretreatment and/or blending to control the concentration of solubility-limiting or phase-separating components such as titanium oxide, sulfate, phosphate, chromium, and noble metals, which would decrease waste loading. Waste loading is also maximized by allowing flexibility in product formulation. This would allow the use of glass, ceramics, and different product types such as phosphate glasses that would result in large increases in specific component loading. Waste loading can be increased by processing the product at high temperatures with reasonably rapid melt cooling to increase waste component solubility.

The glass melt properties (viscosity, conductivity, liquidus temperature, etc.) need to be compatible with the melter and the melter system. Care is necessary in glass formulation to ensure melter component corrosion is not a problem. Liquid salt separation in the melter needs to be avoided to avert the potential for explosion, increased melter component corrosion, increased melt component volatility and affecting glass product quality. A melter designed to handle a solid separated phase adds significantly to processing flexibility, in that glass ceramics could be processed and separated phases (such as noble metals and spinels) could be removed to increase melter component life. Melter feed foaming, spreadability, atomization, melt rate kinetics, and offgasing can also affect melting rate.

Glass formulation will ensure that the product will meet applicable requirements as specified in the Waste Acceptance Preliminary Specification (WAPS). Characteristics such as durability, heat generation rate, radiation properties, gas generation, and glass container/glass compatibility need to be considered. The current glass durability criteria (WAPS 1.3) is based on general borosilicate glass performance as a product quality control measure.

Escape of volatile radionuclides into the melter offgas system could be a problem, lending an incentive to add to the glass forming chemicals components that suppress the volatility of semivolatile materials in the melter. This could alleviate equipment corrosion and reduce waste recycle and its impact on glass formulation.

8.4.1.2 HLW Vitrification Process Chemistry

The waste feed to the vitrification plant and any associated glass formers and feed chemistry additives need to be concentrated for melter feeding to minimize using the melter as an evaporator and thereby significantly reducing its capacity. Thus, it is necessary to define feed preparation slurry properties and characteristics associated with mixing, transport, concentration, and centrifuging on the HLW vitrification flowsheet. As feed preparation slurries are concentrated, their density increases and flow behavior can change dramatically.

Centrifuging has not been previously assessed as a feed preparation operation. To do so, solids removal efficiency, centrifuge capacity, and solids removal flowability need to be assessed as functions of waste type and concentration. Preliminary tests would include determining settling rate and settled solids shear stress. Centrifuges are complex, with many moving pieces that require maintenance. The capability of a centrifuge to operate reliably in a highly radioactive remote environment for extended periods needs to be evaluated.

Testing is also needed to verify that the waste slurries can be concentrated without excessive foaming and entrainment and to determine at what slurry concentration poor flow properties prevent the plant pumps, agitators, concentrator, and centrifuge from effectively processing the slurries. Methods to control slurry rheology for plant operation need to be defined. Materials compatibility is also a concern, particularly in equipment that operates at elevated temperatures and undergoes temperature cycles.

Process chemistry for the different waste compositions fed to the HLW vitrification plant need to be evaluated to ensure compatibility with the plant process and equipment. On the current TWRS HLW vitrification flowsheet organics (such as complexants, NPH, hexone, and small amounts of cyanide) and hazardous metals (such as small amounts of mercury) can enter the waste stream. The path and disposition of these materials through the vitrification plant must be determined to define the hazards of waste emissions, to avoid uncontrolled exothermic reactions, and to prevent over reduction of the glass product and consequent adverse effects on melter operation and product durability. The capability to use the melter as an incinerator may help resolve the issue of how to dispose of the organics in the tank wastes.

Feed preparation is currently a batch process requiring many discrete process and process control steps, which tend to limit plant capacity. Measures to simplify the process and reduce the number of steps can greatly increase capacity and save significant capital and operating expense. Simplifying steps that need to be evaluated include online process control, elimination of waste recycle streams that affect glass formulation, and deletion of a reductant addition or use of one that can be "dumped" in the makeup and does not generate hydrogen and ammonia.

When possible, the number and volume of recycle streams entering the feed preparation system need to be minimized or eliminated because they increase the number of steps and complexity of the feed preparation process and thereby reduce process capacity and probably increase analytical requirements.

Any steps taken to simplify the feed preparation cycle will cause major capital and operating cost savings by reducing the amount of equipment needed, the plant space needed to house the equipment, and staff needed to operate the equipment.

8.4.1.3 HLW Radioactive Testing

If simulant use in process development is not validated, the plant may not function as designed because the actual chemistry of the waste feed could be different from the simulants used for vitrification development testing. Such differences may be due to process history, chemistry history, and differences in composition (omission of minor components in testing or no suitable nonradioactive components) between the simulant and actual waste.

Selected actual waste feed samples from waste tanks that have been pretreated are put through the vitrification process on a laboratory scale to validate stream properties, process behavior, and product quality. It is highly unlikely that any of the tank samples will have the composition of waste feeds to the HLW vitrification plant. The key is to select a range of tank waste compositions to reasonably represent the envelope of waste feed compositions to the plant so that the generic process chemistry can be validated early in process development. This validation is performed in a timely manner to make needed modifications early in plant and process design. A strategy is needed to identify the number and types of samples to be tested.

Selected tests need to be performed at small scale with actual pretreated radioactive wastes. Bench-scale tests would process the waste through key plant equipment to assess whether scaling up the process or processing the waste through equipment similar to the plant has any impact on process or product performance. This extent of radioactive testing may be needed to achieve the level of confidence in process performance required for model validation and regulatory purposes.

8.4.1.4 Initial Design Feed Specification

The primary feed design basis will be constructed around the baseline program strategy, which assumes all tank waste will be processed for geologic disposal, with cesium/strontium capsules overpacked for disposal and not vitrified. Options to this baseline strategy, which impact the feed design basis, depend on decisions that will be developed elsewhere in the program and concern disposition of the capsules and possible separate treatment of TRU tank waste. A clear understanding of tank waste characteristics is also important to establishing the feed design bases. Also important are the retrieval and blending sequences and the pretreatment processes themselves, including pretreatment efficiencies.

8.4.1.5 Feed/Process Evaluation

This evaluation effort characterizes the effects of chemical adjustments on the HLW vitrification plant feed stream. Feed adjustments are needed to provide an acceptable feed rheology for agitation and transfer and to control the system redox for optimizing melter operation. A thorough understanding of the chemical reactions during feed preparation is needed to accommodate variable feed compositions, predict the associated offgas generation rates, assess the safety of the process steps, and evaluate various process options. Laboratory-scale studies help to identify the potential impacts of feed preparation chemical/rheological adjustments. These studies provide input for the large-scale feed preparation test activities and support plant design, permitting, safety, and operations.

8.4.2 Vitrify HLW and Transuranic Waste

8.4.2.1 Candidate Melter Systems Evaluations

Melter systems evaluations are needed to support selection of the appropriate melter system for HLW vitrification plant application. The melter system has to produce glass of a quality acceptable for disposal, process waste into glass at a rate that meets TPA and TWRS mission requirements, reliably process the envelope of waste feeds anticipated from pretreatment, reliably operate over extended periods, and be remotely operated and maintained. The melter and glass formulation efforts must be closely coupled because the operating capability of the melter has a major impact on glass formulation, glass waste loading, and glass quality.

Activities were initiated in FY 1994 to select a melter system that will meet TPA and TWRS mission requirements to process the pretreated HLW/TRU wastes from the Hanford HLW storage tanks. A HLW

Melter Selection Working Group was established to review melting technologies and assess melter systems that could be used in a planned nuclear waste vitrification facility. The goal was to recommend those technologies which have the highest potential to meet the objectives of the HLW vitrification program. In summary, the group made following recommendations:

- All-electric cold-top melters with nickel-base electrodes, developed initially at Westinghouse Hanford Company (WHC) and further developed for worldwide use, provide a solid base technology for HLW vitrification.
- High melter temperatures offer the potential for large reductions in total program costs through increased melting efficiencies, higher waste loadings (fewer canisters to store), less need for waste blending, and lower operating and disposal costs for fewer and smaller melters.
- Of the two methods for achieving high temperature, the first choice is for melters with electrodes.
- High-frequency induction melting offers relief from problems of electrode attack, and is considered a strong backup technology in spite of the relative immaturity of both the melter and its power supplies.
- Several refinements are available to improve the performance of both types of electric melters, and these should be developed further:
    - Agitation by bubbling or by mechanical stirring can greatly increase melting rate.
    - Feed drying or calcining can significantly reduce power that must be supplied by the electrodes or high-frequency power supplies.
    - Sloped bottoms may be needed to minimize accumulation of noble metals and other insoluble components.
- Unfortunately, scale-up of glass melters is currently an experimental process and frequently produces surprises. Full-scale testing should be undertaken as soon as it is practical to do so.
- Major reductions in total HLW vitrification program costs could result from a melter system development program. Although the present nickel-base electrode melter technology is quite mature, the potential savings from the other technologies discussed here greatly exceed their development cost. The program should include substantial efforts on 1) high-temperature electrode materials and designs, 2) glass compositions to take full advantage of higher melting temperatures, 3) high-frequency induction melter design and power supplies, 4) melt agitation and drying methods, and 5) full-scale testing of key design features and total melter systems.

Additional considerations in the melter development program are development and evaluation of melter component materials other than the electrodes, such as the instrumentation and glass contact materials, and the ability to minimize and handle high-volatility material from the melter, which could be radioactive, hazardous, and toxic.

Direct dry glass-former feeding to the melter should be considered. This approach would increase the feed preparation system capacity by reducing the number of process steps. It also significantly reduces the water management problem and waste generation by reducing the amount of water introduced to the process.

The melter system may be used to destroy organic materials and cyanide in the melter feed. The high temperature in the melter and the offgas system would thermally destroy these materials. Development and analyses would be necessary to ensure that the redox properties of the glass would not be affected, or that it could be controlled through oxidizer addition. Also, the capability of the melter system to perform to the requirements of an incinerator needs to be evaluated.

8.4.2.2 Vitrification Process/Product Modeling

Because HLW product recycle capability for out-of-specification product is not included in the current HLW vitrification plant concept, a strong feed-forward product quality control system is required. This system is predicated on controlling HLW glass product properties by controlling the process stream composition and vitrification operating parameters (temperature, residence time, etc.). To implement this approach, glass and melt properties need to be defined as a function of composition and time-at-temperature, as appropriate. The models needed for process control include melt viscosity, melt electrical conductivity, and liquidus temperature. Models needed for product control include durability and softening temperature. It is also necessary to know, or be able to predict, the amount and type of crystallinity in the product.

Controlling the melter feed stream composition is necessary to obtain a product that is within required specifications. To do this with a high degree of confidence requires many feed stream samples with many analyses on each sample. Providing the capability to handle this analytical load can be expensive. Thus, a development effort is needed to use the feed preparation data and analytical data to supplement the feed sample analytical data and reduce the analytical load. A statistically based mass balance model will be used to do this. Models are also needed to determine the quantity of glass formers to add to the waste to make the vitrified product, and what chemical adjustments are needed (if the melter feed makeup is off specification).

Additional process and product models (correlations) can reduce the plant analytical load and the accompanying capital and operating costs by using online process control methods instead of taking samples.

8.4.2.3 Melter Auxiliary Systems Evaluation

WHC capacity increase studies indicate that there would be a significant increase in vitrification costs because of the increase in analytical requirements. This provides a significant incentive to reduce the analytical load. One approach to reduce the number of samples and perhaps the number of analyses per sample is to use online process stream measurements to infer waste control parameters such as composition and rheology. For example, process stream density or temperature and agitator power consumption can be used to indicate concentration and transportability. Verified chemical additions can be used to determine component concentrations, and simple radionuclide analyses with periodic chemical analysis can be used to determine composition. More advanced and automated analytical techniques under development such as laser ablation/ICP/MS and IC/ICP/MS would decrease analytical time per sample and decrease the radiation dose rate to operators per analysis.

The use of formic acid as the ammonia reductant in the process offgas system can cause the formation of nitrous oxides and hydrogen. This can then lead to formation and accumulation of ammonium nitrate in the process offgas system. The ammonium nitrate and hydrogen can cause safety concerns with the potential for uncontrolled exothermic reactions. Thus, a reductant should be developed that reduces or eliminates hydrogen and ammonia generation or, if possible, the reductant itself should be eliminated. Any volatile organics in the plant feed would be steam-stripped into the process offgas system, which would act as a sensitizer for any ammonium nitrate solids accumulated in the system. These solids may also accumulate in the process waste system. This needs to be factored into the plant process design. Process steps need to be taken to ensure volatile organics do not reach the plant or that the organics are managed safely. One approach is to collect the organic and destroy it in the melter system.

The waste feed slurries may foam and contaminate the low-level process waste handling system through the vessel vent system. Methods to detect foaming during slurry concentration are needed, and techniques need to be developed to suppress foaming. These techniques may include using an anti-foaming agent, reducing the boiling rate, and allowing ample head space in the tank.

In the melter offgas system, the use of washable metal fiber filters presents a significant step forward in reducing waste generation from spent High-Efficiency Particulate Air (HEPA) filters. However, there is a need for data on the behavior of this new high-efficiency filter to assess filter media corrosion, washing, and wetting characteristics.

The use of a high-temperature melter could increase the volatility of feed materials and cause plugging and increased corrosion in the offgas piping. In addition to adding specific chemicals to the glass to suppress component volatility or operating the melter at a lower temperature, a particulate filter of glass-forming material that subsequently is fed into the melter could be used.

Means of minimizing use of water in the feed and offgas systems need to be developed as well as economical ways of water treatment and disposal. Maximizing the size of the HLW container has significant economic benefit. This could significantly reduce disposal, transportation, and plant capital/operating costs.

8.4.2.4 HLW Vitrification Process/Equipment Evaluation

Candidate melter system technologies are to be evaluated for application to HLW vitrification with the goal of selecting a single melter concept design by the end of 1998, at which time definitive design will begin. During FY 1994 an initial evaluation of candidate melter technologies was conducted by an independent technical advisory committee. The results of this evaluation and selection will be available early in FY 1995 and will form the basis for melter development plans for FY 1995. These plans will be periodically updated (yearly or more often) to reflect test and analysis results. Melter test plans will be reviewed for application to development plans and the test results will be analyzed for impact on the development plans. The program goal is to reduce to two the candidate melter systems that will continue to be evaluated in FY 1996, 1997, and 1998. A method will be developed to select one of these two concepts for the definitive design stage.

8.4.2.5 HLW Vitrification Process System Requirements and Concepts

This activity will provide engineering data, oversight, and deliverables that will allow initiation of HLW Vitrification Conceptual Design. Deliverables include a reference process flow sheet, a preferred HLW facility configuration, and a Functions and Requirements (F&R) document. Together, these will describe the HLW Vitrification concept and facility.

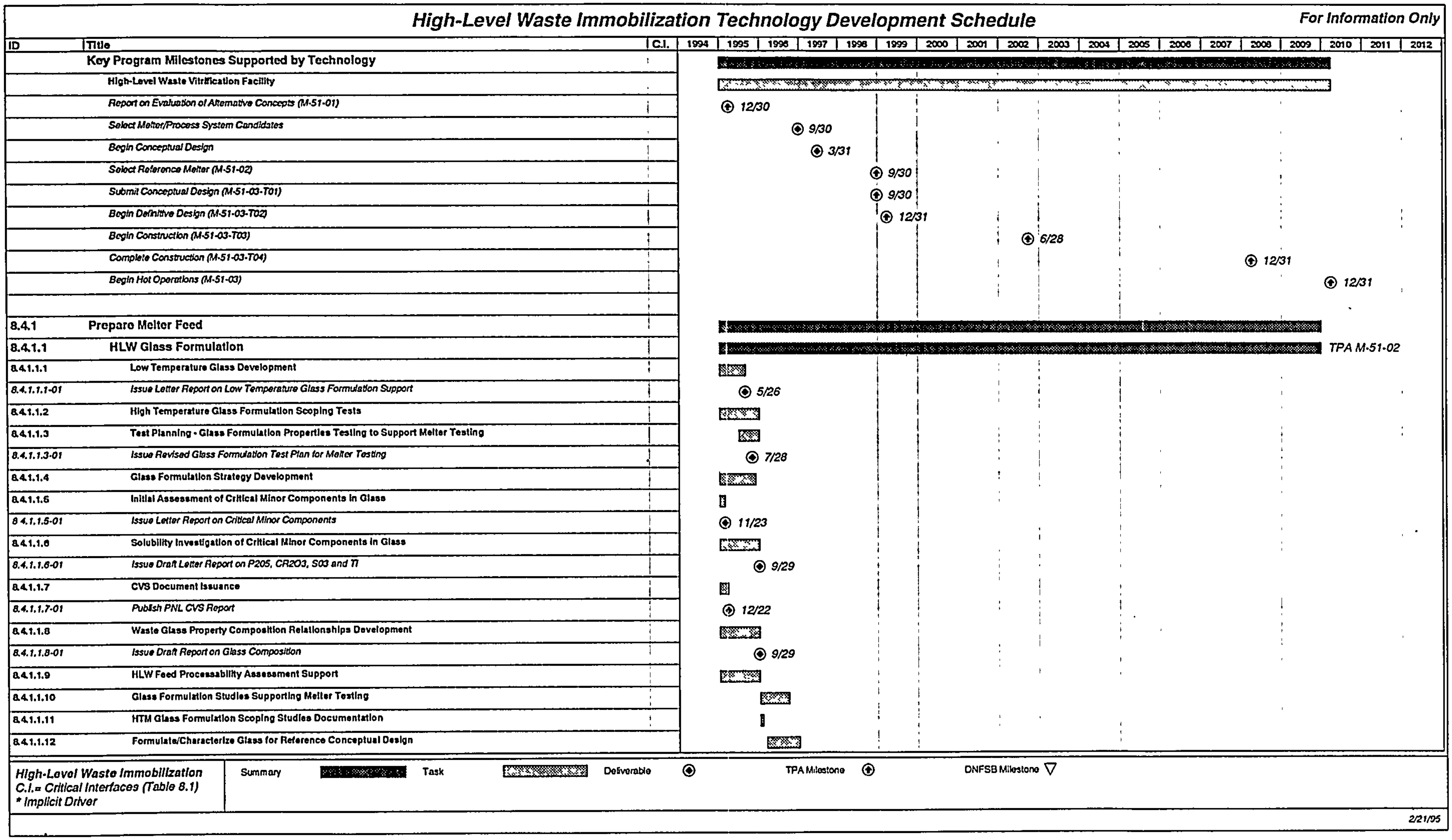
The HLW Vitrification process flowsheets will be updated from feed design, product criteria, and technology baseline revisions. Facility concepts will be developed and a decision analysis performed to achieve optimum facility configuration. This activity will also update the HLW portion of the F&R document before the start of conceptual design.

8.5 Schedule and Budget

The schedule and budget for technology activities supporting the HLW Immobilization Program are shown in Figure 8.2 and Table 8.3, respectively. Figure 8.2 identifies template activities, tasks within each template, deliverables, critical interfaces, and drivers (depicted to the right of each template activity bar). Table 8.3 presents two sets of budget estimates by program element and fiscal year. The first profile consists of activities currently included in the TWRS Multi-Year Work Plan and reflects the estimated budget available for technology. The second profile reflects the estimated budget required to perform all tasks shown in the ITP, including activities that are anticipated to be funded and those that are not (unfunded activities have been prioritized for inclusion in the MYWP at the first opportunity).

8.6 Prioritization (Results)

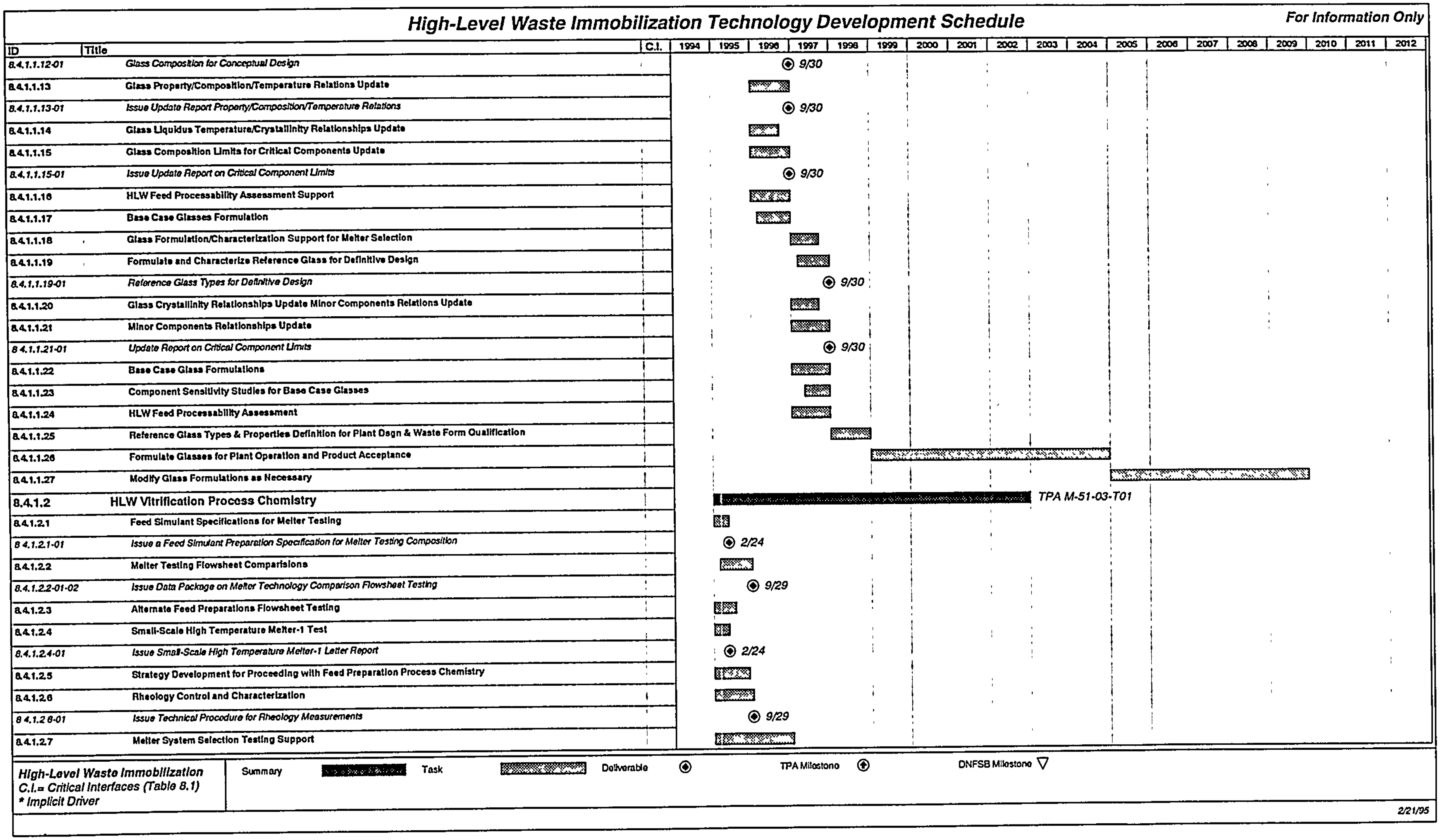
Table 8.2 presented the functions, technology packages, tasks, FY 1995 budgeted costs and estimated FY 1996 costs and a brief statement regarding the benefit of funding these technology activities. Currently, for the HLW Immobilization Program element, all future technology work is funded within the scope of the TWRS Baseline Program for FY 1996 and beyond.



ID	Title	C.I.
	Key Program Milestones Supported by Technology	
	High-Level Waste Vitrification Facility	
	Report on Evaluation of Alternative Concepts (M-51-01)	
	Select Melter/Process System Candidates	
	Begin Conceptual Design	
	Select Reference Melter (M-51-02)	
	Submit Conceptual Design (M-51-03-T01)	
	Begin Definitive Design (M-51-03-T02)	
	Begin Construction (M-51-03-T03)	
	Complete Construction (M-51-03-T04)	
	Begin Hot Operations (M-51-03)	
8.4.1	Prepare Melter Feed	
8.4.1.1	HLW Glass Formulation	
8.4.1.1.1	Low Temperature Glass Development	
8.4.1.1.1-01	*Issue Letter Report on Low Temperature Glass Formulation Support*	
8.4.1.1.2	High Temperature Glass Formulation Scoping Tests	
8.4.1.1.3	Test Planning - Glass Formulation Properties Testing to Support Melter Testing	
8.4.1.1.3-01	*Issue Revised Glass Formulation Test Plan for Melter Testing*	
8.4.1.1.4	Glass Formulation Strategy Development	
8.4.1.1.5	Initial Assessment of Critical Minor Components in Glass	
8.4.1.1.5-01	*Issue Letter Report on Critical Minor Components*	
8.4.1.1.6	Solubility Investigation of Critical Minor Components in Glass	
8.4.1.1.6-01	*Issue Draft Letter Report on P205, CR2O3, S03 and Tl*	
8.4.1.1.7	CVS Document Issuance	
8.4.1.1.7-01	*Publish PNL CVS Report*	
8.4.1.1.8	Waste Glass Property Composition Relationships Development	
8.4.1.1.8-01	*Issue Draft Report on Glass Composition*	
8.4.1.1.9	HLW Feed Processability Assessment Support	
8.4.1.1.10	Glass Formulation Studies Supporting Melter Testing	
8.4.1.1.11	HTM Glass Formulation Scoping Studies Documentation	
8.4.1.1.12	Formulate/Characterize Glass for Reference Conceptual Design	

High-Level Waste Immobilization
C.I.= Critical Interfaces (Table 8.1)
** Implicit Driver*

Figure 8.2. Schedule



ID	Title	C.I.
8.4.1.1.12-01	*Glass Composition for Conceptual Design*	
8.4.1.1.13	Glass Property/Composition/Temperature Relations Update	
8.4.1.1.13-01	*Issue Update Report Property/Composition/Temperature Relations*	
8.4.1.1.14	Glass Liquidus Temperature/Crystallinity Relationships Update	
8.4.1.1.15	Glass Composition Limits for Critical Components Update	
8.4.1.1.15-01	*Issue Update Report on Critical Component Limits*	
8.4.1.1.16	HLW Feed Processability Assessment Support	
8.4.1.1.17	Base Case Glasses Formulation	
8.4.1.1.18	Glass Formulation/Characterization Support for Melter Selection	
8.4.1.1.19	Formulate and Characterize Reference Glass for Definitive Design	
8.4.1.1.19-01	*Reference Glass Types for Definitive Design*	
8.4.1.1.20	Glass Crystallinity Relationships Update Minor Components Relations Update	
8.4.1.1.21	Minor Components Relationships Update	
8.4.1.1.21-01	*Update Report on Critical Component Limits*	
8.4.1.1.22	Base Case Glass Formulations	
8.4.1.1.23	Component Sensitivity Studies for Base Case Glasses	
8.4.1.1.24	HLW Feed Processability Assessment	
8.4.1.1.25	Reference Glass Types & Properties Definition for Plant Dsgn & Waste Form Qualification	
8.4.1.1.26	Formulate Glasses for Plant Operation and Product Acceptance	
8.4.1.1.27	Modify Glass Formulations as Necessary	
8.4.1.2	HLW Vitrification Process Chemistry	
8.4.1.2.1	Feed Simulant Specifications for Melter Testing	
8.4.1.2.1-01	*Issue a Feed Simulant Preparation Specification for Melter Testing Composition*	
8.4.1.2.2	Melter Testing Flowsheet Comparisions	
8.4.1.2.2-01-02	*Issue Data Package on Melter Technology Comparison Flowsheet Testing*	
8.4.1.2.3	Alternate Feed Preparations Flowsheet Testing	
8.4.1.2.4	Small-Scale High Temperature Melter-1 Test	
8.4.1.2.4-01	*Issue Small-Scale High Temperature Melter-1 Letter Report*	
8.4.1.2.5	Strategy Development for Proceeding with Feed Preparation Process Chemistry	
8.4.1.2.6	Rheology Control and Characterization	
8.4.1.2.6-01	*Issue Technical Procedure for Rheology Measurements*	
8.4.1.2.7	Melter System Selection Testing Support	

Figure 8.2. Schedule (cont)

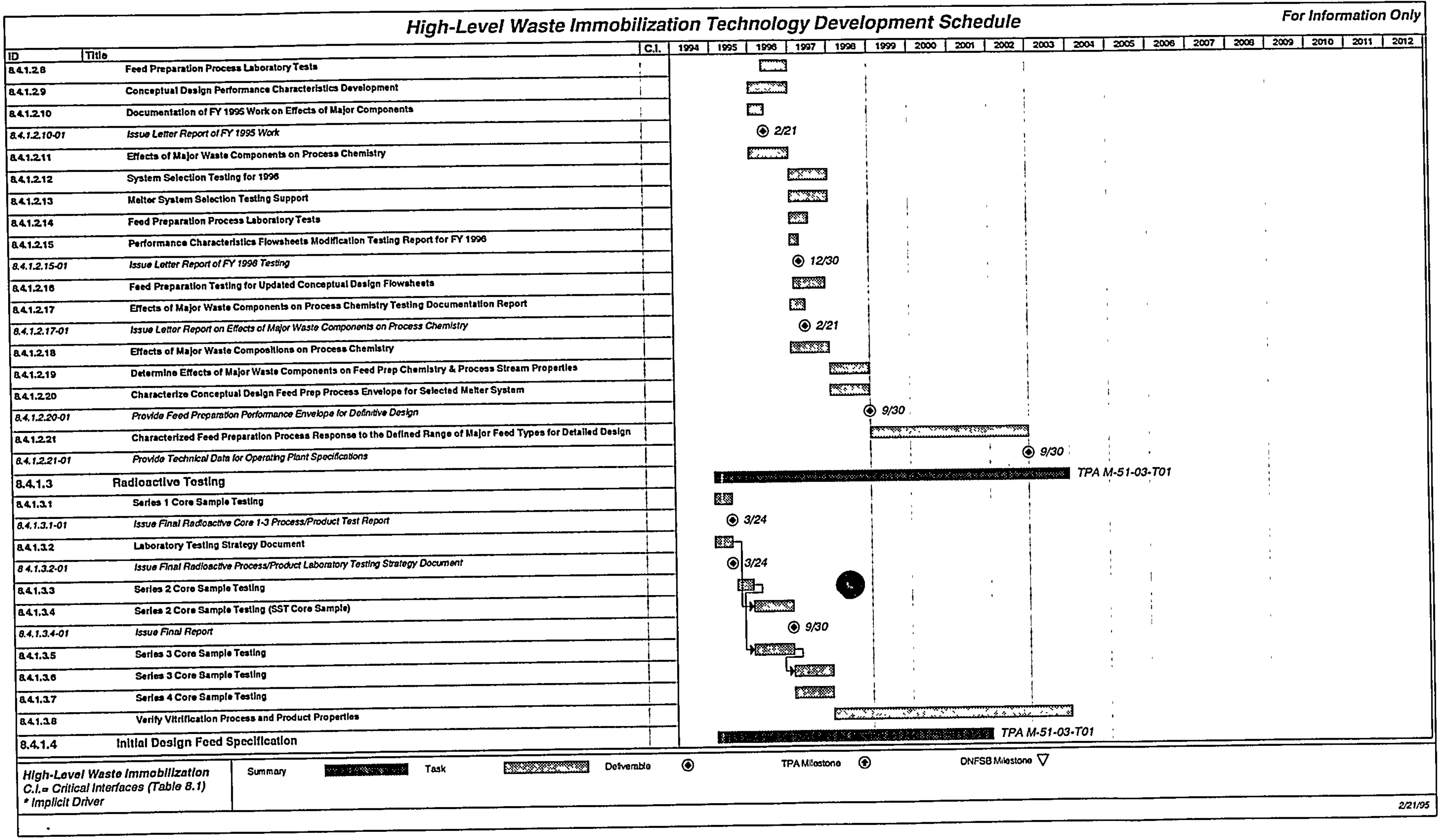
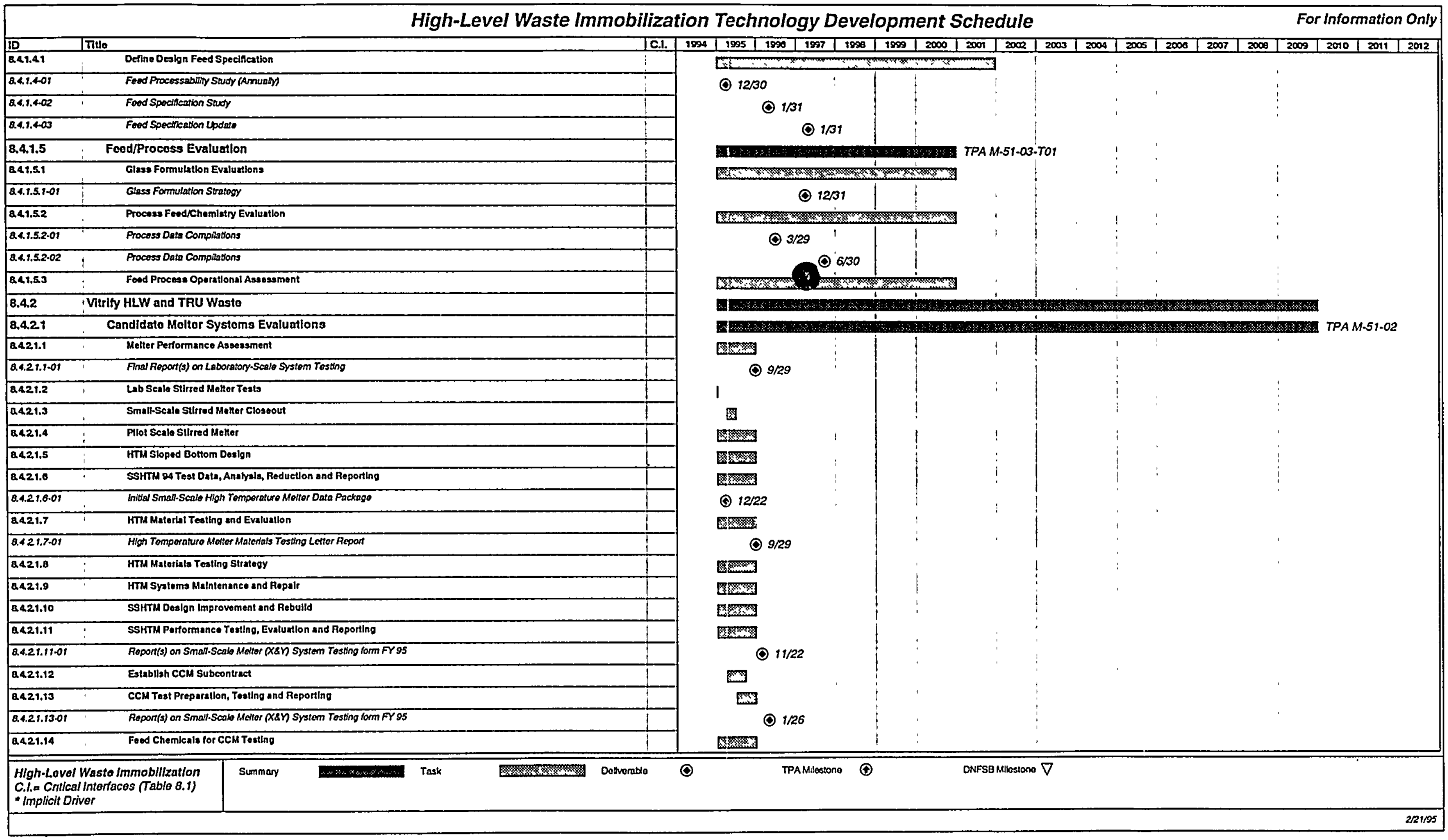


Figure 8.2. Schedule (cont)



High-Level Waste Immobilization Technology Development Schedule

For Information Only

ID	Title	C.I.
8.4.1.4.1	Define Design Feed Specification	
8.4.1.4-01	*Feed Processability Study (Annually)*	
8.4.1.4-02	*Feed Specification Study*	
8.4.1.4-03	*Feed Specification Update*	
8.4.1.5	Feed/Process Evaluation	
8.4.1.5.1	Glass Formulation Evaluations	
8.4.1.5.1-01	*Glass Formulation Strategy*	
8.4.1.5.2	Process Feed/Chemistry Evaluation	
8.4.1.5.2-01	*Process Data Compilations*	
8.4.1.5.2-02	*Process Data Compilations*	
8.4.1.5.3	Feed Process Operational Assessment	
8.4.2	Vitrify HLW and TRU Waste	
8.4.2.1	Candidate Melter Systems Evaluations	
8.4.2.1.1	Melter Performance Assessment	
8.4.2.1.1-01	*Final Report(s) on Laboratory-Scale System Testing*	
8.4.2.1.2	Lab Scale Stirred Melter Tests	
8.4.2.1.3	Small-Scale Stirred Melter Closeout	
8.4.2.1.4	Pilot Scale Stirred Melter	
8.4.2.1.5	HTM Sloped Bottom Design	
8.4.2.1.6	SSHTM 94 Test Data, Analysis, Reduction and Reporting	
8.4.2.1.6-01	*Initial Small-Scale High Temperature Melter Data Package*	
8.4.2.1.7	HTM Material Testing and Evaluation	
8.4.2.1.7-01	*High Temperature Melter Materials Testing Letter Report*	
8.4.2.1.8	HTM Materials Testing Strategy	
8.4.2.1.9	HTM Systems Maintenance and Repair	
8.4.2.1.10	SSHTM Design Improvement and Rebuild	
8.4.2.1.11	SSHTM Performance Testing, Evaluation and Reporting	
8.4.2.1.11-01	*Report(s) on Small-Scale Melter (X&Y) System Testing form FY 95*	
8.4.2.1.12	Establish CCM Subcontract	
8.4.2.1.13	CCM Test Preparation, Testing and Reporting	
8.4.2.1.13-01	*Report(s) on Small-Scale Melter (X&Y) System Testing form FY 95*	
8.4.2.1.14	Feed Chemicals for CCM Testing	

High-Level Waste Immobilization
C.I.= Critical Interfaces (Table 8.1)
** Implicit Driver*

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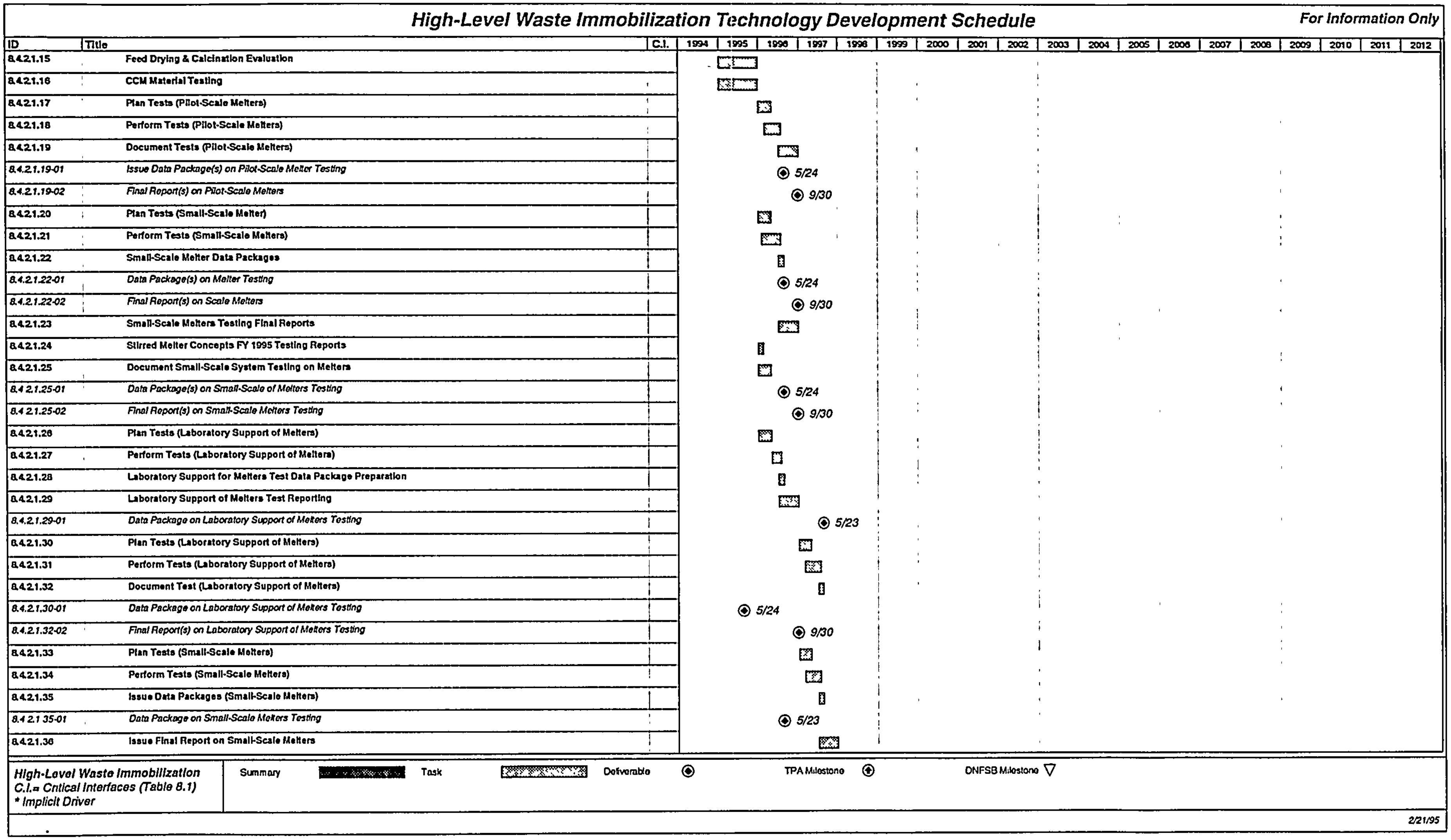
Figure 8.2. Schedule (cont)



High-Level Waste Immobilization Technology Development Schedule

For Information Only

ID	Title	C.I.
8.4.2.1.15	Feed Drying & Calcination Evaluation	
8.4.2.1.16	CCM Material Testing	
8.4.2.1.17	Plan Tests (Pilot-Scale Melters)	
8.4.2.1.18	Perform Tests (Pilot-Scale Melters)	
8.4.2.1.19	Document Tests (Pilot-Scale Melters)	
8.4.2.1.19-01	*Issue Data Package(s) on Pilot-Scale Melter Testing*	
8.4.2.1.19-02	*Final Report(s) on Pilot-Scale Melters*	
8.4.2.1.20	Plan Tests (Small-Scale Melter)	
8.4.2.1.21	Perform Tests (Small-Scale Melters)	
8.4.2.1.22	Small-Scale Melter Data Packages	
8.4.2.1.22-01	*Data Package(s) on Melter Testing*	
8.4.2.1.22-02	*Final Report(s) on Scale Melters*	
8.4.2.1.23	Small-Scale Melters Testing Final Reports	
8.4.2.1.24	Stirred Melter Concepts FY 1995 Testing Reports	
8.4.2.1.25	Document Small-Scale System Testing on Melters	
8.4.2.1.25-01	*Data Package(s) on Small-Scale of Melters Testing*	
8.4.2.1.25-02	*Final Report(s) on Small-Scale Melters Testing*	
8.4.2.1.26	Plan Tests (Laboratory Support of Melters)	
8.4.2.1.27	Perform Tests (Laboratory Support of Melters)	
8.4.2.1.28	Laboratory Support for Melters Test Data Package Preparation	
8.4.2.1.29	Laboratory Support of Melters Test Reporting	
8.4.2.1.29-01	*Data Package on Laboratory Support of Melters Testing*	
8.4.2.1.30	Plan Tests (Laboratory Support of Melters)	
8.4.2.1.31	Perform Tests (Laboratory Support of Melters)	
8.4.2.1.32	Document Test (Laboratory Support of Melters)	
8.4.2.1.30-01	*Data Package on Laboratory Support of Melters Testing*	
8.4.2.1.32-02	*Final Report(s) on Laboratory Support of Melters Testing*	
8.4.2.1.33	Plan Tests (Small-Scale Melters)	
8.4.2.1.34	Perform Tests (Small-Scale Melters)	
8.4.2.1.35	Issue Data Packages (Small-Scale Melters)	
8.4.2.1.35-01	*Data Package on Small-Scale Melters Testing*	
8.4.2.1.36	Issue Final Report on Small-Scale Melters	

High-Level Waste Immobilization
C.I.= Critical Interfaces (Table 8.1)
** Implicit Driver*

Summary ▬ Task ▨ Deliverable ◉ TPA Milestone ◉ DNFSB Milestone ▽

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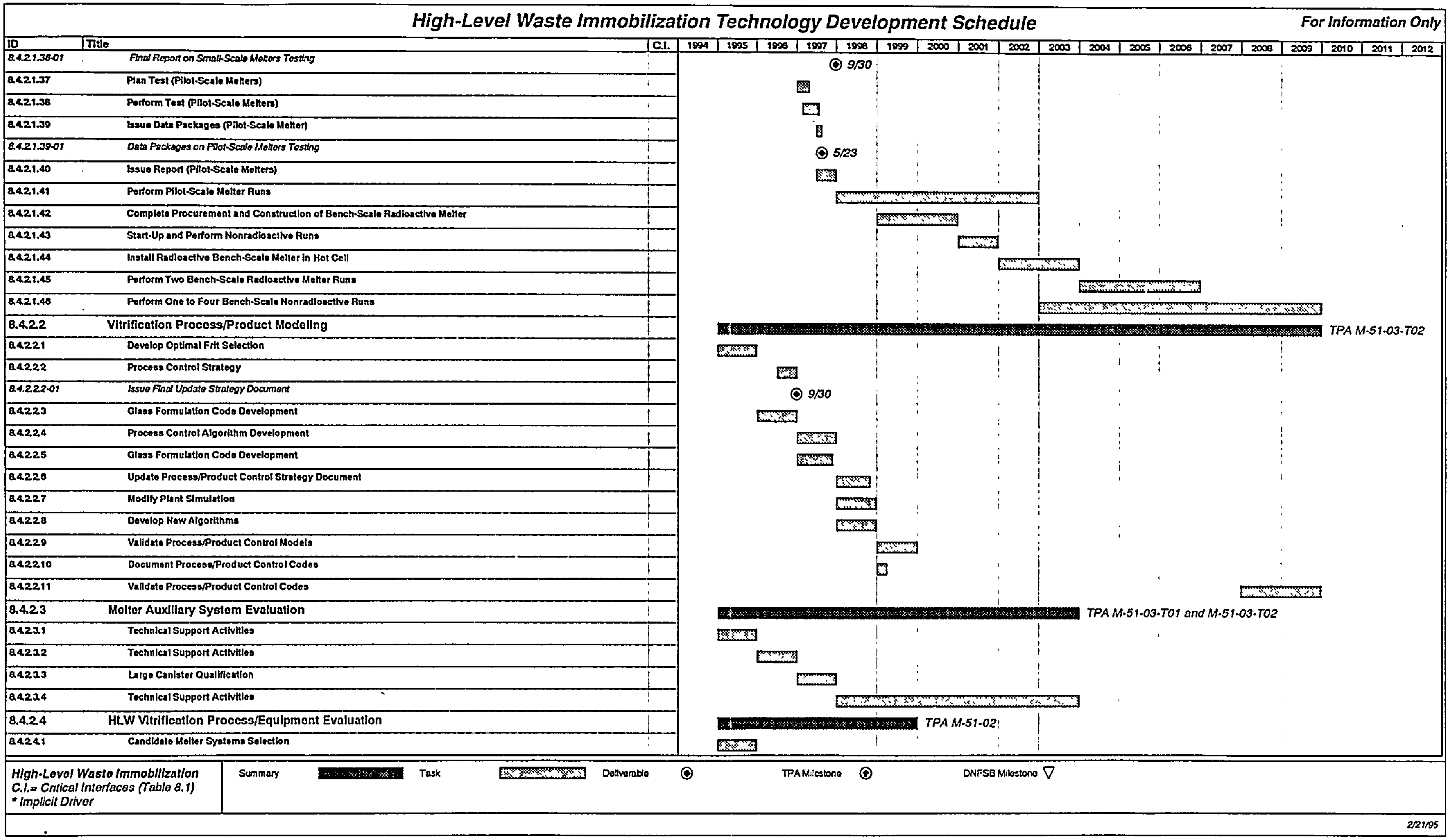
Figure 8.2. Schedule (cont)



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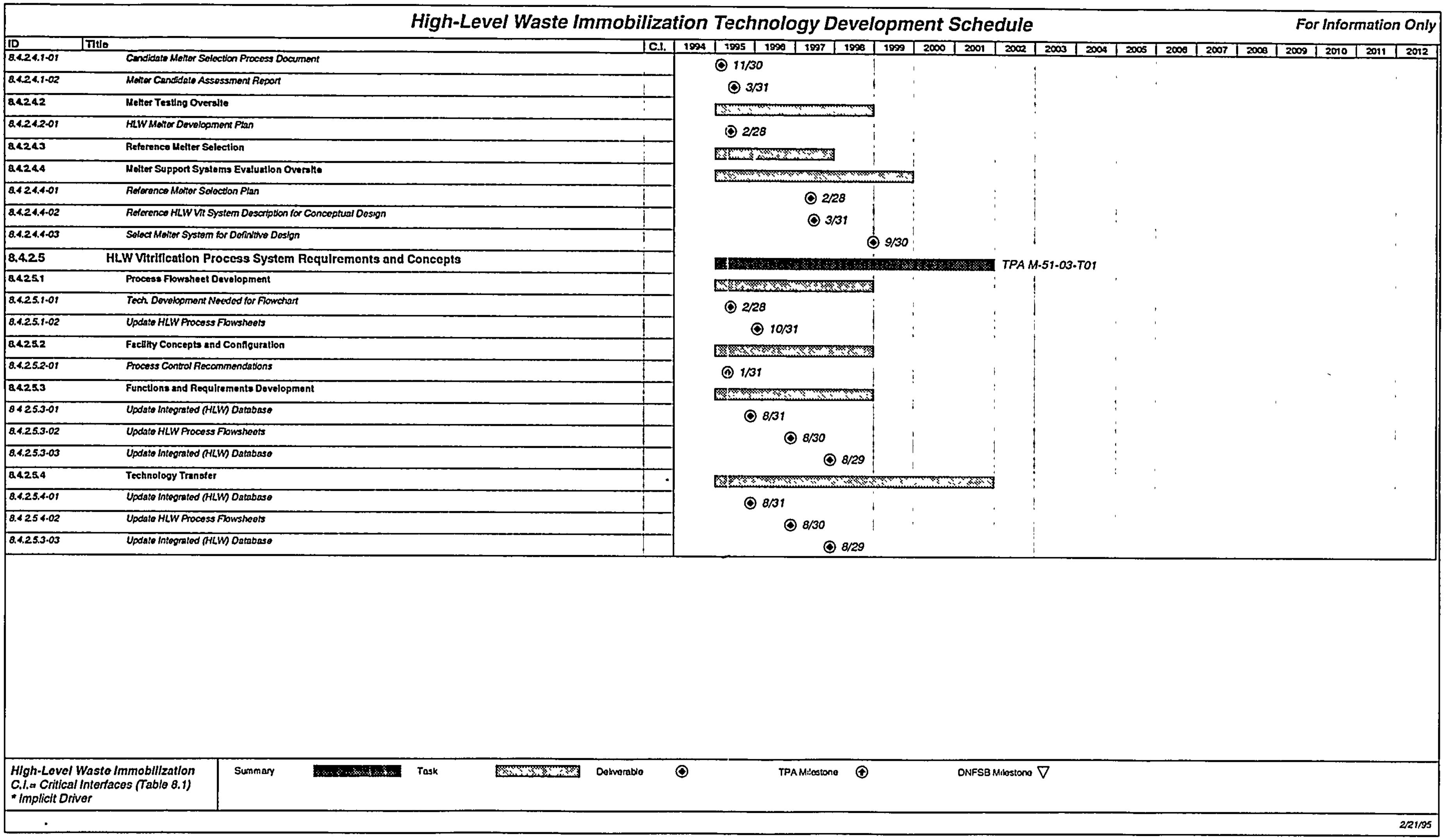

High-Level Waste Immobilization Technology Development Schedule

For Information Only

ID	Title	C.I.
8.4.2.4.1-01	*Candidate Melter Selection Process Document*	
8.4.2.4.1-02	*Melter Candidate Assessment Report*	
8.4.2.4.2	**Melter Testing Oversite**	
8.4.2.4.2-01	*HLW Melter Development Plan*	
8.4.2.4.3	**Reference Melter Selection**	
8.4.2.4.4	**Melter Support Systems Evaluation Oversite**	
8.4.2.4.4-01	*Reference Melter Selection Plan*	
8.4.2.4.4-02	*Reference HLW Vit System Description for Conceptual Design*	
8.4.2.4.4-03	*Select Melter System for Definitive Design*	
8.4.2.5	**HLW Vitrification Process System Requirements and Concepts**	
8.4.2.5.1	**Process Flowsheet Development**	
8.4.2.5.1-01	*Tech. Development Needed for Flowchart*	
8.4.2.5.1-02	*Update HLW Process Flowsheets*	
8.4.2.5.2	**Facility Concepts and Configuration**	
8.4.2.5.2-01	*Process Control Recommendations*	
8.4.2.5.3	**Functions and Requirements Development**	
8.4.2.5.3-01	*Update Integrated (HLW) Database*	
8.4.2.5.3-02	*Update HLW Process Flowsheets*	
8.4.2.5.3-03	*Update Integrated (HLW) Database*	
8.4.2.5.4	**Technology Transfer**	•
8.4.2.5.4-01	*Update Integrated (HLW) Database*	
8.4.2.5.4-02	*Update HLW Process Flowsheets*	
8.4.2.5.3-03	*Update Integrated (HLW) Database*	

High-Level Waste Immobilization
C.I.= Critical Interfaces (Table 8.1)
** Implicit Driver*

Figure 8.2. Schedule (cont)

Table 8.3. Budget

HIGH-LEVEL WASTE IMMOBILIZATION
TWRS Technology Budget Estimates
(Unescalated Dollars in Thousands by Fiscal Year)

TECHNOLOGY PACKAGE NUMBER AND TITLE	1995	1996	1997	1998	1999	2000	2001 +	TOTAL
["Expected Budget Available for Technology" consists of activities in TWRS Multi-Year Work Plan]								
8.4.1.1--HLW Glass Formulation								
Expected Budget Available for Technology	1,700	2,176	2,391	1,900	740	640	5,110	14,657
Total Estimated Budget for Technology Activities in ITP	1,700	2,176	2,391	1,900	740	640	5,110	14,657
8.4.1.2--HLW Vitrification Process Chemistry								
Expected Budget Available for Technology	1,180	1,359	1,398	1,289	780	780	1,560	8,346
Total Estimated Budget for Technology Activities in ITP	1,180	1,359	1,398	1,289	780	780	1,560	8,346
8.4.1.3--Radioactive Testing								
Expected Budget Available for Technology	188	649	1,141	1,260	1,130	1,130	3,360	8,858
Total Estimated Budget for Technology Activities in ITP	188	649	1,141	1,260	1,130	1,130	3,360	8,858
8.4.1.4--Initial Design Feed Specification								
Expected Budget Available for Technology	187	220	142	142	142	142	142	1,117
Total Estimated Budget for Technology Activities in ITP	187	220	142	142	142	142	142	1,117
8.4.1.5--Feed/Process Evaluation								
Expected Budget Available for Technology	249	675	675	675	675	400	0	3,349
Total Estimated Budget for Technology Activities in ITP	249	675	675	675	675	400	0	3,349
8.4.2.1--Candidate Melter System Evaluations								
Expected Budget Available for Technology	5,591	8,719	8,728	3,300	6,700	4,300	41,290	78,628
Total Estimated Budget for Technology Activities in ITP	5,591	8,719	8,728	3,300	6,700	4,300	41,290	78,628
8.4.2.2--Vitrification Process/Product Modeling								
Expected Budget Available for Technology	200	306	327	242	220	0	4,840	6,135
Total Estimated Budget for Technology Activities in ITP	200	306	327	242	220	0	4,840	6,135
8.4.2.3--Melter Auxiliary Systems Evaluation								
Expected Budget Available for Technology	25	27	164	220	200	200	600	1,436
Total Estimated Budget for Technology Activities in ITP	25	27	164	220	200	200	600	1,436

FOR PLANNING PURPOSES ONLY — NOT OFFICIAL COST INFORMATION

Table 8.3 Budget (cont.)

HIGH-LEVEL WASTE IMMOBILIZATION (Continued)
TWRS Technology Budget Estimates
(Unescalated Dollars In Thousands by Fiscal Year)

TECHNOLOGY PACKAGE NUMBER AND TITLE	1995	1996	1997	1998	1999	2000	2001 +	TOTAL
["Expected Budget Available for Technology" consists of activities in TWRS Multi-Year Work Plan]								
8.4.2.4--HLW Vitrification Process\Equipment Evaluation								
Expected Budget Available for Technology	2,328	795	715	715	500	0	0	5,053
Total Estimated Budget for Technology Activities In ITP	2,328	795	715	715	500	0	0	5,053
8.4.2.5--HLW Vitrification Process System Requirements and Concepts								
Expected Budget Available for Technology	3,665	2,765	3,018	3,000	2,000	2,000	0	16,448
Total Estimated Budget for Technology Activities In ITP	3,665	2,765	3,018	3,000	2,000	2,000	0	16,448
HIGH-LEVEL WASTE IMMOBILIZATION TOTALS:								
Expected Budget Available for Technology	15,313	17,691	18,699	12,743	13,087	9,592	56,902	144,027
Total Estimated Budget for Technology Activities In ITP	15,313	17,691	18,699	12,743	13,087	9,592	56,902	144,027

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9.0 References

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Appendix A

Approach

A.1 Process for Preparing the Integrated Technology Plan

The following sections briefly outline how Revision 2 of the Integrated Technology Plan (ITP) was prepared. These sections describe how the technology needs addressed in the ITP were identified, how the technology program documented in the ITP was developed and the groups that were involved, the basis for developing the estimated cost of program implementation, and the basis for developing the integrated technology schedule.

A.2 Source of Technology Needs

The Tank Waste Remediation System (TWRS) program is using a systems engineering process to define the functions that must be performed to accomplish the TWRS mission. Those functions with a significant technology component were identified. The technology needs associated with each of these functions were determined based on a review of the functions (including the requirements and enabling assumptions associated with each function), the TWRS technical strategy, and the current approach for implementing that strategy. Technology needs were also derived from WHC-SD-WM-DTP-033, Rev 0, *Technology Development in Support of the TWRS Process Flowsheet.*

A.3 Source of Technology Tasks

Two different approaches were taken to develop the plans for addressing the TWRS technology needs. For needs associated with tank safety and retrieval, technical input to the plan (technical approach, tasks, and deliverables) was developed by staff from the Technology Development Program Office (TDPO) working with staff from the Integrating Contractor's TWRS Program Office. For needs associated with characterization, pretreatment, low-level waste immobilization (LLW), and high-level waste immobilization (HLW), Systems Architecture Groups (AGs) were tasked with the responsibility for preparing the technical inputs to the plan. Two AGs were involved, the Characterization AG (CAG) and the Waste Processing AG (WPAG). The AGs consisted of experienced technologists from the U.S. Department of Energy's (DOE's) national laboratories, maintenance and operations (M&O) contractors, private industry, universities, and foreign sources.

The Engineering Technology Interface Group (ETIG), which consists of the TDPO Program Element Managers and members representing the corresponding Integrating Contractor's TWRS Program Elements and TWRS Engineering, coordinated preparation of the plan with the TWRS program elements. Key elements of this coordination included ensuring that those involved in preparing the plan had a clear understanding of the TWRS technical strategy and current approach for implementing that strategy, and ensuring that the schedules for the technology activities documented in the ITP (e.g., completion dates for key deliverables) were consistent with the schedules being developed for the overall TWRS program. The ETIG was also the forum for clarifying critical interprogram interfaces that impact technology planning, resolving any other interprogram issues, and facilitating interprogram communication.

A.4 Basis for Estimating Cost

All cost estimates contained in this document are for planning purposes only and are not considered official cost information. Official TWRS cost information is contained in the TWRS program baseline documents.

The cost estimates presented in the ITP are rough order-of-magnitude (ROM) estimates made by individuals with expert knowledge in the technology area and familiarity with the technology work scope being estimated. In many cases, the estimates were prepared using knowledge of costs incurred for similar work, or on the basis of work completed on TWRS technology projects in progress. Cost estimates for work in progress are taken from the TWRS MYWP draft with changes approved through January 1, 1995.

A.5 Development of Integrated Technology Schedules

All schedules contained in this document are for planning purposes only and are not considered official schedules. Official schedules are contained in the TWRS program baseline documents.

The Integrated Technology Schedule is a Gantt chart that consists of three primary elements: 1) schedule line items that summarize the technology schedules by detailed program; 2) technology-specific, high-level programmatic activities, milestones and decision points taken from the TWRS Program Summary Schedule; and 3) interface points that depict the logical relationship between these items.

The Integrated Technology Schedule was developed by rolling up the schedule and interface data from each of the detail technology schedules contained in the individual program element sections of the ITP. The information was summarized in a manner consistent with the TWRS systems engineering-defined functions and requirements (F&Rs). This approach formed the basis for establishing the Integrated Technology Schedule.

An ad-hoc team was formed consisting of ITP chapter authors, ETIG members, and other key individuals that participated in the ITP preparation process, and in TWRS programmatic baseline development. The team started with the summary schedule and added technology-specific, high-level programmatic milestones and decision points from the TWRS Program Summary Schedule and from other sources.

Relationships between the items selected were then identified. The resulting summary integrated schedule is presented in Chapter 2.0 (Figure 2.4) and at a more detailed level in each of the program element chapters (Chapters 3.0 through 8.0) as Figures *X*.1.

A.6 ITP Prioritization Process

The fundamental objective of this process was to prioritize selected technology development activities for Revision 2 of the ITP. A multi-attribute utility prioritization approach was selected for implementation. For each program element, teams of representatives from the TDPO, Architecture Group, TWRS Program Office, and TWRS Engineering evaluated and prioritized activities in their program area.

The following steps guided the process. Specific modifications and shortcuts employed are discussed in subsequent paragraphs.

1. Identify fundamental objectives.
2. Specify attributes that lead to accomplishment of objectives (criteria).
3. Determine if any are requirements (gates or screens).
4. Specify range of outcomes for each attribute.
5. Rank attributes from 1 to n.
6. Assign swing weights to each attribute.
7. Develop utility curves for each attribute.
8. Group tasks that cannot be funded separately.

9. Evaluate options against each utility curve to obtain score.

10. Sum individual scores to obtain overall attribute score.

11. Perform "makes-sense" test.

12. Group the outcomes into "high," "medium," and "low" importance.

The selected activities/tasks to prioritize were those FY 1996 activities/tasks that either do not appear in the MYWP or appeared in the MYWP but were thought unlikely to be included in the FY 1996 budgeted activities/tasks. An assumption of this approach is that FY 1995 activities/tasks that were not funded in the FY 1995 MYWP were pushed into FY 1996 or deleted. Those FY 1995 activities/tasks not deleted were also candidates for this prioritization unless they appeared as budgeted items for the FY 1996 MYWP.

The attributes chosen that led to the accomplishment of the objective (prioritize TD tasks) were the following:

- minimize secondary waste
- minimize ES&H risk
- minimize technical risk
- maximize technical performance
- minimize schedule
- maximize cost savings
- minimize regulatory/deployment risk.

Some attributes were divided into sub-attributes to better define the objective. A complete listing of all the attributes and sub-attributes is shown at Figure A.1. A description of the attributes follows the figure.

The general approach was to score the technology development activities/tasks according to the attributes. The attributes were all expressed as minimizations or maximizations and therefore showed potential impacts (either positive or negative). The individual scores were summed to obtain an overall score. A cost/benefit ratio, determined by dividing the overall impact score by the activity/task costs (measured in thousands of dollars), showed how many positive impact points would be amassed per thousand dollars spent.

Steps one through five were performed before the program element prioritization meetings through direct coordination with the TDPO program element manager and TDPO ITP manager. No specific gates or screens (step #3) were determined. Elicitation of attribute importance weights from key team members was attempted before starting the prioritization meeting. When that was not possible, the beginning of the prioritization meeting was used to determine these importance weights. A modified swing weighting approach was used. Once the swing weighting approach was finished, the total attribute weights were normalized to sum to 1000 possible points.

Utility curves for each attribute in each program area were deemed to be overly complex for this model because it was not possible to specify outcomes for each attribute (step #4). Instead, a constructed attribute scale was used to determine the individual attribute scores. The constructed scale used is shown in Table A.1.

If an attribute, such as "Maximize Schedule," had been determined to be worth 150 possible points, then in the attribute scoring process an activity could score 150 points, 75 points, 0 points, -75 points or -150 points. This was determined by the prioritization team members scoring the activity a 1 through -1, based on the activity's impact on the program schedule.

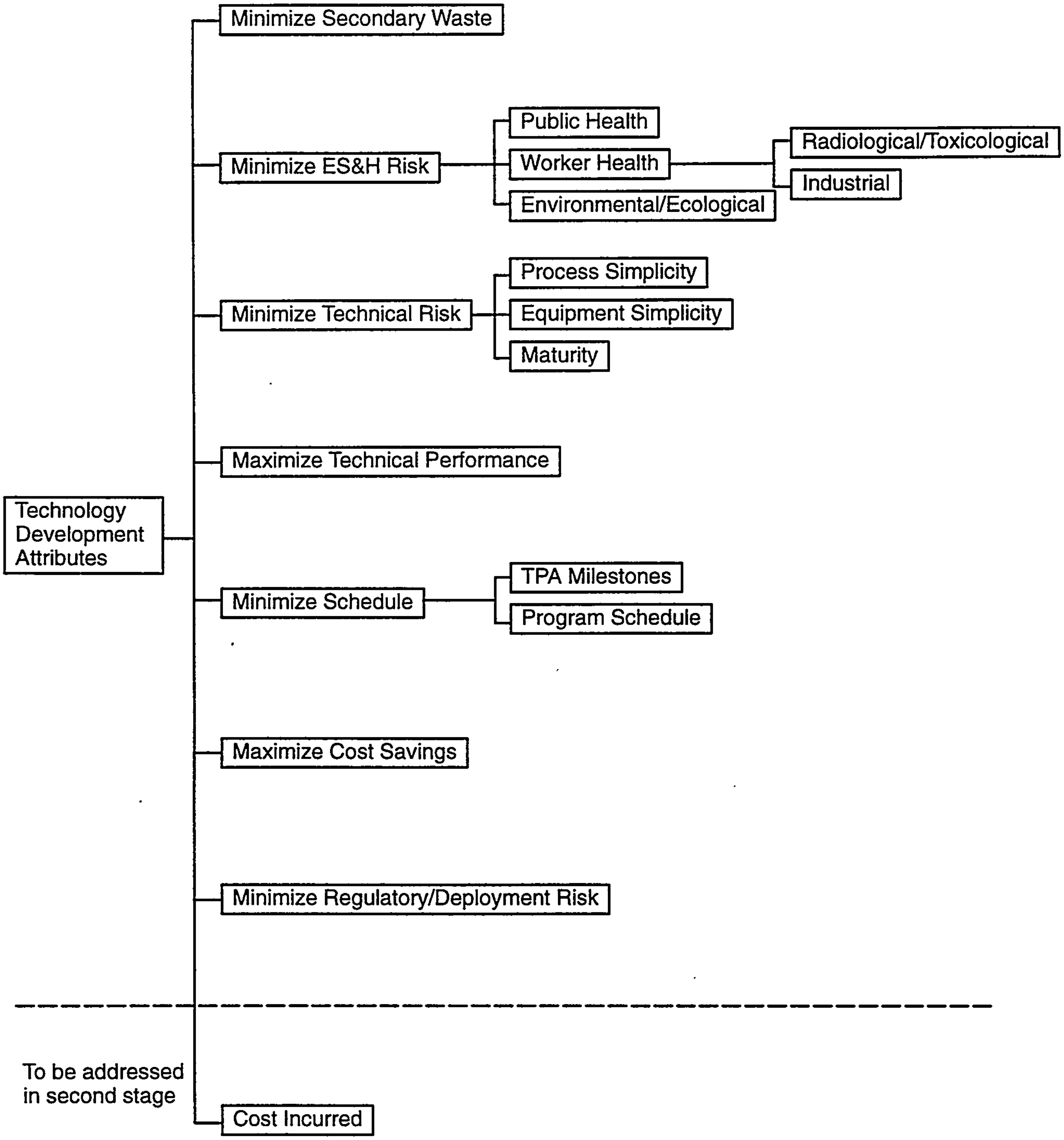

Figure A.1. Technology Development Attributes

Table A.1. TD Activity Attribute Scoring

Scoring Scale

Score	Description	Attribute Weight
1	Significant favorable impact expected	100%
.5	Favorable impact expected	50%
0	No clear impact expected	0%
-.5	Unfavorable impact expected	-50%
-1	Significant unfavorable impact expected	-100%

Each activity was assessed on the seven attributes and the scores were then summed. The resultant score became a number between -1000 and 1000. The program prioritization team then performed an informal "makes-sense" test on the final outcomes of the scored activities.

The overall activity attribute scores were then divided by the cost incurred for that activity measured in thousands of dollars. This provided a benefit-to-cost ratio. This benefit-to-cost ratio was an estimate of the "bang for the buck" in money spent for that technology activity.

The activities were next grouped into an appropriate number of categories. The TDPO program element manager used the summed attribute scores list and/or the benefit-to-cost ratio to base the final prioritized list. Each approach, summed attribute scores or benefit-to-cost ratio, was merely a tool to assist this effort, and was not the total input used. Most prioritization groups thought that two categories, "Fund Immediately" and "Fund If Possible," were sufficient. This is reflected by the Recommended Technology Program table in each program chapter of the ITP.

A.7 Attribute Definitions

Minimize Secondary Waste. Minimizing total waste at the Hanford site is an important stakeholder objective. Each program favors technology development activities that minimize secondary waste over those that do not.

Minimize ES&H Risk. Environment, safety, and health (ES&H) risks should be minimized at all levels of the TWRS programs. The ES&H risks are those risks that occur to the public, the worker, and the environment/ecosystems. The risk to workers can be described by worker risk from radiation/chemical hazards and standard industrial accidents. Technology development activities that minimize these risks should be favored over those that do not.

Minimize Technical Risk. Determinants of technical risk are the complexity of the process, the complexity of the equipment, and the general level of maturity of the activity/process. The level of technical risk is assessed from consideration of those factors. Activities with low technical risk should be favored.

Maximize Technical Performance. The ability of the technology development activity to maximize the technical performance of the process it supports is to be assessed here. Activities that improve process performance should be favored.

Minimize Schedule. What impact does this activity have on the schedule? Will implementation of the technology development activity/task tend to shorten or extend the schedule? Impacts to consider are TPA milestones and the program schedule the technology development (TD) activity is to support. Activities/tasks with the potential to shorten program schedules should be favored.

Maximize Cost Savings. Cost savings can be defined as (Total TWRS Life-Cycle Savings) minus (Total Life-Cycle Implementation Costs). The magnitude of these costs for most activities will need to be approximated by the panel of experts. Activities/tasks with the ability to allow the program's processes to be performed in a more efficient manner should be favored.

Minimize Regulatory/Deployment Risk. This criterion is meant to encompass the compliance/stakeholder involvement issues. Technology development activities should be considered in light of their intended use and opinions determined about the acceptability of that technology to the regulators (for approval) and by the stakeholder (for acceptance). The program office should be a source of this type of information. The program offices are receiving compliance/stakeholder acceptance feedback as part of their strategic planning process. Any activity/task-supporting process perceived as not easily achieving regulator or stakeholder acceptance should not be favored.

Cost Incurred. This is the total amount of money spent for the technology development activity/task in all years. The cutoff date for technology development costs is when the technology is accepted by the user.

Appendix B

ITP Contributing Groups, Charters, and List of Members

Group	Charter	Membership
ITP Chapter Authors	Write the technical, cost, and schedule information contained in Chapters 3 through 8, based on input from the Architecture Groups, TWRS Programs, and TWRS Engineering, as appropriate	Joan Young (Safety) Gary Eller (Characterization) Jim Lee (Retrieval) Tom Slankas (Pretreatment) John Holbrook (LLW) John Carr (HLW)
ITP Steering Committee	Provide vision, direction, and reality check for ITP contents; monitor its progress to completion; ensure its consistency with TWRS baseline documents; provide for adequate review and approval; determine ITP format and purpose; ensure its utility	Steve Burnum, DOE RL Cathy Louie, MacTech Bet Flores, PNL Gary Dunford, WHC George Mellinger, PNL Eric Schmieman, PNL Don Wodrich, WHC
ITP Working Group	Responsible for compilation, integration, approach, ensuring milestones are met	Chair: Eric Schmieman, PNL Editor: Audrey Ignatov, PNL Scheduler: Steve Schlahta, PNL Budget Analyst: Joe Northrop, PNL Technical Advisors: Bet Flores, PNL; and Don Merrick, WHC Decision Analyst: Ray Fleshman, PNL Technical Coordinators: Michael McKinney and Jennifer Stitzel, PNL
ETIG (Engineering Technology Interface Group)	Provide update of technology needs for each TWRS program element based on renegotiated TPA; review appropriate sections of updated ITP for technical and programmatic accuracy; ensure that cost and schedule estimates for outyears are reasonable and reflect TPA milestone commitments	Chair: George Mellinger, PNL Safety: Greg Hanson, WHC Characterization: Dave Forehand, WHC; and Gary Eller, PNL Retrieval: Les Fort and Eric Shen, WHC; Jim Lee, SNL Pretreatment: John Appel, WHC; and Tom Slankas, PNL LLW: Ken Burgard and Ron Gibby, WHC; John Holbrook, PNL HLW: Steve Schaus, WHC; John Carr and Don Larson, PNL

Group	Charter	Membership
Characterization Architecture Group (CAG)	Prepare (through chapter authors) technical inputs to Characterization chapter of ITP; review Characterization chapter of ITP for technical adequacy	Chair: Wally Schulz, Consultant Members: Jimmy Bell, ORNL David Forehand, WHC John Fowler, WSRC David Green, ANL Dawn Kabac, CCEM Bruce Kowalski, University of Washington John Hartman, PNL Bob Villareal, LANL Paul Wang, Ames Laboratory
Waste Processing Architecture Group (WPAG)	Prepare (through chapter authors) technical inputs to Pretreatment, LLW, and HLW chapters of ITP, review these chapters for technical adequacy	Chair: Raymond Wymer, Consultant Members: Reed Jensen, LANL Richard Karnesky, WHC Donald Larson, PNL Michael McKeon, British Nuclear Fuels, Ltd. John Rawlins, WHC Martin Steindler, ANL John Swanson, PNL Larry Tavlarides, Syracuse University Major C. Thompson, WSRC Terry Todd, Westinghouse Idaho Nuclear Co. George Vandegrift, ANL Jack Watson, ORNL

Appendix C

Function Definitions[(a)]

Function	*Definitions*
4.2	**Remediate Tank Waste** *Store, treat, and immobilize highly radioactive Hanford waste (existing and future tank waste and the strontium and cesium capsules) in an environmentally sound, safe, and cost effective manner.*
4.2.1	**Manage Tank Waste (MTW)** *Manage existing tank waste (e.g., waste contained in DSTs, SSTs, and miscellaneous tanks), and new tank waste from Site level interfaces (e.g., facility operations, D&D, ER), prior to retrieval for final processing. Manage Tank Waste will be limited to the storage of waste before retrieval for processing; waste characterization; transfer of supernatants for the resolution of safety issues, optimization of tank space, volume reduction, interim stabilization, and/or emergency pumping; concentration of tank waste to support tank space utilization. This function also includes treatment/preparation of liquid, gaseous, and solid wastes generated during the management of tank waste.*
4.2.1.1	**Store Waste** *Contain and monitor SST waste and waste in miscellaneous tanks. Receive, contain and monitor DST waste and in-process waste. Define and initiate actions for mitigation/resolution of safety issues, and the treatment/preparation of liquid, gaseous, and solid wastes generated during the storage of tank waste.* *Waste is currently being received, contained, and monitored. This will continue until all waste is removed for final processing.*
4.2.1.2	**Characterize Waste** *Provide physical, chemical, and radiological characterization information to support process control, safety issue resolution, treatment/storage/disposal decisions, or other TWRS needs. Waste characterization activities include (1) acquisition and transfer of samples to the laboratory; (2) laboratory analysis of samples; (3) in situ measurements; (4) review of historical data and laboratory results as necessary to complete characterization; and (5) the treatment/preparation of liquid, gaseous, and solid wastes generated during the characterization of tank waste. This function will characterize only those tank wastes being managed under the Manage Tank Waste function; characterization of tank wastes managed by the Process Waste function is not included.*

(a) U.S. DOE/RL. November, 14 1994. *Tank Waste Remediation System Functional Requirements.* DOE/RL-92-60, Rev. 1, U.S. Department of Energy, Richland, Washington.

Function	*Definitions*
4.2.1.3	**Transfer Managed Tank Waste** *Recover supernatant and interstitial from SSTs, DSTs, and active MUSTs and transfer to DSTs for storage as necessary to resolve safety concerns, manage tank space, or provide feed for the Concentrate Waste function. Also included are the receipt and transfer of liquid wastes to DST storage from generators external to the Remediate Tank Waste function and the recovery and transfer of organic layers for treatment and final disposal. This function also includes treatment/preparation of liquid, gaseous, and solid wastes generated during the transfer of tank waste.* *Transfer Managed Tank Waste is ongoing and will continue as long as liquid wastes are accepted from external generators and waste remains in storage awaiting retrieval for treatment and disposal by the Process Waste Function.*
4.2.1.4	**Concentrate Waste** *Remove excess water from supernatant stored in DSTs to maximize utilization of available tank space. This function also includes treatment/preparation of liquid, gaseous, and solid wastes generated during the concentration of tank waste.* *Function is currently being performed and will continue until LLW disposal activities eliminate the need for concentration.*
4.2.2	**Process Waste** *Process tank waste (including DST waste, SST waste, MUSTs that contain HLW, and cesium/strontium capsules (if required), for disposal. This includes retrieval/transfer of tank wastes, in-process waste storage, any pretreatment (if required), immobilization and onsite disposal of LLWs, immobilization, interim storage, and certification of immobilized HLWs for acceptance into the Civilian Radioactive Waste Management System. Also included is treatment/preparation of system-generated gaseous, liquid, and solid wastes. Waste excluded from processing by this function includes the USTs and support structures, production reactor fuels, radioactive materials at reactors, disposal facilities, transfer lines, cribs, ponds, and ditches.* *The Process Waste function is initiated when waste retrieval for treatment begins and will continue until the last IHLW/ITRU package leaves the storage facility shipping dock and the treatment facilities are turned over for D&D.*

(a) U.S. DOE/RL. November, 14 1994. *Tank Waste Remediation System Functional Requirements.* DOE/RL-92-60, Rev. 1, U.S. Department of Energy, Richland, Washington.

Function	*Definitions*
4.2.2.1	**Retrieve/Transfer Waste** *The removal of tank waste from USTs and waste processing lag storage tanks. USTs include SSTs, DSTs, and MUSTs. This function also transfers wastes between treatment/storage/disposal facilities. Waste for retrieval and transfer includes liquids, (except for interim stabilization of SSTs, see Function 4.2.1.3 - Transfer Managed Tank Waste), saltcake, sludges, in-tank hardware (e.g., equipment, concrete, rocks, and lead bricks) and discreet (radioactive) sources (e.g., experimental fuel rods, samarium balls, and cobalt slugs). Some in-tank hardware will be moved around inside the tanks to eliminate interference with the retrieval of other wastes. Wastes will be removed to the extent required to permit completion of tank closure activities. This function also includes treatment/preparation of liquid, gaseous, and solid wastes generated during retrieval and transfer of tank wastes.*
4.2.2.2	**Store In-Process Waste** *Receive, contain, and monitor retrieved waste and pretreated waste in DSTs. Blending of raw wastes may be included. This function also includes treatment/preparation of liquid, gaseous, and solid waste generated during storage of in-process wastes.* *Storage of in-process waste will begin when waste retrieval for treatment begins and will continue until all pretreated waste has been transferred for immobilization.*
4.2.2.3	**Pretreat Waste** *Separate tank waste into a HLW/TRU fraction and LLW fractions suitable for immobilization and into a fraction suitable for reuse. Pretreatment includes preparing all retrieved tank waste for separations processes, including blending of raw wastes, separating the waste constituents suitable for immobilization as LLW and for reuse, and converting the remaining waste into feeds to the HLW and TRU waste immobilization system. Blending of pretreated LLW and HLW solids is included. This function also includes treatment/preparation of liquid, gaseous, and solid wastes generated during pretreatment.* *Tank waste will be pretreated when needed to provide feed for LLW immobilization and/or provide feed for HLW and TRU immobilization. Pretreatment will continue until all tank waste has been converted to feed for immobilization processes.*

(a) U.S. DOE/RL. November, 14 1994. *Tank Waste Remediation System Functional Requirements.* DOE/RL-92-60, Rev. 1, U.S. Department of Energy, Richland, Washington.

Function	*Definitions*
4.2.2.4	**Immobilize and Dispose of LLW** *Receive pretreated LLW from the Retrieval/Transfer Waste function, treat LLW, and dispose LLW onsite. This function includes receipt of the waste from Retrieve/Transfer, treatment of the waste by an immobilization process, disposal of the immobilized waste, and closure of the disposal site. This function also includes treatment/preparation of liquid, gaseous, and solid wastes generated during immobilization/disposal of LLW.* *This function begins when the LLW is received. Treatment will continue until all waste shipped is treated and the disposal site is closed.*
4.2.2.5	**Immobilize, Store, and Ship HLW** *Immobilize pretreated HLW and TRU waste and prepare cesium/strontium capsules for deep geologic disposal. Prepare immobilized/prepared HLW for shipment to appropriate geologic repositories. This function also includes treatment/preparation of liquid, gaseous, and solid wastes generated during immobilization, storage, and shipping of HLW.* *Tank waste immobilization and/or cesium/strontium capsule preparation will begin when the immobilization facility is authorized to begin hot operations and will continue until all of the HLW/TRU is immobilized.* *Note: DOE/WIPP requirements apply only if a decision is made to dispose of ITRU at WIPP.*
(a) U.S. DOE/RL. November, 14 1994. *Tank Waste Remediation System Functional Requirements.* DOE/RL-92-60, Rev. 1, U.S. Department of Energy, Richland, Washington.	

Appendix D

Key Federal Laws and Requirements

Some of the key federal laws, regulatory programs, and requirements that will impact technology activities are described here.

- **Atomic Energy Act (AEA)** (42 U.S.C. 2011 et seq.): Radiation protection limits and standards for radioactive and mixed waste management derived from the AEA apply to activities involving characterization, retrieval, pretreatment, treatment, or other management of radioactive waste. For example, to perform remediation activities in accordance with AEA standards, significant technical innovations in equipment, safety procedures, monitoring equipment, sampling, and sample-handling equipment may be needed.

- **Clean Air Act (CAA)**, as amended by the CAA Amendments of 1990 (42 U.S.C. 7401 et seq.): The CAA requires the use of maximum achievable control technology (MACT) for sources that emit hazardous air pollutants. Waste tank pretreatment and treatment operations may result in hazardous air pollutant emissions and may also meet the definition of a "major source" under the CAA, requiring a permit to operate and install MACT. Declaration of a non-attainment area could also have a profound impact on future operations.

- **Clean Water Act (CWA)** (33 U.S.C. 1251 et seq.): The CWA regulates discharges of specific effluents to surface waters. Pretreatment and high-level waste (HLW) and low-level waste (LLW) vitrification activities may generate liquid effluents subject to this law.

- **Federal Facilities Compliance Act (FFCA)** (PL 102-386): The FFCA subjects federal facilities to federal and state RCRA regulations, and to penalties for failure to comply. It also establishes requirements for plans and reports on the development of mixed waste treatment technologies and capacities.

- **National Environmental Policy Act (NEPA)** (42 U.S.C. 4321 et seq.): NEPA requires considerations of environmental impacts, alternatives, and resource commitments for any major federal action that significantly affects the quality of the human environment. U.S. Department of Energy (DOE) NEPA regulations will likely require an environmental impact statement (EIS) for actions associated with LLW management and those involving siting/construction/operation of HLW pretreatment, treatment, storage, or disposal facilities.

- **Nuclear Waste Policy Act (NWPA)** (42 U.S.C. 10101 et seq.): The NWPA describes performance requirements for a HLW repository and provides specifications for HLW packaging.

- **Resource Conservation and Recovery Act (RCRA)**, as amended by the Hazardous and Solid Waste Amendments (42 U.S.C. 6901 et seq.): Hazardous waste mixed with radioactive waste becomes "mixed waste" and is subject to regulation under RCRA. RCRA establishes standards for treatment, storage, or disposal of hazardous waste. The operation, maintenance, characterization, and closure of the tanks will be regulated by RCRA. Waste received, generated, and managed during tank stabilization and closure may also be subject to RCRA land-disposal restrictions.

- **Pollution Prevention Act of 1990 (PPA)** (42 U.S.C. 13101 et seq.): This Act establishes a pollution prevention hierarchy as national policy. The policy declares that, wherever feasible, pollution should be prevented or reduced at the source; pollution that cannot be prevented should be recycled in an environmentally safe manner; pollution that cannot be prevented or recycled should be treated in an environmentally safe manner, and that disposal or other release into the environment should be employed only as a last resort and should be conducted in a manner that minimizes the impact to the environment. This hierarchy should be taken into consideration when selecting treatment technologies.

- **Waste Minimization/Pollution Prevention**: Orders such as DOE Order 5820.2A require that technical controls be directed to reducing the gross volume of waste generated and/or the amount of radioactivity requiring disposal. Waste reduction efforts must include consideration of process modification, process optimization, materials substitution, and decontamination. RCRA also requires that all hazardous waste generators have a program in place to minimize the volume and toxicity of hazardous waste. Commercial repository capacity for disposal of HLW is currently unavailable, and when licensed, will surely be limited.

Appendix E

Program Element Templates

Appendix E

Program Element Templates

Waste Tank Safety (3.0) E-3-1
Characterization (4.0) E-4-1
Waste Retrieval (5.0) E-5-1
Waste Pretreatment (Chapter 6) E-6-1
Low-Level Waste Immobilization (Chapter 7) E-7-1
High-Waste Immobilization (8.0) E-8-1

Appendix E

Program Element Templates

Contents: Waste Tank Safety (3.0)

3.4.1.1 Evaluate and Define Technology for Flammable Gas-Generating Tanks E-3-3
3.4.2.1 Evaluate and Define Technology for Ferrocyanide-Containing Tanks E-3-7
3.4.2.2 Evaluate and Define the Safety Issue for Ferrocyanide-Containing Tanks E-3-10
3.4.3.1 Technology for Evaluating Organic-Containing Tanks E-3-12
3.4.4.1 Evaluate and Define Safety Issue for High-Heat Tanks E-3-16

Template Title: Evaluate and Define Technology for Flammable Gas-Generating Tanks

Template Number: 3.4.1.1

Technology Package Type (Reference, Enhancement, or Alternative): Reference

Baseline Program (Y/N): Yes

WBS ID Number and Title: 1.1.1.2.02.04.01 Evaluate and Define Technology for Flammable Gas-Generating Tanks

Program Element: Waste Tank Safety

Functional Need Level 4: Store Waste (4.2.1.1)

Functional Need Level 5: Store SST Waste (4.2.1.1.2)

Functional Need Level 6: Store SST Flammable Gas-Generating Tanks (4.2.1.1.2.1)

Functional Need Level 7: None

Scope: For flammable gas tanks, technology is needed to assess the potential 1) for flammable gas mixtures to be generated and released and 2) for the concentration of tank vapors to exceed 25% of the lower flammability limit.

Justification: Understanding of the mechanisms of gas generation, retention, and release is needed for conducting safety analysis and developing mitigation methods.

Drivers:

- Public Law 101-510
- DOE Order 5480.21 and 5820.2A
- Tri-Party Agreement

Level of Maturity (Basic Research, Applied Research, Technology or Laboratory Development, Advanced Development, Engineering Development, Demonstration, First Production, or Operations): Engineering Development

Key Uncertainties:

- The physics of gas release and bubble retention are not completely understood.
- The composition of gas bubbles is not well understood.
- The composition of gas from gas release events is unknown.
- Existing analytical methods for analyzing organic functional groups in the waste are time consuming and expensive.

Key Deliverables (Date, Deliverable):

- Issue final report on gas generation studies (9/96) (Task 1)
- Issue final report on gas bubble retention effects (9/97) (Task 2)

- Issue final report on gas phase reactions (9/97) (Task 3)
- Provide organic analysis methods (9/96) (Task 4)
- Issue TEMPEST theory and user manuals for waste tanks physics modeling (9/95) (Task 5)
- Issue final report on gas release mechanisms (9/96) (Task 6)
- Complete thermal/hydraulic analysis (9/97) (Task 7)
- Complete theory development for waste behavior modeling (9/95) (Task 8)
- Issue report on phase equilibria of gases (9/97) (Task 9)

Basis For Cost Estimates: DOE. 1994. *TWRS Multi-Year Work Plan.* DOE-RL-92-59. Draft Budget Rev. 2 (January 30, 1995. Supplemental. Not yet published.).

Template Title (Technology Package): Evaluate and Define Technology for Flammable Gas-Generating Tanks

Template Number: 3.4.1.1

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total ($K)	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
1.	Gas generation studies	Y	10/94	09/96	FY 1995 FY 1996	75 20	FY 1995 FY 1996	502 370	577 390	
2.	Gas bubble retention studies	Y	10/94	09/97	FY 1995 FY 1996 FY 1997	20 0 0	FY 1995 FY 1996 FY 1997	368 232 95	388 232 95	
3.	Gas reaction studies	Y	10/94	09/97	FY 1995 FY 1996 FY 1997	25 0 0	FY 1995 FY 1996 FY 1997	216 196 95	241 196 95	
4.	Organic analysis and methods development	Y	10/94	09/96	FY 1995 FY 1996	0 0	FY 1995 FY 1996	238 232	238 232	
5.	Waste tank physics modeling	Y	10/94	09/97	FY 1995 FY 1996 FY 1997	0 154 106	FY 1995 FY 1996 FY 1997	326 515 584	326 669 690	
6.	Gas release mechanisms/waste modeling	Y	10/95	09/96	FY 1996	0	FY 1996	515	515	
7.	Thermal/hydraulic analysis	Y	10/94	09/97	FY 1995 FY 1996 FY 1997	0 0 0	FY 1995 FY 1996 FY 1997	408 446 470	408 446 470	
8.	Theory development	Y	10/94	09/95	FY 1995	0	FY 1995	234	234	

Template Title (Technology Package): Evaluate and Define Technology for Flammable Gas-Generating Tanks

Template Number: 3.4.1.1

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total ($K)	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
9.	Phase equilibria studies-gases	Y	10/94	09/97	FY 1995 FY 1996 FY 1997	60 26 0	FY 1995 FY 1996 FY 1997	215 196 202	275 222 202	
Total										

Template Title: **Evaluate and Define Technology for Ferrocyanide-Containing Tanks**

Template Number: **3.4.2.1**

Technology Package Type (Reference, Enhancement, or Alternative): Reference

Baseline Program (Y/N): Yes

WBS ID Number and Title: 1.1.1.2.02.03.04 Evaluate and Define for 18 CeFN Tanks

Program Element: Waste Tank Safety

Functional Need Level 4: Store Waste (4.2.1.1)

Functional Need Level 5: Store SST Waste (4.2.1.1.2)

Functional Need Level 6: Store Ferrocyanide Waste (4.2.1.1.2.2)

Functional Need Level 7: None

Scope: Evaluate and define the safety issue associated with wastes containing potentially reactive mixtures of ferrocyanide.

Justification: Evaluating and defining the safety issue associated with wastes containing potentially reactive mixtures of ferrocyanide compounds is necessary to establish safe operating conditions and to select an appropriate path for resolving the safety issue.

Drivers:

- Public Law 101-510 *Safety Measures for Waste Tanks at the Hanford Nuclear Reservation*
- DOE Order 5480.21 *Unreviewed Safety Questions*
- DOE Order 5820.2A *Radioactive Waste Management*

Level of Maturity (Basic Research, Applied Research, Technology or Laboratory Development, Advanced Development, Engineering Development, Demonstration, First Production, or Operations): Engineering Development

Key Uncertainties:

- The concentration of radionuclides (strontium-90 and cesium-137) and the potential for local hot spots in the sludge is not known.
- The degree to which the ferrocyanide concentrations have decreased over time and the mechanisms resulting in lower ferrocyanide concentrations than expected are not known.

Key Deliverables (Date, Deliverable):

- Issue Final Aging Study Report to WHC (8/95) (Task 1)
- Issue Final Cesium Uptake Capacity Report (3/95) (Task 2)
- Issue Final Sludge Moisture Monitoring Report to WHC (9/95) (Task 3)

Basis For Cost Estimates: DOE. 1994. *TWRS Multi-Year Work Plan*. DOE-RL-92-59. Draft Budget Rev. 2. (January 30, 1995. Supplemental. Not yet published.).

References: Buck, J., C. M. Anderson, B. A. Pulsipher, J. J. Toth, P. J. Turner, R. J. Cash, G. T. Dukelow, and J. E. Meacham. 1993. *Ferrocyanide Safety Program: Data Requirements for the Ferrocyanide Safety Issue Developed Through the Data Quality Objectives (DQO) Process*. WHC-EP-0728. Westinghouse Hanford Company, Richland, Washington.

Template Title: Evaluate and Define Technology for Ferrocyanide-Containing Tanks

Template Number: 3.4.2.1

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total ($K)	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
1.	Aging waste	Y	10/94	9/95	FY 1995	25	FY 1995	535	560	325 and 331 bldg availability/
2.	Cesium uptake	Y	10/94	3/95	FY 1995	0	FY 1995	71	71	325 bldg availability/
3.	Sludge moisture modeling	Y	10/94	9/95	FY 1995	0	FY 1995	135	135	
Total										

Template Title: Evaluate and Define the Safety Issue for Ferrocyanide-Containing Tanks

Template Number: 3.4.2.2

Technology Package Type (Reference, Enhancement, or Alternative): Reference

Baseline Program (Y/N): Yes

WBS ID Number and Title: 1.1.1.2.02.03.01 Evaluate and Define Technology Development

Program Element: Waste Tank Safety

Functional Need Level 4: Store Waste (4.2.1.1)

Functional Need Level 5: Store SST Waste (4.2.1.1.2)

Functional Need Level 6: Store Ferrocyanide Waste (4.2.1.1.2.2)

Functional Need Level 7: None

Scope: Technology tasks are needed to monitor the safe condition of the stored wastes include developing and implementing in situ moisture monitoring systems.

Justification: Monitoring and controlling the moisture content of ferrocyanide waste is needed to resolve the safety issue.

Drivers:

- Public Law 101-510 *Safety Measures for Waste Tanks at the Hanford Nuclear Reservation*
- DOE Order 5480.21 *Unreviewed Safety Questions*
- DOE Order 5820.2A *Radioactive Waste Management*

Level of Maturity (Basic Research, Applied Research, Technology or Laboratory Development, Advanced Development, Engineering Development, Demonstration, First Production, or Operations): Engineering Development

Key Uncertainties: A certain level of moisture needs to be assured during storage of the ferrocyanide-containing wastes to prevent the possibility of exothermic reactions. The moisture content of the waste must be monitored in situ.

Key Deliverables (Date, Deliverable):

- Complete development of moisture measuring devices (9/98) (Task 1)
- Complete installation and testing of neutron probe (9/95) (Task 2)
- Complete installation and testing of the electromagnetic induction probe (9/97) (Task 3)

Basis For Cost Estimates:

DOE. 1994. *TWRS Multi-Year Work Plan.* DOE-RL-92-59. Draft Budget Rev. 2.

Telephone communication with Bob Cash of the Waste Tank Safety Program on 12/13/94. (January 30, 1995. Supplemental. Not yet published.).

Template Title: Evaluate and Define the Safety Issue for Ferrocyanide-Containing Tanks

Template Number: 3.4.2.2

Tasks					Capital ($K)		Expense ($K)			
No.	Title	MYWP	Start Date	End Date	Year	Amount	Year	Amount	Total	Predecessors/ Successors
1.	Surface moisture measuring (CPAC)	Y	9/95	9/98	FY 1996	139	FY 1996	282	421	
					FY 1997	244	FY 1997	344	588	
					FY 1998	248	FY 1998	233	481	
2.	Neutron probe moisture monitor	Y	9/94	9/97	FY 1995	177	FY 1995	490	667	
					FY 1996	0	FY 1996	202	202	
					FY 1997	0	FY 1997	208	208	
3.	Electromagnetic induction probe	Y	9/94	9/97	FY 1995	260	FY 1995	335	595	
					FY 1996	547	FY 1996	119	666	
					FY 1997	566	FY 1997	196	762	
Total										

Template Title: Technology for Evaluating Organic-Containing Tanks

Template Number: 3.4.3.1

Technology Package Type (Reference, Enhancement, or Alternative): Reference

Baseline Program (Y/N): Yes

WBS ID Number and Title: 1.1.1.2.02.03.01 Evaluate and Define Technology Development

Program Element: Waste Tank Safety

Functional Need Level 4: Store Waste (4.2.1.1)

Functional Need Level 5: Store SST Waste (4.2.1.1.2)

Functional Need Level 6: Store Organic/Noxious Waste (4.2.1.1.2.4)

Functional Need Level 7: None

Scope: Evaluate and define of the Organic Safety Issue through an understanding of the risk from fuel-waste oxidizer reactions.

Justification: At issue is the presence of unacceptable concentrations of potentially reactive organic materials in twenty SSTs. Analyses show that propagating organic reactions could occur if there is sufficient concentration of fuel and oxidizer present in the waste, and if a portion of the waste is dried out and heated to temperatures above 180°C. The potential for these conditions to occur must be understood.

Analytical methods are also needed to support studies to evaluate and define the reactivity of unacceptable concentrations of potentially reactive organic materials in twenty SSTs.

Drivers:

- Public Law 101-510 *Safety Measures for Waste Tanks at the Hanford Nuclear Reservation*
- DOE Order 5480.21 *Unreviewed Safety Questions*
- DOE Order 5820.2A *Radioactive Waste Management*
- Methods should result in minimal sample handling and waste production.

Level of Maturity (Basic Research, Applied Research, Technology or Laboratory Development, Advanced Development, Engineering Development, Demonstration, First Production, or Operations): Engineering Development

Key Uncertainties:

- Evaluating and defining the Organic Safety Issue requires an understanding of the risk from fuel-waste oxidizer reactions.
- Potential reaction systems within the tanks and associated energetics are not understood completely.
- Analytical procedures must be identified to resolve uncertainties associated with TOC measurements to estimate tank reactivity.
- The potential for waste concentration mechanisms to result in the formation of small discrete layers of organic solvents in the tank is not known.

- The potential for thermal gradients within the tank is not known.
- Analytical methods for analyzing chelators, chelator fragments, organic acids, other organic functional groups, and high molecular weight compounds are required to support aging and waste concentration studies are time consuming and expensive.

Key Deliverables (Date, Deliverable):

- Issue Topical Report on Organic Concentration Mechanisms (8/95) (Task 1)
- Issue Waste Energetics Progress Report (9/95) (Task 2)
- Issue Final Report on Moisture and Organic Carbon Contents in Hanford SSTs (12/94) (Task 3)
- Issue Final Report on the Value of Information (VOI) Model for Moisture and Organic Carbon Studies (8/95) (Task 3)
- Issue Letter Report on Analytical Chemistry Methods (10/97) (Task 4)

Basis For Cost Estimates:

DOE. 1994. *TWRS Multi-Year Work Plans.* DOE-RL-92-59. Draft Budget Rev.2. (January 30, 1995. Supplemental. Not yet published.).

WHC. March 29, 1994. *Consolidated Contractor Support Budget for WTS Program.* Spreadsheet prepared by E. L. Renner used for schedule.).

Note: Budgets for FY 1998 for Waste Energetics Task are assumed to be the same as the budget for FY 1997.

References: Wood, T., C. E. Willingham, and J. A. Campbell. 1993. *Organic Layer Sampling for SST 241-C-103 Background and Data Quality Objectives and Analytical Plan.* PNL-8871, Pacific Northwest Laboratory, Richland, Washington.

Babad, H., S. M. Blacker, K. S. Redus. 1994. *Data Quality Objectives to Support Resolution of the Organic Fuel Rich Tank Safety Issue.* WHC-SD-WM-DQO-006, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Template Title: Technology for Evaluating Organic-Containing Tanks

Template Number: 3.4.3.1

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total ($K)	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
1.	Organic concentrations mechanisms	Y	10/94	9/97	FY 1995 FY 1996 FY 1997	0 0 0	FY 1995 FY 1996 FY 1997	225 232 95	225 232 95	
2.	Waste energetics	Y	10/94	9/98	FY 1995 FY 1996 FY 1997 FY 1998	0 0 0 0	FY 1995 FY 1996 FY 1997 FY 1998	240 464 239 239	240 464 239 239	Availability of characterization data from tank C-103/Use of tank C-103 for experiments
3.	SST waste carbon and moisture study	Y	10/94	9/97	FY 1995 FY 1996 FY 1997	0 0 0	FY 1995 FY 1996 FY 1997	180 93 48	180 93 48	
4.	Organic analytical methods development	Y	10/94	9/97	FY 1995 FY 1996 FY 1997	0 0 0	FY 1995 FY 1996 FY 1997	450 464 239	450 464 239	325 building availability/Provides data to Tasks 1, 2, and 3
5.	Waste energetics with simulants	Y	10/94	9/97	FY 1995 FY 1996 FY 1997	0 0 0	FY 1995 FY 1996 FY 1997	770 409 211	770 409 211	
6.	Waste moisture with simulants	Y	10/94	9/97	FY 1995 FY 1996 FY 1997	0 0 0	FY 1995 FY 1996 FY 1997	101 102 54	101 102 54	
7.	Basis Safe Ops SSTs—Organic/Nitrate (FAI)	Y	10/94	9/97	FY 1995 FY 1996 FY 1997	0 0 0	FY 1995 FY 1996 FY 1997	270 515 212	270 515 212	

Template Title: Technology for Evaluating Organic-Containing Tanks

Template Number: 3.4.3.1

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total ($K)	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
8.	Basis Safe Ops SSTs—Organic Layer	Y	10/94	9/95	FY 1995	0	FY 1995	88	88	
9.	Basis Safe Ops SSTs—Absorbed Organic	Y	10/94	9/96	FY 1995 FY 1996	0 0	FY 1995 FY 1996	89 52	89 52	
Total										

Template Title: Evaluate and Define Safety Issue for High-Heat Tanks

Template Number: 3.4.4.1

Technology Package Type (Reference, Enhancement, or Alternative): Reference

Baseline Program (Y/N): Yes

WBS ID Number and Title: 1.1.1.2.02.06.01 Evaluate and Define Safety Issue for High-Heat Tanks

Program Element: Waste Tank Safety

Functional Need Level 4: Store Waste (4.2.1.1)

Functional Need Level 5: Store SST Waste (4.2.1.1.2)

Functional Need Level 6: Store SST High-Heat Waste (4.2.1.1.2.3)

Functional Need Level 7: None

Scope: The focus of initial activities for resolution of the high-heat safety issue consists of developing a thermal model for predicting the amount of cooling liquid required versus the temperature of the waste, and validating the model with characterization data.

Justification: There is a concern that structural failure will occur if, in the event of a leak, water currently added for cooling is discontinued.

Drivers:

- Public Law 101-510
- DOE Order 5420.2A
- Tri-Party Agreement M-40-05

Level of Maturity (Basic Research, Applied Research, Technology or Laboratory Development, Advanced Development, Engineering Development, Demonstration, First Production, or Operations): Engineering Development

Key Uncertainties:

- The minimum amount of liquid to be added to the tank is unknown.
- Contingency action plans must be developed.

Key Deliverables (Date, Deliverable):

- Complete results of thermal modeling and analysis (9/95)

Basis For Cost Estimates:

DOE. 1994. *TWRS Multi-Year Work Plan.* DOE-RL-92-59. Draft Budget Rev 2. (January 30, 1995. Supplimental. Not yet published.).

Template Title: Evaluate and Define Safety Issue for High-Heat Tanks

Template Number: 3.4.4.1.

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total ($K)	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
1.	Thermal model analysis	Y	09/94	09/95	FY 1995	0	FY 1995	45	45	
Total										

Appendix E

Program Element Templates

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4.4.4.4 Moisture Analytical Methods E-4-45

Template Title: Technetium Analytical Methods

Template Number: 4.4.1.1

Technology Package Type (Reference, Enhancement, or Alternative): Alternative

Baseline Program (Y/N): Yes

WBS ID Number and Title: 1.1.1.2.04 Characterization

Program Element: Characterization

Functional Need Level 4: Characterize Waste (4.2.1.2)

Functional Need Level 5: Analyze Samples (4.2.1.2.4)

Functional Need Level 6: Prepare and Analyze Samples (4.2.1.2.4.3)

Functional Need Level 7: None

Scope: The scope of this activity is to develop and implement for routine beneficial use reliable, timely, and cost-effective technology to characterize the total quantity and chemical speciation of technetium in HLW in accordance with applicable DQO and test plans.

Justification: Technetium quantitation is needed to bound the total quantity in the HLW waste tanks because volatile technetium oxides could impact melter design and technetium content is likely to have a major impact on performance of the final LLW vitrified product. For these reasons, the process flowsheet may need to address technetium separation, which would be impacted by the chemical form (speciation) of the technetium. Timely, reliable, and cost-effective TWRS procedures for routine technetium analysis (speciation and quantitation) do not currently exist.

Drivers: Improves the ability to meet (but is not explicitly required by) the following milestones:

- TPA M-44-00 Issue Tank Characterization Reports for 177 HLW tanks by 09/99
- TPA M-50-03 Complete evaluation of enhanced sludge washing to determine whether advanced sludge separation processes are required, by 03/98
- TPA-50-04 Start hot operations of HLW pretreatment facility by 06/08
- generally supports DNFSB Recommendation 93-5 Commitment Task 5, Improve the Quality and Quantity of Analyses.

Level of Maturity (Basic Research, Applied Research, Technology or Laboratory Development, Advanced Development, Engineering Development, Demonstration, First Production, or Operations): The technology should be at least in the Advanced Development stage so that implementation is possible to impact the FY 1995-97 period of heavy sampling and the subsequent sludge-washing decision in March 1998. Substantial but lesser benefits would accrue from later deployment.

Key Uncertainties: The key uncertainty is whether or not practical routine technology can be implemented in time to impact the FY 1995-97 period of heavy sampling and the subsequent sludge-washing decision in March 1998.

Key Deliverables (Date, Deliverable): The key deliverable will be reliable, timely, and cost-effective technology that is fully implemented for routine beneficial use for determining the total quantity and chemical speciation of technetium in HLW samples.

Delivery Date(s): For maximum impact, procedures must be implemented in time to impact the FY 1995-97 period of heavy sampling and the subsequent sludge-washing decision in March 1998. Significant but lesser benefits would accrue from subsequent sampling through the life of TWRS.

Basis For Cost Estimates: Costs are derived from best professional judgement based on past experience with similar projects.

Template Title: Technetium Analytical Methods

Template Number: 4.4.1.1

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
1.	Survey existing methods for technetium speciation. The survey will review methods for both liquids and solids against applicable DQO and test plans and will specifically include ICP/MS methods.	Y	10/94	01/95	FY 1995	0	FY 1995	75	75	None/Task 2
2.	Develop and implement technetium speciation and quantification methods. This activity includes a decision point on whether to pursue new methods and concludes when the method is in routine beneficial use in the TWRS production analytical laboratories.	Y	01/95	09/95	FY 1995	25	FY 1995	180	205	Task 1/None
Total										

Template Title: Automated Sample Preparation and Analysis

Template Number: 4.4.1.2

Technology Package Type (Reference, Enhancement, or Alternative): Alternative

Baseline Program (Y/N): Yes

WBS ID Number and Title: 1.1.1.2.04 Characterization

Program Element: Characterization

Functional Need Level 4: Characterize Waste (4.2.1.2)

Functional Need Level 5: Analyze Samples (4.2.1.2.4)

Functional Need Level 6: Prepare and Analyze Samples (4.2.1.2.4.3)

Functional Need Level 7: None

Scope: The scope of this activity is to provide reliable, timely, and cost-effective technology to maximize the efficiency of HLW laboratory analyses through automation.

Justification: Automation of repetitive HLW laboratory activities offers potential for significant reduction of analytical costs and turnaround time, improved throughput and reliability, and personnel exposure reduction.

Drivers: Improves the ability to meet (but is not explicitly required by) the following milestones:

- TPA M-44-00 Issue Tank Characterization Reports for 177 Hanford HLW tanks (09/99)
- TPA M-40-00 Mitigate/resolve tank safety issues for high-priority Watch List tanks (09/2001)
- generally supports: DNFSB Recommendation 93-5 Implementation Plan Task 5, Improve the Quality and Quantity of Analyses
- additional drivers: the potential for significant reduction of analytical costs, schedule, and exposure and improved reliability for repetitive analytical activities.

Level of Maturity (Basic Research, Applied Research, Technology or Laboratory Development, Advanced Development, Engineering Development, Demonstration, First Production, or Operations): For maximum impact, laboratory automation technology should currently be in at least the Technology Development stage to impact the FY 1995-1997 period of intense sampling. However, substantial impact would accrue from subsequent implementation.

Key Uncertainties: The feasibility of developing and implementing reliable, timely, and cost-effective technology that can meet DQO and test plan specifications in time to support the FY 1995-FY 1997 window of heaviest sampling activity is uncertain.

Key Deliverables (Date, Deliverable): The technology deliverable will be reliable, timely, and cost-effective automated laboratory analytical technology, which is fully implemented for routine beneficial use.

Basis For Cost Estimates: Costs are derived from professional judgement based on past experience with similar projects.

Template Title: Automated Sample Preparation and Analysis

Template Number: 4.4.1.2

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
1.	Evaluate HLW analytical automation targets with highest impact potential. Select and begin development and implementation of activities with the highest payoff.	Y	10/94	09/95	FY 1995	0	FY 1995	100	100	Prior laboratory automation development by EM30 and EM50/Task 2
2.	Develop and implement automated laboratory procedure or procedures identified in Task 1 (FY 1995).	Y	10/95	09/96	FY 1996	0	FY 1996	200	200	Task 1 and other laboratory automation development by EM30 and EM50/Task 3
3.	Conclusion of Tasks 1 and 2	Y	10/96	09/97	FY 1997	0	FY 1997	200	200	Task 2 and other laboratory automation development by EM30 and EM50/None
Total										

Template Title: **Total Organic Carbon (TOC) Analysis**

Template Number: **4.4.1.3**

Technology Package Type (Reference, Enhancement, or Alternative): Alternative

Baseline Program (Y/N): Yes

WBS ID Number and Title: 1.1.1.2.04 Characterization

Program Element: Characterization

Functional Need Level 4: Characterize Waste (4.2.1.2)

Functional Need Level 5: Analyze Samples (4.2.1.2.4)

Functional Need Level 6: Prepare and Analyze Samples (4.2.1.2.4.3)

Functional Need Level 7: None

Scope: The scope of this activity is to develop and implement for routine beneficial use practical, reliable, timely, and cost-effective laboratory methods for analyzing TOC in HLW samples in accordance with applicable DQO.

Justification: Reliable TOC analyses currently are required by safety DQO and may be needed for the pretreatment and vitrification programs. In addition to reducing technical risks for these program elements, the availability of a more universal method could reduce analytical uncertainties, eliminate problems of comparing results from several methods, reduce costs, and minimize analytical turnaround time.

Drivers: Improves the ability to meet (but is not explicitly required by) the following milestones:

- TPA M-44-00 Issue Tank Characterization Reports for 177 HLW tanks by 09/99
- TPA M-40-00 Mitigate/resolve tank safety issues for high-priority Watch List tanks by 09/2001
- generally supports DNFSB Recommendation 93-5 Commitment Task 5, Improve the Quality and Quantity of Analyses.

Level of Maturity (Basic Research, Applied Research, Technology or Laboratory Development, Advanced Development, Engineering Development, Demonstration, First Production, or Operations): The technology should be at least in the Technology or Exploration Development stage so that implementation can impact the FY 1995-1997 period of heaviest sampling. Significant but reduced impact would result from later implementation.

Key Uncertainties: The main uncertainty is whether a practical universal method for the wide range of HLW matrices is possible and whether or not such a method could be developed and implemented in time to impact the FY 1995-1997 period of heavy sampling and analysis.

Key Deliverables (Date, Deliverable): The key deliverable will be fully implemented technology for reliable, cost-effective, practical, and timely laboratory quantification of TOC in HLW samples.

Basis For Cost Estimates: Costs are derived from best professional judgement based on past experience with similar projects.

Template Title: Total Organic Carbon (TOC) Analysis

Template Number: 4.4.1.3

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
1.	This task consists of the continuation of the FY 1994 evaluation of existing TOC methods, concluding with a recommendation for either procedure development or continued use of existing procedures. Subtasks will include the establishment of precision and uncertainty requirements from DQO and test plans, assessment of the cost/benefit based on current costs and sampling/ analysis schedule, and an industry-wide review of potential TOC analytical technology.	Y	10/94	09/95	FY 1995	0	FY 1995	200	200	FY 1994 TOC evaluation/Task 2
2.	This task consists of the development of an improved TOC analytical method; conditional on Task 1.	Y	10/95	09/96	FY 1996	0	FY 1996	200	200	Task 1/None
Total										

Template Title: Laboratory Physical/Rheological Property Methods

Template Number: 4.4.1.4

Technology Package Type (Reference, Enhancement, or Alternative): Enhancement

Baseline Program (Y/N): Yes

WBS ID Number and Title: 1.1.1.2.04 Characterization

Program Element: Characterization

Functional Need Level 4: Characterize Waste (4.2.1.2)

Functional Need Level 5: Analyze Samples (4.2.1.2.4)

Functional Need Level 6: Prepare and Analyze Samples (4.2.1.2.4.3)

Functional Need Level 7: None

Scope: The scope of this activity is to develop and implement for routine beneficial use reliable, timely, and cost-effective laboratory analytical methods for characterizing pertinent HLW physical and rheological properties in accordance with applicable DQO and test plans. This activity focuses on those physical parameters that can be measured accurately in the laboratory (e.g., abrasivity, particle size, and settling time).

Justification: Reliable, timely, and cost-effective characterization of HLW waste physical and rheological properties is required to support the formulation of the overall retrieval strategy. Existing in situ and laboratory methods are insufficient to meet the data needs.

Drivers: Improves the ability to meet (but is not explicitly required by) the following milestones:

- TPA M-45-04-T2 Complete design for the initial SST retrieval systems by 12/2000
- TPA M-45-04-T1 Provide initial SST retrieval systems by 11/03
- generally supports DNFSB Recommendation 93-5 Commitment Task 5, Improve the Quality and Quantity of Sampling.

Level of Maturity (Basic Research, Applied Research, Technology or Laboratory Development, Advanced Development, Engineering Development, Demonstration, First Production, or Operations): The current stage of the required physical and rheological property technologies ranges from Technology Development to Operations, depending upon the particular measurement in question.

Key Uncertainties: The key technical uncertainty is whether intrusive sampling can be done without compromising the desired in situ property measurement. Even with a suitably retrieved sample, the efficacy of laboratory methods for strength measurements is poor.

Key Deliverables (Date, Deliverable): The technology deliverable will be fully implemented laboratory procedures that determine the desired in situ physical and rheological properties in a reliable, timely, and cost-effective manner at the levels of precision and accuracy specified by DQO and test plans.

Basis For Cost Estimates: Cost estimates are derived from best professional judgement based on experience with similar projects.

Template Title: Laboratory Physical/Rheological Property Methods

Template Number: 4.4.1.4

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
1.	Development of a suite of laboratory analytical methods that can be used to provide data to infer pertinent in situ HLW physical properties.	Y	10/94	09/96	FY 1995 FY 1996	0	FY 1995 FY 1996	200 200	200 200	FY 1994 laboratory methods development and draft retrieval DQO and retrieval DQO revision
Total										

Template Title: Nickel 59/63 Analysis

Template Number: 4.4.1.5

Technology Package Type (Reference, Enhancement, or Alternative): Alternative

Baseline Program (Y/N): Yes

WBS ID Number and Title: 1.1.1.2.04 Characterization

Program Element: Characterization

Functional Need Level 4: Characterize Waste (4.2.1.2)

Functional Need Level 5: Analyze Samples (4.2.1.2.4)

Functional Need Level 6: Prepare and Analyze Samples (4.2.1.2.4.3)

Functional Need Level 7: None

Scope: The scope of this activity is to develop and implement a laboratory procedure to quickly, reliably, and cost-effectively analyze HLW samples for nickel-59 and nickel-63 in accordance with applicable DQO and test plans.

Justification: Immobilized waste form qualification is dependent upon long-lived radionuclides that contribute greater than 1% of the total sample radioactivity. Although the radionuclides nickel-59 and nickel-63 isotopes are not expected to be present in such concentrations in HLW, documentation must be presented that shows they are below this level. Therefore, analytical methodology must be made available for the measurement of these isotopes.

Drivers: Improves the ability to meet (but is not explicitly required by) the following milestones:

- TPA M-44-00 Issue Tank Characterization Reports for 177 Hanford HLW tanks by 09/99
- generally supports DNFSB Recommendation 93-5 Implementation Plan Task 5, Improve the Quality and Quantity of Analyses

Level of Maturity (Basic Research, Applied Research, Technology or Laboratory Development, Advanced Development, Engineering Development, Demonstration, First Production, or Operations): The analytical technology should be in at least the Advanced Development stage.

Key Uncertainties: The key technical uncertainty is the ability to deliver a practical, cost-effective method with the required sensitivity, precision, and accuracy.

Key Deliverables (Date, Deliverable): The overall technology deliverable will be a practical, fully implemented method for quantifying the amount of nickel-59 and nickel-63 in Hanford HLW.

Delivery Date(s): 09/97

Basis For Cost Estimates: Costs are derived from best professional judgement based on past experience with similar projects and similar activities. It is assumed that ICP/MS instrumentation will be available from other funding sources.

Template Title: Nickel 59/63 Analysis

Template Number: 4.4.1.5

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
1.	Develop and identify practical, cost-effective laboratory radiochemical methods for quantification of nickel-59 and nickel-63.	Y	10/95	07/96	FY 1996	60	FY 1996	80	140	None/None
2.	Implement for routine beneficial use a practical, cost-effective laboratory method for quantification of nickel-59 and nickel-63.	Y	10/95	09/96	FY 1996	0	FY 1996	165	165	None/None
Total										

Template Title: Phosphorus, Sulfur, and Noble Metals Analytical Methods for Water-Washed Sludge

Template Number: 4.4.1.6

Technology Package Type (Reference, Enhancement, or Alternative): Enhancement

Baseline Program (Y/N): Yes

WBS ID Number and Title: 1.1.1.2.04 Characterization

Program Element: Characterization

Functional Need Level 4: Characterize Waste (4.2.1.2)

Functional Need Level 5: Analyze Samples (4.2.1.2.4)

Functional Need Level 6: Prepare and Analyze Samples (4.2.1.2.4.3)

Functional Need Level 7: None

Scope: The scope of this activity is to develop and implement for routine beneficial use reliable, cost-effective and timely laboratory analytical methods for the determination of total phosphorus, sulfur, and noble metals in water-washed sludge in accordance with applicable DQO and test plans.

Justification: The concentration of noble metals is a concern in the design of melters because of the potential for electrode shorting. Also, noble metals could catalyze the conversion of nitrate to ammonia, which could influence melter offgas design. Concentrations of phosphorus and sulfur are needed because their allowable loading in the vitrified waste is limited and could strongly impact the volume of LLW product to be generated. There is also concern about undesired phosphate salt precipitation if the phosphate level is too high.

Drivers: Improves the ability to meet (but is not explicitly required by) the following milestones:

- TPA M-44-00 Issue Tank Characterization Reports for 177 HLW tanks by 09/99
- TPA M-50-03 Complete evaluation of enhanced sludge washing to determine whether advanced sludge separation processes are required by 03/98
- TPA-M-57-02 Complete melter tests and select reference HLW melter by 09/98
- generally supports DNFSB Recommendation 93-5 Commitment Task 5, Improve the Quality and Quantity of Analyses.

Level of Maturity (Basic Research, Applied Research, Technology or Laboratory Development, Advanced Development, Engineering Development, Demonstration, First Production, or Operations): The stage of the technology should be at least in the Advanced Development stage so that implementation can impact the FY 1995-97 period of intense sampling, the subsequent sludge-washing decision in March 1998, and the 09/98 HLW melter selection decision. Significant but reduced impact would result from later implementation.

Key Uncertainties: The key uncertainty is the availability of technology that can be developed and implemented in time to impact the FY 1995-97 period of intense sampling of the sludge and the 1996 HLW melter selection decisions.

Key Deliverables (Date, Deliverable): The key deliverables will be fully implemented procedures that provide timely, cost-effective, and reliable quantitation of phosphorus, sulfur, and noble metals in water-washed sludge.

Delivery Date(s): For maximum impact, procedures must be implemented in time to impact the FY 1995-97 period of intense sampling and 1998 sludge washing and melter selection decisions. Significant but lesser benefits would accrue from later implementation.

Basis For Cost Estimates: Costs are derived from best professional judgement based on past experience with similar projects.

Template Title: Phosphorus, Sulfur, and Noble Metals Analytical Methods for Water-Washed Sludge

Template Number: 4.4.1.6

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
1.	This task consists of the acquisition and deployment of ICP/MS instrumentation and development of procedures for noble metals determination.	Y	10/94	09/95	FY 1995	100	FY 1995	50	150	ICP/MS procurement and procedure development/None
2.	This task consists of a technical survey to identify analytical methods and concepts for sludge dissolution and/or methods that could be applied for routine analysis of phosphorus and sulfur in water-washed sludge. This task will include an assessment of known fusion methods.	Y	10/95	09/96	FY 1996	0	FY 1996	100	100	None
Total										

Template Title: Sample Verification Instrumented Receiver

Template Number: 4.4.2.1

Technology Package Type (Reference, Enhancement, or Alternative): Alternative

Baseline Program (Y/N): Yes

WBS ID Number and Title: 1.1.1.2.04 Characterization

Program Element: Characterization

Functional Need Level 4: Characterize Waste (4.2.1.2)

Functional Need Level 5: Acquire Physical Samples for Analysis (4.2.1.2.3)

Functional Need Level 6: Collect Waste Samples (4.2.1.2.3.3)

Functional Need Level 7: None

Scope: The scope of this activity is to develop and implement technology for the determination of sampler fullness before shipment to the hot cell facilities. In addition, this activity aims to improve the ability to accurately correlate collected sample fractions with actual sampling locations.

Justification: Without the ability to ascertain sampler fullness at the tanks, there is substantial risk of not detecting inadequate sample recovery until the sampler has been retrieved from the tank, sealed in a cask, shipped, and opened in a hot cell facility (a process that can take days). Meanwhile, the sampling rig may have been moved for other scheduled use. Significant cost and schedule penalties are incurred if sampling must be repeated because of poor recovery. Feedback on sampler fullness when the sample is taken also provides flexibility to quickly change to sampling tools with a better likelihood of success, again resulting in cost and schedule efficiencies. The instrumented receiver capability also assists in the evaluation of sampling performance and provides early guidance for follow-on sampling and laboratory analytical planning decisions.

Drivers: Improves the ability to meet (but is not explicitly required by) the following milestone:

- TPA M-44-00 Issue Tank Characterization Reports for 177 Hanford HLW tanks (09/99)
- directly supports DNFSB Recommendation 93-5 Commitment 3.18, Develop Means for Measuring Complete Sample Recovery.

Level of Maturity (Basic Research, Applied Research, Technology or Laboratory Development, Advanced Development, Engineering Development, Demonstration, First Production, or Operations): The first instrumented receiver for routine beneficial use is scheduled for delivery in March 1995. This activity is considered to be in the First Production stage of development.

Key Uncertainties: No major technical uncertainties exist for this technology.

Key Deliverables (Date, Deliverable): The technology deliverable will be delivery of a practical, cost-effective, and reliable instrumented receiver for routine beneficial use in the verification of sampler fullness.

Basis For Cost Estimates: Costs are determined by best professional judgment based on past experience with this project.

Template Title: Sample Verification Instrumented Receiver

Template Number: 4.4.2.1

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
1.	Deliver and implement (for routine beneficial use) an instrumented receiver.	Y	10/94	03/95	FY 1995	0	FY 1995	505	505	Prior development work on instrumented receiver/Task 2
2.	This task includes a decision point on the need for further instrumented receiver development. If the decision is to proceed, further development and implementation would be conducted in FY 1996.	Y	10/95	09/96	FY 1996	0	FY 1996	200	200	Task 1/None
Total										

Template Title: **Multiple Location Sampler**

Template Number: 4.4.2.2

Technology Package Type (Reference, Enhancement, or Alternative): Alternative

Baseline Program (Y/N): Yes

WBS ID Number and Title: 1.1.1.2.04 Characterization

Program Element: Characterization

Functional Need Level 4: Characterize Waste (4.2.1.2)

Functional Need Level 5: Acquire Physical Samples for Analysis (4.2.1.2.3)

Functional Need Level 6: Collect Waste Samples (4.2.1.2.3.3)

Functional Need Level 7: None

Scope: The scope of this activity is to develop and implement technology to allow the acquisition of HLW samples from multiple locations from a single riser.

Justification: The ability to acquire samples from multiple locations at depth within the waste volume from a single riser is desired to ensure that representative and selective sampling is achieved. Samples from specific locations (e.g., near tank bottom, suspected thermally and radioactively hot spots, layers with high ferrocyanide content, etc.) are of particular interest to the Safety Program for the resolution of waste tank safety issues. The Pretreatment and Retrieval Programs also require bounding information on tank content for process and equipment design. Representative data also will assist the Characterization Program Office's verification of historically based models of tank content.

Drivers: Improves the ability to meet (but is not explicitly required by) the following milestones:

- TPA M-44-00 Issue Tank Characterization Reports for 177 Hanford HLW tanks (09/99).
- TPA M-40-00 Mitigate/resolve tank safety issues for high-priority Watch List tanks (09/2001).
- TPA M-40-12 Resolve nuclear criticality safety issue (09/1999).
- generally supports DNFSB Recommendation 93-5 Implementation Plan Task 2, Accelerate Safety Related Characterization and Task 3, Improve the Quality and Quantity of Sampling.

Level of Maturity (Basic Research, Applied Research, Technology or Laboratory Development, Advanced Development, Engineering Development, Demonstration, First Production, or Operations): The technology needs to be in at least the Technology Development stage to impact the FY 1995-1997 period of intense sampling activity. Significant but lesser impact would result from later delivery of the technology.

Key Uncertainties: The feasibility and availability of technology that is implementable in time to impact the FY 1995-1997 window of heaviest sampling activity is uncertain, especially within current budget uncertainties.

Key Deliverables (Date, Deliverable): The key deliverable will be the development and/or implementation for routine beneficial use of reliable, cost-effective, and timely technology for sampling at multiple locations from a single tank access point.

Basis For Cost Estimates: Cost estimates are derived from best professional judgement based on experience with similar projects.

Template Title: Multiple Location Sampler

Template Number: 4.4.2.2

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
1.	This task consists of the conduct of an industry–wide survey of currently available technology and promising technology concepts that could be developed and implemented on the referenced time scale.	Y	10/01/94	09/30/95	FY 1995	75	FY 1995	0	75	Prior sampling technology development/Task 2
2.	The first phase of this task consists of an assessment leading to an early decision point on whether to pursue development of multiple sampling capability identified in Task 1. If the decision is made to proceed, a specific technical approach will be selected, developed, and implemented.	Y	10/01/95	09/30/97	FY 1996 FY 1997	400 400	FY 1996 FY 1997	1,000 1,500	1,400 1,900	Task 1/None
Total										

Template Title: Core Bit Instrumentation

Template Number: 4.4.2.3

Technology Package Type (Reference, Enhancement, or Alternative): Enhancement

Baseline Program (Y/N): Yes

WBS ID Number and Title: 1.1.1.2.04 Characterization

Program Element: Characterization

Functional Need Level 4: Characterize Waste (4.2.1.2)

Functional Need Level 5: Acquire Physical Samples for Analysis (4.2.1.2.3)

Functional Need Level 6: Collect Waste Samples (4.2.1.2.3.3)

Functional Need Level 7: None

Scope: The scope of this activity is to provide technology to determine, during in-tank rotary drilling, the temperature of the core bit and its proximity to the tank bottom.

Justification: Core bit instrumentation development directly supports DNFSB Recommendation 93-5 Implementation Plan Commitment 3.16. This recommendation is concerned with the possibility of unacceptably high rotary bit temperature and inadvertent bit contact with the tank bottom.

Drivers: Explicitly required by DNFSB Recommendation 93-5 Implementation Plan Commitment 3.16, Direct Drill Bit Temperature Monitoring.

Improves the ability to meet (but is not explicitly required by) the following milestones:

- TPA M-44-00, Issue Tank Characterization Reports for 177 HLW tanks by 09/1999.
- TPA M-40-09, Close all USQs for SSTs by 09/1998.

Level of Maturity (Basic Research, Applied Research, Technology or Laboratory Development, Advanced Development, Engineering Development, Demonstration, First Production, or Operations): Temperature monitor development is considered to be in the Engineering Development stage. The proximity monitor is in the Technology Development stage.

Key Uncertainties: Reliability and performance of the temperature monitor in the hostile tank rotary drilling environment remains a concern. The ability to identify a practical proximity sensor also is a concern. Possible delay of the Integrated Sampling Schedule caused by refitting existing drilling systems is a major concern.

Key Deliverables (Date, Deliverable): The technology deliverable will be a reliable, practical, timely, and cost-effective rotary core bit instrumentation system for temperature and proximity monitoring, which is fully implemented for routine beneficial use.

Basis For Cost Estimates: Costs are derived from best professional judgement based on past experience with similar projects.

Template Title: Core Bit Instrumentation

Template Number: 4.4.2.3

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
1.	Deliver final temperature-sensing package to WHC and implement for routine beneficial use. This task concludes when the rotary truck system is routinely using the temperature instrumentation package. This task includes a decision point on whether to pursue proximity technology further.	Y	10/94	09/95	FY 1995		FY 1995	600	600	FY 1994 temperature sensor development activities/Task 2
2.	Develop proximity sensing package, deliver prototype to WHC, and implement for routine beneficial use; conditional on Task 1 decision point.	Y	10/95	09/96	FY 1996		FY 1996	500	500	Task 1/None
Total										

Template Title: In Situ Chemical Sensor Development

Template Number: 4.4.3.1

Technology Package Type (Reference, Enhancement, or Alternative): Alternative

Baseline Program (Y/N): Yes

WBS ID Number and Title: 1.1.1.2.04 Characterization

Program Element: Characterization

Functional Need Level 4: Characterize Waste (4.2.1.2)

Functional Need Level 5: Conduct In Situ Analysis (4.2.1.2.5)

Functional Need Level 6: Obtain Measurements (4.2.1.2.5.3)

Functional Need Level 7: None

Scope: The scope of this activity is to develop and implement, for routine beneficial use, timely, cost-effective, and reliable sensor technology for in situ determination of chemical properties such as moisture and molecular speciation, as per applicable DQO. Template 4.4.4.4 addresses rapid laboratory-based NIR moisture methods development.

Electromagnetic induction methods for in situ moisture determination are being investigated by the TWRS Safety Program.

Justification: In situ characterization should improve the efficiency of HLW chemical characterization by significantly reducing cost and turnaround time and allowing continuous profiling. Personnel exposure and secondary waste generation associated with sample removal also will be reduced.

Drivers: Improves the ability to meet (but is not explicitly required by) the following milestones:

- TPA M-44-00 Issue Tank Characterization Reports for 177 HLW tanks by 09/99
- TPA-M-40-09 Close all USQs for single-shell tanks by 09/99
- TPA-M-40-12 Resolve nuclear criticality safety issue by 09/99
- TPA M-45-05 Retrieve waste from all remaining single-shell tanks by 09/18
- generally supports DNFSB Recommendation 93-5 Commitment Task 2, Accelerate Safety Related Characterization, Task 3, Improve the Quality and Quantity of Sampling, and Task 5, Improve the Quality and Quantity of Analyses. Generally supports DNFSB Recommendation 93-5 Commitment 2.3, Complete Sampling and Analysis of all Watch List tanks by 10/95 and of all 177 HLW tanks by 10/96
- additional drivers are needed to reduce costs and turnaround time for HLW analysis and to provide continuous in situ chemical profiling.

Level of Maturity (Basic Research, Applied Research, Technology or Laboratory Development, Advanced Development, Engineering Development, Demonstration, First Production, or Operations): NIR moisture and Raman molecular speciation probes are in the Advanced Development stage. Copper foil activation moisture probe activity will be concluded in FY 1995 in the Engineering Development stage.

Key Uncertainties: Key uncertainties include deployment platform and riser availability, field implementability of developmental sensors, and ability to develop and implement practical technology in time to impact the FY 1995-97 window of intense field sampling and characterization.

Key Deliverables (Date, Deliverable): The specific technology deliverables will be reliable, timely, and cost-effective in situ moisture and molecular speciation sensors, which are fully implemented for routine beneficial use on a deployment platform such as a cone penetrometer.

Delivery Date(s): For maximum impact, the platform and sensors should be implemented in time to impact the FY 1995-97 period of intense sampling. Significant but lesser benefits would accrue from later deployment.

Basis For Cost Estimates: Costs are derived from best professional judgement based on past experience with similar projects.

Template Title: In Situ Chemical Sensor Development

Template Number: 4.4.3.1

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
1.	Develop, test, and document in situ Raman/NIR probes for in situ sensing of molecular speciation and moisture.	Y	10/94	09/95	FY 1995	0	FY 1995	99	99	Previous technology development related to this activity/Task 2
2.	Implement Raman/NIR probes on cone penetrometer platform, conditional on Task 1 and cone penetrometer status.	Y	10/95	09/96	FY 1996	200	FY 1996	100	300	Task 1 and ongoing DQO revision/None
3.	Calibrate and document copper foil activation method for moisture determination (closeout activity).	Y	10/94	09/95	FY 1995	0	FY 1995	98	98	Prior copper foil activation method development/None
4.	Conduct surveys to establish additional in situ sensor needs and identify promising technology.	Y	10/95	09/96	FY 1996	0	FY 1996	100	100	Applicable DQO and previous development in this technology area/ TBD
Total										

Template Title: In Situ Monitoring, Surveillance, and Stratigraphy

Template Number: 4.4.3.2

Technology Package Type (Reference, Enhancement, or Alternative): Alternative

Baseline Program (Y/N): Yes

WBS ID Number and Title: 1.1.1.2.04 Characterization

Program Element: Characterization

Functional Need Level 4: Characterize Waste (4.2.1.2)

Functional Need Level 5: Conduct In Situ Analysis (4.2.1.2.5)

Functional Need Level 6: Obtain Measurements (4.2.1.2.5.3)

Functional Need Level 7: None

Scope: The primary scope of this activity is to provide reliable, timely, and cost-effective technology to identify phase boundaries, discontinuities, and obstructions at depth in HLW tanks. Mapping of the waste surface and imaging through obscured head space also are included in this template.

Justification: Determination of the location of major waste interfaces and buried objects is needed by the retrieval program to design the overall retrieval strategy, taking into account equipment design for high recovery and the need to avoid equipment damage. Confirmation of waste interfaces also would aid in the validation of tank waste models based on historical data. In addition, field sampling operations need a method to provide advance information on properties of the subsurface directly beneath risers to facilitate selection and operation of sampling devices.

Drivers: Improves the ability to meet (but is not explicitly required by) the following milestones:

- TPA M-44-00 Issue Tank Characterization Reports for 177 HLW tanks by 09/99.
- TPA M-40-00 Mitigate/resolve tank safety issues for high-priority Watch List tanks by 09/01
- generally supports DNFSB Recommendation 93-5 Implementation Plan Task 3, Improve the Quality and Quantity of Sampling.

Level of Maturity (Basic Research, Applied Research, Technology or Laboratory Development, Advanced Development, Engineering Development, Demonstration, First Production, or Operations): Acoustic methods for the purposes of this template are considered to be in the technology development stage. Imaging through obscurants is in the technology demonstration phase.

Key Uncertainties: Some uncertainty remains as to whether acoustic and other imaging methods will have the required resolution, reliability, and general implementability in the complex HLW tank environment for the needs of this template.

Key Deliverables (Date, Deliverable): The key deliverable will be reliable, timely, and cost-effective technology, which is fully implemented for identifying phase boundaries, discontinuities, and obstructions at depth in HLW tanks.

Basis For Cost Estimates: Costs are derived from best professional judgement based on past experience with similar projects.

Template Title: In Situ Monitoring, Surveillance, and Stratigraphy

Template Number: 4.4.3.2

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
1.	This activity is intended to assess the feasibility of cross-hole acoustic imaging methods by demonstration in a HLW tank.	Y	10/94	09/95	FY 1995	0	FY 1995	56	56	Prior technology development on acoustic imaging as applied to HLW tanks/ Task 2
2.	This activity develops and implements acoustic imaging as a routine tool for HLW tank characterization, following a decision point to proceed. Also included in this activity is a compilation of an historical record of physical items of retrieval significance known or strongly suspected to be present in the tanks.	Y	10/95	09/96	FY 1996	0	FY 1996	200	200	Task 1/None
3.	This activity consists of an industry survey to identify methods for characterizing subsurface properties beneath riser.	Y	02/95	09/95	FY 1995	0	FY 1995	75	75	Tasks 1 and 2/ Task 4

Template Title: In Situ Monitoring, Surveillance, and Stratigraphy

Template Number: 4.4.3.2

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
4.	This activity develops and implements promised technology identified in Task 3, including survey to identify methods for characterization subsurface properties beneath risers.	Y	10/95	09/96	FY 1996	0	FY 1996	400	400	
Total										

Template Title: In Situ Physical and Rheological Properties Methods

Template Number: 4.4.3.3

Technology Package Type (Reference, Enhancement, or Alternative): Alternative

Baseline Program (Y/N): Yes

WBS ID Number and Title: 1.1.1.2.04 Characterization

Program Element: Characterization

Functional Need Level 4: Characterize Waste (4.2.1.2)

Functional Need Level 5: Conduct In Situ Analyses (4.2.1.2.5)

Functional Need Level 6: Obtain Measurements (4.2.1.2.4.3)

Functional Need Level 7: None

Scope: The scope of this activity is to develop, deploy, and implement, for routine beneficial use, timely, cost-effective and reliable in situ technology for determining relevant physical and rheological properties of Hanford Site tank HLW, as per applicable DQO.

Justification: Measurement of rheological and physical properties of HLW is needed for a variety of reasons to support development of the overall retrieval strategy. In situ measurement is required to minimize artifacts caused by sampling and handling.

Drivers: Improves the ability to meet (but is not explicitly required by) the following milestones:

- TPA M-44-00 Issue Tank Characterization Reports for 177 HLW tanks by 09/99
- TPA-45-04-T2 Complete design for the initial SST retrieval systems by 12/00
- TPA M-45-04-T1 Provide initial SST retrieval systems by 11/03
- generally supports DNFSB Recommendation 93-5 Commitment Task 3, Improve the Quality of Sampling and Task 5, Improve the Quality and Quantity of Analyses.

Level of Maturity (Basic Research, Applied Research, Technology or Laboratory Development, Advanced Development, Engineering Development, Demonstration, First Production, or Operations): Waveguide technology for in situ HLW applications currently is in the Technology Development stage.

Key Uncertainties: Key uncertainties include the availability of a suitable deployment platform and the feasibility of waveguide technology to measure relevant in situ properties over the extreme range of conditions present in the tank environment.

Key Deliverables (Date, Deliverable): The technology deliverable will be fully implemented technology for timely, cost-effective, rapid, and reliable in situ measurement of relevant HLW physical and rheological properties.

Delivery Date(s): The technology must be implemented in time to impact the 12/00 retrieval design decision. Significant but lesser benefits would accrue over the life of TWRS.

Basis For Cost Estimates: Costs are derived from professional judgement based on past experience with similar projects.

Template Title: In Situ Physical and Rheological Properties Methods

Template Number: 4.4.3.3

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
1.	Develop waveguide sensor technology for in situ measurement of viscosity, density, and temperature	Y	10/94	09/95	FY 1995	0	FY 1995	200	200	Prior technology development work
2.	Document F&R and implement waveguide sensor technology or evaluate alternative technology, as appropriate.	Y	10/95	09/96	FY 1996	0	FY 1996	200	200	Task 1/None
Total										

Template Title: Cone Penetrometer Platform

Template Number: 4.4.3.4

Technology Package Type (Reference, Enhancement, or Alternative): Alternative

Baseline Program (Y/N): Yes

WBS ID Number and Title: 1.1.1.2.04 Characterization

Program Element: Characterization

Functional Need Level 4: Characterize Waste (4.2.1.2)

Functional Need Level 5: Conduct In Situ Analysis (4.2.1.2.5)

Functional Need Level 6: Deploy Delivery Platform (4.2.1.2.5.2)

Functional Need Level 7: None

Scope: The scope of this activity is to develop and deploy, for routine beneficial use, a reliable, timely, and cost-effective cone penetrometer platform for in situ measurement of relevant HLW properties. Development of a fission chamber neutron moisture instrument for the cone penetrometer platform also is included in the work scope.

Justification: In situ characterization will expedite the characterization process, reduce personal exposure and secondary waste generation associated with sample removal, and allow critical measurements (e.g., moisture and retrieval-related properties) to be made that would be inaccurate using samples removed from the HLW tanks. A key advantage is the ability to carry out continuous waste profiling versus discrete sampling. Sensors to perform such measurements require a deployment platform, and the cone penetrometer has been judged to be most appropriate for this purpose.

Drivers: Improves the ability to meet (but is not explicitly required by) the following milestones:

- TPA M-44-00 Issue Tank Characterization Reports for 177 HLW tanks by 09/99
- TPA-40-09 Close all USQs for single-shell tanks by 09/99
- TPA M-45-05 Retrieve waste from all remaining single-shell tanks by 09/18
- TPA M-45-00 Define SST Retrieval Schedule
- Explicitly supports DNFSB Recommendation 93-5 Commitment 3.13, Deploy Cone Penetrometer by 05/95
- generally supports DNFSB Recommendation 93-5 Commitment Task 4, Improve the Quality and Quantity of Sampling, and Task 5, Improve the Quality and Quantity of Analyses
- additional drivers are the need to reduce costs and turnaround time for HLW analysis and the need to provide continuous profiling capability.

Level of Maturity (Basic Research, Applied Research, Technology or Laboratory Development, Advanced Development, Engineering Development, Demonstration, First Production, or Operations): The cone penetrometer platform is in the First Production stage of development, with delivery scheduled by the end of FY 1995 and deployment for beneficial use by 09/96. The fission chamber moisture probe is scheduled for 03/95 delivery.

Key Uncertainties: Key uncertainties include ability to develop and implement the cone penetrometer platform in time to meet the projected delivery dates within the constraints of available funding, riser availability, ability to integrate with the existing tank sampling schedule, dome loading concerns, and implementability of developmental sensors.

Key Deliverables (Date, Deliverable): The technology deliverable will be a reliable, timely, and cost-effective cone penetrometer platform fully implemented for routine beneficial use.

Basis For Cost Estimates: Costs are derived from best professional judgement based on past experience with similar projects.

Template Title: Cone Penetrometer Platform

Template Number: 4.4.3.4

Tasks		MYWP	Start Date	End Date	Capital (K)		Expense (K)		Total	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
1.	This task consists of simulant testing to verify cone penetrometer design and development of a sensor to detect the tank bottom. Following a decision point on whether to proceed further with the project, preliminary and final design and fabrication will begin.	Y	10/94	09/95	FY 1995	900	FY 1995	204	1,104	Prior cone penetrometer development work/Task 3
2.	Complete development of fission chamber neutron moisture detector and integrate with cone penetrometer platform. Does not include related sensor development discussed in other templates.	Y	10/94	09/95	FY 1995	*	FY 1995		*	Prior fission chamber and cone penetrometer platform development work/ Task 3
3.	Complete cone penetrometer platform design fabrication, acceptance testing, delivery, and training.	Y	10/95	09/96	FY 1996	1,000	FY 1996	200	1,200	Task 1/None
Total										

* Funded by EM-50.

Template Title: Rapid Elemental Analytical Methods for Water-Washed Sludge

Template Number: 4.4.4.1

Technology Package Type (Reference, Enhancement, or Alternative): Alternative

Baseline Program (Y/N): Yes

WBS ID Number and Title: 1.1.1.2.04 Characterization

Program Element: Characterization

Functional Need Level 4: Characterize Waste (4.2.1.2)

Functional Need Level 5: Analyze Samples (4.2.1.2.4)

Functional Need Level 6: Prepare and Analyze Samples (4.2.1.2.4.3)

Functional Need Level 7: None

Scope: The scope of this activity is to develop and implement, for routine beneficial use, an analytical procedure for practical, reliable, rapid, and cost-effective elemental characterization of HLW material in accordance with applicable DQO.

Justification: Reliable, timely, and cost-effective methods that can drastically reduce cost and turnaround time are needed for elemental analyses of water-washed sludge. Such capability could dramatically impact the Safety, Pretreatment, and Characterization Programs and potentially could lead to effective process control instrumentation. The method also would be applicable to liquid wastes.

Drivers: Improves the ability to meet (but is not explicitly required by) the following milestones:

- TPA M-44-00 Issue Tank Characterization Reports for 177 HLW tanks by 09/99
- TPA-50-03 Complete evaluation of enhanced sludge washing to determine whether separation processes are required, by 03/98
- generally supports DNFSB Recommendation 93-5 Commitment Task 5, Improve the Quality and Quantity of Analyses.

Level of Maturity (Basic Research, Applied Research, Technology or Laboratory Development, Advanced Development, Engineering Development, Demonstration, First Production, or Operations): The technology must currently be in at least the Technology Development stage to impact the 03/98 sludge washing milestone. Substantial but reduced impact would result from later implementation.

Key Uncertainties: Key uncertainties of the analytical method include:

- ability to operate at high radiation levels associated with HLW samples
- sensitivity in complex matrices
- capability to resolve all elemental constituents of interest in high salt matrices.

Key Deliverables (Date, Deliverable): The technology deliverable will be a micro-characterization elemental analysis method fully implemented for routine beneficial uses.

Basis For Cost Estimates: Costs are derived from best professional judgement based on past experience with similar projects.

Template Title: Rapid Elemental Analytical Methods for Water-Washed Sludge

Template Number: 4.4.4.1

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
1.	Develop XRF microfluorescence methodology for selected analytes.	Y	10/94	09/95	FY 1995	0	FY 1995	*	0	
2.	Implement XRF microfluorescence method in TWRS production analytical laboratories; conditional on Task 1 development work.	Y	10/95	09/96	FY 1996	0	FY 1996	*	0	Task 1/None.
Total										

* FY 1995 activities are being funded by the Pretreatment Program under template number 6.4.3, task entitled “Evaluate Sludge Processing Science.”

Template Title: **Rapid Elemental Analytical Methods**

Template Number: **4.4.4.2**

Technology Package Type (Reference, Enhancement, or Alternative): Alternative

Baseline Program (Y/N): Yes

WBS ID Number and Title: 1.1.1.2.04 Characterization

Program Element: Characterization

Functional Need Level 4: Characterize Waste (4.2.1.2)

Functional Need Level 5: Analyze Samples (4.2.1.2.4)

Functional Need Level 6: Prepare and Analyze Samples (4.2.1.2.4.3)

Functional Need Level 7: None

Scope: The scope of this activity is to develop and implement for routine beneficent use reliable, timely, cost-effective, and practical rapid analytical technologies to meet TWRS elemental analytical requirements. The scope also includes the conduct of a workshop on global status of scanning technology and tradeoffs of new technology vs. upgrades of existing technology, in view of new TWRS sample load projections in accordance with applicable DQO and test plans.

Justification: Timely, reliable, and cost-effective analytical data is needed to ensure that the TWRS mission can be achieved within acceptable budgets and schedule and that programmatic risks for failure are maintained at acceptably low levels. Analysis methods are especially needed that significantly reduce analytical costs, turnaround time, personnel exposure and secondary waste generation while meeting applicable DQO and test plan specifications. Rapid analysis methods that determine many analytes in a single process offer these benefits and provide the basis for subsequent process monitoring methods.

Drivers: Improves ability to meet (but is not explicitly required by) the following TPA milestones:

- M-44-00 Issue tank characterization reports for 177 HLW tanks (9/1999)
- M-40-09 Close all USQs for single-shell tanks (9/1998).
- generally supports DNFSB Recommendation 93-5 Implementation Plan Task 5, Improve the Quality and Quantity of Analyses.

In addition,

- deployment of rapid analytical technologies would accelerate HLW analysis schedules and reduce costs by increasing analytical throughput while reducing facility and staff requirements

- provide rapid analytical data to support TWRS program decisions
- provide rapid analytical data to support TWRS remediation technology developments and selection
- reduce worker radiation exposure during waste characterization (ALARA)
- minimize secondary waste generation.

Level of Maturity (Basic Research, Applied Research, Technology or Laboratory Development, Advanced Development, Engineering Development, Demonstration, First Production, or Operations): The Elemental Laser Ablation/Mass Spectroscopy (LA/MS) method is based on commercial equipment and methodology. The development program addresses the robust conditions needed to meet TWRS applications requirements. Analyses already have been performed with standard ICP/MS instrumentation on "hot" TWRS samples, simulants, and glass standards. The technology is considered to be in the Advanced Development or Engineering Development stage for HLW analysis.

Key Uncertainties: On a system level, key uncertainties include the following:

- ability to develop and implement technology in time to impact the FY 1995-1997 period of intense sampling and analysis
- ability to meet appropriate DQO and test plan specifications
- availability of analytical laboratory hot cell facilities to receive the technology
- availability of trained staff to conduct routine sample analysis and interpret results
- acceptance of a rapid analysis methods and scanning protocol that takes into account effects of interrogation spot size, sample heterogeneity, data presentation and interpretation.

On a technical level, key uncertainties include the following:

- isobaric interference for some mass numbers
- effectiveness of ablation process to respectively ablate all analytes from sample matrices
- independent method for data quantification
- sampling capability with atmospheric carrier gas
- perceived ablation safety issues.

Key Deliverables (Date, Deliverable): The key deliverable is reliable, practical, timely, and cost-effective rapid elemental analysis technology fully implemented for routine beneficial use with an early use planned for sample scanning. The long-term scope includes operations staff training, system documentation, and technical support.

Basis for Cost Estimates: Estimates are inclusive of all costs required to place one fully integrated system with all required documentation, training, and equipment in full routine operation in a TWRS production analytical laboratory. Costs are derived from best professional judgement based on past experience with similar activities. Capital costs are based on equipment costs for existing laboratory systems plus estimated costs for design and fabrication of components suitable for hot cell installation, operation, and maintenance in support of routine, long-term operations. The tasks and budget figures are shown through hot cell deployment. Deployment can be integrated with rapid molecular analysis capability, as described in templates 4.4.4.3.

Template Title: Rapid Elemental Analytical Methods

Template Number: 4.4.4.2

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
1.	Develop and implement LA/MS for routine, rapid HLW elemental and isotopic analysis. Conduct workshop on global status of scanning technology and tradeoffs of new technology versus upgrades of existing technology in view of new TWRS sample load projections.	Y	10/94	09/97	FY 1995 FY 1996 FY 1997	0 900 200	FY 1995 FY 1996 FY 1997	340 1300 1000	340 2,200 1,200	Prior HLW LA/MS development work. LA/MS field demonstration by Ames Lab/None
Total										

Template Title: Rapid Molecular Analytical Methods

Template Number: 4.4.4.3

Technology Package Type (Reference, Enhancement, or Alternative): Alternative

Baseline Program (Y/N): Yes

WBS ID Number and Title: 1.1.1.2.04 Characterization

Program Element: Characterization

Functional Need Level 4: Characterize Waste (4.2.1.2)

Functional Need Level 5: Analyze Samples (4.2.1.2.4)

Functional Need Level 6: Prepare and Analyze Samples (4.2.1.2.4.3)

Functional Need Level 7: None

Scope: The scope of this activity is to develop and implement, for routine beneficent use, reliable, timely, cost-effective, and practical rapid analytical technologies to meet TWRS molecular analytical requirements, in accordance with applicable DQO and test plans.

Molecular LA/MS operates by the same principle and can use the same laser ablation equipment as elemental LA/MS (template 4.4.4.2). However, an ionization method milder than ICP is used for ablation to allow the production of molecular ions with minimal modification to the molecular composition of the sample. The ion-trap mass spectrometer provides simultaneous detection of +/- ion species. This molecular method follows prior experience in aerosol analysis but is not as fully developed as the elemental LA/MS. Some work with HLW is planned for FY 1995.

Raman spectroscopy involves the inference of molecular structure from measured shifts in a laser beam scattered from the sample. The intensity of the scattered beam can be used to quantify the amount of each molecular species in the sample. Commercially available components are being integrated for application to Hanford HLW. Systems will first be implemented in a hot cell scanning mode and then be extended to in situ platforms such as the cone penetrometer.

Justification: Timely, reliable, and cost-effective analytical data is needed to ensure that the TWRS mission can be achieved within acceptable budgets and schedule and that programmatic risks for failure are maintained at acceptably low levels. Analysis methods are especially needed that significantly reduce analytical costs, turnaround time, personnel exposure, and secondary waste generation while meeting applicable DQO specifications. Rapid analysis methods that determine many analytes in a single process offer these benefits and provide the basis for subsequent process and waste form monitoring methods.

Drivers:

- Improves ability to meet (but is not explicitly required by) the following TPA milestones: 1) M-44-00 Issue tank characterization reports for 177 HLW tanks (9/99) and 2) M-40-09 Close all USQs for SSTs (9/98).
- Generally supports DNFSB Recommendation 93-5 Implementation Plan Task 5, Improve the Quality and Quantity of Analyses.
- In addition, deployment of rapid analytical technologies will accelerate HLW analysis schedules and reduce costs by increasing analytical throughput while reducing facility and staff requirements; provide

rapid analytical data to support TWRS program decisions; provide rapid analytical data to support TWRS remediation technology developments and selection; reduce worker radiation exposure during waste characterization (ALARA); and minimize secondary waste generation.

Level of Maturity (Basic Research, Applied Research, Technology or Laboratory Development, Advanced Development, Engineering Development, Demonstration, First Production, or Operations):

- **The LA/MS** method is a spin-off from experience in the analysis of aerosol particles. Industrial Cooperative Research and Development Agreement (CRADA) opportunities with instrument manufacturers have been identified to support laboratory demonstration with HLW. The technology is considered to be in the Exploratory Development stage for HLW.

- **The Raman Spectroscopy** method is based on mature technology using commercially available spectroscopy instrumentation. The HLW application is in the Technology Development stage. Fiber optic probe development is considered to be in the Exploratory Development stage for HLW application. In situ Raman technology development is addressed in template 4.4.3.1.

Key Uncertainties: On a system level, the key uncertainties include the following:

- ability to develop and implement technology in time to impact the FY 1995-1997 period of intense sampling and analysis

- ability to meet appropriate DQO and test plan specifications

- availability of analytical laboratory hot cell facilities to receive the technology

- availability of trained staff to conduct routine sample analysis and interpret results

- acceptance of rapid analysis methods and scanning protocol that takes into account effects of interrogation spot size, sample heterogeneity, data presentation, and interpretation.

On a technical level, key uncertainties include the following:

- **LA/MS** - Molecular fidelity after ablation, calibration standards development, effectiveness of soft ionization methods, isobaric interferences, effectiveness of ablation process to representatively ablate all molecular species from all matrices, independent method for data quantification, and ablation safety issues.

- **Raman Spectroscopy** - Signal degradation due to sample fluorescence and self-absorbance, availability of software for data analysis, ability to meet DQO and test plan specifications, and availability of a practical probe for routine use.

Key Deliverables (Date, Deliverable): The key deliverable is reliable, practical, timely, and cost-effective rapid molecular analysis technology fully implemented for routine beneficial use with an early use planned for sample scanning. The long-term scope includes operations staff training, system documentation, and technical support.

Basis for Cost Estimates: Estimates are inclusive of all costs required to place one fully integrated system with all required documentation, training, and equipment in full routine operation in a TWRS production analytical laboratory. Costs are derived from best professional judgement based on past experience with similar activities. Capital costs are based on equipment costs for existing laboratory systems plus estimated costs for design and fabrication of components suitable for hot cell installation, operation and maintenance in support of routine, long-term operations. The tasks and budget figures are shown through hot cell deployment. Deployment can be integrated with rapid elemental and moisture analysis capability, as described in templates 4.4.4.2 and 4.4.4.4.

Template Title: Rapid Molecular Analytical Methods

Template Number: 4.4.4.3

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
1.	Develop and implement LA/MS for routine molecular analysis.	Y	10/94	09/97	FY 1995 FY 1996 FY 1997	0* 350 150	FY 1995 FY 1996 FY 1997	0* 500 500	0* 850 650	Mass spectroscopy analysis with soft ionization of aerosol particle constituents by NOAA and a number of universities. All FY 1995 work under EM-50 funding/None
2.	Develop and implement Raman spectroscopy for routine, rapid HLW molecular analysis.	Y	10/94	01/97	FY 1995 FY 1996 FY 1997	0* 300** 200**	FY 1995 FY 1996 FY 1997	116* 900** 700**	116* 1,200** 900**	Prior waste simulant and HLW Raman spectroscopy development work by WHC and the University of Florida./None.
Total										

*Funded by EM-50, subject to change.

**EM-50 co-funding not indicated.

Note: The molecular LA/MS costs are based on the assumption that the elemental LA/MS ablation source, control computer system, and in-cell components will be installed and available to support the operation of the molecular LA/MS system by delivering an ablation plume for analysis.

Note: In FY 1995, 140K capital and 300K expenses provided by EM-50.

Template Title: Moisture Analytical Methods

Template Number: 4.4.4.4

Technology Package Type (Reference, Enhancement, or Alternative): Alternative

Baseline Program (Y/N): Yes

WBS ID Number and Title: 1.1.1.2.04 Characterization

Program Element: Characterization

Functional Need Level 4: Characterize Waste (4.2.1.2)

Functional Need Level 5: Analyze Samples (4.2.1.2.4)

Functional Need Level 6: Prepare and Analyze Samples (4.2.1.2.4.3)

Functional Need Level 7: None

Scope: The scope of this activity is to develop and implement, for routine beneficent, use reliable, timely, cost-effective, and practical analytical technologies to meet TWRS moisture analytical requirements, in accordance with applicable DQO.

Justification: Timely, reliable, and cost-effective moisture analytical data is needed to ensure that the TWRS mission can be achieved within acceptable budgets and schedules and that programmatic risks for failure are maintained at acceptably low levels. Analysis methods are needed that significantly reduce analytical costs, turnaround time, personnel exposure, and secondary waste generation while meeting applicable DQO and test plan specifications.

Drivers: Improves ability to meet (but is not explicitly required by) the following TPA milestones:

- M-44-00 Issue tank characterization reports for 177 HLW tanks (9/99)
- M-40-09 Close all USQs for single-shell tanks (9/98)
- Generally supports DNFSB Recommendation 93-5 Implementation Plan Task 5, Improve the Quality and Quantity of Analyses.

Level of Maturity (Basic Research, Applied Research, Technology or Laboratory Development, Advanced Development, Engineering Development, Demonstration, First Production, or Operations): The Near Infrared Spectroscopy Moisture Analysis method addressed in this template is used commercially for numerous laboratory and industrial applications with well-characterized product lines. The technology is considered to be in the Advanced Development phase for HLW moisture analysis with remote fiber optic probes. Development focus is on durable fiber optic probe development and effects of HLW variations. The copper neutron activation moisture method is described in template 4.4.3.1. The fission chamber neutron moisture method is described in template 4.4.3.4.

Key Uncertainties: On a system level, key uncertainties include the following:

- ability to meet appropriate DQO and test plan specifications
- availability of analytical laboratory hot cell facilities to receive the technology

- availability of trained staff to conduct routine sample analysis and interpret results
- acceptance of rapid analysis methods and scanning protocol that takes into account effects of sample hemogeneity, data presentation, and interpretation.

On a technical level, key uncertainties include spectral interferences with the moisture absorbance band and effective interrogation depth.

Key Deliverables (Date, Deliverable): The key deliverable is reliable, practical, timely, and cost-effective rapid moisture analysis technology fully implemented for routine beneficial use with an early use planned for sample scanning. The long-term scope includes operations staff training, system documentation, and technical support.

Basis for Cost Estimates: Estimates are inclusive of all costs required to place one fully integrated system with all required documentation, training, and equipment in full routine TWRS operation. Costs are derived from best professional judgement based on past experience with similar activities. Capital costs are based on equipment costs for existing laboratory systems plus estimated costs for design and fabrication of components suitable for hot cell installation, operation, and maintenance in support of routine, long-term operations. The tasks and budget figures are shown through deployment. Deployment can be integrated with elemental and molecular rapid analysis capability, as described in templates 4.4.4.2 and 4.4.4.3.

Template Title: Rapid Moisture Analytical Methods

Template Number: 4.4.4.4

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
1.	Develop and Implement NIR Spectroscopy for routine, rapid HLW moisture analysis.	Y	10/94	09/97	FY 1995 FY 1996 FY 1997	0* 200** 100**	FY 1995 FY 1996 FY 1997	55* 800** 300**	55* 1,000** 400**	Prior University of Washington/Center for Process Analytical Chemistry and WHC feasibility demonstration with tank waste simulants/None
Total										

*Funded by EM–50, subject to change.

**EM–50 cofunding not indicated.

Appendix E

Program Element Templates

Contents: Waste Retrieval (5.0)

5.4.1.1 Define Characterization Needs/Develop Simulants E-5-3
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5.4.2.2 Evaluate Alternative DST Retrieval Technologies E-5-27

Template Title: Define Characterization Needs/Develop Simulants

Template Number: 5.4.1.1

Technology Package Type (Reference, Enhancement, or Alternative): Reference

Baseline Program (Y/N): Yes

WBS ID Number and Title: 1.1.1.2.05.02 Technology Development and Applied Engineering

Program Element: Waste Retrieval Program Element

Functional Need Level 4: Retrieve Waste (4.2.2.1.)

Functional Need Level 5: Retrieve/Transfer SST Waste (4.2.2.1.1)

Functional Need Level 6: Retrieve SST Saltcake/Sludge (4.2.2.1.1.1)

Functional Need Level 7:

- Mobilize Saltcake/Sludge Waste (4.2.2.1.1.1.2)
- Convey Saltcake/Sludge Waste (4.2.2.1.1.1.3)

Scope: Simulant development to define the waste behavior properties will verify the retrieval and transport technologies. Simulants have and will be developed to exhibit certain physical properties; however, work is needed to validate the fidelity of the choice or ranges of such properties with actual waste properties. Simulant wastes are necessary in developing and evaluating the various retrieval and transport processes.

Work is needed to establish the fundamental relationships between waste properties and physical performance parameters of waste retrieval equipment and solid waste. This understanding of waste behavior will also identify physical parameters that characterize performance requirements and develop methods to establish physical and/or chemical properties for retrieval demonstration.

Certain physical properties of DST and SST waste have a strong influence on the performance of retrieval systems. Some of the properties, such as shear strength, bearing strength, hardness, tensile strength, viscosity and stickiness, need to be measured in these to ensure measurable and "real time" measurement of the property. Success of the waste retrieval effort is directly dependent on proper equipment selection and design based on these waste properties.

Justification: Simulant development is necessary to tank test waste retrieval technologies. In situ sensors are necessary to characterize the tank waste avoiding laboratory analysis and ensuring time consuming and expensive meaningful measurement of the property.

Drivers: Simulants are required in the development of retrieval technologies to ensure confidence with TPA Milestone M-45-04TI. Sensors are required to characterize waste and predict retrieval equipment performance in "real time."

Level of Maturity (Basic Research, Applied Research, Technology or Laboratory Development, Advanced Development, Engineering Development, Demonstration, First Production, or Operations): The definition of waste simulant properties will continue as characterization of actual tank waste becomes established. Verification of simulant properties with actual tank waste will provide meaningful evaluation and testing of waste retrieval concepts and equipment, bracketing the retrieval process design and deployment (Engineering Development and Demonstration).

Waste characterization sensors are at the stage of Applied Research and require advancement to advanced development and demonstration.

Key Uncertainties: Simulants can never replicate actual waste properties. However, high fidelity simulants can provide insight into waste behavior necessary for design and operations of retrieval systems.

Accuracy of in place sensors and the maturity of the technology for the range of waste properties needing measurement is of concern. Identification of key performance measures and the ability of measuring fully quantifying these measurements in place requires applied research and demonstration.

Critical Interfaces: Characterization provides tank waste characterization of bounding DSTs (as to wastes) in FY 1995 through FY 1997. Tank waste properties are identified prioritized and justified through the DQO process and provided by retrieval to characterization in FY 1995. Simulants are developed for testing and development programs in FY 1996 through FY 1999.

Key Deliverables (Date, Deliverable):

- Complete development of preliminary simulants (09/95) (Task 1)
- DQO report (09/96) (Task 2)
- Refine simulants to match actual wastes (09/99) (Task 3)

Basis For Cost Estimates: Cost estimates were generated by the WHC Retrieval Engineering Organizatio with input from PNL.

Define Characterization Needs/Develop Simulants

5.4.1.1

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total ($K)	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
1.	Develop preliminary simulants	Y	on going	09/30/95			FY 1995	125	125	
2.	Determine critical physical properties for simulants from scaled retrieval and develop catalog of actual waste properties. Develop DQO.	Y	on going	09/30/00			FY 1995 FY 1996 FY 1997 FY 1998 FY 1999 FY 2000 Beyond FY 2000	322 350 350 345 340 340 675	322 350 350 345 340 340 675	
3.	Refine simulant properties to match actual waste	Y	03/1/95	09/30/99			FY 1995 FY 1996 FY 1997 FY 1998 FY 1999 FY 2000 Beyond FY 2000	0 320 320 320 320 320 640	0 320 320 320 320 320 640	
4.	Develop sensors for in situ measurement of physical properties		10/01/95	9/30/02			FY 1995 FY 1996 FY 1997 FY 1998 FY 1999 FY 2000 Beyond FY 2000	0 160 160 160 160 160 320	0 160 160 160 160 160 320	
Total										

Template Title: Enhanced SST Sluicing

Template Number: 5.4.1.2

Technology Package Type (Reference, Enhancement, or Alternative): Enhancement

Baseline Program (Y/N): Yes

WBS ID Number and Title: 1.1.1.2.05.02 Technology Development and Applied Engineering

Program Element: Waste Retrieval

Functional Need Level 4: Retrieve/Transfer Waste (4.2.2.1)

Functional Need Level 5: Retrieve/Transfer SST Waste (4.2.2.1.1)

Functional Need Level 6: Retrieve SST Saltcake/Sludge (4.2.2.1.1.1)

Functional Need Level 7: Mobilize Saltcake/Sludge (4.2.2.1.1.1.2)

Scope: Improvements to the sluicing technology are expected to extend the ability of the sluicing system to recover a majority of wastes other than soft sludges, or to improve the recovery limits of the sluicing technology. Closer placement of the sluicing nozzles, higher pressures, and other concepts will be examined to improve recovery efficiencies and reduce retrieval and waste treatment costs.

This task identifies, develops, and evaluates potential enhancements or improvements to past-practice sluicing that will reduce costs, increase efficiency, or improve the range of system performance (hard pan removal). A separate systems engineering activity is building a sluicing model.

Justification: The projected costs for the recovery of wastes from the SSTs are projected to be a significant driver for the overall TWRS budget. Enhanced retrieval systems could reduce waste recovery costs through improvements to effectiveness, reduced cycle time, etc. Data obtained from a sluicing mockup test program will be evaluated for cost-effective improvement SST retrieval actions.

Level of Maturity (Basic Research, Applied Research, Technology or Laboratory Development, Advanced Development, Engineering Development, Demonstration, First Production, or Operations): The enhanced sluicing program seeks to develop enhancements to the baseline sluicing technologies used in the 50s, 60s, and 70s. This program is considered an advanced development or possibly an engineering development effort, because the envisioned enhancements will focus on parametric evaluations of basic functions, such as flow rate and pressure.

Key Uncertainties:

Programmatic: Current Status - Past-practice sluicing is the baseline technology for SST retrieval. Enhanced sluicing is expected to reduce retrieval costs.

Key Uncertainties - Past-practice sluicing uses significant quantities of water. The issue of allowable leakage from a tank during a retrieval operation and the associated environmental damage must be assessed and a position established. Depending upon the resolution, sluicing systems may not meet criteria; or process restriction (dilution) may require design enhancement and process modification. All SSTs have been subjected to nitrite wastes, making stress corrosion the likely cause of the approximately 67 leaking tanks. The need exists to perform SST liner inspection to determine soundness.

Other uncertainties focus upon the ability of sluicing to recover all waste types and forms. Uncertainties also exist over the ability to accomplish the 99% waste recovery goal in the presence of in-tank hardware. Removal of discrete radioactive sources using sluicing technologies will not be possible and alternative methods will be necessary to complete that mission.

Key Deliverables (Date, Deliverable):

- F&R for sluicing system enhancement (12/94) (Task 1)
- Select candidate enhancements (3/95) (Task 2)
- Past-practice performance measurements (7/95) (Task 1)
- Investigate generic enhancement (12/95) (Task 2)
- First SST farm sluicing system description (10/96) (Required date leading to selection process.) (Task 2)

Basis For Cost Estimates: This task includes 6 months of WHC engineering effort to manage the activity and perform various sluicing enhancement activities such as a) conducting a past-practice sluicing technical exchange, b) develop the F&R for the activity, and c) develop list and evaluation of sluicing enhancement ideas and concepts. PNL will have as many as 4 to 8 different staff members working part-time (equivalent to 3 full-time staff) working to set up the 1/4 scale mock-up facility for sluicing. A sluicer to the W-320 unit will be tested to determine its performance with a sludge simulant. These performance measurements will be used to evaluate the benefits achieved from follow-on testing activities.

1995. This will be the first effort to test some of the generic sluicing enhancement ideas developed during item 1 effort. It is anticipated that some of these enhancement ideas will require test facility changes ($100K), such as new pumps, etc. The expense funding provides for the services of the item 1 staff for the remaining portion of the year to do enhancement testing, design the mock-up sluicing enhancement changes, and investigate ways to improve monitoring (seeing) the waste sluicing being performed.

1996. The activity started in the second half of FY 1995 will be continued with emphases being placed upon saltcake waste sluicing enhancement investigations (1.25 WHC staff and 3 PNL staff or $900K expense and $100K cap). The sluicing vision/monitoring activity will continue to develop ways to see through the tank fog or eliminate the fog ($200K). The investigation into the number, size, and type of defects that exist in SST waste tank liners will be started and it is believed that this task will require the development of additional light-duty utility arm (LDUA) end-effectors and their testing ($800K).

1997. The sluicing enhancement activity will continue with emphases placed on sludge type waste and new ideas generated during the FY 1996 activity ($1000K).

1998. The sluicing enhancement activity will investigate ideas generated during a evaluation of C-106 waste removal activity and completion of ideas generated during the FY 1997 effort. It is believed that all development ideas should be exhausted by the end of this effort ($500K).

Template Title: Enhanced SST Sluicing

Template Number: 5.4.1.2

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total ($K)	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
1.	Past-practice sluicing performance testing	Y	ongoing	06/95	1995	0	1995	125	125	
2.	Sluicing enhancements concept study, design, test, demo	Y	10/94	09/98	1995 1996 1997 1998	0 100 0 0	1995 1996 1997 1998	60 1,900 1,000 500	60 2,000 1,000 500	
Total										

Template Title: Develop and Demonstrate SST Arm-Based Retrieval System

Template Number: 5.4.1.3

Technology Package Type (Reference, Enhancement, or Alternative): Alternative

Baseline Program (Y/N): Yes

WBS ID Number and Title: 1.1.1.2.05.02.02 Technology Development and Applied Engineering, SSTs

Program Element: Retrieval

Functional Need Level 4: Retrieve/Transfer Waste (4.2.2.1)

Functional Need Level 5: Retrieve/Transfer SST Waste (4.2.2.1.1)

Functional Need Level 6:

- Retrieve SST Saltcake/Sludge (4.2.2.1.1.1)
- Retrieve SST In-Tank Hardware (4.2.2.1.1.2)
- Retrieve SST Discrete Sources (4.2.2.1.1.3)

Functional Need Level 7: For each functional need listed in 6 (above) there are subtier functions identified: System Deployment, Mobilization, Conveyance, System Monitor-Control, and Disassemble/Package System.

Scope: The purpose of this task is to obtain expertise and data from technology development that will facilitate defensible Systems Engineering arm-based retrieval system architecture selections for specification of equipment to retrieve waste, in-tank hardware, and discrete sources stored in SSTs at the Hanford Site.

Justification: Technologies are needed to recover wastes from the SSTs. TPA Milestone M045-03 requires demonstration of a second retrieval technology. The selected arm-based system will retrieve the more difficult SST wastes not expected to be recoverable by sluicing; it is expected to reduce waste leakage potential during retrieval.

Drivers:

- Programmatic Driver - Arm-based retrieval Demonstration will recover the hard heel in C-106 expected to be left after sluicing.
- TPA Driver - Provides the Technology to meet M-45-03-T1, Complete SST Waste Retrieval Demonstration (9/03) and will probably be needed to help meet M-45-05, retrieve waste from all remaining SSTs (9/18).

Level of Maturity (Basic Research, Applied Research, Technology or Laboratory Development, Advanced Development, Engineering Development, Demonstration, First Production, or Operations): Combination of *Technology Development, Advanced Development, Engineering Development,* and *Demonstration*

Key Uncertainties:

Programmatic: Potential issues surrounding the design and fabrication of the arm-based retrieval demonstration system (for single use in Tank C-106) are anticipated. The operational and maintenance issues associated with extending the use of such a system to include multiple tanks requiring a range of capabilities are not well defined. The tank retrieval sequence for arm-based retrieval following C-106 is unknown. The tank closure requirements may become more stringent in the future. The question of how much leakage is allowed during retrieval may require additional development and/or eliminate certain methods. Incomplete physical characterization of waste and in-tank hardware leaves uncertainties in required performance.

Technical: Development is needed in key technical areas with emphasis on integrated system performance, such as: waste dislodging tool effectiveness in the presence of imbedded objects; integrated dislodging and conveyance dynamics; kinematic analysis; joint performance; optimum control system; damping oscillations; maintenance and decontamination techniques.

Key Deliverables (Date, Deliverable): Deliverable will be in the form of data inputs to trade studies in support of program decisions. Specifically:

- complete waste dislodging and conveyance (WD&C) parametric testing (10/95) (Task 3)
- complete WD&C integrated system testing (6/96) (Task 4)
- complete mining dynamics and deployment testing (6/97) (Task 3)
- preliminary Long-Reach Manipulator Test Bed operational data (6/96) (Task 4)
- kinematic analysis of Demonstration Manipulator (6/97) (Task 4)
- full scale integrated arm-based retrieval feature tests (6/02) (Task 4)

Basis For Cost Estimates:

1. Develop technical basis for judging satisfaction of evaluation criteria. This task began in FY 1993. This entails bringing the results of past and ongoing WD&C and Robotics Program testing to the Arm-Based Retrieval Demonstration team that will provide the technical basis required. Based on last year's experience, it is expected to require 3 to 4 man-years of effort with associated travel between Hanford and ORNL, Sandia, and the University of Missouri (Rolla) (UMR).

2. Resolve vendor inquiries and overview design proposals. This task will begin in FY 1995 after the W340 Arm-Based Retrieval Demonstration purchase requisition is issued. An effort similar in scope to (1) above is anticipated in FY 1995. In FY 1996 and FY 1997 the effort is expected to expand to include oversight duties for the designs at three or more vendors across the country. With more complex situations to evaluate, the team size will expand to more than a dozen with some co-location at the vendors' area anticipated. As with (1) above OTD staff from ORNL, PNL, Sandia and UMR will be involved at their home bases as well as here at Hanford and at the vendor sites.

3. Integrated test bed for end-effector testing. The costs for this activity are based on the on-going OTD effort. The WD&C program budgeted $4,500K in FY 1995 in support of Hanford SST Retrieval activities. This consists of continuing work started under the UST-ID, generating data on the performance of high- and medium-pressure water-jet scarifiers for waste mobilization, and on jet-pump and air-entrainment waste conveyance systems to move the waste out of the tanks. Data on the dynamic interactions of mobilizer and conveyance systems on an arm and the effectiveness of various mining strategies will be generated on the WD&C Hydraulics Test Bed.

4. Tank waste retrieval robotic test bed testing. As in (3) above, the costs for this activity are based on the on-going OTD efforts, both in the Robotics Program and the Cross-Cutting and Advanced Technology (CCAT) program is support of the robotics test bed. The Robotics Program and CCAT

each budgeted $4500K in FY 1995. The Robotics Program is presently working on dynamic compensation for arm stability, operator interfaces, end-effectors for In-Tank Hardware, and the integration of all parameters necessary for the installation and operation of a full-scale long-reach manipulator (LRM) test bed. CCAT directed a large effort this year towards the control system and other areas necessary to setting up the Robotics Program's test bed.

Template Title: Develop and Demonstrate SST Arm-Based Retrieval System

Template Number: 5.4.1.3

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total ($K)	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
1.	Develop technical basis	Y	ongoing	06/95		0		500	0	
2.	Resolve vendor inquiries	Y	03/95	09/97	1995	0	1995		0	
					1996		1996		2,000	
					1997		1997		2,000	
3.	End effector testing	Y	ongoing	06/97	1995	0	1995		5,000	
					1996		1996		2,000	
					1997		1997		2,000	
4.	Test bed feature testing	Y	ongoing	06/02	1995	0	1995		9,000	
					1996		1996		2,580	
					1997		1997		2,580	
					1998		1998		6,580	
					1999		1999		6,580	
					2000		2000		6,580	
					2001		2001		6,580	
					2002		2002		6,580	
Total										

Template Title: Develop Alternative SST Retrieval Technologies

Template Number: 5.4.1.4

Technology Package Type (Reference, Enhancement, or Alternative): Alternative

Baseline Program (Y/N): Yes

WBS ID Number and Title: 1.1.1.2.05.02.02 Technology Development and Applied Engineering, SSTs

Program Element: Waste Retrieval

Functional Need Level 4: Retrieve/Transfer SST Waste (4.2.2.1.1)

Functional Need Level 5: Retrieve/Transfer SST Waste (4.2.2.1.1)

Functional Need Level 6: Retrieve/Transfer SST Saltcake/Sludge (4.2.2.1.1.1)

Functional Need Level 7: For the functional need listed for level 6, there are the following sub-tier functions identified: system deployment, mobilization, conveyance, system monitor-control, and disassemblies/package system.

Scope: The projected high cost of retrieval using the reference retrieval approaches dictates the search for more cost-effective retrieval options. The alternate SST retrieval systems program will identify systems capable of challenging the reference retrieval approaches from the standpoint of cost and performance.

Justification: To allow for more retrieval options, reduce retrieval costs, and reduce environmental risk.

Drivers: TPA has established an aggressive schedule for recovery of wastes. Alternative systems for recovery of wastes are expected to be an integral part of the overall retrieval approach needed to meet TPA Milestone M-45-05.

Level of Maturity (Basic Research, Applied Research, Technology or Laboratory Development, Advanced Development, Engineering Development, Demonstration, First Production, or Operations): The level of maturity is unknown at this time. The SST alternatives program is currently soliciting candidate alternative retrieval technologies from industry and universities. Concepts identified will likely be at an Advanced Development or Engineering Development level.

Key Uncertainties: The key technical uncertainty is developing an alternative retrieval method that can retrieve difficult waste at a large cost savings or a lower use of fluids.

Key Deliverables (Date, Deliverable):

- Industry concept engineering studies (2/96) (Task 3)
- Revised concept engineering studies (4/97) (Task 10)
- Concept definition report (2/00) (Task 11)
- Proposed alternative retrieval technology for second retrieval project (9/00) (Task 12).

Basis For Cost Estimates:

1. This task was initiated in FY 1994. Past experience with purchase requisitions of this complexity and magnitude requires approximately 1 to 1 1/2 full-time engineers for four weeks to incorporate final comments and obtain all the required signatures.

2. This task consists of four subtasks; (1) Issue solicitation—past experience with purchase requisitions of this complexity and magnitude requires an engineer 1/2 time for 6 weeks to assist purchasing personnel in the preparation of the statement of work and evaluation criteria needed for the request for proposal; (2) Proposals—based on LDUA experience, it is anticipated that an engineer will spend full time for 6-8 weeks responding to inquiries from bidders; (3) Evaluate proposals—based on LDUA experience it is expected that 2 engineers will spend 3/4 to full time for eight weeks participating in the source evaluation board; (4) Place contracts—purchasing will require the support of an engineer 1/4 time for contract negotiations and contract placement.

3. Assuming three contracts are awarded and based on past experience with contracts of this magnitude and technical complexity, an engineer can expect to spend 1/2 to 3/4 time responding to inquiries and monitoring each vendor's progress. Appropriate monitoring will require at least one or two visits to each vendor's work site. Based on conversations with individuals experienced at having engineering studies performed by ICF-KH (Kaiser Engineering Hanford), this engineering study might cost $200 to $250K. Assuming private industry will be less expensive, an average cost of $150K per study was used.

4. The contract administrator of this activity advised that one week be allowed for evaluation of each engineering study by each reviewer, two retrieval engineering staff, and three other WHC technical experts. Based on the time required to initially write and review the specification, it will require 1 to 1 1/2 engineers 13 weeks to revise the specification. Purchasing estimates it will require approximately 12 weeks to exercise the next option of the contracts. A 1/2 time engineer will be required to support purchasing to review and approve statements of work and revise evaluation criteria.

5. Assuming two contracts are awarded and based on experience with proof-of-principle testing for the Materials Open Test Assembly, an engineer can expect to spend 1/2 to 3/4 time for the duration of this activity reviewing and approving test plans, monitoring vendor progress, and witnessing planned tests. Assuming the proof-of-principle tests are similar in complexity to tests conducted for the Materials Open Test Assembly a full time engineer will be required for the duration of the activity to plan, conduct, report the test, and revise the engineering report, and two full time technicians for 10 to 12 weeks to conduct the test. This effort will cost $150 to $200K. Assuming private industry will be less expensive, the lower end of the range $150K was used.

6. The contract administrator of the activity advised that one week be allowed to review the test results report and one week to review the revised engineering study by each reviewer, two retrieval engineering staff, and three other WHC technical experts. Based on the time required to initially write and review the specification, it will require 1 to 1 1/2 engineers 13 weeks to revise the specification. The purchasing organization estimates it will require approximately 12 weeks to exercise the next option of the contracts. A 1/2 time engineer will be required to support purchasing to review and approve statements of work and revise evaluation criteria.

7. Based on estimates from staff with experience in the conduct of the University Design Challenge, 2-3 weeks of effort will be required to answers inquiries from participants and an additional 2-3 weeks effort will be required to provide participants with a suitable waste simulant recipe. Retrieval Engineering will furnish two judges for the April Design Challenge conference. Each judge will spend 2-3 weeks reviewing and judging written reports before the conference and 1 week judging participants at the conference. Criteria to be used for judging will be provided by Waste Environmental Remediation Consortium (WERC). Sponsorship of the Design Challenge is $135K.

8. A Retrieval Engineering staff member will spend 2-3 weeks reviewing all the reports from the Design Challenge and selecting 4-5 reports for evaluation. These concepts will be evaluated by two retrieval engineering staff and 3 other WHC technical experts. Each reviewer will spend up to 1 week reviewing each report. Assuming at least one concept will warrant continued development, 4-6 weeks of effort will be required to form a university/onsite team.

9. Assuming one proof-of-principal and based on experience with proof-of-principle testing for Materials Open Test Assembly, an RE engineer can expect to spent 1/4 to 1/2 time for the duration of this activity reviewing and approving test plans, monitoring onsite progress, and witnessing planned tests. Assuming the proof-of-principle tests are similar in complexity to tests conducted for the Materials Open Test Assembly, a full time Engineer will be required for the duration of this activity to plan, conduct, report the test, and revise the concept engineering study provided by the University. University staff will be used as consultant(s), an assumed limit of $10K was used; 2 to 3 full time technicians will be required for 16-18 weeks to conduct the test.

10. One week is planned for review of the test results report and one week to review and evaluate the revised concept engineering report by each reviewer, two retrieval engineering staff, and three other WHC technical experts. Assuming the university concept will warrant continued development, an RE engineer will spend 12-14 weeks effort to form a second university/onsite team to continue concept development.

11. Assuming two concepts will be scale tested and that the complexity and magnitude of scale testing will be at least three times that of the proof-of-principle testing each will cost approximately $1000K. Based on conversations with individuals experienced at having concept design reports performed, each report might cost $1000 to $1100K. The magnitude of this activity will require one FTE to monitor each concept.

12. Evaluation of scale test results, concept design reports, and preparation of input for the second retrieval project technology selection will require 4 to 5 FTEs six months to complete.

Template Title: Develop Alternative SST Retrieval Technologies

Template Number: 5.4.1.4

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total ($K)	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
1.	Purchase req. for industry	Y	11/94	11/94		0	FY 1995	15	0	
2.	Award contracts	Y	12/94	8/95		0	FY 1995	75	0	
3.	Industry concept engineering studies	Y	9/95	2/96		0	FY 1996	520	520	
4.	*Evaluate contracts and award development contracts*	*N*	*3/96*	*9/96*		*0*	*FY 1996*	*200*	*200*	
5.	*Proof-of-principle tests*	*N*	*10/96*	*7/97*		*0*	*FY 1997*	*600*	*600*	
6.	*Evaluate results and award demonstration contracts*	*N*	*8/97*	*4/98*		*0*	*FY 1997* *FY 1998*	*33* *167*	*33* *167*	
7.	University design challenge	Y	11/94	4/95		0	FY 1995	130	130	
8.	Evaluate concepts and form university onsite team	Y	5/95	10/95		0	FY 1995	20	20	
9.	*Proof-of-principle tests*	*N*	*11/95*	*10/96*		*0*	*FY 1996*	*600*	*600*	
10.	*Evaluate results and form university onsite team*	*N*	*11/96*	*4/97*		*0*	*FY 1997*	*200*	*200*	
11.	*Scale tests and concept design*	*N*	*4/98*	*2/00*		*0*	*FY 1998* *FY 1999* *FY 2000*	*1,667* *1,667* *1,667*	*1,667* *1,667* *1,667*	

Template Title: Develop Alternative SST Retrieval Technologies

Template Number: 5.4.1.4

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total ($K)	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
12.	*Provide input to second SST retrieval project for technology selection*	*N*	*3/00*	*9/00*		*0*	*FY 2000*	*500*	*500*	
Total										

Template Title: Evaluate Feasibility of Barriers

Template Number: 5.4.1.5

Technology Package Type (Reference, Enhancement, or Alternative): Alternative

Baseline Program (Y/N): Yes

WBS ID Number and Title: 1.1.1.2.5.2

Program Element: Waste Retrieval Program Element

Functional Need Level 4: Retrieve/Transfer Waste (4.2.2.1)

Functional Need Level 5: Retrieve/Transfer SST Waste (4.2.2.1.1)

Functional Need Level 6: None

Functional Need Level 7: None

Scope: SSBs have been proposed as a method to mitigate leaks from SSTs during retrieval operations. They have been identified as a TWRS safety initiative and TPA Milestone M-45-07 requires evaluation and demonstration testing of related technologies suitable for deployment of SSBs at Hanford. Demonstration testing of barriers will provide data to evaluate the feasibility of confining hazardous waste under SSTs from leaking to the environment. A feasibility study of tank leakage mitigation using SSBs was completed in FY 1994 to support a decision whether or not to proceed with the SSB Program. In addition, specific documents were completed in FY 1994 to establish a baseline for barriers to support the feasibility study.

The decision as to whether or not to proceed with barrier demonstration testing will be made during the second quarter of FY 1995. If the decision is to proceed, industrial partners will be contracted to deploy and test SSB technologies in the arid soils at Hanford. Test data will be evaluated to determine barrier performance.

Tasks:

- Decision to proceed or not to proceed with barrier demonstrations (1/95)
- Proceed as planned or cancel program per pending decision (2/95)
- Initiate demonstration testing (10/95)
- Complete demonstration testing (3/97)
- Establish new milestone for barrier program (9/97)

Justification: Barriers are not in the baseline for SST retrieval; however, they are being considered as a method to mitigate tank leaks during retrieval operations. SSBs have never been deployed beneath underground tanks in arid type soils similar to conditions found at Hanford. Related technologies have been evaluated at other sites as possible candidates for barriers, but should be tested in arid soils to determine their feasibility to prevent ground water contamination by leaking tanks.

Drivers: Demonstration of SSBs is identified as a safety issue and is required to meet TPA Milestone M-45-07.

Level of Maturity (Basic Research, Applied Research, Technology or Laboratory Development, Advanced Development, Engineering Development, Demonstration, First Production, or Operations): Barrier technologies are in the development testing phase. Recent frozen soil barrier demonstration tests were completed in late FY 1994 at ORNL and test results are being evaluated. A frozen soil barrier demonstration test is planned at Hanford in FY 1995. Other barrier technologies are planned to be demonstrated at Hanford pending a favorable decision to proceed (January 1995) with SSB Program activities.

Key Uncertainties: The feasibility study report for SSBs was completed and issued. This satisfies the first TPA interim milestone for barriers. This report documents a baseline for barriers and provides results of risk analyses and cost-risk-benefits to support a decision process whether or not to proceed with barrier demonstrations.

Key Deliverables (Date, Deliverable):

- Reach decision to proceed or not with barriers demonstrations (1/95) (Task 1)
- Initiate demonstration testing (10/95) (Task 2)
- Complete evaluation of SSBs (3/97) (Task 2)

Basis For Cost Estimates:

Activities for SSBs were initiated late in FY 1993. Tasks to support SSB program activities for FY 1995 cost estimates were divided into three major groups; 1) Evaluation and Testing, 2) RKK Cryobarrier Demonstration, and 3) Applied Engineering Testing.

1. Evaluation and Testing—The activity is a continuation of the evaluation study using "key" members of the team. Cost estimates were based on inputs from a subcontractor and previous estimated made from carry-over tasks estimated in FY 1994.
2. RKK Cryobarrier Demonstration—This is a cooperative effort between EM-50, PNL Lead, and EM-30, DST Retrieval Engineering, field testing support. Cost estimates were based on RKK's technical proposal dated April 1994 and PNL's initial schedule dated July 1994. EM-30 cost estimates were based on inputs received from Field Test Engineering for test site support and ICF-KH for site construction and installing site utilities.
3. Applied Engineering Testing—This activity supports PNL's field development testing tasks related to SSBs as identified by Mary Peterson. Cost estimates were based on the number of FTEs estimated to support the field testing activities, site preparation, and project management activities.

Cost estimates for noted activities were developed in late FY 1994 with limited information available and obtaining inputs from previously used sources. However, these activities are constantly changing because of program changes and need to be revisited if and when funding approval is obtained from RL.

Template Title: Evaluate Feasibility of Barriers

Template Number: 5.4.1.5

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total ($K)	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
1.	Analysis to support decision to proceed or not proceed with barrier demonstrations	Y		01/95		0	1995	400	400	
2.	SSB demonstration	Y	02/95	03/30/98	1995 1996 1997	0 0 0	1995 1996 1997	0 4,600 5,900	0 4,600 5,900	
Total										

Template Title: SST Leak Detection and Monitoring (LDM)

Template Number: 5.4.1.6

Technology Package Type (Reference, Enhancement, or Alternative): Reference

Baseline Program (Y/N): Yes

WBS ID Number and Title: 1.1.2.5.2

Program Element: Waste Retrieval

Functional Need Level 4: Retrieve/Transfer Waste (4.2.2.1)

Functional Need Level 5: Retrieve/Transfer SST Waste (4.2.2.1.1)

Functional Need Level 6: None

Functional Need Level 7: None

Scope: Using the systems engineering approach, a Technical Requirements for external LDM for SSTs will be conducted. F&R for external LDM to support before, during, and after remediation activities will be determined. Existing and emerging LDM technologies with the potential to satisfy established F&Rs will be identified. Candidate LDM technologies will be evaluated against the F&Rs and summarized in an Evaluation Report. A feasibility document will be prepared to summarize the requirements for LDM, cost benefit analysis, and risk assessment.

Tasks:

- SST leak detection and monitoring F&R document (10/1/94 - 7/31/95) (Task 1)
- LDM technology review against established F&R (10/1/95 - 7/31/95) (Task 2)
- SST LDM evaluation document (2/1/95 - 9/30/95) (Task 3)
- LDM technical feasibility document (including cost benefit/risk assessment) (5/1/95 - 9/30/95) (Task 5)
- LDM activity integration and action plan FY 1996 (Task 5)
- LDM technology development and engineering application (as needed) FY 1996 - FY 1997 (Task 6)

Justification:

F&R for LDM to support SST waste retrieval and disposal do not currently exist. Without F&R there is no basis to identify, evaluate, or pursue LDM technology that can support ongoing and future SST waste retrieval and disposal activities. Also, without F&R, there is no way to assess the capabilities of currently used LDM devices and methods; they are difficult to defend, within the context of remediation discussions, without F&Rs as a basis.

F&R are needed to establish criteria for the selection and use of LDM technology and methods. Without such a consensus on need there can be no coordinated, organized, efficient forward movement on LDM technology development or engineering applications of existing technologies. Current LDM technology needs are based upon a widely varied collection of real and imagined "requirements." The consequences of this situation include potentially invalid decision-making, non-defensible technical plans and actions, and inefficient investment in potential "solutions." Well-analyzed F&R mitigate such consequences.

Drivers:

- Federal Regulations applicable to tank systems for the storage of hazardous waste are issued by the U.S. Environmental Protection Agency in 40 CFR 265 (Subpart J).
- State Regulations are issued by the Washington State Department of Ecology in Dangerous Waste Regulations, Washington Administrative Code Chapter 173-303.

Key Uncertainties: Enforcement of existing regulations, during remedial action, will force an evaluation of the continued use and adequacy of current LDM systems. If current LDM systems are judged inadequate to support the more dynamic conditions of SSTs while undergoing remedial operations, then attention will turn to 1) the possibility of supplementing or enhancing current LDM capabilities, and 2) deploying or developing new or enhanced technologies. There is a possibility that new technologies will not be capable of providing superior information to that of existing systems. There is also a possibility that regulatory and remedial operations LDM data needs cannot be satisfied by any currently available technology options. This could lead to a re-evaluation of remediation decisions/plans.

Full compliance with these requirements regarding SSTs is impractical due to the lack of secondary confinement. However, a general acceptance of current Operating Safety Requirements and Operating Specification Documents (by DOE, Ecology, EPA, etc.) is in effect. This acceptance has not been tested regarding conditions that could exist during remediation activities. During such activities the data from current LDM systems may or may not prove adequate to support required operational and remediation decisions.

Key Deliverables (Date, Deliverable):

- SST External leak detection and monitoring F&R document (7/31/95)
- Report of LDM technology review against established F&R (7/31/95)
- LDM technical evaluation document (9/30/95)
- LDM technical feasibility document (including Cost Benefit/Risk Assessment) (9/30/95)

Basis For Cost Estimates: Cost estimating for these activities was based on prior experience working with the planned resources, and from knowledge gained from previous, related (successor) activities. The FY 1994 predecessor activities included similar efforts to bring together information on just a few LDM technologies. The FY 1995 efforts, and estimates, required expanded scope. Estimates were based upon a proportional increase in scope from a previous similar effort. The FY 1994 leak detection test bed experience also is a recent cost basis for these activities.

Template Title: SST Leak Detection and Monitoring (LDM)

Template Number: 5.4.1.6

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total ($K)	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
1.	LDM F&R document	Y	10/94	07/95	FY 1995	0	1995	83	83	
2.	LDM Technology Review	Y	10/94	07/95	FY 1995	0	1995	55	55	
3.	LDM Trade Study	Y	02/95	09/95	FY 1995	0	1995	62	62	
4.	Cleanup LDM test site	Y	10/94	09/95	FY 1995	0	1995	10	10	
5.	Feasibility study	Y	05/95	09/95	FY 1995	0	1995	41	41	
6.	LDM Technology Development and Engineering Application (as needed)	Y	10/95	09/97			FY 1996 FY 1997	1,000 1,000	1,000 1,000	
Total										

Template Title: Test/Analyze Mixer Pump Performance

Template Number: 5.4.2.1

Technology Package Type (Reference, Enhancement, or Alternative): Reference

Baseline Program (Y/N): Yes

WBS ID Number and Title: 1.1.1.2.05.07.02, Final DST Retrieval Engineering
1.1.1.2.05.07.03, Final DST Retrieval Procurement

Program Element: Waste Retrieval

Functional Need Level 4: Retrieval/Transfer Waste (4.2.2.1)

Functional Need Level 5: Retrieve/Transfer DST Waste (4.2.2.1.2)

Functional Need Level 6: None

Functional Need Level 7: None

Scope: Develop/design higher reliability mixer pump with improved hydraulic performance over state-of-the-art design and evaluate sonic technology to enhance waste flow properties.

Tasks:

- Mixer pump design and testing (Task 1)
- Evaluate sonic probe technology (Task 2)
- Enhanced mixer pump performance testing (Task 3)

Justification: DSTs are used as node tanks between SSTs and waste process facilities. Before transfer, mixing is required to mobilize and suspend solids, which vary depending on the type of waste involved. Advanced reliability and performance mixers are needed to ensure this "weak link" in the retrieval system remains functional at all times. Sonic probes may eliminate or reduce the need for mixer pumps in high-yield stress tanks. The use of mixer pumps at SRS has shown many problems with high life-cycle costs, seal leaking resulting in poor retrieval performance and even an inability to mobilize some sludges. This project addresses these needed improvements.

Drivers:

- TPA Milestone M-45-00 defines schedules for SSTs.
- The retrieval of DST waste is necessary to make space available for incoming SST waste.
- DST retrieval requires advanced mixer pump technology to meet reliability requirements.

Level of Maturity (Basic Research, Applied Research, Technology or Laboratory Development, Advanced Development, Engineering Development, Demonstration, First Production, or Operations): Advanced Development

Key Uncertainties: Mixer pumps have been identified and justified as the baseline technology for retrieving waste from DSTs. Planned tasks include the determination of the required effectiveness or percent of waste cleanout for both interim DST use and for final DST closure. Several issues to consider include waste compatibility (of residual wastes), the treatment processes planned prior to and following the waste transfer, retrieval of high shear strength wastes, sludge mobilization measurement, tank ventilation requirements during retrieval, and retrieval cooling. Total life cost of unreliable mixer pumps is also a key uncertainty.

Critical Interfaces: Retrieval Operations; Retrieval Projects W-211, W-151 and W-058, Savannah River Retrieval Projects

Key Deliverables (Date, Deliverable):

- establish DST retrieval performance and operating requirements (3/95) (Task 1)
- complete scale testing (12/97) (Task 1)
- award contract for enhanced mixer pump procurement (2/95) (Task 1)
- complete tests of enhanced pump design (12/96) (Task 3)
- complete evaluation of enhanced mixer pump design/test (9/97) (Task 3)
- complete evaluation of sonic probe design/test (9/96) (Task 2)
- complete instrumentation needs document and plan (9/96) (Task 2).

Basis For Cost Estimates:

Task 1: This task is based on the resource summary baseline needs as defined in Pacific Northwest Laboratory MYWP DSTRDP-CY-94-046. The plan shows a need for $2,800K in FY 1994, $3,649K in FY 1995, and $3,379K in FY 1996.

Task 2: The basis for the cost estimate for Task #2 is proposal No. 17-6356, submitted to WHC by Southwest Research Institute of San Antonio, Texas on August 8th, 1994. The report, prepared by the Mechanical and Fluids Engineering Division, was a Conceptual Design Package for the sonic probe. The cost estimate was for $585K to provide a prototype test system. In addition, 0.5 FTE is added to administer the contracts and provide technical coordination with the Hanford Site.

Task 3: This task basis for the Advanced Design Mixer Pump design estimate is the competitive bid solicited by purchasing. A engineering specification was prepared and used by outside vendors to estimate the projected cost of designing the Advanced Design Mixer Pump. Seven vendors submitted bids; of these, two manufacturers were selected. $1,200K of expense funds will be expended in FY 1995 on this task. In addition, coordination with the Hanford and Savannah River Sites is planned.

Template Title: Test/Analyze Mixer Pump Performance

Template Number: 5.4.2.1

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total ($K)	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
1.	Mixer pump design and testing	Y	10/94	9/06	FY 1995 FY 1996 FY 1997 FY 1998	0 500 200 200	FY 1995 FY 1996 FY 1997 FY 1998	800 3,000 3,000 3,000	800 3,500 3,200 3,200	
2.	Evaluate sonic probe	Y	1/95	9/96	FY 1995 FY 1996	0 0	FY 1995 FY 1996	0 40	0 40	
3.	Enhanced mixer pump performance testing		10/94	9/97	FY 1995 FY 1996 FY 1997	0 0 0	FY 1995 FY 1996 FY 1997	250 3,649 3,379	250 3,649 3,379	
Total										

Template Title: Evaluate Alternative DST Retrieval Technologies

Template Number: 5.4.2.2

Technology Package Type (Reference, Enhancement, or Alternative): Reference

Baseline Program (Y/N): Yes

WBS ID Number and Title:

Program Element: Waste Retrieval

Functional Need Level 4: Retrieve/Transfer Waste (4.2.2.1)

Functional Need Level 5: Retrieve/Transfer DST Waste (4.2.2.1.2)

Functional Need Level 6: None

Functional Need Level 7: None

Scope: Identify cost-effective systems for retrieval by comparing alternative systems with the reference system.

Tasks:

- Evaluate alternative DST retrieval technologies (e.g., feasibility test of *Pulsair* mixing concepts; remote manipulator arm-based retrieval systems) to encompass retrieval of all types of DST waste (ongoing 9/97).
- Evaluate the use of past-practice sluicing for DST waste (ongoing).

Justification: Mixer pumps are the referenced retrieval system for DSTs. Evaluation of alternate DST retrieval technologies is necessary as a backup in the event that mixer pumps cannot remove some of the more "difficult" DST waste.

Drivers:

- TPA Milestone M-45-00 defines retrieval schedules for SSTs.
- Retrieval of DSTs is necessary to make tank space available for SST waste.

Level of Maturity (Basic Research, Applied Research, Technology or Laboratory Development, Advanced Development, Engineering Development, Demonstration, First Production, or Operations): Advanced Development

Key Uncertainties: Mixer pumps have been identified and justified as the baseline technology for retrieving waste from DSTs. The projected high cost of retrieval using mixer pumps dictates the search for a more cost-effective retrieval option. The alternative DST retrieval systems program will identify systems capable of challenging the reference retrieval approach.

Critical Interfaces: Coordination with Pacific Northwest Laboratory.

Key Deliverables (Date, Deliverable): Issue final assessment of alternative DST retrieval technologies (9/97) (Task 1)

Basis For Cost Estimates: Cost estimates from SST alternatives project.

Template Title: Evaluate Alternative DST Retrieval Technologies

Template Number: 5.4.2.2

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total ($K)	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
1.	Evaluate alternative retrieval technologies for DST wastes	Y	ongoing	9/97	FY 1995 FY 1996 FY 1997	0 1,118 0	FY 1995 FY 1996 FY 1997	1,200 200 250	0 1,318 250	
2.	Evaluate use of past-practice sluicing for DST waste	Y	ongoing	TBD	FY 1995	0	FY 1995	300	0	
Total										

Appendix E

Program Element Templates

Contents: Waste Pretreatment (Chapter 6)

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Template Title: LLW Pretreatment Development for Reference Process

Template Number: 6.4.1

Technology Package Type (Reference, Enhancement, or Alternative): Reference

Baseline Program (Y/N): Yes

WBS ID Number and Title: 1.1.1.3.01.02.01 LLW Pretreatment Development for Reference Process

Program Element: Pretreatment

Functional Need Level 4: Pretreat Waste (4.2.2.3)

Functional Need Level 5: Pretreat Supernatant 4.2.2.3.2 (WBS Level V Element: Technology Development & Applied Engineering 1.1.1.3.01.02)

Functional Need Level 6: Separate Radionuclides 4.2.2.3.2.1 (WBS Level VI Element: LLW Pretreatment Development for Reference Process 1.1.1.3.01.02.01)

Functional Need Level 7: None

Scope: This activity addresses technology in support of the development of LLW pretreatment processes that are included in the TWRS Reference Flowsheet, i.e., only removal of cesium. This activity includes exploratory development and the advanced development technology, which do not directly provide the Initial Pretreatment Module with scaling/design data.

Tasks within the LLW Pretreatment Development for Reference Process (Unfunded Tasks) include:

- Develop engineered form of CST (SNL).
- Conduct batch tests of engineered form of CST using DSS/DSSF feed (PNL).
- CST optimization for supernatant (SNL).
- Conduct electrochemical elution techniques with waste simulants using RF and CS-100 resin (PNL).
- Construct and test electrochemical elution IX System using actual wastes (PNL).

Justification: The removal of cesium is required to assure that the LLW can safely and acceptably be stored and/or disposed in a near-surface facility. It is also required if a lightly-shielded, possibly contact-maintained LLW vitrification plant is to be feasible. Data are also required for input to an ALARA study of the vitrification plant. Final decision on the type of cesium-removal process must be made prior to initiating Title I design for Module 1 of the LLW pretreatment facility—scheduled to start December 1996 (Driver TPA M-50-01-T02 by 12/31/96). The decision will compare the relative effectiveness and efficiency of removing cesium-137 (and in some cases other radionuclides: strontium-90, TRU) and efficacy of disposing of the spent exchanger, as appropriate, in the HLW glass or elsewhere. A decontamination factor in excess of 10,000 may be required in some instances.

Drivers: TPA M-50-01-T02 by 12/31/96

Level of Maturity (Basic Research, Applied Research, Technology or Laboratory Development, Advanced Development, Engineering Development, Demonstration, First Production, or Operations): Exploratory and advanced development

Key Deliverables:

- Relative capacities and selectivities of alternative processes in removing cesium-137 (and, in some cases, other radionuclides: strontium-90, TRU), e.g., CST performance.
- Efficacy of disposing of the spent exchanger, as appropriate, in the HLW glass or elsewhere (9/97)
- Required cesium decontamination factor (12/96)
- Efficacy of electrochemical elution of cesium from organic IX resins (9/97)

Critical Interfaces:

- After verification of performance by SNL (of engineered form of CST), samples will be provided to PNL for radioactive testing.
- These tests will verify the cesium capacity and selectivity of the CST exchanger and will be basis for IPM to conduct column tests.
- Supernatant samples of actual tank waste for batch tests (from Characterization Program).
- Test Results (to IPM project).
- HLW Treatment regarding exchanger disposal (from HLW).
- Provide CST materials for testing removal of additional radionuclides.
- Effective elution techniques for elutable exchangers (to IPM).

Key Deliverables:

- 6/29/95 Manufacture 10.0 kg of the engineered form of CST at UOP, Inc., facilities and deliver to PNL for batch performance testing.
- 9/29/95 Issue a report on batch testing of engineered form of CST using actual DSS/DSSF waste.

Basis For Cost Estimates: Historical data, comparison of similar projects, actual costs where available.

Template Title: LLW Pretreatment Development for Reference Process

Template Number: 6.4.1

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
1.	Develop engineered form of CST	Y	10/94	09/95		0	FY 1995	1,750	1,750	CST powder performance assessments/ batch tests
2.	Conduct batch tests of engineered form of CST using DSS/DSSF feed	Y	10/94	09/95		0	FY 1995	254	254	Engineered form of CST/column tests
3.	CST optimization for supernatant	Y	10/95	09/97		0	FY 1996 FY 1997	400 400	400 400	Batch tests of CST engineered form
4.	Conduct electrochemical elution techniques with waste simulants using RF and CS-100 resin (PNL)	Y	10/95	09/96		0	FY 1996	489	489	Continuation of studies previously funded
5.	Construct and test electrochemical elution IX System using actual wastes (PNL)	Y	10/96	09/97		0	FY 1997	680	680	Simulant elution tests
Total										

Template Title: LLW Pretreatment Development for Enhancements and Alternatives

Template Number: 6.4.2

Technology Package Type (Reference, Enhancement, or Alternative): Enhancement/Alternatives

Baseline Program (Y/N): Yes

WBS ID Number and Title: 1.1.1.3.01.02.02 LLW Pretreatment Development for Enhancements and Alternatives

Program Element: Pretreatment

Functional Need Level 4: Pretreat Waste (4.2.2.3)

Functional Need Level 5: Pretreat Supernatant 4.2.2.3.2 (WBS Level V Element: Technology Development & Applied Engineering 1.1.1.3.01.02)

Functional Need Level 6: Separate Radionuclides 4.2.2.3.2.1 (WBS Level VI Element: LLW Pretreatment Development for Enhancements and Alternatives 1.1.1.3.01.02.02)

Functional Need Level 7: None

Scope: The goal of this effort is to develop enhancements and alternatives to the reference LLW pretreatment process. This effort addresses the most promising technologies and develops engineering data for those processes that remove strontium, TRU, and technetium from supernatant or dissolved saltcake solutions.

Tasks within the LLW Pretreatment Development for Enhancements and Alternatives include:

- Conduct batch and column IX tests for strontium removal from synthetic CC waste (LANL).
- Conduct batch and column IX tests for strontium removal from actual CC waste that has had the cesium removed (LANL).
- Conduct batch solid sorbent tests with synthetic DSS/DSSF and CC waste to remove strontium.
- Conduct batch and column solid sorbent tests with actual DSS/DSSF and CC waste to remove strontium.
- Conduct batch carrier precipitation tests and sodium titanate adsorption tests to remove TRU from actual DSSF and CC wastes (LANL).
- Conduct column IX tests for technetium removal using synthetic DSSF waste.
- Conduct column IX tests for technetium removal using actual DSSF waste.
- Conduct batch tests on alternate techniques for technetium removal using synthetic DSSF waste.
- Conduct batch tests on alternate techniques for technetium removal using actual DSSF waste.
- Conduct batch carrier precipitation tests and sodium titanate adsorption tests to remove TRU from synthetic DSSF and CC wastes (LANL).
- Batch test of complexant destruction with actual CC waste (PNL).

Justification: The removal of strontium may be required to allow the LLW stream to meet NRC expectations for "incidental waste" classification. Satisfying NRC expectations involves more than merely meeting the requirement to meet or exceed Class C limits. DOE must also demonstrate radionuclide removal to the extent technically and economically feasible (ALARA guideline) and must manage the waste in accordance with the AEA. The "incidental waste" classification allows NRC to avoid licensing the disposal facility. NRC requires a convincing case that DOE's disposal strategy and plan represents a good faith effort to remove the greatest number of curies as reasonable. Such good faith must demonstrate trade studies and evaluations that depend on experimental data instead of assumptions which may or may not be in error. The decision on the need to remove strontium from noncomplexed wastes and, if needed, the process to remove strontium must be made prior to initiating Title 1 design for module 1 of the LLW pretreatment facility, scheduled to start December 1996 (Driver TPA M-50-01-T02 by 12/31/96). The similar decision on the need to remove strontium from highly complexed (CC) waste and the removal process, if needed, must be made for module 2 by January 1998.

The removal of transuranic TRU radionuclides from the supernatant and the solutions from sludge leaching/metathesis and washing may be required to (1) make the LLW a Class C waste and (2) alleviate performance assessment problems for the LLW glass due to migration of TRU, primarily NpO_2+ ion, into the environment. The decision on the need to remove neptunium (most probably in the +5 valence state as NpO_2+ ion) from the DSSF waste and, if needed, the process to remove neptunium must be made before initiating Title 1 design for module 1 of the LLW pretreatment facility scheduled to start December 1996 (submission required by Driver TPA M-50-01-T02 by 12/31/96). Developments for these modules will be based on (1) the relative effectiveness, efficiency, and robustness of the systems for removing not only TRU, but also, in some cases, strontium-90 and/or cesium-137 (a potential strength of the CST), and (2) the disposition of the product after treatment. The need to remove total TRU from CC waste and the process for removal must be complete before the initiation of Title I of module 2 scheduled for January 1998.

The removal of technetium from the supernatant and the solutions from sludge leaching/metathesis and washing may be required to meet performance assessment problems for the LLW glass due to migration of technetium. Technetium has a long half life (210,000 years) and is mobile in the environment. The decision on the need to remove technetium from waste must be made prior to initiating Title 1 design for module 1 of the LLW pretreatment facility scheduled to start December 1996 (submission required by Driver TPA M-50-01-T02 by 12/31/96). Process selection and preliminary development should be completed by 12/31/97 so that Driver TPA M-50-01, Start Construction of LLW Pretreatment Facility, can be met by 11/30/98.

Drivers:

- TPA M-50-01-T02 by 12/31/96
- TPA M-50-01 by 11/30/98

Level of Maturity (Basic Research, Applied Research, Technology or Laboratory Development, Advanced Development, Engineering Development, Demonstration, First Production, or Operations): Applied Research, Laboratory Development

Key Uncertainties:

- Requirements to meet "incidental waste" expectations of the NRC.
- Requirements to meet ALARA "goals".
- Ability to separate TRU and strontium from complexed supernatant.

- Performance assessments for technetium and neptunium.

Key Deliverables (Date, Deliverable):

- Issue reports on strontium removal tests using IX 9/95, 9/96, 9/97.
- Issue a report for removing strontium and TRU from actual waste using the following processes:
  - Heat and Digest 9/95.
  - Permanganate Oxidation 9/95.
- Issue a report on alternate strontium removal tests 9/95.
- Issue draft reports for technetium removal tests using Reillex™ anion exchange resin 9/95, 9/96, 9/97.
- Issue a draft report for alternate technetium removal techniques 9/95.

Template Title: LLW Pretreatment Development for Enhancements and Alternatives

Template Number: 6.4.2

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
1.	Conduct batch and column IX tests for Strontium removal from synthetic CC waste that has had the Cesium removed	Y	10/94	09/95		0	FY 1995	944	944	Characterize IX resins/Use actual waste
2.	Conduct batch and column IX tests for Strontium removal from actual CC waste that has had the Cesium removed	Y	10/95	09/97		0	FY 1996 FY 1997	694 560	694 560	Simulant waste study/
3.	Conduct batch and column solid sorbent tests with synthetic DSS/DSSF and CC waste to remove Strontium	Y	10/94	09/95		0	FY 1995	200	200	
4.	Conduct batch and column solid sorbent tests with actual DSS/DSSF and CC waste to remove Strontium	Y	10/94	09/97		0	FY 1995 FY 1996 FY 1997	200 400 400	200 400 400	Simulant waste study/
5.	Conduct batch carrier precipitation tests and sodium Titanate adsorption tests to remove TRU from actual DSSF and CC wastes	Y	10/94	09/96		0	FY 1995 FY 1996	405 810	405 810	

Template Title: LLW Pretreatment Development for Enhancements and Alternatives

Template Number: 6.4.2

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
6.	Conduct column IX tests for Technetium removal using synthetic DSSF waste	Y	10/94	09/95		0	FY 1995	685	685	Ongoing work/Use actual waste
7.	Conduct column IX tests for Technetium removal using actual DSSF waste	Y	10/94	09/97	FY 1995 FY 1996 FY 1997	50 93 93	FY 1995 FY 1996 FY 1997	485 507 507	560 600 600	Simulant waste study/
8.	Conduct batch tests on alternate techniques for Technetium removal using synthetic DSSF waste	Y	10/94	09/95		0	FY 1995	105	105	/Actual waste study
9.	Conduct batch tests on alternate techniques for Technetium removal using actual DSSF waste	Y	10/94	09/95		0	FY 1995	105	105	Simulant study/
10.	Conduct batch carrier precipitation tests and sodium Titanate adsorption tests to remove TRU from synthetic DSSF and CC wastes	Y	10/94	09/95		0	FY 1995	405	405	/Actual waste study
11.	Batch test of complex destruction with actual CC waste	Y	10/94	09/95		0	FY 1995	450	450	Ongoing work

Template Title: LLW Pretreatment Development for Enhancements and Alternatives

Template Number: 6.4.2

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
12.	Advanced/Innovative Extraction (strontium, TRU, technetium)	Y	10/97	09/01		0	FY 1998	1,000	1,000	Batch carrier precipitation, sodium silicotitanate, "other" absorbers/
							FY 1999	1,000	1,000	
							FY 2000	1,000	1,000	
							FY 2001	1,000	1,000	
Total										

Template Title: HLW Pretreatment Development for Reference Process

Template Number: 6.4.3

Technology Package Type (Reference, Enhancement, or Alternative): Reference

Baseline Program (Y/N): Yes

WBS ID Number and Title: 1.1.1.3.01.02.03 HLW Pretreatment Development for Reference Process

Program Element: Pretreatment

Functional Need Level 4: Pretreat Waste (4.2.2.3)

Functional Need Level 5: Pretreat Sludge/Solids 4.2.2.3.1 (WBS Level V Element: Technology Development & Applied Engineering 1.1.1.3.01.02)

Functional Need Level 6: Separate HLW Solids 4.2.2.3.1.1 (HLW Pretreatment Development for Reference Process 1.1.1.3.01.02.03)

Functional Need Level 7: None

Scope: The primary goal of this activity is to develop the reference HLW pretreatment process. The primary functions of the reference process are solid/liquid separations, sludge washing, and alkaline leaching. This activity will develop engineering data for processes used to accomplish these functions.

Tasks within the HLW Pretreatment Development for Reference Process Include:

- Conduct sludge wash/alkaline leach tests of actual tank waste for 1994-1995 sample cores-PNL (available cores split between PNL & LANL).
- Conduct sludge wash/alkaline leach tests of actual tank waste for 1994-1995 sample cores-LANL (available cores split between PNL & LANL).
- Conduct sludge wash/alkaline leach tests of actual tank waste for 1995-outyears cores-PNL (available cores split between PNL & LANL).
- Conduct sludge wash/alkaline leach tests of actual tank waste for 1995-outyears cores-LANL (available cores split between PNL & LANL).
- Evaluate sludge processing science for actual sludge, 1994-1995.
- Evaluate sludge processing science for actual sludge, 1995-outyears.
- Conduct selective leaching experiments of actual sludges 1994-1995.
- Conduct selective leaching experiments of actual sludges 1995 - outyears.
- Conduct sludge settling tests of actual waste, 1994-1995.
- Conduct sludge settling tests of actual waste, 1995 - outyears cores.
- Establish a radioactive colloid laboratory capability (FY 1995).
- Conduct radioactive colloid tests (FY 1996, 1997).

- Program management 1995.
- Program management 1996-1997.
- Infrastructure support.

Justification: Data on the effectiveness of washing, leaching, and metathesis must be representative for all waste types and must be in place 6 months before the evaluation of the effectiveness of enhanced sludge washing (M-50-03, March 1998). Consequently, these data are required by September 1997. Data on the effectiveness for enhanced sludge washing (including alkaline leaching and metathesis) for all significant waste types should be available before or shortly after starting Title 1 design on the HLW Pretreatment Facility scheduled to start November 1998 (Driver TPA M-50-04-T02.)

Development of solid/liquid methods must be complete in time to support Title I design for module 1 and module 2 of the LLW pretreatment facility. Driver TPA M-50-01-T02 requires submission of conceptual design and initiation of definitive design (Title I of module 1) of the LLW Pretreatment Facility by 12/31/96. Title I of module 1 will be initiated in December 1996 and Title I of module 2 will be initiated in January 1998. This effort also provides data for the design of the HLW Pretreatment Facility. Title 1 of the HLW Pretreatment Facility will be initiated in November 1998 (TPA M-50-04-T02).

Drivers:

- TPA M-50-03 by 3/98
- TPA M-50-04-T02 by 11/30/98

Level of Maturity (Basic Research, Applied Research, Technology or Laboratory Development, Advanced Development, Engineering Development, Demonstration, First Production, or Operations):
Laboratory Development, Advanced Development

Key Uncertainties:

- Effectiveness of enhanced sludge washing with varying waste types.
- Ability to predict solubility behaviors of varying waste types.
- Actual waste types/inventory in Hanford tanks.
- Solid/liquid physical and chemical separation process phenomena.

Critical Interfaces:

- Actual sludge samples to laboratories.
- Sludge study results for models, studies, and reports supporting TPA M-50-03 by 3/98.

Key Deliverables (Date, Deliverable):

- Issue draft reports on sludge washing/alkaline leaching tests at PNL 9/29/95, 9/28/96, 9/30/97.
- Issue draft reports on sludge washing/alkaline leaching tests at LANL 9/29/95, 9/28/96, 9/30/97.
- Issue a report on findings from the sludge science and chemistry program (PNL) 9/29/95, 9/28/96, 9/30/97.

- Issue a report on the selective leaching of actual tank sludges (PNL) 9/29/95, 9/28/96, 9/30/97.
- Issue reports on settling tests 9/29/95, 9/28/96, 9/30/97.

Basis For Cost Estimates: Historical data, comparison with similar projects, actual costs where possible.

Template Title: HLW Pretreatment Development for Reference Process

Template Number: 6.4.3

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
1.	Conduct sludge wash/alkaline leach tests of actual tank waste for 1994-1995 sample cores—PNL	Y	10/94	09/95		0	FY 1995	941	941	PNL sludge tests 1994/1996-1997 tests
2.	Conduct sludge wash/alkaline leach tests of actual tank waste for 1994-1995 sample cores—LANL	Y	10/94	09/95		0	FY 1995	1,508	1,508	PNL sludge tests 1994/1996-1997 tests
3.	Conduct sludge wash/alkaline leach tests of actual tank waste for 1995-outyears cores—PNL	Y	10/95	09/97		0	FY 1996 FY 1997	2,200 2,200	2,200 2,200	1995 Sludge tests
4.	Conduct sludge wash/alkaline leach tests of actual tank waste for 1995-outyears cores—LANL	Y	10/95	09/97		0	FY 1996 FY 1997	2,300 2,300	2,300 2,300	1995 sludge tests
5.	Evaluate sludge processing science for actual sludge, 1994-1995.	Y	10/94	09/95	FY 1995	60,000	FY 1995	2,231	2,291	Sludge work/1996-1997 studies
6.	Evaluate sludge processing science for actual sludge, 1995-outyears	Y	10/95	09/97		0	FY 1996 FY 1997	2,178 2,178	2,178 2,178	1995 sludge study
7.	Conduct selective leaching experiments of actual sludges 1994-1995	Y	10/94	09/95		0	FY 1995	275	275	1994 PNL work/1996-1997 work

Template Title: HLW Pretreatment Development for Reference Process

Template Number: 6.4.3

Tasks			Start	End	Capital ($K)		Expense ($K)			Predecessors/
No.	Title	MYWP	Date	Date	Year	Amount	Year	Amount	Total	Successors
8.	Conduct selective leaching experiments of actual sludges 1995 - outyears	Y	10/95	09/97		0	FY 1996 FY 1997	282 290	282 290	1995 study
9.	Conduct sludge settling tests of actual waste, 1994-1995	Y	10/94	09/95		0	FY 1995	1,300	1,300	/1996-1997 work
10.	Conduct sludge settling tests of actual waste, 1995 - outyears cores	Y	10/95	09/97		0	FY 1996 FY 1997	1,200 1,200	1,200 1,200	1995 work
11.	Establish a radioactive colloid laboratory capability (FY 1995)	Y	10/94	09/95	FY 1995	450,000	FY 1995	716	1,166	
12.	Conduct radioactive colloid tests (FY 1996, 1997)	Y	10/95	09/97		0	FY 1996 FY 1997	605 605	605 605	1995 construct
13.	Program management 1995	Y	10/94	09/95		0	FY 1995	1,700	1,700	
14.	Program management 1996	Y	10/95	09/97		0	FY 1996 FY 1997	1,600 1,600	1,600 1,600	
15.	Infrastructure support 1996-1997	Y	10/94	09/97		0	FY 1995 FY 1996 FY 1997	549 1,200 1,618	549 1,200 1,618	
16.	Solid-liquid separation	Y	10/95	09/97		0	FY 1996 FY 1997	505 1,000	505 1,000	
17.	Program Management 1998-2001	Y	10/97	09/01		0	FY 1998 FY 1999 FY 2000 FY 2001	1,200 1,200 500 500	1,200 1,200 500 500	

Template Title: HLW Pretreatment Development for Reference Process

Template Number: 6.4.3

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
18.	Advanced Sludge Reduction	Y	10/97	09/01		0	FY 1998 FY 1999 FY 2000 FY 2001	4,800 5,100 2,195 2,195	4,800 5,100 2,195 2,195	Sludge wash and Alkaline leach tests/
19.	Sludge Processing Science/Solid-Liquid Separation FY 1998-FY 2023	Y	10/97	09/03		0	FY 1998 FY 1999 FY 2000 FY 2001 FY 2002 FY 2003	2,000 2,000 1,000 1,000 959 600	2,000 2,000 1,000 1,000 959 600	Sludge Processing Science 1994, 1995, 1996, 1997
20.	Infrastructure Support (Sampling/Sample Handling and Preparation/ Shipping)	Y	10/97	09/01+		0	FY 1998 FY 1999 FY 2000 FY 2001	1,700 1,844 1,000 1,000	1,700 1,844 1,000 1,000	
Total										

Template Title: HLW Pretreatment Development for Enhancements and Alternatives

Template Number: 6.4.4

Technology Package Type (Reference, Enhancement, or Alternative): Enhancements/Alternatives

Baseline Program (Y/N): Yes

WBS ID Number and Title: 1.1.1.3.01.02.04 HLW Pretreatment Development for Enhancements and Alternatives

Program Element: Pretreatment

Functional Need Level 4: Pretreat Waste (4.2.2.3)

Functional Need Level 5: Pretreat Sludges/Solids (4.2.2.3.1) (WBS Level V Element: Technology Development & Applied Engineering 1.1.1.3.01.02)

Functional Need Level 6: Separate HLW Solids 4.2.2.3.1.1. (WBS Element Level VI: HLW Pretreatment Development for Enhancements and Alternatives 1.1.1.3.01.02.04)

Functional Need Level 7: None

Scope: The goal of this effort is to provide enhancements and alternatives to the reference HLW pretreatment process. This effort addresses the most promising technologies and develops engineering data for those processes that address solid/liquid separations, sludge washing, leaching, and other techniques to reduce the amount of waste sludge material in the HLW stream.

Tasks within the LLW Pretreatment Development for Enhancements and Alternatives include:

- Conduct non-thermal reconstitution tests, FY 1994-1995 cores (PNL).
- Conduct non-thermal reconstitution tests, FY 1995 - outyears cores (PNL).

Justification: Technologies for additional acid dissolution and reneutralization (reconstitution) must be complete to support Title I design for the HLW pretreatment facility scheduled to start in November 1998.

Even after reconstitution, the HLW volumes may be too large and require further reduction. Thus the entire sludge may need to be dissolved in concentrated acids. Technologies for total dissolution must be developed to the point that they are representative for all waste types so that their benefits and tradeoffs can be assessed for their addition/revision to the base case 3 months before the milestone to evaluate the effectiveness of such treatment (M-50-03, March 1998), therefore by December 1997. For planning purposes, it is assumed that this March 1998 TPA decision will support the planning assumption, and therefore this work will terminate after the March 1998 decision.

Drivers:

- M-50-03 by 3/31/98
- M-50-04-T02 by 11/30/98

Level of Maturity (Basic Research, Applied Research, Technology or Laboratory Development, Advanced Development, Engineering Development, Demonstration, First Production, or Operations): Applied Research, Laboratory Development, Advanced Development

Key Uncertainties:

- Sludge chemical/radiochemical compositions in individual tanks.
- Chemical form/speciation of components that govern the amount of HLW.
- Effectiveness of enhanced sludge washing in reducing HLW volume.
- Effectiveness of enhancement processes, such as oxidation of chromium (III), to further reduce HLW volume.
- Effectiveness of alternative processes, such as acid dissolution in reducing HLW volume.

Key Deliverables (Date, Deliverable):

- Issue a report on acid dissolution tests with actual sludge 9/29/95.
- Issue a report on non-thermal reconstitution tests 9/29/95, 9/28/96, 9/30/97.
- Issue a report on batch solvent extraction tests for strontium and TRU removal 9/29/95.

Basis For Cost Estimates: Historical data, comparison with similar projects, actual costs where possible.

Template Title: HLW Pretreatment Development for Enhancements and Alternatives

Template Number: 6.4.4

Tasks			Start	End	Capital ($K)		Expense ($K)			Predecessors/
No.	Title	MYWP	Date	Date	Year	Amount	Year	Amount	Total	Successors
21.	Conduct non-thermal re-constitution tests, FY 1994-1995 cores	Y	10/94	09/95		0	FY 1995	500	500	PNL study/1996-1997 studies
22.	Conduct non-thermal re-constitution tests, FY 1996 - outyears cores	Y	10/95	09/97		0	FY 1996 FY 1997	500 500	500 500	1995 study
23.	Hydrothermal Closeout at PNL and LANL	Y	10/94	09/95		0	FY 1995	505	505	
24.	Outyear Innovations Alternatives/Enhancements	Y	10/97	09/01		0	FY 1998 FY 1999	800 800	800 800	
Total										

* Dropped from MYWP FY 1996 and beyond - Not included in totals.

Template Title: Engineering Studies and Functions and Requirements (F&R)

Template Number: 6.4.5

Technology Package Type (Reference, Enhancement, or Alternative): Reference

Baseline Program (Y/N): Yes

WBS ID Number and Title: 1.1.1.3.01.04.02 Engineering Studies and Functions and Requirements (F&R)

Program Element: Pretreatment

Functional Need Level 4: Pretreat Waste (4.2.2.3)

Functional Need Level 5: Pretreat Sludge/Solids 4.2.2.3.1 (WBS Level V Element: Systems Definition 1.1.1.3.01.04

Functional Need Level 6: Separate HLW Solids 4.2.2.3.1.1 (WBS Level VI Element: Engineering Studies and Functions and Requirements (F&R) 1.1.3.01.04.02)

Functional Need Level 7: None

Scope: This activity integrates and defines functions and requirements before the initiation of the conceptual design review (CDR). The ongoing awareness of progress/plans at other DOE sites and similar non-DOE projects worldwide will be included in this cost account and will serve as a means to effectively control the pretreatment strategy. Pretreatment system models will be prepared as needed.

Justification: The objective of the Engineering Studies and Functions and Requirements (F&R) activity is to establish the technical and process design baselines for the LLW pretreatment facility (Project W-236B, Initial Pretreatment Module), the HLW pretreatment facility, and in-tank processing to ensure that the Waste Pretreatment Program Element supports the Tank Waste Remediation System (TWRS) mission requirements.

Drivers:

- TPA M-50-01-T02 by 12/31/96
- TPA M-50-03 by 3/31/98
- TPA M-50-01 by 11/30/98
- TPA M-50-04-T02 by 11/30/98

Level of Maturity (Basic Research, Applied Research, Technology or Laboratory Development, Advanced Development, Engineering Development, Demonstration, First Production, or Operations): Advanced Development, Engineering Development

Key Deliverables (Date, Deliverable): Detailed deliverables for this activity are:

- 01/95 Decant and Fill Tank 101-AZ
- 12/94 Prepare LLW Facility Design Requirement Document (DRD) to reflect the results of the Facility Options Studies.

- 02/95 Prepare HLW Pretreatment Facility DRD
- 02/95 Determine Liquid Effluent Treatment Concept
- 03/95 Select Supernate Pretreatment Facility Concept
- 04/95 Issue Evaluation of Water Reuse and Implementation Strategy
- 06/95 Determine Waste Concentration Mechanism
- 08/95 Issue Final Report on Basis for Selecting "Separate Waste Into Fractions" for Planning
- 09/95 Issue Final Report "Determine Waste Separations Process"
- 08/95 Issue Progress Report on Sludge Washing Demonstration
- 10/96 Initiate AZ-101 Sludge Washing Process Test
- 09/96 Issue Progress Report on Sludge Washing Process Test
- 10/96 Update LLW DRD based on completion of the LLW Pretreatment Conceptual Design Report - Updates (FY 1996 and FY 1997)
- 07/97 Complete Sludge Washing Process Test and Issue Report
- 10/97 Issue In-Tank Processing Functions and Requirements (F&R)
- 03/95 Determine System Generated Waste Disposal Strategy
- 01/95 Determine Liquid Effluent Treatment Concept
- 05/95 Determine Waste Concentration Mechanism

Basis For Cost Estimates: Engineering estimates, comparison with similar projects, actual costs, etc.

Template Title: Engineering Studies and Functions and Requirements (F&R)

Template Number: 6.4.5

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
Technology and Technology Development-Related tasks (within "engineering Studies and Functions and Requirements (F&R)" 1.1.3.01.04.02-Level VI WBS include:										
1.	Retrieval Sequence and Blending Strategy	Y				0	FY 1995 FY 1996 FY 1997	572 703 225	572 703 225	
2.	In-Tank Sludge Washing Technical Support	Y				0	FY 1995 FY 1996 FY 1997	500 500 263	500 500 263	
3.	Thermal Reconstitution Process Chemistry Development	Y				0	FY 1995	140	140	
4.	Determine Waste Processing Strategy	Y				0	FY 1995 FY 1996 FY 1997	860 1,081 1,105	860 1,081 1,105	
5.	In-tank Sludge Washing Process Text	Y				0	FY 1995 FY 1996 FY 1997	764 536 5,836	764 536 5,836	
6.	Thermal Reconstitution of Tank Waste Sludge	Y				0	FY 1995	98	98	
7.	Evaluate Process Alternatives	Y				0	FY 1995 FY 1996 FY 1997	520 495 497	520 495 497	
Total										

Template Title: **Applied Technology, W-236B Pretreatment Facility (Initial Pretreatment Module)**

Template Number: **6.4.6**

Technology Package Type (Reference, Enhancement, or Alternative): Reference

Baseline Program (Y/N): Yes

WBS ID Number and Title: 1.1.1.3.01.05.02 Applied Technology, W-236B Pretreatment Facility

Program Element: Pretreatment

Functional Need Level 4: Pretreat Waste (4.2.2.3)

Functional Need Level 5: Pretreat Supernatant 4.2.2.3.2 (WBS Level V Element: W-236B Pretreatment Facility 1.1.1.3.01.05)

Functional Need Level 6: Separate Radionuclides 4.2.2.3.2.1 (WBS Level VI Element: Applied Technology 1.1.1.3.01.05.02)

Functional Need Level 7: None

Scope: The primary goal of LLW pretreatment is the removal of cesium from the tank waste supernatant, the liquid from the solids/liquid separations, and the liquids produced from the HLW pretreatment process. The removal of technetium, strontium, and transuranics (TRUs) may also be required depending upon the determination of operational requirements, LLW glass performance requirements, and ALARA requirements/considerations. The equipment needed for LLW pretreatment must be tested and evaluated to ensure proper performance and execution of task. The equipment requirements are influenced by the design and feed specifications for the LLW vitrification facility. The testing and evaluation will provide the necessary data to make recommendations to be incorporated in the design of the LLW pretreatment facility. The processes needed for LLW pretreatment must be tested to determine the design specifications and to validate proper operation of the processes selected. The process testing requirements are influenced by the feed specifications for the LLW vitrification facility. The testing and evaluation of the processes will provide the necessary data to make recommendations concerning process selection, exchanger selection, process operating conditions, and process operating efficiency to support project design activities.

Tasks within the Applied Technology, W-236B Pretreatment Facility include:

- Equipment Testing
    - Equipment Testing Evaluation and Oversight.
    - Gross Solids/Liquid Separations.
    - Supernatant Colloid Evaluation and Polishing Filtration.
    - Ion Exchange (IX) Column Equipment Testing.
    - Instrumentation and Process Control Testing.
    - Operations Support Testing and Training.
- Sludge Sampler Truck (CENRTC)

  - Sludge Sampler Truck (CENRTC).
  - Transportation Casks and Liners (CENRTC).
- TRU Monitor (CENRTC)
  - TRU Monitor (CENRTC).
- Applied Process Testing

Justification: Engineering activities to implement the recommendation of T3A-94-151 Milestone will be initiated after DOE-RL concurrence with the recommendation. Low-cost critical path permitting activities will be initiated in October 1994. Permitting activities will assume the use of WESF as the facility to be used for pilot-scale testing.

Drivers:

- TPA M-50-01 by 11/30/98
- TPA M-50-01-T02 by 12/31/96

Level of Maturity (Basic Research, Applied Research, Technology or Laboratory Development, Advanced Development, Engineering Development, Demonstration, First Production, or Operations): Advanced Development, Engineering Development, Demonstration, Operations

Key Uncertainties: The selection of a cesium ion exchanger has not been completed at this time. The reference resin is cesium-100, but the exchangers R-F, CST, and super lig 625 are all under evaluation to help determine the best exchanger to use on Hanford waste.

Selection of processes and exchangers, if applicable, has not yet been made for technetium, strontium, and TRU separations.

Critical Interfaces: Support process testing of candidate processes to develop criteria for selection of preferred processes, including exchanger selection, if applicable. In addition, this task will interface with other DOE-funded technology development activities to help support refinement of their testing programs to provide appropriate data for inclusion into process and/or IX resins selection. Upon selection of process and/or IX exchangers, perform testing to develop all A/E-identified design data. In addition, this WBS activity will support process validation.

Key Deliverables (Date, Deliverable):

Equipment Testing:

- Validation of waste simulant characteristics for solid/liquid separations testing.
- Recommendation of preferred gross filtration equipment, including sizing, solids loading precoat requirements, and operating characteristics.
- Recommendation of preferred polishing filtration equipment, including sizing, solids loading precoat requirements, and operating characteristics.
- Test requirements for hot pilot-scale testing of separations processes.
- Design and construction of hot testing units for radionuclide separations and for solid/liquid separations.

- Validation of LLW pretreatment processes with pilot-scale demonstration operations with actual tank wastes.
- Evaluation of process equipment with respect to fluid leakage and its effect on removal efficiency.
- Validation of the performance of the TRU monitor based on testing with actual wastes.
- Design and construction of full-scale mockup units for operator training and for readiness review documentation preparation.

Sludge Sampler Truck:

- 25-liter sludge sampler truck, casks, and cask liners are delivered onsite.
- Options to be considered: Trade study between an additional sample line to WESF or continued use of the truck will be performed

TRU Monitor:

- A full-scale operational TRU monitor, ready for field installation and testing.

Process Testing:

- Select exchanger for cesium separations process.
- Cesium separations process performance with selected exchanger and configuration.
- Provide technical data to support selection of technetium separation process.
- Provide technical data to support selection of strontium separation process.
- Provide technical data to support selection of TRU separation process.

Basis For Cost Estimates: Engineering estimate, comparison with similar projects,actual costs, etc.

Template Title: Applied Technology, W-236B Pretreatment Facility (Initial Pretreatment Module)

Template Number: 6.4.6

Tasks					Capital ($K)		Expense ($K)			
No.	Title	MYWP	Start Date	End Date	Year	Amount	Year	Amount	Total	Predecessors/ Successors
Technology and Technology-Development Related Tasks (within "Applied Technology W-236B Pretreatment Facility" 1.1.1.3.01.05.02-Level VI WBS) include:										
1.	Equipment Testing	Y				0	FY 1995	10,084	10,084	
							FY 1996	12,342	12,342	
							FY 1997	10,952	10,952	
2.	Sludge Sampling Truck	Y				0	FY 1995	3,810	3,810	
							FY 1996	360	360	
							FY 1997			
3.	TRU Monitor	Y				0	FY 1995	531	531	
							FY 1996			
							FY 1997			
4.	Process Testing	Y				0	FY 1995	2,765	2,765	
							FY 1996	5,901	5,901	
							FY 1997	7,750	7,750	
Total										

Template Title: LLW Pretreatment Development for Reference Process (Unfunded Tasks)

Template Number: 6.4.7

Technology Package Type (Reference, Enhancement, or Alternative): Reference

Baseline Program (Y/N): No

WBS ID Number and Title: 1.1.1.3.01.02.01 LLW Pretreatment Development for Reference Process

Program Element: Pretreatment

Functional Need Level 4: Pretreat Waste (4.2.2.3)

Functional Need Level 5: Pretreat Supernatant 4.2.2.3.2 (WBS Level V Element: Technology Development & Applied Engineering 1.1.1.3.01.02)

Functional Need Level 6: Separate Radionuclides 4.2.2.3.2.1 (WBS Level VI Element: LLW Pretreatment Development for Reference Process 1.1.1.3.01.02.01)

Functional Need Level 7: None

Scope: This activity addresses technology in support of the development of LLW pretreatment processes that are included in the TWRS Reference Flowsheet, i.e., only removal of cesium. This activity includes exploratory development and the advanced development technology which do not directly provide the Initial Pretreatment Module with scaling/design data. Tasks listed in this template are not funded.

Tasks:

- Competing Ion Effect Studies.
- Cesium Elution and Resin Disposal Alternatives.
- Actual Waste Column Tests with Resorcinol-Formaldehyde and Crystalline Silicotitanates.
- Evaporation/Concentration of Process Streams.

Justification: The removal of cesium is required to assure that the LLW can safely and acceptably be stored and/or disposed in a near-surface facility. It is also required if a lightly-shielded, possibly contact-maintained LLW vitrification plant is to be feasible. Data are also required for input to an ALARA study of the vitrification plant. Final decision on the type of cesium-removal process must be made prior to initiating Title I design for Module 1 of the LLW pretreatment facility--scheduled to start December 1996 (Driver TPA M-50-01-T02 by 12/31/96). The decision will compare the relative effectiveness and efficiency of removing cesium-137 (and in some cases other radionuclides: strontium-90, TRU) and efficacy of disposing of the spent exchanger, as appropriate, in the HLW glass or elsewhere. A decontamination factor in excess of 10,000 may be required in some instances.

Drivers: TPA M-50-01-T02 by 12/31/96

Level of Maturity (Basic Research, Applied Research, Technology or Laboratory Development, Advanced Development, Engineering Development, Demonstration, First Production, or Operations): Exploratory and advanced development.

Key Uncertainties:

- relative capacities and selectivities of alternative processes in removing cesium-137 (and in some cases other radionuclides: strontium-90, TRU)

- efficacy of disposing of the spent exchanger, as appropriate, in the HLW glass or elsewhere
- required cesium decontamination factor
- efficacy of electrochemical elution of cesium from organic IX resins

Critical Interfaces:

- After verification of performance by SNL (of engineered form of CST), samples will be provided to PNL for radioactive testing. These tests will verify the cesium capacity and selectivity of the exchanger.
- Supernatant samples of actual tank waste for batch tests from Characterization Program
- Test Results from TWRS IPM project
- HLW Treatment regarding exchanger disposal
- Provide CST materials for testing removal of additional radionuclides

Key Deliverables (Date, Deliverable): None

Basis For Cost Estimates: Historical data, comparison of similar projects, actual costs where available.

Template Title: LLW Pretreatment Development for Reference Process (Unfunded Tasks)

Template Number: 6.4.7

Tasks		MYW P	Start Date	End Date	Capital ($K)		Expense ($K)		Total	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
1.	*LEVEL 1: Competing Ion Effect Studies*[(a)]	*N*				*0*	*1st year* *2nd year*	*750* *375*	*1,125*	*Batch-Column Performance Tests*
2.	*LEVEL 1: - DEFERRED TO HLW PROGRAM ELEMENT - Disposition of spent or Loaded Cesium Sorbents*[(a)]	*N*				*0*	*1st year*	*125*	*125*	
3.	*LEVEL 1: - DEFERRED TO IPM PROJECT - Actual Waste Column Tests with Rescorcinol-Formaldehydes and Crystalline Silicotitanates*[(a)]	*N*				*0*	*1st year* *2nd year*	1,050 800	*1,850*	
4.	*LEVEL 2: -REQUIRING ENGINEERING TRADE STUDY EVALUATION - Cesium Elution and Resin Disposal Alternatives*	*N*				*0*	*1st year*	450	*450*	
5.	*LEVEL 2: -REQUIRING ENGINEERING TRADE STUDY EVALUATION - Evaporation/ Concentration of Process Streams*	*N*				*0*	*1st year* *2nd year* *3rd year*	150 750 1,250	*1,150*	

(a) Fund immediately.
(b) "Best" estimates at this time. Need better assumptions before estimating reasonable costs.

Template Title: LLW Pretreatment Development for Enhancements and Alternatives (Unfunded Tasks)

Template Number: 6.4.8

Technology Package Type (Reference, Enhancement, or Alternative): Enhancement/Alternatives

Baseline Program (Y/N): No

WBS ID Number and Title: 1.1.1.3.01.02.02 LLW Pretreatment Development for Enhancements and Alternatives

Program Element: Pretreatment

Functional Need Level 4: Pretreat Waste (4.2.2.3)

Functional Need Level 5: Pretreat Supernatant 4.2.2.3.2 (WBS Level V Element: Technology Development & Applied Engineering 1.1.1.3.01.02)

Functional Need Level 6: Separate Radionuclides 4.2.2.3.2.1 (WBS Level VI Element: LLW Pretreatment Development for Enhancements and Alternatives 1.1.1.3.01.02.02)

Functional Need Level 7: None

Scope: The goal of this effort is to develop enhancements and alternatives to the reference LLW pretreatment process. This effort addresses the most promising technologies and develops engineering data for those processes that remove strontium, TRU, and technetium from supernatant or dissolved saltcake solutions. Tasks in this template are not funded.

Tasks within the LLW Pretreatment Development for Enhancements and Alternatives (Unfunded Tasks) include:

- Determine the Effectiveness of Competition Reactions to Overcome Effects of Organic Compexants on Strontium and TRU Removal.
- Uranium Removal from Supernatant.
- Competing Ion Studies for Technetium Ion Exchange.
- Study Removal of Cesium and Technetium by Volatilization during Calcination.
- Study Additional Technetium Ion Exchange Materials.
- Study Precipitation/Reduction Methods for Removal of Technetium.

Justification: The removal of strontium may be required to allow the LLW stream to meet NRC expectations for "incidental waste" classification. Satisfying NRC expectations involves more than merely meeting the requirement to meet or exceed Class C limits. DOE must also demonstrate radionuclide removal to the extent technically and economically feasible (ALARA guideline) and must manage the waste in accordance with the AEA. The "incidental waste" classification allows NRC to avoid licensing the disposal facility. NRC requires a convincing case that DOE's disposal strategy and plan represents a good faith effort to remove the greatest number of curies as reasonable. Such good faith must demonstrate trade studies and evaluations that depend on experimental data instead of assumptions which may or may not be in error. The decision on the need to remove strontium from noncomplexed wastes and, if needed, the process to remove strontium must be made prior to initiating Title 1 design for module 1 of the LLW pretreatment facility, scheduled to start December 1996 (Driver TPA M-50-01-T02 by 12/31/96). The similar decision on the need to remove strontium from highly complexed (CC) waste and the removal process, if needed, must be made for module 2 by January 1998.

The removal of TRU radionuclides from the supernatant and the solutions from sludge leaching/metathesis and washing may be required to (1) make the LLW a Class C waste and (2) alleviate performance assessment problems for the LLW glass due to migration of TRU, primarily NpO_2^+ ion, into the environment. The decision on the need to remove neptunium (most probably in the +5 valence state as NpO_2^+ ion) from the DSSF waste and, if needed, the process to remove neptunium must be made before initiating Title 1 design for module 1 of the LLW pretreatment facility scheduled to start December 1996 (submission required by Driver TPA M-50-01-T02 by 12/31/96). Developments for these modules will be based on (1) the relative effectiveness, efficiency, and robustness of the systems for removing not only TRU, but also, in some cases, strontium-90 and/or cesium-137 (a potential strength of the crystalline silicotitanate), and (2) the disposition of the product after treatment. The need to remove total TRU from CC waste and the process for removal must be complete before the initiation of Title I of module 2 scheduled for January 1998.

The removal of technetium from the supernatant and the solutions from sludge leaching/metathesis and washing may be required to meet performance assessment problems for the LLW glass due to migration of technetium. Technetium has a long half life (210,000 years) and is mobile in the environment. The decision on the need to remove technetium from waste must be made before initiating Title 1 design for module 1 of the LLW pretreatment facility scheduled to start December 1996 (submission required by Driver TPA M-50-01-T02 by 12/31/96). Process selection and development should be completed by 12/31/97 so that Driver TPA M-50-01, Start Construction of LLW Pretreatment Facility, can be met by 11/30/98.

Drivers:

- TPA M-50-01-T02 by 12/31/96
- TPA M-50-01 by 11/30/98

Level of Maturity (Basic Research, Applied Research, Technology or Laboratory Development, Advanced Development, Engineering Development, Demonstration, First Production, or Operations): Applied Research, Laboratory Development

Key Uncertainties:

- Requirements to meet ALARA "goals".
- Requirements to meet "incidental waste" definition .
- Ability to separate TRU and strontium from complexed supernatant.
- Performance assessments for technetium, neptunium, and uranium.

Critical Interfaces:

- Actual waste material for experimental studies.
- Effective elution of technetium.

Basis For Cost Estimates: Historical data, comparison of similar projects, actual costs where available.

Template Title: LLW Pretreatment Development for Enhancements and Alternatives (Unfunded Tasks)

Template Number: 6.4.8

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
1.	*LEVEL 1: - Determine the Effectiveness of Competition Reactions to Overcome Effects of Organic Complexants on Strontium and TRU Removal*[(a)]	*N*				*0*	*1st year* *2nd year*	*200* *200*	*400*	
2.	*LEVEL 1: - Uranium Removal from Supernatant (Add to Existing TRU studies)*[(a)]	*N*				*0*	*1st year* *2nd year*	*250* *250*	*500*	
3.	*LEVEL 2: - Competing Ion Studies for Technetium Removal*	*N*				*0*	*1st year* *2nd year*	*450* *200*	*650*	
4.	*LEVEL 2/3: - Removal of Cesium and Technetium by Volatilization during Calcination*	*N*				*0*	*1st year* *2nd year*	*300* *TBD*	*300* *TBD*	

(a) Fund immediately.
(b) "Best" estimates at this time. Need better assumptions before estimating reasonable costs.

Template Title: LLW Pretreatment Development for Enhancements and Alternatives (Unfunded Tasks)

Template Number: 6.4.8

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
5.	*LEVEL 2/3: - Study Additional Technetium Ion Exchange Materials*	*N*				*0*	*1st year* *2nd year*	*200* *200*	*400*	
6.	*LEVEL 2/3: - Study Precipitations/Reduction Methods for Removal of Technetium*	*N*				*0*	*1st year* *2nd year*	*300* *300*	*600*	

(a) Fund immediately.
(b) "Best" estimates at this time. Need better assumptions before estimating reasonable costs.

Template Title: HLW Pretreatment Development for Reference Process (Unfunded Tasks)

Template Number: 6.4.9

Technology Package Type (Reference, Enhancement, or Alternative): Reference

Baseline Program (Y/N): No

WBS ID Number and Title: 1.1.1.3.01.02.03 HLW Pretreatment Development for Reference Process

Program Element: Pretreatment

Functional Need Level 4: Pretreat Waste (4.2.2.3)

Functional Need Level 5: Pretreat Sludge/Solids 4.2.2.3.1 (WBS Level V Element: Technology Development & Applied Engineering 1.1.1.3.01.02)

Functional Need Level 6: Separate HLW Solids 4.2.2.3.1.1 (HLW Pretreatment Development for Reference Process 1.1.1.3.01.02.03)

Functional Need Level 7: None

Scope: The primary goal of this activity is to develop the reference HLW pretreatment process. The primary functions of the reference process are solid/liquid separations, sludge washing, and alkaline leaching. This activity will develop engineering data for processes used to accomplish these functions. The tasks in this template are not funded.

Tasks within the LLW Pretreatment Development for Reference Process (Unfunded Tasks) include:

- Retrieval Chemistry Impacts on HLW Glass Volume.
- Evaporation/Concentration of Eluted Cesium Product.
- Glass Frit Filters Lifetime Studies.

Justification: Data on the effectiveness of washing, leaching and metathesis must be representative for all waste types and must be in place 6 months before the evaluation of the effectiveness of enhanced sludge washing (M-50-03, March 1998). Consequently these data are required by September 1997. Data on the effectiveness for enhanced sludge washing (including alkaline leaching and metathesis) for all cores should be available prior to or shortly after starting Title 1 design on the HLW Pretreatment Facility scheduled to start November 1998 (Driver TPA M-50-04-T02).

Development of solid/liquid methods must be complete in times to support Title I design for module 1 and module 2 of the LLW pretreatment facility. Driver TPA M-50-01-T02 requires submission of conceptual design and initiation of definitive design (Title I of module 1) of the LLW Pretreatment Facility by 12/31/96. Title I of module 1 will be initiated in December 1996 and Title I of module 2 will be initiated in January 1998. This effort also provides data for the design of the HLW Pretreatment Facility. Title 1 of the HLW Pretreatment Facility will be initiated in November 1998 (TPA M-50-04-T02).

Drivers:

- TPA M-50-03 by 3/31/98
- TPA M-50-04-T02 by 11/30/98

- TPA M-50-01-T02 by 12/31/98

Level of Maturity (Basic Research, Applied Research, Technology or Laboratory Development, Advanced Development, Engineering Development, Demonstration, First Production, or Operations): Laboratory Development, Advanced Development

Key Uncertainties:

- Effectiveness of enhanced sludge washing with varying waste types.
- Ability to predict solubility behaviors of varying waste types.
- Actual waste types/inventory in Hanford tanks.
- Solid/liquid physical and chemical separation process phenomena.

Critical Interfaces:

- Actual sludge samples to laboratories.
- Sludge study results for models.

Key Deliverables (Date, Deliverable): none

Basis For Cost Estimates: Historical data, comparison of similar projects, actual costs where available.

Template Title: HLW Pretreatment Development for Reference Process (Unfunded Tasks)

Template Number: 6.4.9

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
1.	*LEVEL 1: - Retrieval Chemistry Impacts on HLW Glass Volume*(a)	*N*				*0*	*1st year* *2nd year* *3rd year*	*300* *150* *150*	*600*	
2.	*Glass Frit Filters Lifetime Studies*	*N*				*0*	*1st year*	*150*	*150*	
3.	*Glass Frit Filters Lifetime Studies*(b)	*N*				*0*	*1st year* *2nd year* *3rd year*	*50* *TBD* *TBD*	*TBD*	
4.	*Large-Scale Tests with Real Waste for Scaling/ Confirmation and to Provide Sludge for Vitrification*(b)	*N*				*0*	*1st year* *2nd year*	*500* *2,000*	*2,500*	

(a) Fund immediately.
(b) "Best" estimates at this time. Need better assumptions before estimating reasonable costs.

Template Title: HLW Pretreatment Development for Enhancements and Alternatives (Unfunded Tasks)

Template Number: 6.4.10

Technology Package Type (Reference, Enhancement, or Alternative): Enhancements/Alternatives

Baseline Program (Y/N): No

WBS ID Number and Title: 1.1.1.3.01.02.04 HLW Pretreatment Development for Enhancements and Alternatives

Program Element: Pretreatment

Functional Need Level 4: Pretreat Waste (4.2.2.3)

Functional Need Level 5: Pretreat Sludges/Solids 4.2.2.3.1 (WBS Level V Element: Technology Development & Applied Engineering 1.1.1.3.01.02)

Functional Need Level 6: Separate HLW Solids 4.2.2.3.1.1 (WBS Element Level VI: HLW Pretreatment Development for Enhancements and Alternatives 1.1.1.3.01.02.04)

Functional Need Level 7: None

Scope: The goal of this effort is to provide enhancements and alternatives to the reference HLW pretreatment process. This effort addresses the most promising technologies and develops engineering data for those processes that address solid/liquid separations,sludge washing, leaching, and other techniques to reduce the amount of waste sludge material in the HLW stream. <u>This template includes tasks that are not funded.</u>

Tasks within the LLW Pretreatment Development for Enhancements and Alternatives (Unfunded Tasks) include:

- Conduct acid dissolution tests with actual sludges, FY 1994-1995 cores (PNL).
- Conduct acid dissolution tests with actual sludges, FY 1995 - outyears cores (PNL).
- Conduct batch solvent extraction (SX) tests for strontium and TRU removal, FY 1994-1995 cores (PNL).
- Conduct batch solvent extraction (SX) tests for strontium and TRU removal, FY 1995-outyears cores (PNL).
- Conduct tests on alternatives to acid side solvent extraction (PNL).
- Conduct bench scale solvent extraction study, cold systems, FY 1995 tests (PNL).
- Conduct bench scale solvent extraction studies, cold systems, FY 1996 - outyears tests (PNL).
- Conduct bench scale solvent extraction system, design hot system, FY 1995 (PNL).
- Conduct bench scale solvent extraction system, construct hot system, FY 1995-1997 (PNL).
- Conduct bench scale solvent extraction system, hot system, FY 1997 (PNL).
- **NOTE**: The previous three tasks (xx.10, xx.11, xx.12) are all part of an integrated project. All or none must be funded.

- Develop acid side cesium solvent extraction system (ANL).
- Conduct acid side cesium extraction system (PNL).
- Conduct acid side cesium removal test using CST and actual waste for batch (PNL).
- Conduct acid side cesium removal test using CST and actual waste for column (PNL).
- Update generic TRUEX model (ANL).
- Improved Solid/Liquid Separation through Addition of Co-precipitants.
- Treatment of Residue from Acid Dissolutions.
- Evaporation/Concentration of Separated Radionuclide Product Streams.
- Thermal reconstitution to improve caustic leaching.

Justification: Technologies for additional acid dissolution and reneutralization (reconstitution) must be complete to support Title I design for the HLW pretreatment facility scheduled to start in November 1998.

Even after reconstitution, the HLW volumes may be too large and require further reduction. Thus the entire sludge may need to be dissolved in concentrated acids. Technologies for total dissolution must be developed to the point that they are representative for all waste types so that their benefits and tradeoffs can be assessed for their addition/revision to the base case 3 months before the milestone to evaluate the effectiveness of such treatment (M-50-03, March 1998), therefore by December 1997. For planning purposes, it is assumed that this 3/98 TPA decision will support the planning assumption, and therefore this work will terminate after the 3/98 decision.

Drivers:

- M-50-03, 3/31/98
- M-50-04-T02 by 11/30/98

Level of Maturity (Basic Research, Applied Research, Technology or Laboratory Development, Advanced Development, Engineering Development, Demonstration, First Production, or Operations): Applied Research, Laboratory Development, Advanced Development

Key Uncertainties:

- Sludge chemical/radiochemical compositions in individual tanks.
- Chemical form/speciation of components that govern the amount of HLW.
- Effectiveness of enhanced sludge washing in reducing HLW volume.
- Effectiveness of enhancement processes, such as oxidation of chromium (III), to further reduce HLW volume.
- Effectiveness of alternative processes, such as acid dissolution in reducing HLW volume.

Key Deliverables (Date, Deliverable):

- Issue a report on acid dissolution tests with actual sludge.

- Issue a report on non-thermal reconstitution tests.
- Issue a report on batch solvent extraction tests for strontium and TRU removal.

Basis For Cost Estimates: Historical data, comparison with similar projects, actual costs where possible.

Template Title: HLW Pretreatment Development for Enhancements and Alternatives (Unfunded Tasks)

Template Number: 6.4.10

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
1.	*Conduct acid dissolution tests with actual sludges*(a)	*N*				*0*	*1st year* *2nd year* *3rd year*	*500* *500* *500*	*1,500*	*PNL FY 1994-1995 studies*
2.	*Level 3. Conduct bench scale solvent extraction system, design hot system, FY 1995*	*N*				*0*	*1st year*	*0.0* *500*	*0.0* *500*	
3.	*Level 3. Conduct bench scale solvent extraction system, construct hot system, FY 1995-1997 (PNL)*	*N*				*0*	*3rd year program*	*0.0* *3,800*	*0.0* *3,800*	
4.	*Level 3. Conduct bench scale solvent extraction system, hot system, FY 1997*	*N*				*0*	*1st yar*	*0.0* *4,200*	*0.0* *4,200*	
5.	*Level 3. Treatment of Residue from Acid Dissolutions*	*N*				*0*	*1st year* *2nd year* *3rd year*	*450* *450* *450*	*1,350*	
6.	*Level 3. Deferred for Engineering Study Evaporation/Concentration of Separated Radionuclide Product Streams*	*N*				*0*	*1st year* *2nd year*	*50* *TBD*	*50* *TBD*	

(a) Fund immediately.
(b) "Best" estimates at this time. Need better assumptions before estimating reasonable costs.

Template Title: HLW Pretreatment Development for Enhancements and Alternatives (Unfunded Tasks)

Template Number: 6.4.10

Tasks					Capital ($K)		Expense ($K)			
No.	Title	MYWP	Start Date	End Date	Year	Amount	Year	Amount	Total	Predecessors/ Successors
7.	*Deferred for Engineering Study Improved solid/liquid separation through addition of co-precipitants*	*N*				*0*	*1st year* *2nd yar*	*300* *300*	*600*	
8.	*Deferred for Engineering Study. Thermal reconstitution to improve caustic leaching*	*N*				*0*	*1st year* *2nd year*	*150* *TBD*	*150* *TBD*	

(a) Fund immediately.
(b) "Best" estimates at this time. Need better assumptions before estimating reasonable costs.

Appendix E

Program Element Templates

Contents: Low-Level Waste Immobilization (Chapter 7)

7.4.1 Develop/Adapt Suitable Melter Feed Preparation Flowsheet and System E-7-3
7.4.2 Develop Simulant Characteristics for Phase II Melter Testing E-7-6
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Template Title: **Develop/Adapt Suitable Melter Feed Preparation Flowsheet and System**

Template Number: **7.4.1**

Technology Package Type (Reference, Enhancement, or Alternative): Reference

Baseline Program (Y/N): Yes

WBS ID Number and Title: 1.1.1.3.02.02.03 Integrated Process Systems

Program Element: LLW Immobilization

Functional Need Level 4: Immobilize & Dispose LLW (4.2.2.4)

Functional Need Level 5: Treat LLW (4.2.2.4.1)

Functional Need Level 6: None

Functional Need Level 7: None

Scope: Evaluate and select candidate feed preparation methods for melters under consideration. Identify technology development issues. Perform required analyses, development work, and testing to resolve issues.

Justification: The TPA technical strategy is that LLW will be vitrified and disposed of in retrievable form using, if possible, commercial melter technology.

Feed preparation before vitrification has significant economic, product quality, and effluent impacts. Use of dried or calcined feeds can reduce the melter power requirements and make more efficient use of the melter, rather than using the melter as an evaporator. As noted, a number of species can be contained or released from the glass melt depending on feed preparation and chemistry, which has a significant impact upon both product quality and effluents.

Drivers:

- TPA Milestone M-60-01 requires that LLW melter testing with simulants begin by September 1994
- TPA Milestone M-60-02 requires that the melter feasibility and system operability tests be completed
- reference melter(s) selected 6/96; M-60-02
- reference LLW glass formulation (meeting complete system requirements) established by June 1996
- Radiological Air Emissions permit, WAC 246-247

Constraints: The operation of the melter and the composition of the vitrified LLW must meet the requirements of the Federal, State, and local laws, rules, and regulations. This will be in addition to the system/processing requirements, production capability, and program costs.

Level of Maturity (Basic Research, Applied Research, Technology or Laboratory Development, Advanced Development, Engineering Development, Demonstration, First Production, or Operations): Advanced Development

Key Uncertainties: The LLW melter has not been selected. Trade offs between feed characteristics and melter performance have not been defined. Chemistry, behavior, and performance of Hanford LLW feeds in many candidate feed preparation technologies has not been evaluated. Waste recycle compositions have not been evaluated for impact.

Key Deliverables (Date, Deliverable):

- recommend initial feed specification to A/E (6/96) (Task 1)
- recommend disposition of recycle stream (6/96) (Task 2)

Template Title: Develop/Adapt Suitable Melter Feed Preparation Flowsheet and System

Template Number: 7.4.1

Tasks		MYWP	Start Date	End Date	Capital		Expense		Total	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
1.	Evaluate melter feed prep techniques	Y	1/95	9/97		0	FY 1995 FY 1996 FY 1997	400 700 90	400 700 90	Melter testing
2.	Process recycle streams	Y	4/95	9/96		0	FY 1995 FY 1996	90 550	90 550	Melter testing
Total										

Template Title: Develop Simulant Characteristics for Phase II Melter Testing

Template Number: 7.4.2

Technology Package Type (Reference, Enhancement, or Alternative): Reference

Baseline Program (Y/N): Yes

WBS ID Number and Title: 1.1.1.3.02.02.02 LLW Simulant Development & Specifications

Program Element: LLW Immobilization

Functional Need Level 4: Immobilize & Dispose LLW (4.2.2.4)

Functional Need Level 5: Treat LLW (4.2.2.4.1)

Functional Need Level 6: None

Functional Need Level 7: None

Scope: Develop three to five simulants for Phase II melter testing. These simulants will represent more difficult waste than the DSSF simulant used in the Phase I testing. Phase II recipes for simulants will be developed which describe the chemical composition, mixing procedure, agitation, and storage conditions. Recipes will be supplied to a commercial chemical supplier for production of quantities adequate to conduct the Phase II melter tests.

Justification: Choice of simulants that represent reality and can discriminate between melters relative to their performance are critical in making the appropriate selection of melter feed, melter, and offgas technology.

Drivers: This activity interfaces with melter testing and is necessary to support TPA milestone M-60-01: Begin LLW melter testing with simulant. This activity also key to milestone M-60-02 (which calls for selection of a reference melter technology) because a simulant that is a good substitute for real waste is required to make a valid melter selection.

Level of Maturity (Basic Research, Applied Research, Technology or Laboratory Development, Advanced Development, Engineering Development, Demonstration, First Production, or Operations): Engineering Development

Key Uncertainties: Inadequate knowledge of waste chemistry in some tanks. That the choice of simulant is (a) a good test of melter performance and (b) accurately reflects actual future feed to the LLW plant.

Key Deliverables (Date, Deliverable):

- Phase II LLW Simulant Recipe (4/95) (Task 1)
- LLW simulant to Phase II melter vendors (6/95-6/96) (Task 1)

Template Title: Develop Simulant Characteristics for Phase II Melter Testing

Template Number: 7.4.2

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
1.	Develop and supply Phase II simulant	Y	10/94	6/96		0	FY 1995 FY 1996	500 430	500 430	Phase I simulant
Total										

Template Title: Develop Acceptable Methods of Incorporating Recycle Streams into Melter Product

Template Number: 7.4.3

Technology Package Type (Reference, Enhancement, or Alternative): Reference

Baseline Program (Y/N): Yes

WBS ID Number and Title: 1.1.1.3.02.02.02 Integrated Process System

Program Element: LLW Immobilization

Functional Need Level 4: Immobilize & Dispose LLW (4.2.2.4)

Functional Need Level 5: Treat LLW (4.2.2.4.1)

Functional Need Level 6: None

Functional Need Level 7: None

Scope: This activity will evaluate and develop recycle systems or waste forms and strategies for chemical species that are not soluble in the glass waste form, volatilize before vitrification, or create unstable glass matrices. Included in this scope are activities to monitor potential recycle streams for compatibility with vitrification and evaluate alternative waste forms and processes.

Justification: Utilization of waste streams through recycle can help alleviate waste generation streams and volumes; however, the addition of recycle streams can impact process chemistry, melter options, and glass product quality.

Drivers:

- TPA milestones for LLW, HLW, and Pretreatment
- type of melter/waste composition
- regulations regarding effluent release
- disposal regulations for nonrecycled components
- instability (or stability) of the waste forms with recycled components.

Level of Maturity (Basic Research, Applied Research, Technology or Laboratory Development, Advanced Development, Engineering Development, Demonstration, First Production, or Operations): Engineering Development

Key Uncertainties: LLW and TWRS baseline process flow sheets are not finalized. Streams available for recycle must be analyzed in conjunction with flow sheet development. The species to volatilize from melter operations have yet to be quantitatively defined. Whether the recycle streams can be incorporated into a vitreous waste form or any other waste form has yet to be defined. The addition of recycle streams containing volatile flouride, chloride, and sulfate could present significant corrosion issues.

Key Deliverables (Date, Deliverable):

- BARCT, BACT, and T-BACT analyses (6/97) (Task 4)

- Alternative technologies for offgas treatment (3/95) (Task 5)
- Evaluation of minor components on glass formulation (9/95) (Task 4)
- Nonvitrifiable waste forms (6/96) (Task 5)
- Technetium volatility report (1/95) (Task 2)

Template Title: Develop Acceptable Methods of Incorporating Recycle Streams into Melter Product

Template Number: 7.4.3

Tasks		MYWP	Start Date	End Date	Capital		Expense		Total	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
1.	*Identify potential recycle streams*	*N*	*12/94*	*6/95*		*0*	*FY 1995*	*150*	*150*	*TWRS process flowsheet*
2.	*Determine recycle compositions, concentrations and quantities*	*N*	*3/94*	*6/95*		*0*	*FY 1994* *FY 1995*	*300* *200*	*300* *200*	*TWRS process flowsheet*
3.	Determine and verify melter system impacts	Y	6/94	1/96		0		0	0	Melter tests
4.	Determine and verify product quality impacts	Y	6/94	9/97		0	FY 1995 FY 1996 FY 1997	140 150 150	140 150 150	Glass composition tests
5.	Evaluate and develop alternatives to recycle including alternative waste forms	Y	10/94	9/96		0	FY 1995 FY 1996	550 340	550 340	Task 2
6.	*Perform trade studies to evaluate alternate recycle concepts including recycle versus disposal*	*N*	*1/96*	*5/96*		*0*	*FY 1996*	*200*	*200*	*Task 5*
7.	*Perform additional melter and product effects studies*	*N*	*5/96*	*9/99*		*0*	*FY 1996* *FY 1997* *FY 1998* *FY 1999*	*100* *300* *400* *400*	*100* *300* *400* *400*	*Task 3*

Template Title: Develop Acceptable Methods of Incorporating Recycle Streams into Melter Product

Template Number: 7.4.3

Tasks		MYWP	Start Date	End Date	Capital		Expense		Total	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
8.	*Materials erosion/corrosion evaluation*	*N*	*6/96*	*9/98*		*0*	*FY 1996* *FY 1997* *FY 1998*	*200* *400* *500*	*200* *400* *500*	
Total										

Template Title: **Radioactive Testing**

Template Number: **7.4.4**

Technology Package Type (Reference, Enhancement, or Alternative): Reference

Baseline Program (Y/N): Yes

WBS ID Number and Title: 1.1.1.3.02.02.03 Integrated Process Systems

Program Element: LLW Immobilization

Functional Need Level 4: Immobilize & Dispose LLW (4.2.2.4)

Functional Need Level 5: Treat LLW (4.2.2.4.1)

Functional Need Level 6: None

Functional Need Level 7: None

Scope: Perform radioactive and nonradioactive testing to ensure the simulants used in process development provide results representative of the actual waste, to provide process development data that cannot be obtained from nonradioactive simulants, and validate the process and product models developed using simulants for safety, environmental analyses, permitting, licensing, and plant operations. The scope of the work here includes bench-scale nonradioactive and radioactive testing and includes the construction and installation of bench-scale vitrification systems for both cold and hot testing. Laboratory-scale testing to support glass formulation development and process chemistry evaluations are described within those templates.

Justification: The TPA technical strategy is that LLW will be vitrified and disposed of in retrievable form using, if possible, commercial melter technology.

Radioactive testing is required 1) to ensure that the simulants used in product and process development provide results representative of the actual wastes, 2) to provide process and product data on radioactive species that cannot be obtained from nonradioactive simulants, and 3) to validate the process and product models developed using simulants. If the simulants used in the product and process development are not validated, the vitrification plant and/or the glass product may not function as designed because the chemistry of the waste feed to the plant could be different because of process history, chemical history, and/or minor differences in composition.

Drivers:

- TPA milestone M-60-01 requires that LLW melter testing with simulants begin by September 1994.
- TPA milestone M-60-02 requires that the melter feasibility and system operability tests be completed, that the reference melter(s) be selected, and the reference LLW glass formulation (meeting complete system requirements) be established by June 1996.
- Radioactive testing is needed for simulant validation, to determine the behavior and impacts of minor waste components, and to validate process and product models.

Level of Maturity (Basic Research, Applied Research, Technology or Laboratory Development, Advanced Development, Engineering Development, Demonstration, First Production, or Operations): Advanced Development

Key Uncertainties: Does the development and design data obtained through experimental programs using nonradioactive simulants provide the same process behavior and product characteristics as the actual radioactive waste that the LLW vitrification plan will process? Are the radioactive waste samples received representative of the tank contents? Is the pretreatment process simulated representative of the processes planned for the actual wastes?

Key Deliverables (Date, Deliverable):

- Design for bench-scale LLW vitrification system (9/97) (Task 1)
- Complete installation of bench-scale LLW vitrification system for non-radioactive testing (9/99) (Task 2)
- Test plan for non-radioactive testing of bench-scale LLW vitrification system (3/99) (Task 3)
- Initiate non-radioactive testing of bench-scale LLW vitrification system (10/99) (Task 4)
- Report on non-radioactive testing of bench-scale LLW vitrification system (9/00) (Task 4)
- Test plan for radioactive testing of bench-scale LLW vitrification system (3/01) (Task 8)
- Complete installation of bench-scale LLW vitrification system for radioactive testing (9/01) (Task 7)
- Initiate radioactive testing of bench-scale LLW vitrification system (10/01) (Task 9)
- Report on radioactive testing of bench-scale LLW vitrification system comparing to nonradioactive testing and verifying design of LLW vitrification facility (6/03) (Task 9).

Basis For Cost Estimates: G. J. Sevigny, R. M. Burnside, and R. L. Bogart. 1991. Bench-Scale Radioactive Vitrification System - Implementation Plan. HWVP-C91-05.06A. Pacific Northwest Laboratory, Richland, Washington.

Template Title: Radioactive Testing

Template Number: 7.4.4

Tasks		MYWP	Start Date	End Date	Capital		Expense		Total	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
1.	*Design non-rad system*	*N*	*10/95*	*9/97*		*0*	*FY 1996* *FY 1997*	*200* *600*	*200* *600*	
2.	*Procure and install non-rad system*	*N*	*10/96*	*9/99*		*0*	*FY 1997* *FY 1998* *FY 1999*	*400* *3,000* *1,100*	*400* *3,000* *1,100*	1 year after start of 235
3.	*Plan and prepare non-rad tests*	*N*	*10/97*	*1/00*		*0*	*FY 1998* *FY 1999* *FY 2000*	*100* *100* *100*	*100* *100* *100*	235
4.	*Conduct and report tests*	*N*	*2/00*	*6/00*		*0*	*FY 2000*	*800*	*800*	237
5.	*Design rad mods*	*N*	*10/96*	*9/2000*		*0*	*FY 1997* *FY 1998* *FY 1999* *FY 2000*	*25* *300* *300* *25*	*25* *300* *300* *25*	1 year after start of 235
6.	*Rad permitting*	*N*	*10/96*	*9/00*		*0*	*FY 1997* *FY 1998* *FY 1999* *FY 2000*	*200* *150* *250* *50*	*200* *150* *250* *50*	1 year after start of 235
7.	*Install rad system*	*N*	*10/99*	*9/01*		*0*	*FY 2000* *FY 2001*	*1,000* *1,400*	*1,000* *1,400*	238
8.	*Plan and prepare rad tests*	*N*	*10/99*	*6/01*		*0*	*FY 2000* *FY 2001*	*150* *550*	*150* *550*	237

Template Title: Radioactive Testing

Template Number: 7.4.4

Tasks		MYWP	Start Date	End Date	Capital		Expense		Total	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
9.	*Conduct and report rad tests*	*N*	*7/01*	*9/04*		*0*	*FY 2001* *FY 2002* *FY 2003* *FY 2004*	*1,900* *3,300* *3,550* *3,300*	*1,900* *3,300* *3,550* *3,300*	242
10.	*Hot-cell decommissioning*	*N*	*10/00*	*9/04*		*0*	*FY 2001* *FY 2002* *FY 2003* *FY 2004*	*600* *800* *800* *1,300*	*600* *800* *800* *1,300*	1 year after start of install rad equipment
Total										

Template Title: Evaluate/Adapt Melter Technology for LLW Vitrification

Template Number: 7.4.5

Technology Package Type (Reference, Enhancement, or Alternative): Reference

Baseline Program (Y/N): Yes

WBS ID Number and Title: 1.1.1.3.02.02.01 Melter Selection

Program Element: LLW Immobilization

Functional Need Level 4: Immobilize & Dispose LLW (4.2.2.4)

Functional Need Level 5: Treat LLW (4.2.2.4.1)

Functional Need Level 6: None

Functional Need Level 7: None

Scope: Provide the basis for selecting a reference melter technology to immobilize LLW. This will be accomplished by phased testing of melters using simulated waste feed. The melter vendors will produce glass with simulated waste and collect data to be used in evaluation of the melters. Melters will be evaluated for operability, maintainability, stability, footprint, maturity of the system, applicability of operation in a radioactive environment, ability to scale up capacity, and ease of decontamination.

Justification: The TWRS program strategy developed as a result of the TPA specifies the use of commercial melter technologies if possible. To accomplish this, a selected range of commercially available systems need to be evaluated and feasibility established by testing. Results will be used in determining a reference system to be carried forward by A&E firm to design the facility.

Drivers:

- TPA milestone M-60-02 calling for selection of the reference LLW melter technology by June 1996
- variation of waste feeds from tanks dictate the need for a melter with adequate flexibility
- operational and maintenance requirements
- design-basis information to an A&E.

Level of Maturity (Basic Research, Applied Research, Technology or Laboratory Development, Advanced Development, Engineering Development, Demonstration, First Production, or Operations): Demonstration

Key Uncertainties: Absence of experience in vitrification processing of high sodium and nitrate chemicals; composition uncertainties of melter feed and variability; glass product specifications based on performance are to be determined; product testing and control requirements are to be determined; ability to scale up melter design unit based on available test system.

Key Deliverables (Date, Deliverable):

- Phase I Report and selection (6/95) (Task 1)
- Phase II Report identifying reference technology selected, supporting test results, and remaining technology development issues (6/96) (Task 2)

Template Title: Evaluate/Adapt Melter Technology for LLW Vitrification

Template Number: 7.4.5

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
1.	Phase I melter testing	Y	10/94	6/95		0	FY 1995	8,000	8,000	
2.	Phase II melter testing	Y	6/95	6/96		0	FY 1995 FY 1996	3,000 5,000	3,000 5,000	Phase I
3.	Phase III melter testing for A&E	Y	6/96	12/96		0	FY 1996 FY 1997	2,000 500	2,000 500	Phase II
Total										

Template Title: Develop Glass Waste Form and Glass Specification

Template Number: 7.4.6

Technology Package Type (Reference, Enhancement, or Alternative): Reference

Baseline Program (Y/N): Yes

WBS ID Number and Title: 1.1.1.3.02.02.02 LLW Simulant Development & Specifications

Program Element: LLW Immobilization

Functional Need Level 4: Immobilize & Dispose LLW (4.2.2.4)

Functional Need Level 5: Treat LLW (4.2.2.4.1)

Functional Need Level 6: None

Functional Need Level 7: None

Scope: Develop LLW glass waste form and glass specification including identification of a reference glass formulation and developing a computer model of glass composition and property. Develop supporting experimental basis for melter processability, waste loading, minor troublesome components in the waste, and glass durability.

Justification: The Tri-Party Agreement (TPA) calls for the vitrification of the low-activity portions of Hanford's DST and SST wastes. The LLW Immobilization Program will vitrify wastes received from the retreatment end function and must operate and produce an acceptable waste glass to meet regulatory requirements. This activity is needed to define the constraints that the LLW vitrification end function will impose on the other TWRS components to meet the LLW immobilization mission.

Drivers:

- TPA Milestone M-60-02 specifies defining a reference LLW glass which meets complete system requirements by June 1996.
- TPA Milestone M-60-03 calls for completion of a definitive design of the LLW vitrification facility by November 1996.
- The reference glass formulation will guide the LLW product specification and Performance Assessment (PA).

Level of Maturity (Basic Research, Applied Research, Technology or Laboratory Development, Advanced Development, Engineering Development, Demonstration, First Production, or Operations): Technology Development

Key Uncertainties: Whether durability tests reflect actual performance in service. Key uncertainties include the waste compositions to be vitrified, the final melter technology and glass formulation(s) to be used, and the overall process flowsheet to be implemented.

Key Deliverables (Date, Deliverable):

- Reference glass formulation and backup; supporting data on waste loading, problem waste components, and durability (Task 1) (6/96)

- Computer-based glass composition model (Task 6) (6/97)
- Recommend standardized durability test (Task 5) (9/97)

Template Title: Develop Glass Waste Form and Glass Specification

Template Number: 7.4.6

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
1.	Reference glass composition	Y	10/94	6/96		0	FY 1995 FY 1996	1,185 1,000	1,185 1,000	
2.	Glass optimization	Y	6/96	9/03		0	FY 1995 FY 1996 FY 1997 FY 1998 FY 1999 FY 2000 FY 2001 FY 2002 FY 2003	0 200 500 500 500 500 500 500 500	0 200 500 500 500 500 500 500 500	Task 1
3.	[High] waste loading	Y	10/94	9/96		0	FY 1995 FY 1996	160 160	160 160	
4.	Troublesome components	Y	10/94	9/97		0	FY 1995 FY 1996 FY 1997	540 350 390	540 350 390	

Template Title: Develop Glass Waste Form and Glass Specification

Template Number: 7.4.6

Tasks			Start	End	Capital ($K)		Expense ($K)			Predecessors/
No.	Title	MYWP	Date	Date	Year	Amount	Year	Amount	Total	Successors
5.	Durability testing	Y	10/94	9/03		0	FY 1995 FY 1996 FY 1997 FY 1998 FY 1999 FY 2000 FY 2001 FY 2002 FY 2003	1,120 1,450 1,520 600 600 600 600 600 600	1,120 1,450 1,520 600 600 600 600 600 600	
6.	Glass modeling	Y	10/94	9/97		0	FY 1995 FY 1996 FY 1997	300 300 300	300 300 300	
7.	Improved glass durability (glass surface treatments)	Y	10/94	9/96		0	FY 1995 FY 1996	100 500	100 500	
Total						0.00				

Template Title: **Develop/Adapt Suitable Melter Offgas System**

Template Number: **7.4.7**

Technology Package Type (Reference, Enhancement, or Alternative): Reference

Baseline Program (Y/N): Yes

WBS ID Number and Title: 1.1.1.3.02.02.03 Integrated Process System

Program Element: LLW Immobilization

Functional Need Level 4: Immobilize & Dispose LLW (4.2.2.4)

Functional Need Level 5: Immobile LLW (4.2.2.4.1)

Functional Need Level 6: None

Functional Need Level 7: None

Scope: This activity will provide data for offgas analyses (BACT, T-BACT, and BARCT), system design, and operation and will collect data from radioactive and cold vitrification and melter tests. Recommendations for technology to be incorporated in the facility design will be prepared for the Architect/Engineer (A/E).

Justification: The vitrification process will generate volatile and semi-volatile radioactive and hazardous effluents that must be recycled or treated to have a successful operation and meet environmental requirements to air emissions and waste minimization standards. For the combustion-driven melter, these materials must be trapped or managed in the presence of a very large stream of combustion and reduction products.

Drivers:

- TPA milestone and local, State, and Federal clean air regulations
- 40 CFR 61, subpart H National Emission Standards for Hazardous Air Pollutants
- WAC 246-247, Radiation Protection—Air Emissions
- WAC 173-400, General Regulations for Air Pollution Sources
- WAC 173-460, Controls for New Sources of Toxic Air Pollutants
- Washington Clean Air Act of 1967, Chapter 70.94.

Level of Maturity (Basic Research, Applied Research, Technology or Laboratory Development, Advanced Development, Engineering Development, Demonstration, First Production, or Operations): Engineering Development

Key Uncertainties: Offgas treatment systems have been developed for HLW vitrification systems, which operate at much lower capacities than that required for Hanford's LLW vitrification system. Gaseous effluent treatment systems have also been developed for commercial glass melters. The requirements of the LLW vitrification offgas system combine the qualitative and quantitative challenges of high-level radioactive waste processing and commercial vitrification.

There is a question of whether any emission controls are needed by TWRS for tritium or carbon-14. For this development plan it is assumed that, pending tank data collection, tritium or carbon-14 treatment will not be needed, and that release limits will be higher than the concentrations in plant effluent. Nitrous oxides released from the entire site must meet regulatory limits. The nitrous oxides control technology using the catalyzed reaction with ammonia is well developed, but its application would need to be demonstrated for this offgas stream.

The requirements of the Hanford system are qualitatively and quantitatively different from previous radioactive offgas treatment systems and will be a key design challenge and constraint. Key uncertainties include the waste compositions to be vitrified, the melter concept to be used, melter operating conditions (temperature, residence time, degree of mixing, redox conditions, etc.) discharge limits and margins to be used in the flow sheet design, composition and behavior of the offgas and the overall process flowsheet to be implemented.

Key Deliverables (Date, Deliverable): TBD

- BACT analysis (12/97) (Task 11)
- BARCT analysis (12/97) (Task 11)
- T-BACT analysis (12/97) (Task 11)
- Air Permits (NESHAP, etc.) (12/97) (Task 11)
- Test results for offgas emissions (9/96) (Task 6)

Template Title: Develop/Adapt Suitable Melter Offgas System

Template Number: 7.4.7

Tasks		MYWP	Start Date	End Date	Capital		Expense		Total	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
1.	Develop Process flowsheet	Y	3/94	12/94		0		0		Pretreatment
2.	Determine likely offgas products and quantities for melter type, operating conditions, waste composition and recycle streams	Y	10/94	9/96		0	FY 1995 FY 1996	200 400	*200* 400	
3.	Preliminary BARCT/BACT	Y	10/94	9/95		0	FY 1995	55	55	
4.	Final BARCT/BACT/T-/BACT	Y	3/95	12/97		0	FY 1996 FY 1997 FY 1998	250 500 100	250 500 100	
5.	Evaluate recycles	Y	3/94	9/99		0		0	0	Pretreatment
6.	*Testing and evaluation support to design*	*N*	*10/96*	*9/00*		*0*	*FY 1997* *FY 1998* *FY 1999* *FY 2000*	*200* *200* *200* *200*	*200* *200* *200* *200*	
7.	Review melter offgas test data	Y	12/94	6/96		0		0		Melter testing
8.	*Materials compatibility*	*N*	*10/96*	*9/98*		*0*	*FY 1997* *FY 1998*	*400* *400*	*400* *400*	

Template Title: Develop/Adapt Suitable Melter Offgas System

Template Number: 7.4.7

Tasks		MYWP	Start Date	End Date	Capital		Expense		Total	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
9.	Characterization of offgas deposits	Y	12/94	6/96				0	*0*	Melter testing
10.	Melter offgas treatment evaluation	Y	1/95	9/96		0	FY 1995 FY 1996	265 300	265 300	
Total										

Template Title: Develop Additional Waste Forms

Template Number: 7.4.8

Technology Package Type (Reference, Enhancement, or Alternative): Reference

Baseline Program (Y/N): Yes

WBS ID Number and Title: 1.1.1.3.02.02.08 Non-Vitrifiable Waste

Program Element: LLW Immobilization

Functional Need Level 4: Immobilize & Dispose LLW (4.2.2.4)

Functional Need Level 5: Immobilize LLW (4.2.2.4.1)

Functional Need Level 6: None

Functional Need Level 7: None

Scope: Identify nonvitrifiable products from the vitrification process. Review process flowsheets to determine if nonvitrifiable products can be captured in HLW or recycled through pretreatment. Determine the best disposal form for nonvitrifiable products and develop a disposal system. Emphasis will be on low temperature stabilization mechanisms for the volatile components from the LLW vitrification plant.

Justification: TPA milestone M-60-03 requires start of definitive design of the LLW vitrification plant by November 1996. Issues of flowsheets, partitioning waste, and recycle streams must be defined for inclusion in that design process.

Drivers: The need to:

- immobilize or recycle all waste coming from pretreatment
- melter technology and offgas systems not yet decided
- ability or inability of HLW to accept recycle streams.

Level of Maturity (Basic Research, Applied Research, Technology or Laboratory Development, Advanced Development, Engineering Development, Demonstration, First Production, or Operations): Technology Development

Key Uncertainties: Lack of knowledge of some tank chemistries; feed chemistry and variability of feed stream; performance of LLW offgas and recycle stream systems; performance specification of LLW glass; existence of suitable alternate waste forms; emissions issues related to recycling volatiles.

Key Deliverables (Date, Deliverable):

- Candidate additional waste forms (1/96) (Task 2)
- Flowsheet and process engineering data for treating nonvitrifiable components (9/96) (Task 2)

Basis For Cost Estimates:

Task 1--3.5 FTE plus incidentals; Task 2--2 FTE plus incidentals.

Template Title: Develop Additional Waste Forms

Template Number: 7.4.8

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
1.	Identify waste forms and validate proposed components	Y	10/94	9/95		0	FY 1995	500	500	
2.	Final waste form validation	Y	10/95	9/96		0	FY 1996	490	490	Task 1
Total										

Template Title: Develop/Adapt LLW Vitrification System Instrumentation and Controls

Template Number: 7.4.9

Technology Package Type (Reference, Enhancement, or Alternative): Reference

Baseline Program (Y/N): Yes

WBS ID Number and Title: 1.1.1.03.02.02.03 Integrated Process System

Program Element: LLW Immobilization

Functional Need Level 4: Immobilize & Dispose LLW (4.2.2.4)

Functional Need Level 5: Analyze Immobilized LLW Samples (4.2.2.4.2), Monitor & Control Immobilized LLW Process (4.2.2.4.3)

Functional Need Level 6: None

Functional Need Level 7: None

Scope: This activity will identify facility data needs for product quality, process control, regulatory reporting, and other supporting requirements. Technical evaluations will provide data and recommended selections for instrumentation, controls, and analytical methods in sensitive (non-routine) applications. Where data requirements or the service conditions (i.e., radiation, chemistry, heat) are unique and cannot be serviced by existing commercial vendors, this activity will develop instrumentation.

Justification: The LLW vitrification and disposal facilities include processes and generate products/effluents that require control and monitoring. The vitrification process and disposal operations must be controlled in a safe and environmentally sound manner. Melter and support systems operations must be monitored and controlled to ensure the final product meets specifications.

Drivers:

- pretreatment waste composition and variability
- LLW product quality requirements
- melter design and melter performance requirements
- offgas system design and recycle streams
- melter subsystems (feed, recycle, product, etc.)
- TPA milestones related to LLW melter testing, selection, design, and construction
- need for instrumentation to be long-lived and easily maintained with minimum worker radiation exposure.

Level of Maturity (Basic Research, Applied Research, Technology or Laboratory Development, Advanced Development, Engineering Development, Demonstration, First Production, or Operations): First Production

Key Uncertainties: The LLW vitrification and disposal facilities are currently preparing for conceptual design. The facility design, processes, operating constraints, and permit requirements have yet to be deplant. The selection and/or availability of commercial instrumentation to meet plant and program needs has yet to be defined.

Key Deliverables (Date, Deliverable):

- Process and Disposal data requirements (9/98) (Task 6)
- Process and Disposal facility control and monitoring approach (9/98) (Task 7)
- Conceptual Design (9/99) (Task 5)
- Instrumentation and control technical needs definition (9/98) (Task 7)

Template Title: Develop/Adapt LLW Vitrification System Instrumentation and Controls

Template Number: 7.4.9

Tasks		MYWP	Start Date	End Date	Capital		Expense		Total	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
1.	Melter operational models evaluate and recommend	N	10/95	9/99		0	FY 1996 FY 1997 FY 1998 FY 1999	100 100 200 200	100 100 200 200	
2.	Develop melter head end control methods	N	10/95	9/99		0	FY 1996 FY 1997 FY 1998 FY 1999	150 200 350 300	150 200 350 300	
3.	Develop melter sampling systems	N	10/96	9/99		0	FY 1997 FY 1998 FY 1999	200 200 300	200 200 300	
4.	Develop operational analysis techniques	N	10/95	9/99		0	FY 1996 FY 1997 FY 1998 FY 1999	300 400 500 400	300 400 500 400	
5.	Develop melter operational strategies and methods	N	10/97	9/99		0	FY 1998 FY 1999	50 100	50 100	
6.	Evaluate process and disposal data requirements	N	10/95	9/98		0	FY 1996 FY 1997 FY 1998	150 150 150	150 150 150	
7.	Process and disposal control and monitoring approach	N	10/95	9/98		0	FY 1996 FY 1997 FY 1998	200 300 200	200 300 200	

Template Title: Develop/Adapt LLW Vitrification System Instrumentation and Controls

Template Number: 7.4.9

Tasks		MYWP	Start Date	End Date	Capital		Expense		Total	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
8.	*Evaluate commercial instrumentation availability*	*N*	*10/95*	*9/96*		*0*	*FY 1996*	*200*	*200*	
9.	*Technology development/ verification testing*	*N*	*10/95*	*9/98*		*0*	*FY 1996* *FY 1997* *FY 1998* *FY 1999*	0 *300* *400* *400*	0 *300* *400* *400*	
Total										

Template Title: Develop Systems to Form, Sample, and Prepare/Transport LLW Product

Template Number: 7.4.10

Technology Package Type (Reference, Enhancement, or Alternative): Reference

Baseline Program (Y/N): Yes

WBS ID Number and Title: 1.1.1.3.02.02.03 Integrated Process System

Program Element: LLW Immobilization

Functional Need Level 4: Immobilize & Dispose LLW (4.2.2.4)

Functional Need Level 5: Treat LLW (4.2.2.4.1)

Functional Need Level 6: None

Functional Need Level 7: None

Scope: This activity will assist the development of auxiliary systems to

- receive glass from the melter
- prepare the containers or the bulk transport materials (i.e., sulfur polymer cement)
- package the glass waste form (if necessary)
- transport the glass waste form to the storage/disposal facility
- recycle out-of-specification glass to the melter feed
- retrieve waste from the storage/disposal facility.

Justification: The TPA calls for the storage/disposal of vitrified LLW on the Hanford Site. Systems need to be developed to receive the sample melter vitrified product and to prepare and transport it to the storage/disposal facility.

Drivers:

- melter discharge features
- waste product specification
- storage/disposal location
- waste physical characteristics
- retrieval constraints
- vitrification and storage/disposal facilities must begin operations by 2005.

Level of Maturity (Basic Research, Applied Research, Technology or Laboratory Development, Advanced Development, Engineering Development, Demonstration, First Production, or Operations): Engineering development

Key Uncertainties: The LLW vitrification and disposal facilities are currently undergoing conceptual design. The melter and disposal configuration have yet to be defined. Information developed during the Grout Facility Program concerning waste transport that may be applicable has yet to be evaluated.

Key Deliverables (Date, Deliverable):

- disposal/packaging system concepts (3/96) (Task 2)
- final selection of disposal/packaging concept (12/97) (Task 3)

Template Title: Develop Systems to Form, Sample, and Prepare/Transport LLW Product

Template Number: 7.4.10

Tasks		MYWP	Start Date	End Date	Capital		Expense		Total	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
1.	*Obtain melter discharge recording system data*	*N*	*10/95*	*9/97*		*0*	*FY 1996* *FY 1997*	*200* *200*	*200* *200*	*Melter selection*
2.	Engineering disposal/ packaging system concepts	Y	6/95	3/96		0	FY 1995 FY 1996	30 30	30 30	
3.	Engineering disposal/ packaging system evaluation	Y	6/95	12/97		0	FY 1995 FY 1996 FY 1997	20 30 100	20 30 100	
4.	Field test disposal systems	Y	1/96	1/05		0	FY 1996 FY 1997 FY 1998 FY 2005	200 250 TBD TBD	200 250	
5.	Develop process flow–sheets	Y	1/95	9/96		0		0	0	Pretreatment
6.	Identify development needs	Y	3/96	3/98		0	FY 1997	50	50	
Total										

Template Title: **Develop Other Melter Subsystems**

Template Number: **7.4.11**

Baseline Program (Y/N): Yes

WBS ID Number and Title: 1.1.1.3.02.02.03 Integrated Process Systems

Program Element: LLW Immobilization

Functional Need Level 4: Immobilize & Dispose LLW (4.2.2.4)

Functional Need Level 5: Analyze Immobilized LLW Samples (4.2.2.4.2), Monitor & Control Immobilized LLW Process (4.2.2.4.3)

Functional Need Level 6: None

Functional Need Level 7: None

Scope: The LLW vitrification plant requires several subsystems to support waste vitrification. This package would include subsystems and unit operations not covered elsewhere, including product handling, solid and liquid waste treatment, and cold chemical handling. This activity will provide data for design and operation of these subsystems.

Justification: The TPA calls for the vitrification of the LLW portion of the tank waste. The melter used to produce the vitrified waste product will require support systems to perform glass former and cold chemical handling, product handling/packaging, product recycle, and waste treatment.

Drivers:

- TPA milestones related to LLW melter testing, selection, design, and construction
- dangerous waste permit regulations (WAC 173-303, 40 CFR 264, 265, 270)
- pretreatment waste discharge composition
- LLW product specification
- melter design and melter performance requirements.

Level of Maturity (Basic Research, Applied Research, Technology or Laboratory Development, Advanced Development, Engineering Development, Demonstration, First Production, or Operations): Engineering Development

Key Uncertainties: A number of commercial and nuclear concepts have been used or demonstrated for these plant subsystems. However, there is little or no experience using the equipment with the waste chemistry and in the same design configuration currently envisioned for the LLW vitrification plant. Data will be needed to ensure materials compatibility, radiation stability, remote operability, and maintainability. The current, baseline process flow sheet, which defines specific unit processes for the LLW vitrification facility, is based on the best available information. This activity will provide data to confirm, update, or optimize the process flow sheet and designs.

Key Deliverables (Date, Deliverable):

- System for conveying, loading, and retrieving (9/98) (Task1)

- System for rework/recycle (9/98) (Task 2)
- Frit handling system (9/98) (Task 4)

Template Title: Develop Other Melter Subsystems

Template Number: 7.4.11

Tasks		MYWP	Start Date	End Date	Capital		Expense		Total	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
1.	*Develop concepts design for material conveying and loading and retrieval subsystems*	*N*	*10/95*	*9/98*		*0*	*FY 1996* *FY 1997* *FY 1998*	*300* *500* *500*	*300* *500* *500*	
2.	*Develop product rework/ recycle concepts for out-of-specification product*	*N*	*10/95*	*9/98*		*0*	*FY 1996* *FY 1997* *FY 1998*	*500* *600* *400*	*500* *600* *400*	
3.	Material compatibility	Y	10/95	9/98		0	FY 1996 FY 1997 FY 1998	200 200 300	200 200 300	
4.	*Develop system for handling frit*	*N*	*10/95*	*9/98*		*0*	*FY 1996* *FY 1997* *FY 1998*	*200* *200* *300*	*200* *200* *300*	
5.	*Develop methods for treating liquid effluents*	*N*	*10/95*	*9/98*		*0*	*FY 1996* *FY 1997* *FY 1998*	*300* *400* *500*	*300* *400* *500*	
Total										

Template Title: Develop Waste Form Product Matrix/Packaging

Template Number: 7.4.12

Technology Package Type (Reference, Enhancement, or Alternative): Reference

Baseline Program (Y/N): Yes

WBS ID Number and Title: 1.1.1.3.02.02.07 LLW Packaging & Materials

Program Element: LLW Immobilization

Functional Need Level 4: Immobilize & Dispose LLW (4.2.2.4)

Functional Need Level 5: LLW (4.2.2.4.1)

Functional Need Level 6: None

Functional Need Level 7: None

Scope: Matrix and packaging materials and processes must be identified, evaluated, and developed for containing the vitrified LLW waste.

Justification: The glass discharged from the melter must be placed in a package for transport to the LLW storage/disposal facility. In some concepts, glass in the form of a cullet or other small shape will be placed in a matrix material before packaging and/or transport to the storage/disposal facility. These matrices and/or packaging materials must be identified/developed and evaluated before implementation for the immobilization of the LLW wastes.

Drivers:

- TPA Milestones M-60-03 Submit conceptual design and initiate definitive design of the LLW vitrification facility, and M-60-05 Initiate hot operations of the LLW vitrification facility.
- Processing considerations suggest that manufacturing glass pieces, such as a cullet or marbles rather than glass in canisters, may result in a cost saving and a reduction in radiation exposure to workers.
- Performance assessment analyses may show that glass pieces alone are not an adequate waste form for disposal of the LLW. Matrix materials would then be one option for improving the waste form performance. Alternatively, the design of the disposal system may evolve to provide the required performance.
- It is desired that the LLW vitrified waste form be readily retrievable from storage/disposal for at least 50 years after production.

Level of Maturity (Basic Research, Applied Research, Technology or Laboratory Development, Advanced Development, Engineering Development, Demonstration, First Production, or Operations): Applied Research, Engineering Development

Key Uncertainties: The final form of the glass to be immobilized will have a significant impact on the direction of this activity. If the disposal form is glass poured into a container, the focus of the work will be on the glass/canister interface and the properties (cracking, crystallization) of the glass in the canister. If the disposal form is glass pieces in a matrix, then the focus of the work will be on the glass matrix interface and the long-term stability of the matrix material in a disposal environment.

Key Deliverables (Date, Deliverable):

Identification and evaluation of waste form matrix/container alternatives (6/96) (Task 1)

Data to support selection of reference waste form concept, conceptual design of vitrification facility, and interim performance assessment (6/96) (Task 4)

Data to support preliminary performance assessment and bench- and pilot-scale vitrification system testing (6/98) (Task 4)

Template Title: Develop Waste Form Product Matrix/Packaging

Template Number: 7.4.12

Tasks		MYWP	Start Date	End Date	Capital		Expense		Total	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
1.	Identify and develop matrix/container materials	Y	10/94	9/96	0	0	FY 1995 FY 1996	300 200	300 200	Start
2.	Characterize sulfur polymer cement as matrix material	Y	10/94	9/98	0	0	FY 1995 FY 1996 FY 1997 FY 1998	700 700 600 400	700 700 600 400	Start
3.	Characterize alternative matrix material	Y	10/94	9/98	0	0	FY 1995 FY 1996 FY 1997 FY 1998	400 300 400 400	400 300 400 400	Task 1
4.	Characterize container material	Y	10/95	9/98	0	0	FY 1996 FY 1997 FY 1998	200 200 200	200 200 200	Start/Disposal system concept selection
5.	Characterize matrix/container materials from process testing	Y	10/97	9/05		0	FY 1998 FY 1999 FY 2000 FY 2001 FY 2002 FY 2003 FY 2004 FY 2005	300 500 300 300 100 0 150 150	300 500 300 300 100 0 150 150	2 years after start of Task 3
Total										

Template Title: Develop Method for Controlling and Verifying Glass Waste Form Quality

Template Number: 7.4.13

Technology Package Type (Reference, Enhancement, or Alternative): Reference

Baseline Program (Y/N): Yes

WBS ID Number and Title: 1.1.1.3.02.02.04 Product Quality Verification

Program Element: LLW Immobilization

Functional Need Level 4: Immobilize & Dispose LLW (4.2.2.4)

Functional Need Level 5: Analyze Immobilized LLW Samples (4.2.2.4.2), Monitor & Control Immobilized LLW process (4.2.2.4.3), Dispose & Immobilized LLW/Close Site (4.2.2.4.5)

Functional Need Level 6: None

Functional Need Level 7: None

Scope: Develop methods other than destructive testing to verify vitrified product quality and performance.

Justification: Verification under the purview of the RCRA as implemented in Title 40 of the CFR Parts 264, 265, and 268, and the Tri-Party Agreement, Chapters 173-303 of the WAC and DOE Order 5820.2A.

Drivers:

- Part B Permit for disposal of LLW
- quality of glass to meet Performance Assessment (PA) requirements
- integrity of waste form
- ability to perform onsite disposal of LLW and obtain necessary regulatory documentation.

Level of Maturity (Basic Research, Applied Research, Technology or Laboratory Development, Advanced Development, Engineering Development, Demonstration, First Production, or Operations): Technology Development

Key Uncertainties: Design of disposal and LLW glass handling systems; packaging of vitrified materials (container design).

Key Deliverables (Date, Deliverable):

- Candidate NDE approaches identified and screened (6/95) (Task 1)
- Technique demonstration (6/96) (Task 1)
- Electrochemical or other NDE system to measure quality of glass and waste form (6/98) (Task 2)

Template Title: Develop Method for Controlling and Verifying Glass Waste Form Quality

Template Number: 7.4.13

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
1.	Conduct laboratory development on optical electrical and spectroscopic monitoring	Y	10/94	9/97		0	FY 1995 FY 1996 FY 1997	400 500 400	400 500 400	Previous scoping evaluations
2.	*Prototyping and advanced development*	*N*	*10/97*	*6/98*		*0*	*FY 1998*	*1,000*	*1,000*	*Task 1*
Total										

Template Title: Develop LLW Disposal System Components

Template Number: 7.4.14

Technology Package Type (Reference, Enhancement, or Alternative): Reference

Baseline Program (Y/N): Yes

WBS ID Number and Title: 1.1.1.03.02.04.01.04 Define Process & Disposal System Requirements & Concept

Program Element: LLW Immobilization

Functional Need Level 4: Immobilize & Dispose LLW (4.2.2.4)

Functional Need Level 5: Dispose Immobilized LLW/Close Site (4.2.2.4.5)

Functional Need Level 6: None

Functional Need Level 7: None

Scope: Physical, chemical and hydraulic barriers and other required components will be identified, evaluated, and developed as part of an engineered disposal system for the near-surface disposal of vitrified LLW. This work is focused on the disposal system itself. The glass and any matrices and containers are discussed in other sections on the glass formulation and matrix/packaging materials respectively.

Justification: Performance assessment analyses may indicate the a glass waste form in its matrix and/or container by itself may not adequately control the long-term release of radionuclides to meet safety and environmental protection requirements. The engineered disposal system would then require physical, chemical and/or hydraulic barriers to meet the performance objectives. The barriers must be identified/ developed and evaluated prior to implementation for the disposal of the LLW wastes.

Drivers:

- TPA Milestones M-60-03 Submit conceptual design and initiate definitive design of the LLW vitrification facility, and M-60-05 Initiate hot operations of the LLW vitrification facility.
- Performance assessment analyses may show that glass pieces alone are not an adequate waste form for disposal of the LLW. Matrix materials would then be one option for improving the waste form performance. Alternatively, the design of the disposal system may evolve to provide the required performance.
- It is desired that the LLW vitrified waste form be readily retrievable from storage/disposal for at least 50 years after production.

Level of Maturity (Basic Research, Applied Research, Technology or Exploratory Development, Advanced Development, Engineering Development, Demonstration, First Production, or Operations): Applied Research, Engineering Development

Key Uncertainties: The inventory of radionuclides to be disposed and the performance of the packaged vitrified waste including the glass and any matrices and/or containers will have a significant impact on the direction of this activity. Performance assessment analyses will indicate the need for additional barriers in the engineered disposal system.

Key Deliverables (Date, Deliverable):

- Procedures and data to support analysis and evaluation of disposal system concepts (9/04) (Task 3)
- Identify candidate barriers materials and TD needs (9/97) (Task 7)
- Data to support design, permitting and construction of the engineered disposal system (9/04) (Task 3)

Template Title: Develop LLW Disposal System Components

Template Number: 7.4.14

Tasks		MYWP	Start Date	End Date	Capital		Expense		Total	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
1.	Identify candidate physical, chemical, hydraulic barriers	Y	10/95	9/97		0	FY 1996	200	200	
2.	Initiate technology development for needed barriers	Y	10/97	9/02		50	FY 2002	500	550	
3.	Characterize performance/degradation of barrier concepts	Y	10/98	09/04		150	FY 2004	200	350	
4.	Field demonstration of barrier systems	Y	10/01	09/05		100	FY 2005	1,000	1,100	
Total										

Template Title: Determine Data and Tools Required to Support LLW Performance Assessment

Template Number: 7.4.15

Technology Package Type (Reference, Enhancement, or Alternative): Reference

Baseline Program (Y/N): Yes

WBS ID Number and Title: 1.1.1.03.02.04.02 Prepare LLW Performance Assessment

Program Element: Low Level Waste

Functional Need Level 4: Immobilize & Dispose LLW (4.2.2.4)

Functional Need Level 5: Dispose Immobilized LLW./Close Site (4.2.2.4.5)

Functional Need Level 6: None

Functional Need Level 7: None

Scope: Determine LLW radioactive inventories, vadose zone transport parameters, ground water transport parameters, dosimetry parameters, and facility dose allocation.

Justification: These data are required for a defensible Performance Assessment (PA). DOE Order 5820.2A, with expected revisions, will require completion and approval of a final PA before construction startup of the LLW disposal facility.

Drivers:

Schedule Drivers

- complete Interim PA in support of start of processing facility design (Fall 1996)
- approve (DOE) final PA in support of start of disposal facility construction (June 1999)
- DOE Order 5820.2A, to be revised to 5820.2B.

Level of Maturity (Basic Research, Applied Research, Technology or Laboratory Development, Advanced Development, Engineering Development, Demonstration, First Production, or Operations): Technology (data measurement and assessment)

Key Uncertainties: Of all parameters of importance to the PA, the most uncertain ones, to which the results are most sensitive, may be associated with the engineered part of the disposal system (or near-field) design. Therefore, the degree to which the far-field data are worth improving is not yet known. A key uncertainty in the inventory is the amount of technetium that will end up in the LLW glass. An important regulatory uncertainty is whether the Nuclear Regulatory Commission will be the ultimate party responsible for approval of the PA; at present, the assumption is that the DOE has approval responsibility.

Key Deliverables (Date, Deliverable):

- Report on total chemical inventory projected for LLW glass (6/95) (Task 1)
- Report on conceptual model of hydraulic properties from literature (6/95) (Task 2)
- Report on transport parameters through barriers (7/95) (Task 2)

- Report on vadose zone flow/transport properties for 200 area (9/95) (Task 2)
- Report on field experiment methodology and results of hydraulic property measurements (9/95) (Task 2)
- Report: Laboratory Tests on Source-Term Release Modeling (9/96) (Template 7.4.4)
- Report on hydraulic property measurement results (9/96) (Task 3)

Template Title: Determine Data and Tools Required to Support LLW Performance Assessment

Template Number: 7.4.15

Tasks		MYWP	Start Date	End Date	Capital		Expense		Total	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
1.	Inventory of Radionuclides	Y	6/94	9/98		0	FY 1995 FY 1996 FY 1997 FY 1998	200 200 200 200	200 200 200 200	N/A
2.	Vadose transport parameters	Y	10/94	9/98	FY 1996	100	FY 1995 FY 1996 FY 1997 FY 1998	2,100 2,000 2,000 2,000	2,100 2,000 2,000 2,000	N/A
3.	Ground water transport parameters	Y	10/94	9/98		0	FY 1995 FY 1996 FY 1997 FY 1998	200 200 200 200	200 200 200 200	N/A
4.	Dosimetry parameters	Y	10/94	9/98		0	FY 1995 FY 1996 FY 1997 FY 1998	100 100 50 50	100 100 50 50	N/A
Total										

Appendix E

Program Element Templates

Contents: High-Waste Immobilization (8.0)

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Template Title: **HLW Glass Formulation**

Template Number: **8.4.1.1**

Technology Package Type (Reference, Enhancement, or Alternative): Reference

Baseline Program (Y/N): Yes

WBS ID Number and Title: 1.1.1.3.03.02.01 HLW Process/Product Development

Program Element: HLW

Functional Need Level 4: Immobilize HLW/TRU Waste (4.2.2.2)

Functional Need Level 5: Treat HLW/TRU Waste (4.2.2.2.1)

Functional Need Level 6: Prepare Melter Feed (4.2.2.2.1.1)

Functional Need Level 7: None

Scope: Develop glass formulations for the HLW/TRU vitrification plant that are compatible with the plant vitrification process/equipment, maximize waste content in the glass, and meet regulatory and functional requirements for handling, inspection, storage, transportation, and disposal.

Justification: Glass formulation is required to make a product from HLW/TRU feeds that maximizes waste content, meets requirements for handling, inspection, storage, transportation, and disposal and is compatible with the plant vitrification process/equipment. To formulate such a glass product the relationships between waste loading in the product, product forming additives, and processing conditions (time at temperature history) need to be determined and controlled.

Drivers:

- TPA Milestone M-51-02, Complete melter tests and select reference melter (9/98).
- Glass formulations are needed for each major feed composition to the vitrification plant for melter system selection and testing and to ensure that an acceptable glass can be formulated and is compatible with plant processes and equipment.
- If acceptable glass formulations are not possible or practical with the feed composition, limitations on this composition and additional pretreatment actions may be necessary.

Level of Maturity (Basic Research, Applied Research, Technology or Laboratory Development, Advanced Development, Engineering Development, Demonstration, First Production, or Operations):
Advanced Development

Key Uncertainties:

- The composition and range of variation in wastes to be vitrified are unclear because of uncertainties and unavailability of tank waste composition data, and data on changes caused by waste processing and pretreatment.
- The type of melter may have a significant impact on the melter feed and glass product requirements; the melter has not been selected.
- Borosilicate glass may not have adequate capability to retain semivolatile and selected potentially volatile materials in the waste.

- Borosilicate glass may not be the most economic waste form (i.e., waste loading not maximum) or possess the best performance properties for all Hanford Site waste types.

Key Deliverables (Date, Deliverable):

11/23/94	issue letter report on critical minor components
12/22/94	publish formal PNL composition variability study (CVS) report
05/26/95	issue letter report on low-temperature glass formulation support for melter selection
07/28/95	issue revised glass formulation test plan for melter testing
09/29/95	issue draft report on P_20_5, Cr_20_3, and $S0_3$ in glass experimental study
09/29/95	issue draft project report on glass composition and durability data
09/30/96	formulate glass composition for melter conceptual design
09/30/96	issue update report on property, composition, and temperature relations
09/30/96	issue update report on critical component limits
09/30/97	specify reference glass types for definitive melter design
09/30/97	issue update report on critical component limits

Basis For Cost Estimates: Cost estimates are based on professional judgement of a panel of experts familiar with work of this nature.

Template Title: HLW Glass Formulation

Template Number: 8.4.1.1

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total ($K)	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
1.	Low temperature glass development	Y	10/94	5/96	FY 1995 FY 1996	50	FY 1995 FY 1996	289 0	330 0	• HLW glass formulation strategy • Glass formulation • Feed processability assessment • Feed composition spec
2.	High temperature glass formulation scoping tests	Y	10/94	9/95	FY 1995	0	FY 1995	342	342	• HLW glass formulation strategy • Glass formulation • Feed processability assessment • Feed composition spec

Template Title: HLW Glass Formulation

Template Number: 8.4.1.1

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total ($K)	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
3.	Test planning of glass formulation properties testing to support melter testing	Y	3/95	9/95	FY 1995	0	FY 1995	228	228	Issue CVS document/Second phase pretreatment–HLW interface optimization
4.	Glass formulation strategy development	Y	10/94	8/95	FY 1995	0	FY 1995	30	30	Develop optimal frit selection–process strategies–tools/
5.	Initial assessment of critical minor components in waste feeds	Y	10/94	11/94	FY 1995	0	FY 1995	32	32	/Second phase pretreatment–HLW interface optimization
6.	Solubility investigation of critical minor components in glass	Y	10/94	9/95	FY 1995	0	FY 1995	418	418	Initial assessment of critical minor components in waste feeds/Second phase pretreatment–HLW optimization
7.	CVS document issuance	Y	10/94	12/94	FY 1995	0	FY 1995	49	49	/Second phase pretreatment–HLW interface optimization
8.	Waste glass property composition relationships development	Y	10/94	9/95	FY 1995	0	FY 1995	181	181	Glass formulation/ Second phase pretreatment–HLW interface optimization

Template Title: HLW Glass Formulation

Template Number: 8.4.1.1

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total ($K)	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
9.	HLW feed processability assessment support	Y	10/94	9/95	FY 1995	0	FY 1995	81	81	Develop optimal frit selection–process strategies–tools/ Complete initial feed processability study
10.	Glass formulation studies supporting melter testing	Y	10/95	6/96	FY 1995 FY 1996	0 50	FY 1995 FY 1996	0 273	0 323	Plan melter testing glass formulation properties testing/ Update technical development test composition bases
11.	HTM glass formulation scoping studies documentation	Y	10/95	10/95	FY 1995 FY 1996	0 0	FY 1995 FY 1996	0 109	0 109	High temperature glass formulation scoping tests/Update technical development test composition basis
12.	Formulate/characterize glass for reference conceptual design	Y	12/95	9/96	FY 1995 FY 1996	0 0	FY 1995 FY 1996	0 273	0 273	Document HTM glass formulation scoping studies/Preliminary HLW product description document

Template Title: HLW Glass Formulation

Template Number: 8.4.1.1

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total ($K)	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
13.	Glass property/ composition/ temperature relationships update	Y	10/95	9/96	FY 1996	0	FY 1996	218	218	Document HTM glass formulation scoping studies/Estimate potential feed composition ranges FY 1997
14.	Glass liquidus temperature/crystallinity relationships update	Y	10/95	6/96	FY 1996	0	FY 1996	218	218	Document HTM glass formulation scoping studies/ HLW glass formulation strategy
15.	Glass composition limits for critical components update	Y	10/95	9/96	FY 1996	0	FY 1996	327	327	Investigate solubility of critical minor components in glass/Glass formulation/characterization support for melter selection
16.	HLW feed processability assessment support	Y	10/95	9/96	FY 1996	0	FY 1996	109	109	Feed composition range/Issue report feed processability
17.	Base case glass formulation	Y	11/95	9/96	FY 1996	0	FY 1996	599	599	Second phase pretreatment/HLW interface optimization

Template Title: HLW Glass Formulation

Template Number: 8.4.1.1

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total ($K)	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
18.	Glass formulation/ characterization support for melter selection	Y	10/96	6/97	FY 1997	100	FY 1997	382	482	Estimate potential feed composition ranges FY 1996
19.	Formulation and characterization of reference glass for definitive design	Y	12/96	9/97	FY 1997	0	FY 1997	273	273	Glass formulation supporting melter testing
20.	Glass crystallinity relationships update	Y	10/96	6/97	FY 1997	0	FY 1997	218	218	Update glass property/composition/temperature relationships/Series 3 core sample testing. Support melter testing.
21.	Minor components relationships update	Y	10/96	9/97	FY 1997	0	FY 1997	218	218	Update glass property/composition/temperature relationships. Support melter testing.
22.	Base case glass formulations	Y	10/96	9/97	FY 1997	0	FY 1997	382	382	Formulate base case glasses. Support melter testing.

Template Title: HLW Glass Formulation

Template Number: 8.4.1.1

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total ($K)	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
23.	Component sensitivity studies for base case glasses	Y	2/97	9/97	FY 1997	0	FY 1997	709	709	Estimate potential feed composition ranges FY 1996. Support melter testing.
24.	HLW feed processability assessment	Y	10/96	9/97	FY 1997	0	FY 1997	109	109	Update glass composition limits for critical components. Support melter testing.
25.	Reference glass types and properties definition for plant design and waste form qualification (10/96–9/98)	Y	10/97	9/98	FY 1998	50	FY 1998	1850	1900	Update design data needs. Update EIS supplement. Support melter testing.
26.	Formulate glasses for plant operation and product acceptance using nonradioactive laboratories and modeling while accounting for composition variations (formulate 15 glasses at about 2–3 per year) (10/98–9/04)	Y	10/98	9/04	FY 1999 FY 2000 FY 2001 FY 2002 FY 2003 FY 2004	100 0 0 0 0 0	FY 1999 FY 2000 FY 2001 FY 2002 FY 2003 FY 2004	640 640 640 640 640 640	740 640 640 640 640 640	Retrieval and blending plans. Tank sample results.

Template Title: HLW Glass Formulation

Template Number: 8.4.1.1

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total ($K)	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
27.	Modify glass formulations as necessary and verify glass properties based on tank samples and TWRS operating experience (10/04–9/09)	Y	10/04	9/09	FY 2005 FY 2006 FY 2007 FY 2008 FY 2009	10 10 10 10 10	FY 2005 FY 2006 FY 2007 FY 2008 FY 2009	500 500 500 500 500	510 510 510 510 510	Tank sample results. TWRS operating reports.
Total										

Template Title: **HLW Vitrification Process Chemistry**

Template Number: **8.4.1.2**

Technology Package Type (Reference, Enhancement, or Alternative): Reference

Baseline Program (Y/N): Yes

WBS ID Number and Title: 1.1.1.3.03.02.01 HLW Process/Product Development

Program Element: HLW

Functional Need Level 4: Immobilize HLW/TRU Waste (4.2.2.2)

Functional Need Level 5: Treat HLW/TRU Waste (4.2.2.2.1)

Functional Need Level 6: Prepare Melter Feed (4.2.2.2.1.1)

Functional Need Level 7: none

Scope: Develop vitrification process chemistry to ensure that feed streams (waste and glass former) and feed chemistry for HLW vitrification will result in acceptable process properties in the melter and produce an acceptable glass product and will do so at a production rate compatible with the vitrification process.

Justification: Process chemistry development is needed to make up feed for vitrification that will result in acceptable process properties in the melter and produce an acceptable glass product at a rate compatible with the vitrification process and to do this utilizing process within safety and vitrification plant operating parameters.

Drivers:

- TPA Milestone M-51-03-T01, Submit conceptual design (to include capacity and process) of HLW vitrification facility: 9/1998
- process chemistry development to design the HLW feed preparation process

Level of Maturity (Basic Research, Applied Research, Technology or Laboratory Development, Advanced Development, Engineering Development, Demonstration, First Production, or Operations): Advanced Development

Key Uncertainties:

- feed chemistry and process requirements for systems other than the liquid feed ceramic melter
- composition of major waste feed types to vitrification plant
- plant system requirements such as capacity, process stream properties, and effluent/waste treatment
- the feed process has not been optimized with regard to removing hazardous hydrogen and ammonia generation and increasing capacity and batch size
- the chemical form of glass formers and means of transport and addition
- definition of process waste recycle and processing requirements for whatever vitrification process is selected and major waste types processed have not been determined.

Key Deliverables (Date, Deliverable):

- 02/24/95 issue a feed simulant preparation specification for melter testing comparison
- 09/29/95 issue data package on melter technology comparison flowsheet testing
- 02/24/95 issue small-scale high temperature melter-1 letter report
- 09/29/95 issue technical procedure for rheology measurements
- 02/21/96 issue letter report of FY 1995 work
- 12/30/96 issue letter report of FY 1996 testing
- 02/21/97 issue report on effects of major waste components on process chemistry
- 09/98 provide feed preparation performance envelope for definitive design
- 09/02 provide technical data for operating plant specifications

Basis For Cost Estimates: Cost estimates are based on professional judgement of a panel of experts familiar with work of this nature.

Template Title: HLW Vitrification Process Chemistry

Template Number: 8.4.1.2

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total ($K)	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
1.	Feed simulant specifications for melter testing	Y	10/94	2/95	FY 1995	0	FY 1995	19	19	/Conduct small–scale stirred melter performance test run 1 & 2
2.	Melter testing flowsheet comparisons	Y	11/94	9/95	FY 1995	50	FY 1995	545	595	/Perform small–scale melter system testing
3.	Alternate feed preparation flowsheet testing (NCAW)	Y	10/94	4/95	FY 1995	0	FY 1995	100	100	/Plan tests (Pilot–scale melter concepts)
4.	Small–scale high temperature melter–1 test	Y	10/94	2/95	FY 1995	0	FY 1995	281	281	/Plan tests (Pilot–scale melter concepts)
5.	Strategy development for proceeding with feed preparation process chemistry	Y	10/94	8/95	FY 1995	0	FY 1995	40	40	/Support melter system selection testing
6.	Rheology control and characterization	Y	10/94	9/95	FY 1995	0	FY 1995	145	145	Establish feed simulant specifications for melter feeding/Plan tests (Pilot–scale melter concepts)

Template Title: HLW Vitrification Process Chemistry

Template Number: 8.4.1.2

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total ($K)	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
7.	Melter system selection testing support	Y	10/95	9/96	FY 1996	0	FY 1996	164	164	Melter test plans/ Melter testing
8.	Feed preparation process laboratory tests	Y	1/96	9/96	FY 1996	0	FY 1996	490	490	Test plans/Test reports
9.	Conceptual design performance characteristics development	Y	10/95	9/96	FY 1996	50	FY 1996	273	323	Revise F&R document #2/Perform feed preparation testing for updated conceptual flowsheet
10.	Documentation of FY 1995 work on effects of major components	Y	10/95	2/96	FY 1996	0	FY 1996	109	109	Develop a strategy for proceeding with feed preparation process chemistry/ HLW feed processability
11.	Effects of major waste components on process chemistry	Y	10/95	9/96	FY 1996	0	FY 1996	273	273	Develop a strategy for proceeding with feed preparation process chemistry/ Report effects of major waste components on process chemistry testing

Template Title: HLW Vitrification Process Chemistry

Template Number: 8.4.1.2

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total ($K)	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
12.	System selection testing for 1996	Y	10/96	9/97	FY 1997	0	FY 1997	27	27	Support melter system selection testing/Perform tests (Pilot–scale melter concepts A&B)
13.	Melter system selection testing support	Y	10/96	9/97	FY 1997	0	FY 1997	136	136	Support melter system selection testing/
14.	Feed preparation process laboratory tests	Y	10/96	3/97	FY 1997	0	FY 1997	382	382	Feed preparation process laboratory tests/
15.	Performance characteristics flowsheet modification testing report for FY 1996	Y	10/96	12/96	FY 1997	0	FY 1997	27	27	Establish conceptual design performance characteristics/ Perform tests (Pilot–scale melter concepts A&B)
16.	Feed preparation testing for updated conceptual design flowsheets	Y	11/96	8/97	FY 1997	100	FY 1997	245	345	Establish conceptual design performance characteristics/
17.	Effects of major waste components on process chemistry testing documentation report	Y	10/96	2/97	FY 1997	0	FY 1997	55	55	Determine effects of major waste components on process chemistry/

Template Title: HLW Vitrification Process Chemistry

Template Number: 8.4.1.2

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total ($K)	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
18.	Effects of major waste compositions effects on process chemistry	Y	10/96	9/97	FY 1997	0	FY 1997	436	436	
19.	Determine effects of major waste components on feed preparation chemistry and process stream properties	Y	10/97	9/98	FY 1998	50	FY 1998	1230	1280	
20.	Characterize conceptual design feed preparation process envelope for selected melter system	Y	10/97	9/98		*Included in item above*		*Included in item above*	*Included in item above*	
21.	Characterize feed preparation process response to the defined range of major feed types for detailed design	Y	10/98	9/02	FY 1999 FY 2000 FY 2001 FY 2002	30 30 30 30	FY 1999 FY 2000 FY 2001 FY 2002	750 750 750 750	780 780 780 780	
22.	After FY 2002 this effort is combined with glass formulation and budgeted there for any data needed								0.00	
Total										

Template Title: HLW Radioactive Testing

Template Number: 8.4.1.3

Technology Package Type (Reference, Enhancement, or Alternative): Reference

Baseline Program (Y/N): Yes

WBS ID Number and Title: 1.1.1.3.03.02.01 HLW Process/Product Development

Program Element: HLW

Functional Need Level 4: Immobilize HLW/TRU Waste (4.2.2.2)

Functional Need Level 5: Treat HLW/TRU Waste (4.2.2.2.1)

Functional Need Level 6: Prepare Melter Feed (4.2.2.2.1.2)

Functional Need Level 7: None

Scope: Perform radioactive testing to ensure that the nonradioactive simulants used in process development and melter testing provide results representative of the actual waste; provide process development data that cannot otherwise be obtained with nonradioactive simulants, and validate the process and product models developed with simulants intended for use in safety and environmental analyses, permitting, licensing, and plant operation.

Justification: Radioactive testing is needed to ensure that the simulants used in process development provide results representative of the actual waste, to provide process development data that cannot be obtained by use of nonradioactive simulants, and to validate the process and product models that were developed with simulants for safety, environmental analyses, permitting, licensing, and plant operation. If simulants and their use in process development is not validated, the plant may not function as designed.

Drivers:

- TPA Milestone M-51-03-T01, Submit conceptual design (to include selected capacity and process) of HLW vitrification facility (9/98)
- Radioactive testing is needed to ensure that process and product development performed with simulants is applicable to processing actual wastes and to generate credible data for safety and permitting.

Level of Maturity (Basic Research, Applied Research, Technology or Laboratory Development, Advanced Development, Engineering Development, Demonstration, First Production, or Operations): Advanced Development

Key Uncertainties:

- Do the development data obtained through experimental programs using nonradioactive simulant plant feed slurries provide the same process behavior and product characteristics as actual radioactive waste that the plant will process?
- Are radioactive waste core samples received representative of tank contents?
- Are pretreatment processes representative of those planned for the actual waste?

- The ability to obtain results representative of plant-scale processes from laboratory-scale experiments is uncertain.

Key Deliverables (Date, Deliverable):

- 03/24/95 issue final radioactive core 1-3 process/product test report
- 03/24/95 issue final radioactive process/product laboratory testing strategy document
- 09/30/96 issue FY testing report on series of core samples
- 09/30/97 annual core sample testing reports

Basis For Cost Estimates: Cost estimates are based on a panel of experts familiar with work of this nature.

Template Title: HLW Radioactive Testing

Template Number: 8.4.1.3

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total ($K)	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
1.	Series 1 core sample testing	Y	10/94	3/95	FY 1995	0	FY 1995	118	118	Update glass property/composition/temp. relationships
2.	Laboratory testing strategy document	Y	10/94	3/95	FY 1995	0	FY 1995	50	50	Series 2 core sample testing (SST core sample)
3.	Series 2 core sample testing	Y	5/95	9/95	FY 1995	0	FY 1995	20	20	Establish feed simulant specifications for melter testing/Series 3 core sample testing
4.	Series 2 core sample testing (SST core sample)	Y	10/95	9/96	FY 1995 FY 1996	0 50	FY 1995 FY 1996	0 490	0 540	Establish feed simulant
5.	Series 3 core sample testing	Y	10/95	9/96	FY 1995 FY 1996	0 0	FY 1995 FY 1996	0 109	0 109	Series 2 core sample testing/Series 3 core sample testing
6.	Series 3 core sample testing	Y	10/96	9/97	FY 1997	50	FY 1997	600	650	Series 3 core sample testing
7.	Series 4 core sample testing	Y	10/96	9/97	FY 1997	0	FY 1997	491	491	Glass formulation studies supporting melter testing

Template Title: HLW Radioactive Testing

Template Number: 8.4.1.3

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total ($K)	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
8.	Verify vitrification process and product properties by radioactive testing for each major vitrification feed type. The number of feed types is unknown, but it is assumed that 15 samples will be processed (some of these will be multiple samples from the same tank.) It is assumed that 2 samples are usually received and processed per year, and a report is issued on every 2 samples.	Y	10/97	9/03	FY 1998 FY 1999 FY 2000 FY 2001 FY 2002 FY 2003	30 30 30 30 30 0	FY 1998 FY 1999 FY 2000 FY 2001 FY 2002 FY 2003	1230 1100 1100 1100 1100 1100	1260 1130 1130 1130 1130 1100	Cores from pretreatment and simulants from glass formulation
Total										

Template Title: Initial Design Feed Specification

Template Number: 8.4.1.4

Technology Package Type (Reference, Enhancement, or Alternative): Reference

Baseline Program (Y/N): Yes

WBS ID Number and Title: 1.1.1.3.3.4.1 Define Initial Design Feed Specifications

Program Element: HLW

Functional Need Level 4: Immobilize HLW/TRU Waste (4.2.2.2)

Functional Need Level 5: Treat HLW/TRU Waste (4.2.2.2.1)

Functional Need Level 6: Prepare Melter Feed (4.2.2.2.1.1)

Functional Need Level 7: None

Scope: Develop feed specification to be used for HLW vitrification system definition and conceptual design.

Justification: Needed to ensure that HLW vitrification conceptual design is interfaced and optimized with Pretreatment, and is in accordance with TWRS decisions concerning cesium/strontium capsules, TRU disposal, tank blending, and retrieval sequencing.

Drivers: TPA Milestone M-51-03-T01: Submit conceptual design (to include capacity and process) of HLW Vitrification Facility (9/98).

Level of Maturity (Basic Research, Applied Research, Technology or Laboratory Development, Advanced Development, Engineering Development, Demonstration, First Production, or Operations): Engineering Development

Key Uncertainties:

- feed chemistry and process requirements of various candidate melters
- waste composition and variation of HLW waste stream from Pretreatment
- relationships between waste loading, product-forming additives, and processing conditions.

Key Deliverables (Date, Deliverable):

Annual	estimate of feed composition
12/94	feed processability study
01/96	feed specification update
01/97	feed specification update.

Basis For Cost Estimates: Summaries taken from MYWP. Outyears and second order detail made on basis of judgement and experience of author(s).

Template Title: Initial Design Feed Specification

Template Number: 8.4.1.4

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total ($K)	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
1.	Define Design Feed Specification	Y	10/94	9/01	1995	0	1995	187	187	Pretreatment Reports. Vitrification results reports./To Pretreatment and design
					1996	0	1996	220	220	
					1997	0	1997	142	142	
							1998	142	142	
							1999	142	142	
							2000	142	142	
							2001	142	142	
Total										

Template Title: Feed/Process Evaluation

Template Number: 8.4.1.5

Technology Package Type (Reference, Enhancement, or Alternative): Reference

Baseline Program (Y/N): Yes

WBS ID Number and Title: 1.1.1.3.03.02.06 Plant/Process Engineering Design Support

Program Element: HLW

Functional Need Level 4: Immobilize HLW/TRU Waste (4.2.2.2)

Functional Need Level 5: Treat HLW/TRU Waste (4.2.2.2.1)

Functional Need Level 6: None

Functional Need Level 7: None

Scope: Assess feed processing developments with regard to pretreatment and feed specifications and the results of glass formulation, feed chemistry, rheology, and melter testing. Formulate data needs and strategy.

Justification: Need to focus Technology Development activities in glass formulation, feed chemistry/ rheology, and melter testing.

Drivers: TPA Milestone M-51-03-T01: Submit conceptual design (to include capacity and process) of HLW Vitrification Facility (9/98).

Level of Maturity (Basic Research, Applied Research, Technology or Laboratory Development, Advanced Development, Engineering Development, Demonstration, First Production, or Operations): Engineering Development

Key Uncertainties:

- feed chemistry and process requirements of various candidate melters
- the waste composition and variation of HLW waste stream from pretreatment
- relationships between waste loading, product forming additives, and processing conditions.

Key Deliverables (Date, Deliverable):

• 12/96	glass formulation strategy
• Annual	feed Processability Assessment
• 03/96	process data compilations
• 06/97	process data compilations.

Basis For Cost Estimates: Summaries taken from MYWP. Outyears and second order detail based on author(s)' judgement and experience.

Template Title: Feed/Process Evaluation

Template Number: 8.4.1.5

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
1.	Glass Formulation Evaluation	Y	10/94	9/00		0	FY 1995 FY 1996 FY 1997 FY 1998 FY 1999 FY 2000	100 200 200 200 200 100	100 200 200 200 200 100	Reports–testing/analysis/Processability report
2.	Process Feed/Chemistry Evaluation	Y	10/94	9/00		0	FY 1995 FY 1996 FY 1997 FY 1998 FY 1999 FY 2000	100 275 275 275 275 150	100 275 275 275 275 150	Analysis/testing reports/Processability report
3.	Feed Process Operational Assessment	Y	10/94	9/00		0	FY 1995 FY 1996 FY 1997 FY 1998 FY 1999 FY 2000	49 200 200 200 200 150	49 200 200 200 200 150	Studies and analysis/ Process ability report
Total										

Template Title: Candidate Melter Systems Evaluations

Template Number: 8.4.2.1

Technology Package Type (Reference, Enhancement, or Alternative): Reference

Baseline Program (Y/N): Yes

WBS ID Number and Title: 1.1.1.3.03.02.02 HLW Equipment/Process Development

Program Element: HLW

Functional Need Level 4: Immobilize HLW/TRU Waste (4.2.2.2)

Functional Need Level 5: Treat HLW/TRU Waste (4.2.2.2.1)

Functional Need Level 6: Vitrify HLW and TRU Waste (4.2.2.2.1.2)

Functional Need Level 7: None

Scope: Evaluate melter systems to support selection of the appropriate melter system for HLW vitrification plant application to meet mission requirements.

Justification: Melter evaluation is needed to select the appropriate melter system for HLW plant application to meet mission requirements. The melter system has to produce glass of a quality acceptable for disposal, process waste into glass at a rate to meet TPA and TWRS mission requirements, be able to reliably process the envelope of feeds anticipated for plant operation, reliably operate over extended periods, and be remotely operated and maintained. The melter and glass formulation efforts must be closely coupled because the operating capability of the melter temperature has a major impact on glass formulation and waste form quality.

Drivers:

- TPA Milestone M-51-02; Complete melter tests and select reference melter (9/98).
- Melter system must be selected to enable process and plant design to proceed.

Level of Maturity (Basic Research, Applied Research, Technology or Laboratory Development, Advanced Development, Engineering Development, Demonstration, First Production, or Operations): Advanced Development

Key Uncertainties:

- melter type to be used for HLW vitrification
- applicability of melter types to meet TPA and TWRS requirements
- melter and related system performance requirements
- waste compositions and characteristics for processing
- vitrification and other process impacts of selecting a new melter system that has not been fully developed or adapted to the application for which it will be used.

Key Deliverables (Date, Deliverable):

Date	Deliverable
12/22/94	initial small-scale high temperature melter data package
06/30/95	data package small-scale stirred melter test runs 1 & 2
06/23/95	final test plan(s) for small-scale melter testing
09/29/95	high temperature melter materials testing letter report
09/29/95	final report(s) on laboratory-scale system testing
05/24/96	data package(s) on pilot-scale melters
09/30/96	final reports(s) (pilot-scale melter concepts A & B)
05/24/96	data package(s) on small-scale melter concepts testing A & B
09/30/96	final report(s) on small-scale melter concepts A & B testing
11/22/95	final small-scale stirred melter report for FY 95 testing
01/26/96	final report(s) on small-scale melter (X&Y) system testing from FY95
05/24/96	data package(s) on laboratory support of melters A & B testing
09/30/96	final report(s) on laboratory support of melters A & B testing
05/23/97	data package on laboratory support of melter concepts A & B testing
05/23/96	data package(s) on small-scale melter concepts A & B testing
09/30/97	final report on small-scale melter concepts A & B testing
05/23/97	data packages on pilot-scale melter concepts A & B testing

Basis For Cost Estimates: Cost estimates are based on professional judgement of a panel of experts familiar with work of this nature.

Template Title: Candidate Melter Systems Evaluations

Template Number: 8.4.2.1

Tasks		MYWP	Start Date	End Date	Capital		Expense		Total	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
1.	Melter performance assessment	Y	10/94	9/95	FY 1995	0	FY 1995	447	447	Melter downselection decision and candidate melters
2.	Lab-scale stirred melter tests	Y	10/94	6/95	FY 1995	0	FY 1995	0	0	
3.	Small-scale stirred melter closeout	Y	12/94	3/95	FY 1995	0	FY 1995	95	95	
4.	Pilot-scale stirred melter	Y	10/94	9/95	FY 1995	970	FY 1995	0	975	
5.	HTM sloped bottom design	Y	10/94	9/95	FY 1995	0	FY 1995	66	66	
6.	SSHTM 1994 test data analysis, reduction and reporting	Y	10/94	9/95	FY 1995	0	FY 1995	325	325	
7.	HTM material testing and evaluation	Y	10/94	9/95	FY 1995	220	FY 1995	324	610	
8.	HTM materials testing strategy	Y	10/94	9/95	FY 1995	0	FY 1995	47	47	
9.	HTM systems maintenance and repair	Y	10/94	9/95	FY 1995	0	FY 1995	90	90	
10.	SSHTM design improvements and rebuild	Y	10/94	9/95	FY 1995	305	FY 1995	0	305	

Template Title: Candidate Melter Systems Evaluations

Template Number: 8.4.2.1

Tasks		MYWP	Start Date	End Date	Capital		Expense		Total	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
11.	SSHTM performance testing, evaluation, and reporting	Y	10/94	9/95	FY 1995	0	FY 1995	1,039	1,039	
12.	Establish CCM subcontract	Y	12/94	6/95	FY 1995	0	FY 1995	83	83	
13.	CCM test preparation; testing and reporting	Y	4/94	9/95	FY 1995	0	FY 1995	611	611	
14.	Feed chemicals for CCM testing	Y	10/94	9/95	FY 1995	0	FY 1995	513	513	
15.	Feed drying and calcination evaluation	Y	10/94	9/95	FY 1995	0	FY 1995	140	140	
16.	CCM material testing	Y	10/94	9/95	FY 1995	0	FY 1995	245	245	
17.	Plan tests (Pilot-scale melters)	Y	10/95	1/96	FY 1996	0	FY 1996	142	142	Update vitrification system development test requirements/ Perform tests (Pilot-scale melters)
18.	Perform tests (Pilot-scale melters)	Y	11/95	4/96	FY 1996	0	FY 1996	5,065	5,065	Plan tests/Document tests
19.	Document tests (Pilot-scale melters)	Y	4/96	9/96	FY 1996	0	FY 1996	164	164	Perform tests

Template Title: Candidate Melter Systems Evaluations

Template Number: 8.4.2.1

Tasks		MYWP	Start Date	End Date	Capital		Expense		Total	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
20.	Plan tests (Small-scale melters)	Y	10/95	1/96	FY 1996	0	FY 1996	327	327	Update vitrification system development test requirements/ Perform tests (Small-scale melters)
21.	Perform tests (Small-scale melters)	Y	11/95	4/96	FY 1996	0	FY 1996	1,090	1,090	Plan tests/Prepare data packages
22.	Small-scale melter data packages	Y	4/96	5/96	FY 1996	0	FY 1996	164	164	Perform tests (Small-scale melters) /Prepare information package for CDR
23.	Small-scale melters testing final reports	Y	4/96	9/96	FY 1996	0	FY 1996	55	55	Perform tests (Small-scale melters) /Prepare information package for CDR
24.	Melter concepts FY 1995 testing reports	Y	10/95	11/95	FY 1996	0	FY 1996	164	164	Perform tests (Small-scale melters) Prepare information package for CDR

Template Title: Candidate Melter Systems Evaluations

Template Number: 8.4.2.1

Tasks		MYWP	Start Date	End Date	Capital		Expense		Total	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
25.	Document small-scale system testing on melters	Y	10/95	1/96	FY 1996	0	FY 1996	55	55	Document small-scale system testing) /Prepare information package for CDR
26.	Plan tests (Laboratory support of melters)	Y	10/95	1/96	FY 1996	0	FY 1996	490	490	/Perform tests
27.	Perform tests (Laboratory support of melters)	Y	1/96	4/96	FY 1996	0	FY 1996	349	349	Plan tests (Laboratory support of melters)
28.	Laboratory support for melters test data package preparation	Y	4/96	5/96	FY 1996	0	FY 1996	436	436	Perform tests (Laboratory support of melters)
29.	Laboratory support of melters test reporting	Y	4/96	9/96	FY 1996	0	FY 1996	218	218	Perform tests (Laboratory support of melters) /Prepare information package for CDR
30.	Plan tests (Laboratory support of melters)	Y	10/96	1/97	FY 1997	0	FY 1997	142	142	/Perform tests
31.	Perform tests (Laboratory support of melters)	Y	11/96	4/97	FY 1997	0	FY 1997	349	349	Performance characteristics flowsheet modification testing report FY 1996/

Template Title: Candidate Melter Systems Evaluations

Template Number: 8.4.2.1

Tasks		MYWP	Start Date	End Date	Capital		Expense		Total	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
32.	Document test (Laboratory support of melters)	Y	4/97	5/97	FY 1997	0	FY 1997	164	164	Perform tests
33.	Plan tests (Small-scale melters)	Y	10/96	1/97	FY 1997	0	FY 1997	327	327	Glass formulation studies supporting melter testing/Perform tests (Small-scale melters)
34.	Perform tests (Small-scale melters)	Y	11/96	4/97	FY 1997	0	FY 1997	1,091	1,091	
35.	Issue data packages (Small-scale melters)	Y	4/97	5/97	FY 1997	0	FY 1997	273	273	Perform tests (Small-scale melters)
36.	Issue final report on small scale melters	Y	4/97	9/97	FY 1997	0	FY 1997	164	164	Issue data packages on small-scale melters
37.	Plan test (Pilot-scale melters)	Y	10/96	1/97	FY 1997	0	FY 1997	491	491	Glass formulation studies supporting melter testing/Perform tests (Pilot-scale melters)
38.	Perform test (Pilot-scale melters)	Y	11/96	4/97	FY 1997	0	FY 1997	5,073	5,073	

Template Title: Candidate Melter Systems Evaluations

Template Number: 8.4.2.1

Tasks		MYWP	Start Date	End Date	Capital		Expense		Total	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
39.	Issue data packages (Pilot-scale melter)	Y	4/97	5/97	FY 1997	0	FY 1997	436	436	Perform tests (Pilot-scale melters)
40.	Issue report (Pilot-scale melters)	Y	4/1/97	9/30/97	FY 1997	0	FY 1997	218	218	Issue data Packages (Pilot-scale melters) testing
41.	Perform one to two pilot-scale melter runs per year to provide data for design/ operations/permitting/ safety/WFQ	Y	10/97	9/02	FY 1998 FY 1999 FY 2000 FY 2001 FY 2002	0 0 0 0 0	FY 1998 FY 1999 FY 2000 FY 2001 FY 2002	3,300 3,000 3,000 3,000 3,000	3,300 3,000 3,000 3,000 3,000	
42.	Complete procurement and construction of bench-scale radioactive melter and bench scale nonradio-active melter	Y	10/98	9/00	FY 1999 FY 2000	2,400 0	FY 1999 FY 2000	1,300 1,300	3,700 1,300	
43.	Start up and perform non-radioactive runs with bench-scale radioactive melters	Y	10/00	9/01	FY 2001	100	FY 2001	1,500	1,600	
44.	Install radioactive bench-scale melter in hot cell	Y	10/01	9/03	FY 2002 FY 2003	400 400	FY 2002 FY 2003	2,900 2,900	2,900 2,900	

Template Title: Candidate Melter Systems Evaluations

Template Number: 8.4.2.1

Tasks		MYWP	Start Date	End Date	Capital		Expense		Total	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
45.	Perform two bench-scale radioactive melter runs per year for three years on different types of feed	Y	10/03	9/06	FY 2004 FY 2005 FY 2006	50 50 50	FY 2004 FY 2005 FY 2006	8,500 8,500 8,500	8,550 8,550 8,550	
46.	Perform one to four runs per year on nonradioactive bench-scale melter to assess effects of different feed compositions on melter performance	Y	10/02	9/09	FY 2003 FY 2004 FY 2005 FY 2006 FY 2007 FY 2008 FY 2009	20 20 20 20 20 20 20	FY 2003 FY 2004 FY 2005 FY 2006 FY 2007 FY 2008 FY 2009	300 300 300 300 300 300 300	320 320 320 320 320 320 320	
Total										

Template Title: Vitrification Process/Product Modeling

Template Number: 8.4.2.2

Technology Package Type (Reference, Enhancement, or Alternative): Reference

Baseline Program (Y/N): Yes

WBS ID Number and Title: 1.1.1.3.03.02.01 HLW Process/Product Development

Program Element: HLW

Functional Need Level 4: Immobilize HLW/TRU Waste (4.2.2.2)

Functional Need Level 5: Treat HLW/TRU Waste (4.2.2.2.1)

Functional Need Level 6: Vitrify HLW and TRU Waste (4.2.2.2.1.2)

Functional Need Level 7: None

Scope: Perform modeling for HLW vitrification process and product control and quality assurance.

Justification: Process and product model development is needed to provide mathematical models to ensure a quality product that meets specifications, and to reduce the amount of sampling and analytical effort.

Drivers:

- TPA Milestone M-51-03-T02: Initiate definitive design of the HLW vitrification facility (12/98).
- Requirements to monitor and control the process/product to ensure acceptable product properties.

Level of Maturity (Basic Research, Applied Research, Technology or Laboratory Development, Advanced Development, Engineering Development, Demonstration, First Production, or Operations): Advanced Development.

Key Uncertainties:

- performance of the process control systems
- the applicable models are not fully validated
- changes in the HLW vitrification process could require changes in the associated models.

Key Deliverables (Date, Deliverable):

9/30/96	annual update or strategy document

Basis For Cost Estimates: Cost estimates are based on professional judgement of a panel of experts familiar with work of this nature.

Template Title: Vitrification Process/Product Modeling

Template Number: 8.4.2.2

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
1.	Develop optimal frit selection/process strategies/tools	Y	10/94	9/95	FY 1995	0	FY 1995	200	200	Glass formulation strategy
2.	Process control strategy	Y	4/96	9/96	FY 1996	0	FY 1996	55	55	Process control algorithm development
3.	Glass formulation code development	Y	10/95	9/96	FY 1996	0	FY 1996	251	251	Melter testing glass formulation properties testing/Base case glass formulations
4.	Process control algorithm development	Y	10/96	9/97	FY 1997	0	FY 1997	142	142	
5.	Glass formulation code development	Y	10/96	8/97	FY 1997	0	FY 1997	185	185	Update glass composition limits for critical components
6.	Update process/product control strategy document for reconfigured HLW vitrification system	Y	10/97	7/98	FY 1998	0	FY 1998	77	77	

Template Title: Vitrification Process/Product Modeling

Template Number: 8.4.2.2

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
7.	Modify Plant Simulation Code, Measurement Error Model, Feed Test Algorithm, and other algorithms to accommodate HLW vitrification plant process configuration	Y	10/97	9/98	FY 1998	0	FY 1998	88	88	
8.	Develop new algorithms needed for product/process control	Y	10/97	9/98	FY 1998	0	FY 1998	77	77	
9.	Validate process/product control models using HLW vitrification data and any relevant data from the DWPF and WVDP programs	Y	10/98	9/99	FY 1999	0	FY 1999	170	170	
10.	Document process/product control codes/models for use in the HLW vitrification plant system design	Y	10/98	12/98	FY 1999	0	FY 1999	50	50	

Template Title: Vitrification Process/Product Modeling

Template Number: 8.4.2.2

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
11.	Validate process/product control codes/models in HLW vitrification plant cold runs	Y	10/07	9/09	FY 2008 FY 2009	25 25	FY 2008 FY 2009	2395 2395	2420 2420	
Total										

Template Title: **Melter Auxiliary Systems Evaluation**

Template Number: **8.4.2.3**

Technology Package Type (Reference, Enhancement, or Alternative): Reference

Baseline Program (Y/N): Yes

WBS ID Number and Title: 1.1.1..03.02.02 HLW Equipment/Process Development

Program Element: HLW

Functional Need Level 4: Immobilize HLW/TRU Waste (4.2.2.2)

Functional Need Level 5: Treat HLW/TRU Waste (4.2.2.2.1)

Functional Need Level 6: Vitrify HLW and TRU Waste (4.2.2.2.1.2)

Functional Need Level 7: None

Scope: Develop technology as required to support the vitrification system in performing its mission as defined in the Tri-Party Agreement (TPA).

Justification: Process waste and effluent treatment development are needed to evaluate and select optimum approaches so that federal, state, and local regulations are met for the plant and process/melter system selected.

Waste form qualification support is needed to provide technical assistance and data to the TWRS contractor to ensure that the HLW vitrification package is acceptable at the federal repository for disposal.

Canister development is needed to provide the maximum economical size HLW package with related systems such as closure, decontamination, inspection, and handling.

Analytical methods evaluation is needed to assess and develop analytical techniques as required to ensure that analytical requirements for the plant can be accommodated with the needed turnaround time, accuracy, and precision.

Instrumentation and controls development is needed to provide effective process and product monitoring/ control systems such as reliable online methods that have the required accuracy, longevity, low maintenance requirements, and minimize process stream sampling and associated analytical requirements.

Drivers:

- TPA Milestone M-51-03-T01, Submit conceptual design (to include selected capacity and process) of HLW vitrification facility (9/98)
- TPA Milestone M-51-03-T02, Initiate definitive design of the HLW vitrification facility (12/98)
- The process and facility cannot be fully defined until the auxiliary systems are defined.

Level of Maturity (Basic Research, Applied Research, Technology or Laboratory Development, Advanced Development, Engineering Development, Demonstration, First Production, or Operations): Advanced Development

Key Uncertainties:

Process Waste and Effluent Treatment

- the need for an individual hazardous component (such as technetium-99, cesium-137, carbon-14, iodine-129, sulfurous oxides, nitrous oxides, C1, F1, tritium) treatment has not been fully defined because of uncertainties in the content and concentrations of the components in the feeds

- the ability of the HLW vitrification design to meet regulatory, TPA, and TWRS program requirements
- discharge limits, waste feed compositions, glass formulations, melter type, heater method, operating conditions, and the need for plant release control for many of the components.

Waste Form Qualification Support

- the program's waste form qualification strategy
- the extent to which HWVP, DWPF, and WVDP development work can be applied and used in the HLW vitrification program
- potential changes in waste acceptance specifications.

Canister Development and Qualification

- acceptability of a large canister (~10 cubic meters) to the repository
- effects of canister size increase on canister handling systems, storage, transportation, disposal, decontamination, closure, and inspection.

Analytical Methods Evaluation

- ability of analytical methods to obtain the desired accuracy and turnaround time in the process matrices with the needed turnaround time.

Instrumentation And Controls Development

- the adequacy and applicability of certain instrument and control systems to various melter concepts
- operability and maintainability of the instruments and controls in a remotely operated production environment.

Key Deliverables (Date, Deliverable): These activities are in the early planning stages. Deliverables have not yet been defined.

Basis For Cost Estimates: Cost estimates are based on professional judgement of a panel of experts familiar with work of this nature.

Template Title: Melter Auxiliary Systems Evaluation

Template Number: 8.4.2.3

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
1.	Technical support activities	Y	10/94	2/95	FY 1995	0	FY 1995	25	25	None/HLW glass formulation strategy
2.	Technical support activities	Y	10/95	9/96	FY 1996	0	FY 1996	27	27	HLW glass formulation strategy
3.	Large Canister Qualification (Incl. QA)	Y	10/96	9/97	FY 1997	0	FY 1997	164	164	Develop basis for product qualification/ additional formulation work
4.	Technical support activities	Y	10/97	9/03	FY 1998 FY 1999 FY 2000 FY 2001 FY 2002 FY 2003	0 0 0 0 0 0	FY 1998 FY 1999 FY 2000 FY 2001 FY 2002 FY 2003	220 200 200 200 200 200	220 200 200 200 200 200	
Total										

Template Title: HLW Vitrification Process/Equipment Evaluation

Template Number: 8.4.2.4

Technology Package Type (Reference, Enhancement, or Alternative): Reference

Baseline Program (Y/N): Yes

WBS ID Number and Title: 1.1.1.3.03.02.05 Feed/Process Evaluation

Program Element: High Level Waste (HLW)

Functional Need Level 4: Immobilize HLW/TRU Waste (4.2.2.2)

Functional Need Level 5: Treat HLW/TRU Waste (4.2.2.2.1)

Functional Need Level 6: Vitrify HLW/TRU Waste (4.2.2.2.1.2)

Functional Need Level 7: None

Scope: Select a reference HLW melter system for Conceptual Design by evaluating results of melter testing. Do this by formulating a melter development program and reference melter selection methodology.

Justification: Provides a basis for the candidate melter testing program and a documented methodology for selecting the reference melter.

Drivers: Milestone M-51-02: Complete melter tests and select reference melter (9/98).

Level of Maturity (Basic Research, Applied Research, Technology or Laboratory Development, Advanced Development, Engineering Development, Demonstration, First Production, or Operations): Engineering Development.

Key Uncertainties:

- the waste stream composition(s) from Pretreatment
- TRU and cesium/strontium capsule disposition
- relationships of feed composition, throughput, melter lifetime, and facility size, auxiliary systems, and operational considerations for the candidate melters

Key Deliverables (Date, Deliverable):

11/94	candidate melter selection process document
02/95 + update	HLW melter development plan (and updates)
02/97	reference melter selection plan
03/95	melter candidate assessment report
03/97	reference HLW vitrificaton system description for conceptual design
09/98	select melter system for definitive design

Basis For Cost Estimates: Summaries taken from MYWP. Outyears and second order detail are made on the basis of judgement and experience of author(s).

Template Title: HLW Vitrification Process/Equipment Evaluation

Template Number: 8.4.2.4

Tasks					Capital ($K)		Expense ($K)			
No.	Title	MYWP	Start Date	End Date	Year	Amount	Year	Amount	Total	Predecessors/ Successors
1.	Candidate Melter Systems Selection (H102004)	Y	10/94	9/95		0	FY 1995	1500	1500	Develop selection process. Gather Melter information/Develop test plans
							FY 1996	0		
							FY 1997	0	0	
							FY 1998	0	0	
							FY 1999	0	0	
2.	Melter Testing Oversite (HL02005)	Y	10/94	9/98		0	FY 1995	375	375	Develop approve test plans. Subcontracting actions/Testing recommendations
							FY 1996	295	295	
							FY 1997	250	250	
							FY 1998	100	100	
							FY 1999	250	250	
3.	Reference Melter Selection (HL02006)	Y	10/94	9/97		0	FY 1995	78	78	Develop selection methodology. Compute testing/Selection report
							FY 1996	250	250	
							FY 1997	250	250	
							FY 1998	515	515	
							FY 1999			
4.	Melter Support Systems Evaluation Oversite (HL02007)	Y	10/94	9/99		0	FY 1995	375	375	Test plans. Test results/System design recommendations
							FY 1996	250	250	
							FY 1997	215	215	
							FY 1998	100	100	
							FY 1999	250	250	
Total										

Template Title: HLW Vitrification Process System Requirements and Concepts

Template Number: 8.4.2.5

Technology Package Type (Reference, Enhancement, or Alternative): Reference

Baseline Program (Y/N): Yes

WBS ID Number and Title: 1.1.1.3.3.4.3 Define Initial Process System Requirements

Program Element: HLW

Functional Need Level 4: Immobilize HLW/TRU Waste (4.2.2.2)

Functional Need Level 5: Treat HLW/TRU Waste (4.2.2.2.1)

Functional Need Level 6: None

Functional Need Level 7: None

Scope: Perform studies and decision analysis to determine the HLW vitrification facility concept; revise process flowsheets and Functions and Requirements as required.

Justification: Need to begin Conceptual Design Activity and provide data and requirements to the architect/engineer (A/E).

Drivers: TPA Milestone M-51-03-T01: Submit conceptual design (to include capacity and process) of HLW Vitrification Facility.

Level of Maturity (Basic Research, Applied Research, Technology or Laboratory Development, Advanced Development, Engineering Development, Demonstration, First Production, or Operations): Engineering Development

Key Uncertainties:

- TRU tank waste and cesium/strontium capsule decisions
- facility configuration studies
- melter selection process
- composition and variation of entering waste stream.

Key Deliverables (Date, Deliverable):

- 01/95 process control recommendation
- 02/95 technology development needed for flowsheet
- 10/95 update HLW process flowsheets
- 08/96 update HLW process flowsheets
- 08/95 update integrated (HLW) database
- 08/96 update integrated (HLW) database

- 08/97 update integrated (HLW) database
- multi trade study reports.

Basis For Cost Estimates: Summaries taken from Multi-Year Work Plan (MYWP). Outyears and second order detail made on basis of judgement and experience of author(s).

Template Title: HLW Vitrification Process System Requirements and Concepts

Template Number: 8.4.2.5

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
1.	Process flowsheet development	Y	10/94	9/98		0	FY 1995 FY 1996 FY 1997 FY 1998 FY 1999 FY 2000	1,200 1,000 1,000 500 0 0	1,200 1,000 1,000 500 0 0	Trade study results. Results of testing and analysis
2.	Facility concepts and configuration	Y	10/94	9/98		0	FY 1995 FY 1996 FY 1997 FY 1998 FY 1999 FY 2000	1,500 1,000 1,000 800 0 0	1,500 1,000 1,000 800 0 0	Trade study results
3.	Functions and Requirements Development	Y	10/94	9/98		0	FY 1995 FY 1996 FY 1997 FY 1998 FY 1999 FY 2000	500 200 200 500 0 0	500 200 200 500 0 0	Trade study results

Template Title: HLW Vitrification Process System Requirements and Concepts

Template Number: 8.4.2.5

Tasks		MYWP	Start Date	End Date	Capital ($K)		Expense ($K)		Total	Predecessors/ Successors
No.	Title				Year	Amount	Year	Amount		
4.	Technology Transfer	Y	10/94	10/00		0	FY 1995	465	465	Testing and data results
							FY 1996	565	565	
							FY 1997	818	818	
							FY 1998	1,200	1,200	
							FY 1999	2,000	2,000	
							FY 2000	2,000	2,000	
Total										

Appendix F

Technologies Considered But Not Carried Forward

An important result of the TWRS Program's evaluation of technology responses to functional needs is documentation of concepts that have been considered, but not recommended, for funding. This appendix documents an initial listing of these technologies for each program element.

Concepts not carried forward are specific technical options that were not selected to address functional needs within the proposed TWRS technical strategy. This list is limited to concepts initially identified in the 1992 TWRS National Workshop, proposed to program element staff during their budget-building task for FY 1993 and FY 1994, or considered by the Architecture Groups (AGs). Items on the list received "low priority" rankings due to technical limitations, the availability of more suitable technical options, or a lack of sufficient information at that particular time to further evaluate them. The nonvitrification (grout) technologies were eliminated from further consideration as a result of the TPA negotiations.

This list will be continually re-evaluated as new technical information becomes available.

F.1 Waste Tank Safety (Chapter 3)

F.1.1 Technologies Dropped in ITP Rev. 1

The following concepts were considered by the Tank Safety Program but were not carried forward:

- Explosion and/or fire suppression systems for flammable gas and organic tanks (not technically feasible).
- Closed loop cooling of high heat Tank C-106 (serious shortcoming because if leak develops in closed-loop system, the safety issue would reappear).
- Segregate waste types (not economically feasible).
- Each of the concepts listed below were considered in detail for the Flammable Gas Watch List (FGWL) tanks (WHC-EP-0516).[(a)] Upon evaluation, four alternatives were selected for further investigation. These four alternatives were mixer pumps, introduction of ultrasonic/sonic energy, heating, and dilution.
    - Compression Waveguide
    - Vertical Draft Tube (DT) Down
    - Liquid Piston
    - Vertical Draft Tube Up
    - Surfactant
    - Vibration through Wall
    - Waste Boiling

(a) Babad, H., and J. L. Deichman. 1992. *Mitigation/Remediation Concepts for Hanford Site Flammable Gas-Generating Tanks.* WHC-EP-0516, Westinghouse Hanford Company, Richland, Washington.

  - Waste Cooling
  - Lower pH
  - Liquid Whistles
  - Inert Gas or Air Lancing
  - Mechanical Rake
  - Remove Convection Layer
- Sonic probe for hydrogen mitigation.

F.1.2 Technology Templates Dropped in ITP Rev. 2

The following templates were dropped from the ITP because they were not considered technology by the WTS Program or the tasks were completed:

- Close USQ for Flammable Gas-Generating Tanks. There was no technology required to close the USQ. Recommendations for closure of the USQ will require technology from the Evaluate and Define Safety Issue (EDSI) function.
- Store and Monitor Flammable Gas-Generating Tanks. There is no technology required for installing SST gas monitors, upgrading ventilation systems, upgrading surface level measurement instruments, or installing multifunctional instrument trees. Work is considered applied engineering.
- Close USQ for Ferrocyanide-Containing Tanks. The USQ for ferrocyanide-containing tanks was closed in March 1994.
- Resolve Safety Issue for Ferrocyanide-Containing Tanks. Preparation of safety documentation and interpretation core sample data is not currently considered technology. A number of technologies for resolving the safety issue are being evaluated and tested under the EDSI Function.
- Evaluate and Define Safety Issue for Criticality Safety Issue. The USQ was closed in March 1994, and most of the work activities have been transferred back to Waste Tank Operations.
- Mitigation Program Support for Waste Tank Hydrogen Mitigation. The tasks are considered engineering application.
- Evaluate and Define Safety Issue for Flammable Gas-Generating Tanks. The tasks are considered engineering application.

F.2 Characterization (Chapter 4)

F.2.1 Laboratory-Based Technology Systems

Numerous technology activities funded by TWRS were concluded in FY 1994 or are expected to be concluded in FY 1995. Templates for some of these activities were either dropped in the current revision or probably will be dropped in the next ITP revision because of the mature state of the technology activity.

- Radiation Screening - Instrumentation has been developed by WHC and placed in the hot cell at 222-S Laboratory to screen tank waste materials for gamma- and beta-emitting radionuclides. This system is to be set up initially for step scanning an extruded core and can be attached to the extruder to measure differences in count rate along the length of a core sample. Measurements will continue to require a high level of scientist interface for data interpretation until sufficient operating experience is obtained to routinize the procedure for technologist operation.

- Speciation - X-ray absorption fine structure (XAFS) experiments carried out by a PNL/LANL team at the Stanford Synchrotron Radiation Laboratory verified that HLW can be taken offsite for XAFS measurements, and that the technique can provide useful speciation information. The TWRS-related XAFS work is no longer considered a development effort and is being supported in FY 1995 by the Pretreatment Program for sludge speciation measurements.

- Thermal conductivity - A fully developed thermal conductivity method now is available in the WHC Process Chemistry Laboratory. Although the procedure has not been formalized in the TWRS production laboratory, the analysis is available as requested.

- Viscosity/Rheology - A viscometer system has been received, tested, and documented to support requests from tank farm operations. The system will continue to be operational in the WHC Process Chemistry Laboratory until sufficient requests are received to justify incorporation into the production analytical laboratory. Both "bob and cup" and "cone and plate" capabilities are available and measurements can be made at temperatures that vary widely from ambient. Shear stress and shear rate values are calculated from the viscometer measurements. Requests for analyses must specify conditions under which measurements are to be made.

- Offgas Analysis - A test sequence traditionally used for headspace gas analysis has been documented for use in the WHC Analytical Operations Laboratory to qualify percent water analyses. Other TWRS laboratory moisture measurements rely on warming a sample aliquot to volatilize the water and measuring the difference in mass before and after warming. In those methods, assurance is required to verify that organic materials are not volatilized with the water.

- Thermal capacity/thermal conductivity - A thermal capacity measurement method using milligram quantities of sample was completed late in FY 1994. This method extends the capability of standard differential scanning calorimetry. The methodology is available for tank farm operations analytical requests. A thermal conductivity method also has been made available in the Process Chemistry Laboratory. Although the procedure has not been formalized in the production laboratory, the analysis is available on an as-requested basis. PNL is expected to complete a procedure using gram quantities of sample by the end of FY 1995.

- Total Cyanide - Methodology was developed at PNL for complete dissolution of cyanide-containing species that may be present in tank wastes. Because tank wastes can be relatively intractable with the prior dissolution procedure, results of the prior method could be biased low. The new cyanide dissolution methodology was transferred to the WHC Laboratory, incorporated into a formal procedure, and currently is in use.

- Hard Saltcake Homogenization - A commercially available homogenizer was purchased, modified for use in a hot cell, and demonstrated at PNL. The demonstration unit was transferred to an operating WHC hot cell, formal procedures prepared, training was conducted, and the unit is now available for immediate use.

- Microwave Digestion - A microwave sample digestion system has been acquired for hot cell use. Testing, installation, and TWRS procedure documentation for routine application is expected to be completed in FY 1995. This technique is needed to ensure total sludge dissolution prior to sample analysis.

- Iodine-129 and Noble Metals - A procedure for iodine-129 and noble metals determination was completed by PNL and delivered to the TWRS production analytical laboratory in FY 1994. The method can be placed in routine operation when ICP/MS instrumentation is in place, as expected in FY 1996.

- Abrasivity - A procedure for determination of abrasivity was completed by PNL and delivered to the TWRS production analytical laboratory in FY 1994. The procedure is based on pipe loop wear measurements using simulants.
- Chelating Agents - A procedure for determination of chelating agents in HLW was completed by PNL and delivered to the TWRS production analytical laboratory in FY 1994. This method, based on capillary zone electrophoresis, is expected to provide significant cost and time savings for chelator analysis.

F.2.2 Field-Based Technology Systems

- Fission-chamber neutron moisture detector - The delivery SAIC of a fully developed fission-chamber neutron moisture detector for cone penetrometer application is expected this spring.
- Sample verification instrumented receiver - A fully developed sample verification instrumented receiver for determining sampler fullness at the tank should be delivered by SWRI this spring and should see field use during the summer.
- Core bit temperature monitor - An engineering model of a temperature monitor for the rotary core bit system has been developed and successfully demonstrated by SNL. The interface requirements with the core sampler and the tangible benefits of deployment are being re-examined before completing design and fabrication of a unit for field use.
- Gas monitoring systems - During FY 1994, GC/FTIR gas monitoring systems were fully developed, have functioned well on tank 101SY, and are being extended to other tanks in FY 1995. Development of a gas sampling cart is expected to be completed in FY 1995.
- Copper neutron activation moisture method - During FY 1995, calibration and documentation of the copper neutron activation method for in situ moisture determination will be completed. The system is designed for cone penetrometer deployment.

F.3 Waste Retrieval (Chapter 5)

The concepts described in this section were discussed in the 1992 TWRS workshops by the Retrieval Technology Working Group (RTWG), but were considered impractical for this application and thus will not be carried forward by the Retrieval Program. The RTWG was chartered with identifying and considering a broad range of technologies that may be applicable to UST retrieval. The RTWG had representatives from DOE, private industry, the U.S. Bureau of Mines, Lawrence Livermore National Laboratory, WHC, PNL, Kaiser Engineers Hanford, Washington State Department of Ecology, and Sandia National Laboratory. The group had expertise in remote systems, robotics, control system design, sensor system design, conventional mining methods, systems analysis, regulatory analysis, design and construction hydraulic testing and analysis, and project management. More detail on the RTWG and its accomplishments can be found in the March 31, 1993 *TWRS—Retrieval Technology Plan* (WHC-SD-WM-PLN-060).

F.3.1 Technologies Dropped in ITP Rev. 1

- Mechanical Dredge - The mechanical dredge concept consists of a floating dredge device that scoops up the waste as it is pulled along a positioning arm by a drag cable, operating on a blanket of water over the waste. The dredge transports the waste to a floating air conveyance hose. This concept was not carried forward because 1) it cannot operate in tank with numerous risers or in-tank debris, 2) it cannot remove waste near debris, 3) it requires a blanket of water over waste, 4) it cannot remove hard wastes, 5) it is difficult to operate, and 6) it cannot remove waste around stiffening angles at sides of tank.

- Drag Arm - The drag arm concept consists of a chopper pump with a cutter head to chop up the waste, operating on a blanket of water above the waste. This concept was not carried forward because 1) it requires a blanket of water over waste, 2) it cannot remove hard wastes, 3) it cannot operate in tank where numerous steel measuring tapes were disposed, 4) it cannot operate in a tank with numerous risers or in-tank debris, 5) it cannot remove waste around stiffening angles at sides of tank, and 6) it is difficult to operate.
- Continuous Miner/Elevation - The continuous miner/elevator concept uses a self-propelled mining system introduced into the tank through a large opening in the top of the tank. The miner propels itself around the inside of the tank, mechanically chews and cuts up waste, and transports the waste out of the tank with a bucket or belt conveyor. This concept was not carried forward because 1) a self-propelled vehicle would not work on an uneven surface of tank waste, 2) a mixer would sink below surface of soft waste, 3) mechanical elevators cannot work remotely, and 4) a continuous mixer would have difficulty operating around tank risers.
- Load-Haul-Dump-Elevate - The load-haul-dump-elevate concept uses a self-propelled front loader-type device to scoop up the waste and transport it to a bucket or belt conveyor that transports it out of the tank. This concept was not carried forward because 1) it cannot operate on an uneven waste surface, 2) it would sink below the surface on soft waste, 3) bucket and belt elevators are not suited for remote operation, and 4) it would have difficulty operating around tank risers and other debris.
- Drift Tunneling - The drift tunneling concept inserts mining equipment into tunnels bored in the side or bottom of the tank. The waste is loaded into "cars" that transport the waste to the treatment facility. This concept was not carried forward because 1) it would require a hole in the tank below the surface of the waste, 2) it is not likely that mining equipment could operate across the full distance of a tank, 3) a tunnel would be dug in contaminated soil, 4) the concept is more complex than the reference mechanical system, 5) it is difficult to provide confinement for contaminated soil and waste, and 6) loading, transport, and decontamination of cars would be impractical.
- In Situ Vitrification - The in situ vitrification concept involves vitrifying waste and tank to produce a glass form in place. This is not a retrieval process, but a treatment approach, therefore it is beyond the scope of the retrieval program.

F.3.2 Technologies Dropped in ITP Rev. 2

No additional technologies were dropped from the retrieval program in 1994.

F.4 Waste Pretreatment (Chapter 6)

In developing the suggested pretreatment program for FY 1995, many decisions were made by the group as to what process concepts were worthy of study during the coming year. It seems to be of doubtful value to list all of the specific processes judged as not suitable for emphasis as those that were addressed. However, a list of some of the more visible process concepts not recommended to be carried forward would include:

F.4.1 Technologies Dropped in ITP Rev. 1

- Transuranic (TRU) removal by solvent extractants other than CMPO or CMP - The basis for these choices is that these two extractants are the best developed, it appears that either can be developed for use with Hanford Site tank wastes, and other candidates appear to provide no clear benefit for this application.

- Primary TRU removal by ion exchange - The bases for excluding ion exchange for the primary removal of TRU elements include a) lack of adequate selectivity (relative to other metals that are present in the sludge) of cation exchange resins, and b) lack of Americium removal capability for anion exchange resins.

- Cesium removal by co-precipitation with potassium tetraphenylborate - This approach, which is planned for use at the Savannah River Site, does not appear to be suitable for use at the Hanford Site because of the technical and safety problems encountered at Savannah River and because much larger amounts of potassium are present in the Hanford Site wastes.

F.4.2 Technologies Dropped in ITP Rev. 2

- Technologies associated with the destruction of organics to resolve safety issues were dropped after a down selection process in FY 1994. Wet air oxidation was retained only on a contingency basis, because mitigation (mixing) of the tank wastes was demonstrated to be effective where needed. Hydrothermal processing was specifically dropped.

- For Enhancements and Alternatives to the HLW, all acid-side separations processes were deleted for FY 1995 and beyond. They will only be investigated if enhanced sludge washing is found not to meet program goals.

F.5 Low-Level Waste Immobilization (Chapter 7)

F.5.1 Technologies Dropped in ITP Rev. 1

Nonglass waste forms (e.g., grout) were not carried forward because such waste forms are not included in the Tri-Party Agreement (TPA).

F.5.2 Technologies Dropped in ITP Rev. 2

The technology framework for LLW has been centered around a phased-testing program to determine a reference melter system. Until a melter system is selected, all technologies identified in the previous revision of the ITP will be carried forward. The only exception to this is the work associated with determining whether contact maintenance of the melter is possible. TWRS has elected to abandon plans for a lightly shielded LLW facility.

F.6 High-Level Waste Immobilization (Chapter 8)

HLW immobilization technologies considered and believed to have significant merit were carried forward in the proposed program, at least through an initial assessment phase. Other HLW immobilization technologies considered but not carried forward are listed below.

F.6.1 Technologies Dropped in ITP Rev. 1

- Plant feed concentration by centrifuging - Not carried forward due to high maintenance rate, low throughput for high-efficiency solids removal, inability to handle soluble radionuclide/hazardous components.

- Plant feed concentration by filtration - Not carried forward due to high maintenance rate, inability to handle soluble radionuclide/hazardous components.

- Recycle off-specification product - Not carried forward due to cost, Hanford Waste Vitrification Plant process control approach. Also, possibility of generation of minor amounts of off-specification product appears to be internationally accepted.

F.6.2 Technologies Dropped in ITP Rev. 2

Some candidate melter concepts for the vitrification of HLW have been eliminated from further consideration. They were not carried forward because the down selection process ranked them as unfavorable in comparison to other concepts, which are being carried forward. The concepts dropped from further consideration include: combustion melters, plasma arc furnaces, microwave, and hot isostatic pressing.

Appendix G

Glossary

This glossary supplies definitions for terms used in the Integrated Technology Plan.

alternative systems technology	Technologies within the program strategy that (1) support significantly different approaches, (2) potentially could significantly improve performance, and (3) if proven, would make it possible to replace the reference system with an alternative approach.
authorize	Sanction an activity, obligation, or expenditure within the program.
baseline	A quantitative definition of cost, schedule, and technical performance that serves as a base or standard for measurement and control during the performance of an effort; the established plan against which the status of resources and the effort of the overall program, field programs, projects, tasks, or subtasks are measured, assessed, and controlled. Once established, baselines are subject to change control procedures.
baseline, cost	A budget that has been developed from the cost estimate made at approval of the technical baseline; the majority of the budget has been time phased in accordance with the project schedule. The cost baseline is referred to as a baseline because it is integrated with the technical and schedule baselines and is subject to formal change control. The cost baseline normally contains direct and indirect budget; management reserve budget; undistributed budget and higher level budgets; contingency amount; and amount for fee, as appropriate.
baseline, preliminary TWRS baseline funding level	The planning case, as described in the PMP, consistent with the funding profile used in the TPA negotiations.
baseline, program	The program baseline is composed of the program's technical, schedule, and cost baselines. This baseline is subject to change control procedures.
baseline, schedule	The time-phased plan with a logical sequence of interdependent activities, milestones, and events necessary to complete the project. The schedule baseline shall be formally changed during the execution of the project when required.
baseline, technical	A configuration identification document or set of documents formally designated and approved by DOE. The initial technical baseline, plus DOE-approved changes to the baseline, constitutes the current technical baseline.
budget	The planned resources in man-hours or dollars associated with the work constitute the budgeted cost of work scheduled (BCWS). This budget data is not official. Budgets and costs in this document are estimates for planning purposes only.
characterization	One of the six TWRS program elements. The quantitative physical, chemical, and radiological descriptions of tank waste in support of process control, safety issue resolution, treatment, storage and disposal decisions, or other TWRS needs.
* Denotes a Systems Engineering term (Functions, Requirements, and Architecture).	

constraints*	Restrictions or limitations that must be met. Constraints are used to screen alternative strategies and are always nontradable by the designer (as opposed to requirements, which are tradable).
Cost, life-cycle (TWRS Program)	The sum total of direct, indirect, recurring, nonrecurring, and other related costs incurred or estimated to be incurred in the acquisition, operation, and decommissioning of a designated item.
criteria (for prioritization)	The factors used to prioritize technologies into three categories: Recommended Program, Minimum Safe Operations and TPA Program, and the Health and Safety Only Program. These criteria included: Resolving safety issues (flammable tanks, ferrocyanide, etc.), meeting legal commitments (TPA milestones, regulatory compliance, etc.), meeting production requirements (filling in gaps in the baseline and addressing unacceptable risks), and enhancing TWRS performance (expediting disposal/minimizing time to; reducing uncertainty, enhancing public/worker safety; reducing environmental insult; minimizing volume or toxicity of waste; minimizing cost, etc.).
critical interface	An important system boundary/point of coordination between two TWRS program elements in order for both elements to successfully meet program objectives.
cross-cutting issues	Problems identified in a program that occur in more than one program element.
current status	What is known to have been done so far in the area of technology development to address this functional need.
data	Any given, measured, or otherwise determined fact used for an analysis or to draw a conclusion.
deliverable	A required output or product resulting from the performance of a specified task or project work.
double-shell tank (DST)	A reinforced concrete underground vessel with two inner steel liners that provide containment and backup containment of liquid waste; annulus (space between the two liners) is configured to permit detection of leaks from the inner liner.
driver	Milestones (e.g., TPA milestones), key decision points or regulatory issues that require, compel, or otherwise motivate a particular activity.
enhancements (to the reference systems technologies)	Technologies within the program strategy that (1) provide backup where reference technology is very uncertain, (2) could potentially improve performance, and (3) if proven, could replace the reference system.
equipment	Assembled units that serve a function within a plant system. This definition relates to capital equipment but does not relate to construction fund classification.
fiscal year work plan (FYWP)	That portion of the multi-year work plan that is applicable to the current fiscal (execution) year.
function*	A specific task, action, activity, or process that supports the achievement of an objective (e.g., an operation that a system must perform to accomplish its mission).

* Denotes a Systems Engineering term (Functions, Requirements, and Architecture).

functional requirement*	Necessary task, action, or activity that must be accomplished. Top-level functions are identified by requirements analysis and subdivided by functional analysis.
functions and requirements analysis*	The determination of system-specific characteristics based on analyses of customer needs, requirements, and objectives; missions; project environments for people, products, and processes; constraints; and measures of effectiveness. Functions and requirements analysis assists the customers in defining and refining functions and requirements for the system's life-cycle.
funds, capital equipment	Funds approved and appropriated by Congress for the purchase of capital equipment used in operation of a DOE facility. These are items for which DOE will retain title, which cost in excess of $5,000, have an expected service life of more than two years, and are not required to complete a construction project.
funds, operating expense	Funds approved and appropriated by Congress to finance the testing, startup, and operation of DOE facilities excepting capital equipment purchases and construction projects.
Health and Safety Only Program	A subset of the recommended technology activities that would be required to maintain tank safety only. The major assumption made to form this technology package is that only the safety issues will be resolved—tanks will not be remediated.
high-level waste (HLW)	High-level radioactive waste is defined in the *Nuclear Waste Policy Act of 1982* (PL 97-425) as "(A) the highly radioactive material resulting from the reprocessing of spent nuclear fuel, including liquid waste produced directly in reprocessing and any solid material derived from such liquid waste that contains fission products in sufficient concentrations; and (B) other highly radioactive material that the [Nuclear Regulatory Commission], consistent with existing law, determines by rule requires permanent isolation." HLW at Hanford was generated from the reprocessing of production reactor fuel for the recovery of plutonium, uranium, and neptunium for defense and other national programs of spent reactor fuel and irradiated targets.
input*	Anything that enters a function or system.
interface*	System boundary across which material, data, or responsibility passes. The identifiable point of connection or coordination between two or more defined entities that must be properly coordinated for successful operations. Entities may be physical items, organizations, and/or people.
key assumptions	The set of important TWRS program assumptions which, at a minimum, includes those identified in the TWRS Technical Strategy (draft), dated 2/4/94.

* Denotes a Systems Engineering term (Functions, Requirements, and Architecture).

key uncertainties	Critical unknowns that could potentially affect successful development/ deployment of technologies. Lack of technical, schedule, cost, or institutional information that could adversely impact a program's outcome or ability to accomplish the mission.
level*	In a functional analysis, functions are decomposed to successively lower levels. Each function is identified by a unique number. The number of digits indicates the decomposition level [e.g., 4.2, Remediate Tank Waste, is a level 2 TWRS function, 4.2.1 identifies the next lower level functions (level 3) that comprise Remediate Tank Waste, and 4.2.1.1 identifies the next level functions (level 4), etc.].
low-level waste (LLW)	Low-level radioactive waste is defined in the *Nuclear Waste Policy Act of 1982* (PL 97-425) as "radioactive material that (A) is not high-level radioactive waste, spent nuclear fuel, transuranic waste, or by-product material...; and (B) the [Nuclear Regulatory Commission], consistent with existing law, classifies as low-level radioactive waste." Byproduct material is defined in the *Atomic Energy Act of 1954* [42 U.S.C. 2014(e)(2)] as "(1) any radioactive material (except special nuclear material) yielded in or made radioactive by exposure to the radiation incident to the process of producing or utilizing special nuclear material, and (2) the tailings or wastes produced by the extraction or concentration of uranium or thorium from any ore processed primarily for its source material content."
milestone	A designated event that must occur to achieve stated objectives. Milestones are specifically defined and identified and include an objective statement of the criteria for completion. See definition of "event."
Minimum Safe Operations and TPA Program	A subset of the recommended technology activities that would be required to meet the bare minimum for safe compliance with the TPA and other related regulatory requirements. This set of technologies has increased risk, cost, schedule, etc. because high-risk reference technologies may be used instead of the recommended enhancements or alternatives.
multi-year program plan (MYPP)	Objectives, performance criteria, system (program) requirements, schedules, and high-level cost estimates for the foreseeable life of the program. The approved MYPP becomes the multi-year program baseline description document. The TWRS Program Management Plan is the equivalent of an MYPP.
objectives	Discrete, measurable events that, if accomplished, will contribute to achieving a goal.
output*	Anything that leaves a function or system.
out-year planning	The definition of program work for those fiscal years past the planning year; ensures the continuity of work across the years.
plan	A description of what needs to be done now and through the end of the program to resolve an issue. Includes descriptions of key tasks (milestones) and key decision points.
* Denotes a Systems Engineering term (Functions, Requirements, and Architecture).	

pretreatment	One of the six TWRS program elements. Chemical and physical processes applied to separate Hanford tank waste into an HLW/TRU fraction, a LLW fraction, and a reusable materials fraction.
process	A set of interrelated work activities characterized by a set of specific inputs, tasks, knowledge, and procedures that produce a set of specific outputs.
product	The output or accomplishment of work.
program	An organized set of activities directed toward a common purpose or goal undertaken or proposed in support of an assigned mission area. A program may include one or more major system acquisitions or major projects, other projects, operations, or some combination thereof. For the purposes of this plan, a program is considered to be a minimum requisite mix of technologies to support reference, enhancement, or alternative systems required to implement a plan. Each TWRS program element identifies and funds technology development activities that are required for overall successful deployment of TWRS as an integral part of its planning.
program element	A major program component that requires a closely interrelated set of processes for successful execution. Sometimes referred to as an end function or system element. In TWRS there are six program elements: safety, characterization, retrieval, pretreatment, LLW and HLW.
Recommended Program	Those technology activities that are essential to a successful TWRS program. Each program element has considered a larger set of technologies to construct this subset of recommended technologies.
reference system	The selected and approved function (or functions) (i.e., the set of processes and equipment selected and combined into a system to perform required program functions).
reference system technologies	Technologies required to implement the technical strategy for the program, including technology development required to support reference system selection.
requirement*	How well the system needs to perform a function. The extent to which a function must be executed, generally measured in terms of quantity, quality, coverage, timelines, or safety. Requirements are always tradable by the system designer.
retrieval	One of the six TWRS program elements. Removing waste from tanks and transporting it to the pretreatment function.
risk	The combined result of the probability and consequences of failure of an item expressed in quantitative terms.
schedule	A time-phased sequencing of a plan's work scope in a logical sequence of interdependent activities. Schedules provided in this document are not official, and are for planning purposes only.
scope	The set of parameters bounding a defined piece of work.
single-shell tank (SST)	One of 149 single-shell carbon steel tanks (ranging in size from 55,000 to 1,000,000 gal) that have been used to store high-level radioactive waste at the Hanford Site.

* Denotes a Systems Engineering term (Functions, Requirements, and Architecture).

special nuclear material	Plutonium, uranium-223, uranium enriched in the isotope 233 or in the isotope 235, and any other material that the U.S. Nuclear Regulatory Commission, according to section 51 of the *Atomic Energy Act of 1954*, determined to be special nuclear material, but does not include source material. Any material artificially enriched by any of the above-mentioned isotopes, but that does not include source material.
spent nuclear fuel	Spent nuclear fuel is defined in the *Nuclear Waste Policy Act of 1982* (PL 97-425) as "fuel that has been withdrawn from a nuclear reactor following irradiation, the constituent elements of which have not been separated by reprocessing."
strategy	A plan or approach to accomplish the mission.
system*	A combination of related functions or equipment integrated into a single functioning unit.
systems engineering	An interdisciplinary approach to evolve and verify an integrated and life-cycle balanced set of products and process solutions that satisfy customer needs.
systems engineering management	Organizing and directing the tasks, activities, and performance of technical work, defining the systems engineering process, ensuring that the process is followed, reviewing technical results, and making strategic technical decisions based on those results for the system under development.
tank waste	Waste currently contained in SSTs, DSTs, and all new waste added to DSTs. Cesium and strontium stored in capsules are also managed under the Tank Waste Remediation System Program.
Tank Waste Remediation System (TWRS) Program	An integrated Program for carrying out the specific functions associated with remediating specific tank wastes at the Hanford Site.
task	A discrete assignment or activity to be performed within an existing statement of work.
technology	See Memorandum of Understanding between PNL and WHC, prepared in February 1993, and associated correspondence. The application of science to accomplish a function according to defined requirements. Technology for TWRS includes the entire technology life-cycle, from basic research through engineering development.
technology application	The sum of activities necessary to implement a technology after a choice has been made between competing technologies.
technology development	The process of the application of science to achieve commercial objectives and solve technical problems. Technology development includes conceiving of new ideas, proof-of-principle testing, bench-scale testing, pilot-scale testing, and technology transfer activities necessary for technology application. Note that not all of these activities may be performed for the development of a particular technology and that technology development activities are considered complete when a technology has been selected for technology application.
* Denotes a Systems Engineering term (Functions, Requirements, and Architecture).	

technology improvement	An incremental advance or modification of a commercially available technology to meet specific site needs (e.g., adding radiation monitoring equipment, up- or down-sizing equipment, and making equipment mobile).
technology package	A suite of technologies that need to be evaluated or developed to respond to a functional need. May include technologies to address/support the reference case or enhancements or alternatives to the reference case.
trade study*	The process of comparing or trading the strengths and weaknesses of alternative approaches or attributes; a feedback process for resolving inconsistencies between steps or levels; the analysis of the ability of a design solution to meet its stated objectives as inputs are varied.
transuranic (TRU) waste	TRU waste is defined in the *Atomic Energy Act of 1954* [42 U.S.C. 2014(ee)] as "material contaminated with elements that have an atomic number greater than 92, including neptunium, plutonium, americium, and curium, and that are in concentrations greater than 10 nanocuries per gram, or in such other concentrations as the Nuclear Regulatory Commission may prescribe to protect the public health and safety." TRU waste is primarily generated by research and development activities, plutonium recovery, weapons manufacturing, environmental restoration, and decontamination and decommissioning. Most TRU waste exists in solid form (e.g., protective clothing, paper trash, rags, glass, miscellaneous tools, and equipment). Some TRU waste is in liquid form (sludges) resulting from chemical processing for recovery of plutonium or other TRU elements.
treatment	Process or processes that alter waste in preparation for disposal.
Tri-Party Agreement	The *Hanford Federal Facility Agreement and Consent Order* is a legally enforceable agreement that outlines a cleanup program for the Hanford Site; signed in May 1989 by DOE, the U.S. Environmental Protection Agency, and the State of Washington, most recently revised on January 25, 1994.
vitrification	The act of applying heat to waste and turning it into a stable, glass-like substance that can be safely and permanently disposed.
* Denotes a Systems Engineering term (Functions, Requirements, and Architecture).	

Appendix H

Acronyms

A/E	architect/engineer
AA	atomic absorption
ADS	Activity Data Sheet
AEA	Atomic Energy Act
AG	Architecture Group(s)
AHCAT	Advanced Hot Cell Analytical Technology
ALARA	as low as reasonably achievable
AMP	ammonium molybdophosphate
ANL	Argonne National Laboratory
ASI	Advanced Sciences Inc.
BACT	Best Available Current Technology
BOA	Basic Ordering Agreement
BW-ID	Buried Waste Integrated Demonstration
CAA	Clean Air Act
CAG	Characterization Architecture Group
CC	complexant concentrate
CCAT	cross-cutting and advanced technology
CDR	conceptual design review
CDU	Cesium Demonstration Unit
CFR	Code of Federal Regulations
CMST-IP	Characterization, Monitoring, and Sensors Technology Integrated Program
CPU	Compact Processing Unit
CRADA	Cooperative Research and Development Agreement
CST	crystalline silicontitanates
CVS	composition variability study
CWA	Clean Water Act
D&D	decontamination and decommissioning
DEF	disposition excess facilities

DF	decontamination factor
DGE	disposition gaseous effluent
DHDECMP	dihexyl-N,N-diethlcarbamoylmethyl phosphonate
DLE	disposition liquid effluent
DNFSB	Defense Nuclear Facilities Safety Board
DOE/RL	U.S. Department of Energy/Richland Operations Office
DOE	U.S. Department of Energy
DQO	Data Quality Objectives
DRD	design requirement document
DRM	disposition reusable materials
DSC	differential scanning calorimetry
DSSF	double-shell slurry feed
DST	double-shell tank
DSW	disposition solid waste
DT	draft tube
DWPF	Defense Waste Processing Facility
ECA	Environmental Corporation of America
EDSI	Evaluate and Define Safety Issue
EDXRF	energy dispersive x-ray fluorescence
EIS	environmental impact statement
EMI	electromagnetic induction
ER	Environmental Restoration
ERT	electrical resistance tomography
ES&H	Environment, Safety, and Health
ESPIP	Efficient Separations and Processing Integrated Program
ESW	Enhanced Sludge Washing
ETIG	Engineering Technology Interface Group
F&R	functions and requirements
FFCA	Federal Facilities Compliance Act
FGWL	Flammable Gas Watch List
FIA	flow injection analysis

FTE	full time equivalency
FYWP	fiscal year work plan
GAO	Government Accounting Office
GC-MS	gas chromatography-mass spectrometry
GEA	gamma energy analysis
HAB	Hanford Advisory Board
HEPA	High-Efficiency Particulate Air (filter)
HLW	high-level waste
HSO	Health and Safety only (program)
HTM	high-temperature melter
HWVP	Hanford Waste Vitrification Project
IC	ion chromatography
ICF-KH	Kaiser Engineering Hanford
ICP/AA	inductively coupled plasma/atomic absorption
ICP/MS	inductively coupled plasma/mass spectrometry
IHLW	immobilized high-level waste
ILLW	immobilized low-level waste
INEL	Idaho National Engineering Laboratory
IPM	Initial Pretreatment Module
IR	infrared
ISR-IP	In Situ Remediation Integrated Program
ITP	Integrated Technology Plan
ITRU	immobilized transuranic
IX	ion exchange
LA/MS	laser ablation/mass spectrometry
LANL	Los Alamos National Laboratories
LDM	leak detection and monitoring
LDUA	light-duty utility arm
LFCM	liquid-fed ceramic melter
LFL	lower flammability limit
LIMS	laboratory information management systems

LLW	low-level waste
LOM	level of maturity
LOW	liquid observation well
LRM	long-reach manipulator
M&O	maintenance and operations
MAWS	Minimum Additive Waste Stabilization Program
ME	Mechanical Equipment (group)
MSC	mitigate safety condition
MSO&TPA	Minimum Safe Operations and Tri-Party Agreement
MTW	manage tank waste
MUSTs	miscellaneous underground storage tanks
MW-IP	Mixed Waste Integrated Program
MWL-ID	Mixed Waste Landfill Integrated Demonstration
MYPP	multi-year program plan
MYWP	multi-year work plan
NAS	National Academy of Sciences
NCAW	neutralized current acid waste
NEPA	National Environmental Policy Act
NESHAP	National Emission Standards for Hazardous Air Pollutants
NIR	near infrared (spectroscopy)
NOAA	National Oceanic and Atmospheric Administration
NRC	U.S. Nuclear Regulatory Commission
NWPA	Nuclear Waste Policy Act
ORNL	Oak Ridge National Laboratory
OSHA	Occupational Safety and Health Administration
OTD	Office of Technology Development
PA	performance assessment
PFP	Plutonium Finishing Plant
PMP	Program Management Plan
PNL	Pacific Northwest Laboratory
PPA	Pollution Prevention Act

PT	Pretreatment
R-F	resorcinol-formaldehyde
RCRA	Resource Conservation and Recovery Act
RFP	Request for Proposal
RIP	Robotics Integrated Program
RL	Richland Operations Office
ROD	Record of Decision
ROM	rough order-of-magnitude
RTDP	Robotics Technology Demonstration Program
RTWG	Retrieval Technology Working Group
RW	retrieve waste
SA	safety assessment
SAR	safety analysis report
SCWO	Supercritical Waste Oxidation Program
SIA	sequential injection analysis
SNL	Sandia National Laboratory
SPC	sulphur polymer cement
SR	Savannah River
SREX	solvent extraction process
SRL	Savannah River Laboratory
SRS	Savannah River Site
SSB	subsurface barriers
SSHTM	small-scale, high-temperature melter
SSSM	small-scale, stirred melter
SSTs	single-shell tanks
SX	solvent extraction
TAP	Tanks Advisory Panel
TCRs	tank characterization reports
TDPO	Technology Development Program Office
TDR	time domain reflectometry
TOC	total organic carbon

TPA	Tri-Party Agreement
TRG	Test Review Group
TRU	transuranic
TRUEX	transuranic extraction
TWRS	Tank Waste Remediation System
UMR	University of Missouri at Rolla
USBM	U.S. Bureau of Mines
USQ	Unreviewed Safety Question
UST	underground storage tanks
UST-ID	Underground Storage Tank-Integrated Demonstration
VOC-Arid ID	Volatile Organic Compound-Arid Integrated Demonstration
VOI	Value of Information
WAC	Washington Administrative Code
WAPS	Waste Acceptance Preliminary Specification
WBS	work breakdown structure
WCP	waste compliance plan
WD&C	waste dislodging and conveyance
WERC	Waste Environmental Remdiation Consortium
WESF	Waste Encapsulate and Storage Facility
WFQ	waste form qualification
WHC	Westinghouse Hanford Company
WIPP	Waste Isolation Pilot Plant
WPAG	Waste Processing Architecture Group
WSRC	Westinghouse Savannah River Corporation
WSTC	Westinghouse Savannah River Technology Center
WTS	Waste Tank Safety (staff)
WVDP	West Valley Demonstration Project
XAFS	x-ray absorption fine structure
XRF	x-ray fluorescence

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