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ORNL/ER-356

# ENVIRONMENTAL RESTORATION PROGRAM

# Treatment, Storage, and Disposal Alternatives for the Gunite and Associated Tanks at the Oak Ridge National Laboratory, Oak Ridge, Tennessee



ENERGY SYSTEMS

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MANAGED BY
LOCKHEED MARTIN ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY



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Energy Systems Environmental Restoration Program

# Treatment, Storage, and Disposal Alternatives for the Gunite and Associated Tanks at Oak Ridge National Laboratory, Oak Ridge, Tennessee

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# PREFACE

This report, *Treatment, Storage, and Disposal Alternatives for the Gunite and Associated Tanks* (ORNL/ER-356), was performed under Work Breakdown Structure 1.4.12.6.1.01.41.12.04 (Activity Data Sheet 3301, "Waste Area Grouping 1"as part of the Gunite and Associated Tanks (GAAT) Treatability Study. This document provides the Environmental Restoration Program with an evaluation of alternatives for the treatment, storage, and disposal (TSD) of the sludge and supernate waste from the GAAT Operable Unit. It includes a brief waste characterization summary, TSD evaluation criteria, TSD alternative descriptions, and order-of-magnitude cost estimates for various alternatives. Information provided in this document forms the basis for determining which alternatives will be further evaluated in the feasibility study.

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## TABLES

# ACRONYMS

| | |
|---|---|
| ALARA | as low as reasonably achievable |
| ARAR | applicable or relevant and appropriate requirements |
| BVESTs | Bethel Valley evaporator storage tanks |
| CERCLA | Comprehensive Environmental Response, Compensation, and Liability Act |
| CFR | Code of Federal Regulations |
| CH | contact handled |
| CIP | Capacity Increase Project |
| DOE | U.S. Department of Energy |
| DOT | U.S. Department of Transportation |
| EPA | U.S. Environmental Protection Agency |
| ESWMO | Energy Systems Waste Management Organization |
| FS | feasibility study |
| FTE | full-time equivalent |
| FY | fiscal year |
| GAAT | Gunite and Associated Tanks |
| GPP | General Plant Project |
| HLW | high-level radioactive waste |
| INEL | Idaho National Engineering Laboratory |
| ISV | in-situ vitrification |
| ITT | inactive tank transfer |
| IWMF | interim waste management facility |
| LCO | laboratory certification officer |
| LDR | land disposal restrictions |
| LLLW | liquid low-level waste |
| LLW | low-level radioactive waste |
| LLMW | low-level mixed waste |
| LMES | Lockheed Martin Energy Systems |
| LSA | low specific activity |
| LWSP | Liquid Waste Solidification Project |
| M&O | managing and operating |
| MPI | multipoint injection |
| MVSTs | Melton Valley Storage Tanks |
| NRC | Nuclear Regulatory Commission |
| NTF | North Tank Farm |
| NTS | Nevada Test Site |
| O&M | operation and maintenance |
| ORNL | Oak Ridge National Laboratory |
| ORO | Oak Ridge Operations |
| ORR | Oak Ridge Reservation |
| OSR | operational safety report |
| OTE | out-of-tank evaporation |
| OU | operable unit |
| PA | performance assessment |
| PCB | polychlorinated biphenyl |

| | |
|---|---|
| RCRA | Resource Conservation and Recovery Act |
| RI | remedial investigation |
| ROD | record of decision |
| SLLW | solid low-level waste |
| STF | South Tank Farm |
| STP | site treatment plan |
| SWB | standard waste box |
| TCLP | toxicity characteristic leaching procedure |
| TDEC | Tennessee Department of Environment and Conservation |
| TPF | TRU processing facility |
| TRU | transuranic |
| TRUPACT | TRU waste packaging and transportation system |
| TS | treatability study |
| TSD | treatment, storage, and disposal |
| TVS | transportable vitrification system |
| WAC | waste acceptance criteria |
| WAG | waste area grouping |
| WAP | waste analysis plan |
| WCP | waste certification procedures |
| WIPP | Waste Isolation Pilot Plant |
| WMRAD | Waste Management and Remedial Action Division (ORNL) |

# EXECUTIVE SUMMARY

The Gunite and Associated Tanks (GAAT) are inactive, liquid low-level waste tanks located in and around the North and South Tank Farms at Oak Ridge National Laboratory. These underground tanks, which vary in size and geometry and contain supernate over a layer of radioactive sludge, are the subject of an ongoing treatability study that will determine the best remediation alternatives for the tanks. The GAAT Operable Unit was chosen as a high priority for remediation because of the potential risk presented by the concentration of contaminants and the deteriorating conditions of the gunite tank walls. As part of the treatability study, an assessment of viable treatment, storage, and disposal (TSD) alternatives has been conducted.

The report summarizes relevant waste characterization data and statistics obtained to date. Items of particular interest are waste volumes; curie distribution; Resource, Conservation, and Recovery Act waste status; and transuranic (TRU) and "greater than Class C" (>C) waste status (unfit for near-surface disposal facilities). The report describes screening and evaluation criteria for evaluating TSD options. Individual options that pass the screening criteria are described in some detail. TSD options are combined into complete TSD system alternatives that map strategies for "cradle-to-grave" handling of the GAAT wastes. Order-of-magnitude cost estimates are presented for each of the TSD system alternatives. All alternatives are compared to the baseline approach of pumping all of the GAAT sludge and supernate to the Melton Valley Storage Tank (MVST) facility for eventual TSD along with the existing MOST waste.

Four TSD systems are identified as alternatives to the baseline approach. The baseline is the most expensive of the five identified alternatives. The least expensive alternative is in-situ grouting of all GAAT sludge followed by in-situ disposal. The other alternatives are: 1)ex-situ grouting with on-site storage and disposal at Nevada Test Site (NTS); 2) ex-situ grouting with on-site storage and disposal at NTS and the Waste Isolation Pilot Plant (WIPP); and 3) ex-situ vitrification with on-site storage and disposal at NTS and WIPP.

Several findings are presented in the report. The potential exists for creating an "orphan" final waste form (waste is below the TRU waste limits but >C and has no disposal option identified) from the GAAT sludge. It is imperative that no "orphan" waste is created regardless of the treatment technology selected. Appropriate on-site solid waste storage capacity is marginal for storing all of the treated GAAT waste. Alternatives to traditional on-site storage are identified in the report. In-situ disposal is financially attractive, but is associated with many regulatory uncertainties.

# ABSTRACT

Potential alternatives for the treatment, storage, and disposal (TSD) of the wastes in the inactive Gunite and Associated Tanks (GAAT) at the Oak Ridge National Laboratory have been reviewed and evaluated. This effort is an extension of an initial study of various waste treatment and tank stabilization alternatives. Potential waste storage and disposal options were identified and treatment options developed based on the waste acceptance criteria for selected disposal options. Screening criteria were developed to assist in the selection of the most viable individual TSD options. The individual TSD options that did not meet the screening criteria were eliminated. The remaining TSD options were then combined to create a number of systematic approaches (TSD system alternatives) for the final disposal of the GAAT waste. Evaluation criteria were developed to assist in the selection of the most viable TSD system alternatives. Each TSD system alternative was then described in terms of key evaluation criteria. Rough order-of-magnitude cost information for the selected treatment and stabilization alternatives are also provided.

The primary recommendations and conclusions from this study are summarized as follows:

1. After the necessary quantities of the waste are removed from the tanks, they should be stabilized to prevent groundwater intrusion and collapse through the use of a nonshrinking concrete or aggregate material.

2. In-situ stabilization and immobilization of the wastes in the GAAT appears technically feasible and fiscally advantageous, but will require further regulatory approval and scrutiny before implementation. **Risk reduction is a key parameter in evaluating in-situ disposal but is not within the scope of this document.**

3. Vitrification and grouting demonstrations should be pursued as a means of 1) demonstrating and comparing immobilization technologies, 2) establishing disposal pathways for ORNL waste streams, and 3) demonstrating cost-effective methods of establishing waste disposal facilities for long-term use by the Oak Ridge Complex.

4. The currently available on-site storage and disposal facilities for immobilized sludges and supernates have only marginal capacity to contain the GAAT wastes. New facilities may have to be designed and constructed to hold the immobilized GAAT wastes. However, from a cost and schedule standpoint, it is more attractive to store the immobilized GAAT waste outdoors in individual storage containers or casks similar to those used to store the liquid waste solidification project waste.

5. The primary off-site disposal sites for the GAAT wastes are the Nevada Test Site for low-level wastes and the Waste Isolation Pilot Plant (WIPP) for TRU wastes.

6. Special care must be taken to avoid creating a final waste form that cannot be accepted at the currently available disposal sites (orphan waste). In particular, no final waste form should be created that exceeds Nuclear Regulatory Commission Class C limits (unfit for near-surface disposal facilities) and that is also not TRU waste (unacceptable for disposal at WIPP).

7. The least expensive TSD system alternative of those considered is in-situ grouting and disposal of the GAAT waste. This alternative eliminates many of the costs and logistical problems associated with handling, transporting, and storing the waste. The primary obstacle for in-situ disposal is obtaining regulatory and stakeholder approval.

8. The most expensive TSD system alternative of those considered appears to be the baseline alternative of transferring all of the GAAT waste to the Melton Valley Storage Tanks followed by eventual treatment and disposal by the U.S. Department of Energy TRU waste processing program.

# 1. OBJECTIVE

The Treatment, Storage, and Disposal (TSD) alternatives evaluation is part of the Gunite and Associated Tanks (GAAT) Treatability Study (TS). This report extends and updates the findings from an initial study of waste treatment and tank stabilization alternatives for the GAAT[1] and is based on statistical evaluations of the most recent GAAT waste characterization data. The primary objective of this report is to evaluate and recommend various TSD system alternatives for the GAAT waste and provide input to the TS feasibility study (FS) and record of decision (ROD) for the remediation of the GAAT.

# 2. INTRODUCTION

The GAAT are located at the Oak Ridge National Laboratory (ORNL) and are a part of Waste Area Grouping (WAG) 1. These tanks and their associated structures and piping were constructed between 1943 and 1951 and were designed to contain the radioactive and chemical wastes generated by ORNL operations. A total of 12 gunite tanks and 4 stainless steel tanks (W-1A, W-13, W-14, W-15) are located in the GAAT Operable Unit (OU), which is situated in a high-traffic area in the middle of the ORNL site. Figure 2.1 is a sketch of the approximate location of the GAAT at ORNL that shows:

1. The North Tank Farm (NTF) composed of tanks W-1, W-1A, W-2, W-3, W-4, W-13, W-14, and W-15;
2. the South Tank Farm (STF) composed of tanks W-5, W-6, W-7, W-8, W-9, and W-10;
3. tank W-11 located east of the STF;
4. tank TH-4 located southwest of Bldg. 3500; and
5. various other active and inactive storage tanks.

The gunite tanks are composed of a mixture of cement, sand, and water that is sprayed over steel reinforcing material. Visual inspections of the interior of the gunite tanks have shown varying degrees of deterioration to the point that the structural integrity of the tanks cannot be guaranteed. A high priority has been placed on the remediation of the site since 1) the structural integrity of the tanks cannot be verified, 2) leaking appurtenances are allowing groundwater infiltration into some of the tanks, and 3) the tank contents present potential off-site and on-site risks to personnel and the environment. Based on the perceived risks, the tanks have been categorized into three distinct groups:

- Tank Group 1 (W-1, W-2, W-11);
- Tank Group 2 (W-3, W-4, W-5, W-6, TH-4); and
- Tank Group 3 (W-7, W-8, W-9, W-10).

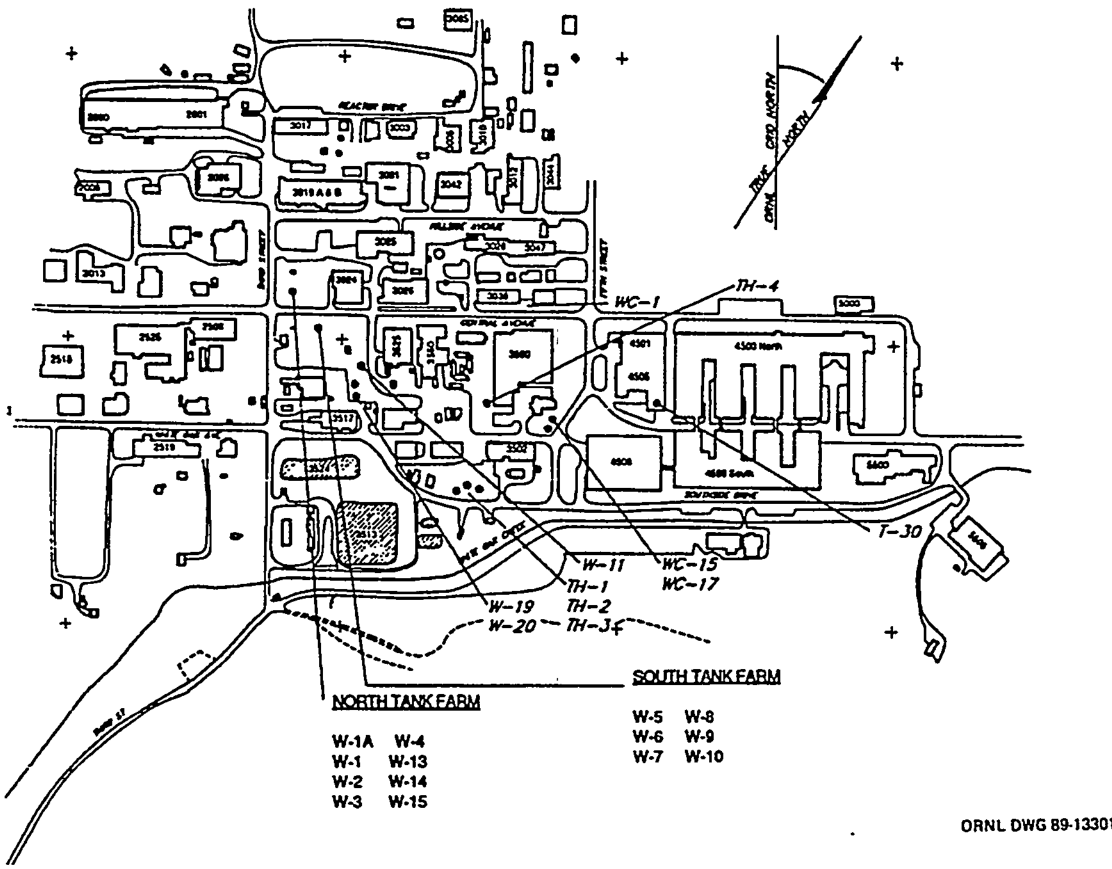


**Fig. 2-1 Inactive tank locations at ORNL showing the GAAT North and South Tank Farms.**

The Group 1 tanks contain supernate and only a small quantity of sludge. These tanks contain little or no activity and represent little or no risk to personnel or the environment. The Group 2 tanks contain primarily sludges with lower radioactivity levels with moderate but acceptable health and environmental risks. The Group 2 tanks may be feasible for in-situ disposal. The Group 3 tanks contain the highest activity sludges and supernates and could represent significant risks to personnel and the environment. The GAAT OU has been designated a Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) site.

This report represents an extension and update of a previous study describing waste treatment and tank stabilization alternatives for the GAAT. Certain elements of the previous report have been included in this document for clarity and continuity. This report includes additional characterization data taken since the initial report was written and uses a statistical analysis of previously existing data combined with the most recent data. This report also evaluates order-of-magnitude life cycle costs for TSD system alternatives. Several of the key references used in this report are summarized in Appendix A: Annotated Bibliography of Selected Literature.

## 2.1 SCOPE

The activities associated with the TSD alternatives study provide support to the GAAT TS for a planned FS in fiscal year (FY) 98 and a ROD in FY99. This effort presents order-of-magnitude cost estimates for selected alternatives, uses various criteria for screening TSD options and selecting TSD system alternatives, incorporates the most recent characterization information, provides summary information on treatment alternatives, interim storage capacities, and disposal sites, clarifies key interfaces, lists the necessary transportation requirements, estimates final waste form quantities and characteristics, and evaluates the impacts of regulatory and compliance issues on the various alternatives. Leveraging opportunities for demonstration of TSD options that are consistent with the goals of the GAAT Project are also identified.

## 2.2 RELATED ISSUES

Various opportunities exist to leverage resources and share information with related tank waste remediation projects around the U.S. Department of Energy (DOE) Complex. Two examples of these opportunities are:

1. The Melton Valley Storage Tanks (MVSTs) with the associated Bethel Valley Evaporator storage tanks (BVESTs) and
2. The High-Level Waste Tanks on the DOE Hanford Reservation.

Of these projects, the GAAT has the least inventory of sludge with an estimated volume of about 50,000 gal, while MVSTs/BVESTs have an estimated inventory of about 225,000 gal and the Hanford High-Level Waste Tanks contain several million gallons of sludge.

The physical configurations of the GAAT and the MVSTs/BVESTs are significantly different. However, the GAAT provide an important corollary to MVSTs/BVESTs because most of the sludge waste currently stored in the MVSTs originated in the GAAT. Therefore, comparison of the physical and chemical characteristics of the sludges from both sets of tanks should reveal similarities that can be generalized and applied to the design and selection of sluicing, pumping, settling, dewatering, and stabilizing processes for each application.

The Hanford tanks are significantly larger than the GAAT, at roughly 1 M gal each, versus the maximum GAAT size of 170,000 gal. Both systems have similar physical configurations that result in several parallel physical/mechanical waste retrieval problems. These parallel problems have resulted in similar methods of planned remote entry and waste retrieval.

Several aspects of retrieval of the GAAT wastes will provide valuable insight into the problems inherent in dealing with the remote removal and subsequent handling of heterogeneous, radioactive/hazardous sludges. One of the more difficult challenges to be solved during the GAAT TS is the handling of solid debris (piping, plastic bags, sample bottles, etc.) that has been deposited in the sludge as a result of various operations, maintenance, observation, and sampling activities. The desire to minimize generation, handling, packaging and storage/disposal of secondary wastes from these activities has led to the undesirable historical practice of depositing some of the materials associated with these activities back into the tanks. The methods used in the GAAT remediation to collect, handle, process/stabilize, package and store/dispose of these wastes is expected to have important implications for future projects encountering similar impediments to sludge mobilization and removal.

Another important issue associated with sludge retrieval is minimization of the amount of process water used to mobilize and transfer the sludges to either interim storage or a treatment facility. If a large ratio of process water to sludge is required to mobilize and retrieve the sludge, then there will be significant economic incentives to remove the excess water prior to further processing.

Many of the issues associated with waste immobilization are driven mainly by the waste acceptance criteria (WAC) promulgated by the disposal sites. The WAC then incorporate the pertinent requirements of DOE, the Nuclear Regulatory Commission (NRC), the U.S. Department of Transportation, the U.S. Environmental Protection Agency (EPA), etc. Unfortunately, some of the requirements have been developed without consideration of the requirements of other stakeholder agencies. Conflicting requirements can be problematic to the selection of treatment processes for low-level radioactive waste (LLW); particularly when portions of the wastes are transuranic (TRU) and/or Resource Conservation and Recovery Act (RCRA) hazardous.

In particular, the concentrations of the many radioactive and hazardous contaminants of concern in the final waste form will have a significant impact on how that waste will be categorized, packaged, handled, stored, transported, and disposed. While concerns for reducing the risks associated with generating greater than NRC Class C LLW will tend to drive the waste form toward a more dilute formulation, initial interpretation of DOE Order 5820.2A suggests that such dilution of the TRU contaminants to reduce the specific activity below TRU limits could be an inappropriate action.

Significant dilution of the waste in a final grout or glass waste form would also increase the number of waste packages, interstate transportation events, consumption of valuable disposal space, and the overall cost and duration of the project. However, this document assumes that dilution during immobilization of the waste is an acceptable treatment method.

As the cost, duration, and number of transportation events increase, so does the concern for public acceptance and political/budgetary support. The resolution (both means and outcome) of this complex web of interrelated concerns is not only important to the GAAT remediation, but has important implications for future DOE projects. The achievement of a disposal end point that is acceptable to all responsible and affected parties will be a significant milestone for the Lockheed Martin Energy Systems (LMES) Environmental Restoration Program, Lockheed Martin Energy Research/ORNL, DOE-Oak Ridge Operations (ORO), the City of Oak Ridge, surrounding communities, and the DOE Complex.

# 3. CHARACTERIZATION DATA SUMMARY

Statistical evaluation of the characterization data from the GAAT 1988 sampling and analysis campaign,[2] the 1994 Phase I sampling results, [3]and the 1995 Phase II sampling efforts have been performed and documented in another report. Some of the conclusions and observations from the statistical analysis report are included in this chapter. Data from Toxicity Characteristic Leaching Procedure (TCLP) tests on select sludges[5] have also been reviewed and summary information has been included. The summary information given in this chapter is provided to support the identification, evaluation, and recommendation of preferred TSD alternatives.

A summary of the radionuclide concentrations and curie loadings for the sludge and supernate in each tank is presented in Table 3-1. Table 3-2 gives the relative percentages of the radionuclide concentration and curie loadings by tank and by tank grouping. Each table reports both the 50% (50%-tile) and 95% (95%-tile) confidence levels for the data.

The tanks are categorized into three distinct groups: Tank Group 1 (W-1, W-2, W-11), Tank Group 2 (W-3, W-4, W-5, W-6, TH-4), and Tank Group 3 (W-7, W-8, W-9, W-10). The Group 1 tanks contain supernate and only a small quantity of sludge, with little or no activity. The Group 2 tanks contain primarily sludges with lower radioactivity levels. The Group 3 tanks contain the highest activity sludges and supernates and contain >90% of the curie inventory in the GAAT OU. These groupings are used to organize and present the data within this chapter.

## 3.1 SLUDGE AND SUPERNATE VOLUME ESTIMATES

Sludge and supernate volume estimates are provided in Table 3-3 for all the GAAT. Sludge volume estimates are derived from information gathered during either the 1994 Phase I sampling or 1995 Phase II sampling efforts. Supernate estimates are current as of December 5, 1995. The volume of supernate in the GAAT varies with time due to inleakage and transfers to the active waste system. Tank W-1A, for example, receives inleakage from rain water that must periodically be sent to the active liquid low-level waste (LLLW) system for evaporation and storage. The estimated volume of supernate contained in the GAAT as of December 5, 1995, was ~ 345,560 gal (1,302,945 L). The estimated wet sludge volume in the GAAT is ~49,132 gal (185,964 L).

All the stainless steel tanks in the GAAT (W-1A, W-13, W-14, and W-15) were reported to contain little or no residual sludge. Therefore, since these tanks contain no significant quantities of wastes and appear to be in relatively good condition (with the exception of tank W-1A), no further consideration has been given to them in the remainder of this report. However, it has been suggested in another report that these tanks be stabilized by being filled with grout during the remediation of the balance of the GAAT OU. Tank W-1A has a hole in the top due to corrosion from past operations. As previously cited, inleakage to this tank is periodically transferred to the LLLW system for processing.

**Table 3-1 Curie loading for the GAAT**

| Tank | Phase | Conc (Bq/g, Bq/mL) | | Curies (Ci) | |
|---|---|---|---|---|---|
| | | 50%-tile | 95%-tile | 50%-tile | 95%-tile |
| W-1 | Sludge | 0.00E+00 | 0.00E+00 | 0 | 0 |
| | Supernate | 2.00E+02 | 2.04E+02 | 0 | 0 |
| W-2 | Sludge | 0.00E+00 | 0.00E+00 | 0 | 0 |
| | Supernate | 2.12E+02 | 2.16E+02 | 0 | 0 |
| W-11 | Sludge | 0.00E+00 | 0.00E+00 | 0 | 0 |
| | Supernate | 2.28E+01 | 8.31E+01 | 0 | 0 |
| **Group 1 Subtotals:** | Sludge | 0.00E+00 | 0.00E+00 | 0 | 0 |
| | Supernate | 4.35E+02 | 5.03E+02 | 0 | 0 |
| | Sludge+Sup | 4.35E+02 | 5.03E+02 | 0 | 0 |
| W-3 | Sludge | 2.36E+05 | 5.42E+05 | 16 | 37 |
| | Supernate | 9.08E+02 | 1.25E+03 | 1 | 2 |
| W-4 | Sludge | 1.87E+05 | 5.20E+05 | 32 | 89 |
| | Supernate | 4.19E+03 | 2.06E+04 | 13 | 63 |
| W-5 | Sludge | 5.95E+04 | 9.74E+04 | 24 | 40 |
| | Supernate | 3.40E+03 | 4.95E+03 | 10 | 14 |
| W-6 | Sludge | 6.11E+05 | 1.01E+06 | 523 | 861 |
| | Supernate | 8.41E+04 | 5.03E+05 | 364 | 2,178 |
| TH-4 | Sludge | 6.10E+03 | 9.50E+03 | 4 | 6 |
| | Supernate | 3.13E+02 | 4.91E+02 | 0 | 0 |
| **Group 2 Subtotals:** | Sludge | 1.10E+06 | 2.17E+06 | 599 | 1,033 |
| | Supernate | 9.29E+04 | 5.30E+05 | 388 | 2,258 |
| | Sludge+Sup | 1.19E+06 | 2.70E+06 | 988 | 3,291 |
| W-7 | Sludge | 1.95E+06 | 2.84E+06 | 2,367 | 3,461 |
| | Supernate | 6.41E+05 | 6.41E+05 | 238 | 238 |
| W-8 | Sludge | 2.96E+06 | 3.49E+06 | 3,714 | 4,386 |
| | Supernate | 3.08E+05 | 3.74E+05 | 2,065 | 2,511 |
| W-9 | Sludge | 2.20E+06 | 2.60E+06 | 803 | 950 |
| | Supernate | 4.50E+04 | 5.77E+04 | 212 | 272 |
| W-10 | Sludge | 5.59E+06 | 1.60E+07 | 6,536 | 18,764 |
| | Supernate | 1.02E+05 | 2.00E+05 | 1,123 | 2,197 |
| **Group 3 Subtotals:** | Sludge | 1.27E+07 | 2.50E+07 | 11,053 | 27,562 |
| | Supernate | 1.10E+06 | 1.27E+06 | 3,401 | 5,219 |
| | Sludge+Sup | 1.38E+07 | 2.62E+07 | 14,453 | 32,780 |
| **Grand Totals:** | Sludge | 1.38E+07 | 2.71E+07 | 11,652 | 28,595 |
| | Supernate | 1.19E+06 | 1.80E+06 | 3,789 | 7,476 |
| | Sludge+Sup | 1.50E+07 | 2.90E+07 | 15,441 | 36,071 |

**Table 3-2 Curie distribution for the GAAT — Relative Percentages**

| Tank | Phase | Curies (Ci - %) 0.50 | 0.95 |
|---|---|---|---|
| W-1 | Sludge | 0 | 0 |
| | Supernate | 57 | 55 |
| W-2 | Sludge | 0 | 0 |
| | Supernate | 41 | 39 |
| W-11 | Sludge | 0 | 0 |
| | Supernate | 2 | 5 |
| **Group 1 Subtotals:** | Sludge | 0 | 0 |
| | Supernate | 0 | 0 |
| | Sludge+Sup | 0 | 0 |
| W-3 | Sludge | 3 | 4 |
| | Supernate | 0 | 0 |
| W-4 | Sludge | 5 | 9 |
| | Supernate | 3 | 3 |
| W-5 | Sludge | 4 | 4 |
| | Supernate | 3 | 1 |
| W-6 | Sludge | 87 | 83 |
| | Supernate | 94 | 96 |
| TH-4 | Sludge | 1 | 1 |
| | Supernate | 0 | 0 |
| **Group 2 Subtotals:** | Sludge | 5 | 4 |
| | Supernate | 10 | 30 |
| | Sludge+Sup | 6 | 9 |
| W-7 | Sludge | 21 | 13 |
| | Supernate | 7 | 5 |
| W-8 | Sludge | 34 | 16 |
| | Supernate | 57 | 48 |
| W-9 | Sludge | 7 | 3 |
| | Supernate | 6 | 5 |
| W-10 | Sludge | 59 | 68 |
| | Supernate | 31 | 42 |
| **Group 3 Subtotals:** | Sludge | 95 | 96 |
| | Supernate | 90 | 70 |
| | Sludge+Sup | 94 | 91 |
| **Grand Totals:** | Sludge | 100 | 100 |
| | Supernate | 100 | 100 |
| | Sludge+Sup | 100 | 100 |

**Table 3-3 Sludge and Supernate Volume Estimates**

| Tank | Tank Capacity (gal) | Phase | Vol (gal) | Vol (% of Group) | Vol (% of Total) | Max Density (g/cc, g/mL) |
|---|---|---|---|---|---|---|
| W-1 | 4,800 | Sludge | 0 | 0 | 0 | 0.000 |
| | | Supernate | 2,926 | 52 | 1 | 1.002 |
| W-2 | 4,800 | Sludge | 0 | 0 | 0 | 0.000 |
| | | Supernate | 1,995 | 35 | 1 | 1.000 |
| W-11 | 1,500 | Sludge | 0 | 0 | 0 | 0.00 |
| | | Supernate | 722 | 13 | 0 | 1.00 |
| **Group 1 Subtotals:** | | Sludge | 0 | | 0 | |
| | | Supernate | 5,643 | | 2 | |
| | 6,700 | Sludge+Sup | 5,643 | | 1 | |
| W-3 | 42,500 | Sludge | 628 | 4 | 1 | 1.070 |
| | | Supernate | 15,688 | 13 | 5 | 1.006 |
| W-4 | 42,500 | Sludge | 1,313 | 7 | 3 | 1.275 |
| | | Supernate | 29,754 | 25 | 9 | 1.008 |
| W-5 | 170,000 | Sludge | 3,422 | 19 | 7 | 1.165 |
| | | Supernate | 27,964 | 23 | 8 | 1.013 |
| W-6 | 170,000 | Sludge | 7,037 | 39 | 14 | 1.190 |
| | | Supernate | 41,479 | 34 | 12 | 1.020 |
| TH-4 | 14,000 | Sludge | 5,452 | 31 | 11 | 1.07 |
| | | Supernate | 5,410 | 4 | 2 | 1.06 |
| **Group 2 Subtotals:** | | Sludge | 17,852 | | 36 | |
| | | Supernate | 120,295 | | 35 | |
| | 439,000 | Sludge+Sup | 138,147 | | 35 | |
| W-7 | 170,000 | Sludge | 8,812 | 28 | 18 | 1.350 |
| | | Supernate | 3,565 | 2 | 1 | 1.020 |
| W-8 | 170,000 | Sludge | 10,309 | 33 | 21 | 1.190 |
| | | Supernate | 64,581 | 29 | 19 | 1.015 |
| W-9 | 170,000 | Sludge | 2,861 | 9 | 6 | 1.250 |
| | | Supernate | 45,616 | 21 | 13 | 1.011 |
| W-10 | 170,000 | Sludge | 9,298 | 30 | 19 | 1.230 |
| | | Supernate | 105,860 | 48 | 31 | 1.013 |
| **Group 3 Subtotals:** | | Sludge | 31,280 | | 64 | |
| | | Supernate | 219,622 | | 64 | |
| | 680,000 | Sludge+Sup | 250,902 | | 64 | |
| **Grand Totals:** | | Sludge | 49,132 | | 100 | |
| | | Supernate | 345,560 | | 100 | |
| | 1,125,700 | Sludge+Sup | 394,692 | | 100 | |

## 3.2 SUMMARY OF SLUDGE AND SUPERNATE CHARACTERISTICS

The vast majority (~90%) of the total activity (36,071 Ci) in the GAAT waste can be attributed to the sludge and supernate in the Group 3 tanks, based on the 95%-tile data. The sludge and supernate in tanks W-8 and W-10 account for about 85% (27,858 Ci) of the activity of this grouping of tanks and 77% of the total GAAT waste activity.

### 3.2.1 Summary of Supernate Characteristics

The primary beta/gamma contributing constituents are $^{137}Cs$ and $^{90}Sr$. In the Group 3 sludge samples, $^{137}Cs$-specific activity levels range from 3.30E+05 Bq/g in tank W-9 to 3.10E+06 Bq/g in tank W-07, and $^{90}Sr$-specific activity levels range from 1.80E+04 Bq/g in tank W-7 to 2.40E+06 Bq/g in tank W-10.

Classification of the GAAT waste as TRU has been based on DOE Order 5820.2A, "Radioactive Waste Management" (9-26-88). The definition of TRU waste in Attachment 2 of the order states:

> "Without regard to source or form, waste that is contaminated with alpha-emitting transuranium radionuclides with half-lives greater than 20 years and concentrations greater than 100 ηCi/g at the time of assay. "Transuranium Radionuclide" is defined as: "Any radionuclide having an atomic number greater than 92."

DOE Order 5820.2A (9-26-88) has an additional sentence that can be greatly misunderstood:

> "Heads of Field Elements can determine that other alpha-contaminated wastes, peculiar to a specific site, must be managed as transuranic waste."

DOE-ORO and LMES require the inclusion of $^{233}U$, $^{244}Cm$, and $^{252}Cf$ in the TRU determination for on-site storage and disposal. However, since the Waste Isolation Pilot Plant (WIPP) is the only disposal site identified for TRU waste and does not include $^{233}U$, $^{244}Cm$, and $^{252}Cf$ in its definition of TRU waste, these isotopes were not included in the TRU concentration calculations.

From evaluation of the Phase I sample analysis data, the concentrations of TRU constituents in the GAAT supernates fall well below the TRU limits described above.

The RCRA metals in the GAAT supernates having the highest concentrations relative to the TCLP limits are Cr, Hg, and Tl. The supernates in tanks W-3, W-4, and W-8 exceed the RCRA limit for chromium. The mercury and thallium limits are exceeded in tank W-8 and the thallium limit is exceeded by the supernate in tank W-9.

All of the Group 2 and Group 3 tank supernates contain relatively high concentrations of Na (1,705 - 14,500 mg/L); moderate to high concentrations of U (78.5 - 7,865 mg/L) and K (19.75 - 896 mg/L); and moderate levels of Ca (6.84 - 263 mg/L). Moderate levels of Th are found in tanks W-4 (39.6 mg/L) and TH-4 (130.9 mg/L).

### 3.2.2 Summary of Sludge Characteristics

Based on the TRU waste definition given in Sect. 3.2.1, the sludges in tanks W-5 and TH-4 do not exceed the DOE TRU limit. The 50%-tile TRU concentrations in these tanks range from 1 ηCi/g in TH-4 to 64 ηCi/g in W-7. However, the 50%-tile TRU concentration in W-4 is below the TRU limit (89 ηCi/g) but the 95%-tile concentration is above the TRU limit (315 ηCi/g). The 50%-tile TRU concentration in W-7 is below the TRU limit (96 ηCi/g) but the 95%-tile concentration is above the TRU limit (183 ηCi/g). The sludges in tanks W-3, W-6, W-8, W-9, and W-10 exceed the DOE TRU limit with 50%-tile concentrations ranging from 130 ηCi/g in tank W-3 to 278 ηCi/g in W-10 and 95%-tile concentrations ranging from 186 ηCi/g in W-3 to 355 ηCi/g in W-6 and W-9.

The RCRA metals Cr, Hg, and Pb have the highest relative concentrations in the GAAT sludges. Several of the tank sludges have total concentrations of RCRA metals that, when diluted by a factor of 20 in accordance with TCLP procedures, exceed the RCRA limits. Those sludges that contain total RCRA metal concentrations greater than 20 times the established RCRA metal limits may be classified as a RCRA waste under the assumption that all the individual RCRA constituents are leached from the sludge. Based on the dilution factor assumption, all sludges except those in tank TH-4 are suspect RCRA (exhibiting the toxicity characteristic) in chromium and mercury and tanks W-5, W-6, W-8, W-9, and W-10 are suspect RCRA in lead. However, TCLP test results on sludge samples from tanks W-3, W-4, W-6, W-7, and W-10 show that Hg (in W-6, W-7, and W-10) is the only RCRA metal that exceeds the TCLP limits. This suggests that a relatively small portion of the RCRA metals in the sludge are likely to be leached under the existing conditions.

All of the Group 2 and Group 3 tank sludges contain relatively high concentrations of Na (5,070 - 68,700 mg/kg) and moderate to high levels of Al (733 - 51,100 mg/kg), Ca (384 - 31,600 mg/kg), Fe (195 - 20,300 mg/kg), K (219 - 13,000 mg/kg), Mg (47.8 - 11,100 mg/kg), Th (86.2 - 237,000 mg/kg), and U (895 - 211,000 mg/kg).

The sludge in tank W-10 was the only sludge containing polychlorinated biphenyl (PCB) concentrations in excess of the 2-ppm limit established by ORNL for classification as PCB contaminated waste. The PCB concentration in the sludge in tank W-10 is 34.3 ppm. When combined with the other TRU sludges in the GAAT OU, the PCB concentration would still be over the 2- ppm limit for on-site disposal at ORNL. Based on this knowledge, tank W-10 sludge should not be mixed with other sludges. This report assumes that the PCB issue will be resolved and the tanks can be mixed and/or discharged to the MVST. In addition, it should be noted that the maximum allowable PCB concentration according to EPA standards is 50 ppm. Based on this ruling, the sludge would not require treatment to reduce the PCB content.

Various physical properties of the Group 2 sludges include water content that ranged from 65.1% (TH-4) to 87.9% (W-3); bulk density from 1.07 kg/L (W-3) to 1.335 kg/L (TH-4); total organic carbon from 453 mg/kg (W-4) to 6,700 mg/kg (TH-4); and pH from 8.995 in TH-4 to 11.1 in W-6. For the Group 3 sludges, the water content ranged from 60.4% (W-7) to 86.6% (W-9); bulk density from 1.19 kg/L (W-5) to 1.35 kg/L (W-7); total organic carbon from 1193 mg/kg (W-7) to 6420 mg/kg (W-8); and pH from 9.1 in W-8 to 10.6 in W-10.

### 3.3 SUMMARY OF DOSE RATE CALCULATIONS

Dose rate calculations were performed to determine the range of expected dose rates for a variety of final waste forms for the GAAT sludges. Calculations were performed for five GAAT tanks (W-3, W-4, W-7, W-10, and TH-4) using the Phase I sampling data. These five tanks were selected for the analysis because they represent the anticipated range of radiation levels from all of the tanks. Five waste forms were initially examined, including: dewatered sludge, melted sludge, two grouted sludges, and a vitrified sludge. After the initial calculations were completed, additional characterization data was obtained, the waste form assumptions were refined, and three grouted waste forms and one vitrified waste form were added. The following general assumptions were applied:

1. W-3 and W-4 sludge will be combined prior to final treatment.
2. All nonwater mass remains in the final waste form (i.e., no credit is taken for removal of sludge constituents other than water).
3. Except for the grouted waste forms, all water is removed from the sludge.
4. The final waste form for vitrified waste has a density of 2.8 g/ml.
5. Grout solids used in grout mixes have a density of 3.0 g/ml.
6. For the grouted waste forms, the ratio of total water mass to total solids mass is 0.50.
7. For the grouted waste forms, the final waste volume is the sum of the individual component volumes ($V_{final} = V_{sludge} + V_{grout\ solids} + V_{added\ water}$).

The final waste forms for which dose rate calculations were conducted are further defined as follows:

- Raw dewatered assumes that all water is removed. The volume of the sludge is reduced by the volume of water removed and then increased slightly to account for some interstitial spacing between solid particles.
- Melted assumes that all water is removed from the sludge. The sludge volume is reduced by the volume of water removed.
- Grout 1 (12.5% loading) assumes a dry sludge solids loading of 12.5 % in the final waste form.
- Grout 2 (Waste Volume Minimized) assumes no water is removed from the sludge and water is added only if necessary to meet general assumption 6 above..
- Grout 3 (Dilute to below TRU limits) assumes that the sludge is diluted until the specific activity of DOE TRU constituents is 90 ηCi/g (i.e., not TRU waste). If the waste is below TRU limits as treated in Grout 2 case above, then no further dilution is required and the Grout 2 values are used.
- Grout 4 (Dilute to Class C or Less) assumes that the sludge is diluted until the Sum of Fractions for the NRC Class C tables equals 0.90 (i.e., Class C or lower final waste according to the NRC definition in 10CFR61.55). If the waste is Class C or lower as treated in Grout 2 case above, then no further dilution is required and the Grout 2 values are used.
- Grout 5 (Dilute by Retrieval) assumes that each gram of sludge is diluted with 2 g of process water as a result of removing the sludge from the tanks.
- Vitrified (20%) assumes that all nonwater sludge mass forms oxides in the final waste form and that these oxides make up 20% by mass of the vitrified waste.
- Vitrified (5 %) assumes that nonwater sludge mass oxides make up 5% by mass of the vitrified waste.

Dose rate calculations were performed for the following three types of waste containers: 1) an unshielded 55-gal stainless steel drum, 2) a cylindrical concrete cask with 6-in wall thickness, and 3) a cylindrical steel cask with 2-in. lead shielding and 1-in. steel wall thickness. The 55-gal drum case is of interest because it is identified as the primary container for disposal of TRU wastes at WIPP. It also represents other primary disposal containers having minimal shielding such as poly high-integrity containers and the WIPP standard waste box (SWB). The concrete cask and lead-shielded steel cask are chosen to represent storage and transport containers.

The results of the dose rate calculations are summarized below. The calculated dose rates for the concrete cask, given in Table 3-4, and the lead-shielded steel cask, given in Table 3-5, have not been updated to reflect the Phase II sampling data or refined waste form assumptions. Dose rates for the vitrified case are higher than they should be. However, they should represent order-of-magnitude estimates of the dose rates at container surface contact. The dose rates in these two tables will be refined and updated in later revisions to this document. The results for the 55-gal drum case have been updated and are shown in Table 3-6 for all of the tank wastes and all grouted and vitrified waste forms. The shaded values in these tables represent potentially remote-handled (RH) waste forms (i.e., ≥200 mR/h).

# 4. DESCRIPTION OF SELECTION AND EVALUATION CRITERIA

The scope of the TSD alternatives evaluation is to support the FS for the GAAT TS and remediation within the proposed milestones, budget, and schedule. The objective of the TSD alternatives evaluation is to identify, evaluate, and recommend a set of cost-effective TSD system alternatives that meet the intent of EPA Remedial Investigation(RI)/FS criteria. In brief, the EPA criteria are:

- Overall protection of human health
- Compliance with applicable requirements and regulations (applicable or relevant and appropriate requirements [ARARs]),
- Long term effectiveness,
- Toxicity/mobility and volume reduction,
- Short term effectiveness,
- Implementability,
- Cost, and
- State and community acceptance.

**Of the TSD options considered technically feasible, cost is used as the primary evaluation criterion and to screen out various TSD options.** Alternatives are described to address the EPA criteria to the maximum extent possible. Where finite values are unavailable to describe an alternative in terms of the criteria, it is described relative to another alternative (e.g., effectiveness and toxicity/mobility reduction). An alternative that obviously does not meet the criterion for protection of human health is not considered further. **Risk models, required to determine human health risk for in-situ disposal alternatives, are outside the scope of this document.** Therefore, in-situ disposal alternatives are described in terms of the remaining criteria, but issues regarding risk models to determine risk to human health will be within the scope of the FS. Table 4-1 presents the technical approach used to identify, evaluate, and recommend preferred TSD system alternatives for the GAAT.

Table 3-4 Surface Dose Rates for Concrete Cask (rem/hr)

| | Tank | | | | |
|---|---|---|---|---|---|
| Waste form case | TH-4 | W-3 | W-4 | W-7 | W-10 |
| Raw dewatered | 0.020 | 0.183 | 0.064 | 4.06 | 11.5 |
| Melted | 0.022 | 0.187 | 0.064 | 4.15 | 13.2 |
| Grout case 1 | 0.007 | 0.061 | 0.024 | 1.20 | 2.1 |
| Grout case 2 | 0.002 | 0.020 | 0.008 | 0.37 | 0.6 |
| Vitrified | 0.025 | 0.217 | 0.081 | 4.48 | 9.3 |

Table 3-5 Surface Dose Rates for Lead-shielded Steel Cask (rem/hr)

| | Tank | | | | |
|---|---|---|---|---|---|
| Waste form case | TH-4 | W-3 | W-4 | W-7 | W-10 |
| Raw dewatered | 0.003 | 0.003 | 0.001 | 0.079 | 0.293 |
| Melted | 0.003 | 0.003 | 0.001 | 0.090 | 0.401 |
| Grout case 1 | 0.001 | 0.001 | 0.0002 | 0.013 | 0.025 |
| Grout case 2 | 0.0002 | 0.0002 | 0.0001 | 0.004 | 0.006 |
| Vitrified | 0.003 | 0.003 | 0.001 | 0.080 | 0.234 |

Table 3-6 Surface Dose Rates for 55-gal Drum (rem/hr)

| | Tank | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Waste form case | TH-4 | W-3 | W-4 | W-5 | W-6 | W-7 | W-8 | W-9 | W-10 |
| Grout case 1 | 0.020 | 0.471 | 1.83 | 0.258 | 1.65 | 13.56 | 12.10 | 8.02 | 85.03 |
| Grout case 2 | 0.042 | 0.558 | 1.81 | 0.216 | 1.69 | 16.02 | 6.51 | 3.41 | 90.72 |
| Grout case 3 | 0.042 | 0.558 | 0.862 | 0.216 | 1.04 | 16.02 | 5.64 | 0.591 | 12.17 |
| Grout case 4 | 0.042 | 0.558 | 0.710 | 0.216 | 0.309 | 4.57 | 1.33 | 0.210 | 5.16 |
| Grout case 5 | 0.013 | 0.170 | 0.609 | 0.068 | 0.554 | 5.21 | 2.14 | 1.15 | 30.68 |
| Vitrified (20%) | 0.012 | 0.244 | 1.01 | 0.134 | 1.07 | 7.90 | 7.81 | 5.25 | 51.35 |
| Vitrified (5%) | 0.003 | 0.063 | 0.251 | 0.033 | 0.282 | 1.92 | 1.89 | 1.30 | 12.08 |

Table 4-1 Technical Approach Used to Identify, Evaluate, and Recommend Preferred TSD System Alternatives

| Step | Activity |
|---|---|
| 1 | Define the objective and scope of the TSD system alternative evaluation |
| 2 | Identify the parameters to describe the TSD system alternatives |
| 3 | Define the screening and evaluation criteria that will be used to evaluate the TSD system alternatives |
| 4 | Perform a literature search and collect data so that the TSD system alternatives may be described and evaluated |
| 5 | Identify and describe individual TSD components and remove from further consideration those that do not meet the screening criteria |
| 6 | Identify and describe specific TSD system alternatives in terms of the evaluation criteria |
| 7 | Evaluate the TSD system alternatives |
| 8 | Present the results and recommendations of the TSD alternatives evaluation |

In addition to the EPA criteria listed above, another criterion is used to qualify acceptable treatment alternatives. For a TSD system alternative to be acceptable, a pathway from retrieval to disposal must be identified. Treatment options that produce waste forms for which no disposal site can be identified are eliminated from further consideration. In particular, final waste forms that exceed NRC Class C limits (unfit for near-surface disposal facilities such as the Nevada Test Site [NTS]) but are below TRU waste limits (unfit for disposal at WIPP) have no identifiable disposal site and must be eliminated. Such waste is commonly referred to as "orphan waste."

Figures 4-1, 4-2, and 4-3 are block diagrams illustrating the concept of various potential "cradle-to-grave" TSD system alternatives for disposal at NTS and WIPP and for the orphan wastes, respectively. It should be noted that NTS has developed a draft performance assessment (PA) that will be included as part of the next revision of the NTS WAC document due out late this year. The NTS PA limits for radioisotopes are generally more restrictive than the Class C limits.

Each TSD alternative is described using a systems engineering perspective. The TSD alternatives are composed of 1) a treatment subsystem, 2) a storage subsystem, and 3) a disposal subsystem. Each subsystem is broken into components specific to the subsystem. The detailed description of each TSD component is presented in Chap. 5 of this report.

Table D-1 in Appendix D contains a checklist of items used in the general description of the TSD system alternatives. These items follow the EPA remedial investigation (RI)/FS criteria summarized above. Chap. 8 presents the conclusions and recommendations of the TSD alternatives evaluation.

# 5. TREATMENT, STORAGE, AND DISPOSAL

It is generally assumed throughout this chapter that the solidified supernate is packaged in liners similar to the Liquid Waste Solidification Project (LWSP) liners and stored in casks similar to the LWSP casks. It is also assumed that the primary packaging for the solidified supernate will fit the storage cask as well as the transportation cask without any alterations. Solidified sludge that is RH TRU will be packaged in 55-gal drums (the default packaging for WIPP RH TRU). Solidified sludge that is contact-handled (CH)-TRU can be packaged in either 55-gal drums or the SWB for WIPP. Packaging in the SWB would be more efficient, but concerns about weight and handling must be examined more closely. Regardless of the packaging to be used, it is assumed that the packaging will fit the storage cask as well as the transportation cask without any alterations.

## 5.1 SUPERNATE

The GAAT supernate accounts for about 30% of the total curie content of the GAAT OU. The supernate would be the most mobile of the GAAT tank contents in the event of a tank leak, thus posing a significant risk for contamination of groundwater, White Oak Creek, and the Clinch River. Removal of the supernate from the tanks is a relatively straightforward process that has been done several times before. However, it is recommended that any additional removal of supernate from particular gunite tanks (in advance of full remediation of that tank) be carefully examined in terms of ensuring that sludges are adequately shielded by the supernate to protect area workers and that sludges are protected from drying. Drying of sludges in the tanks could lead to dusting, which could become a problematic airborne pathway for radionuclide contamination and exposure during remediation.

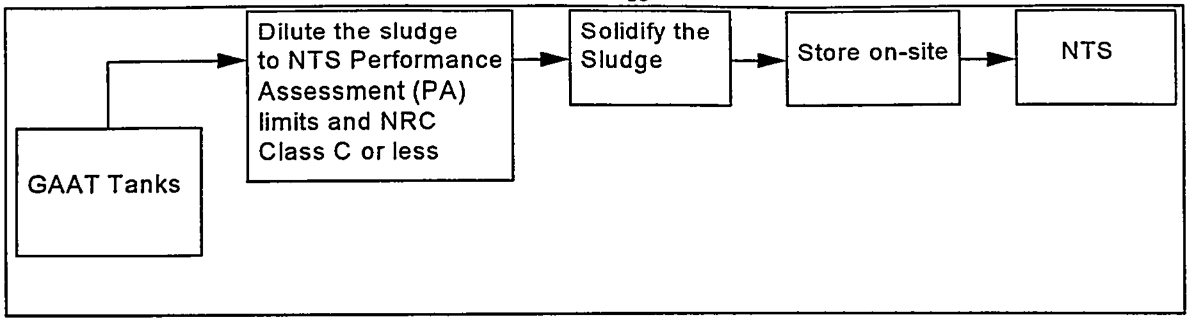


**Figure 4.1 Treatment by Dilution for Disposal at NTS**

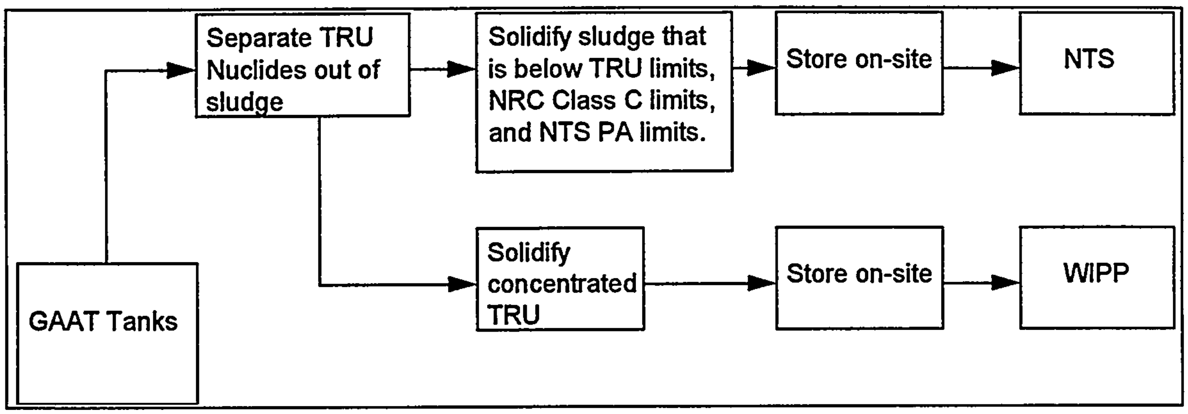


**Figure 4.2 Treatment by Separation - Disposal at NTS and WIPP**

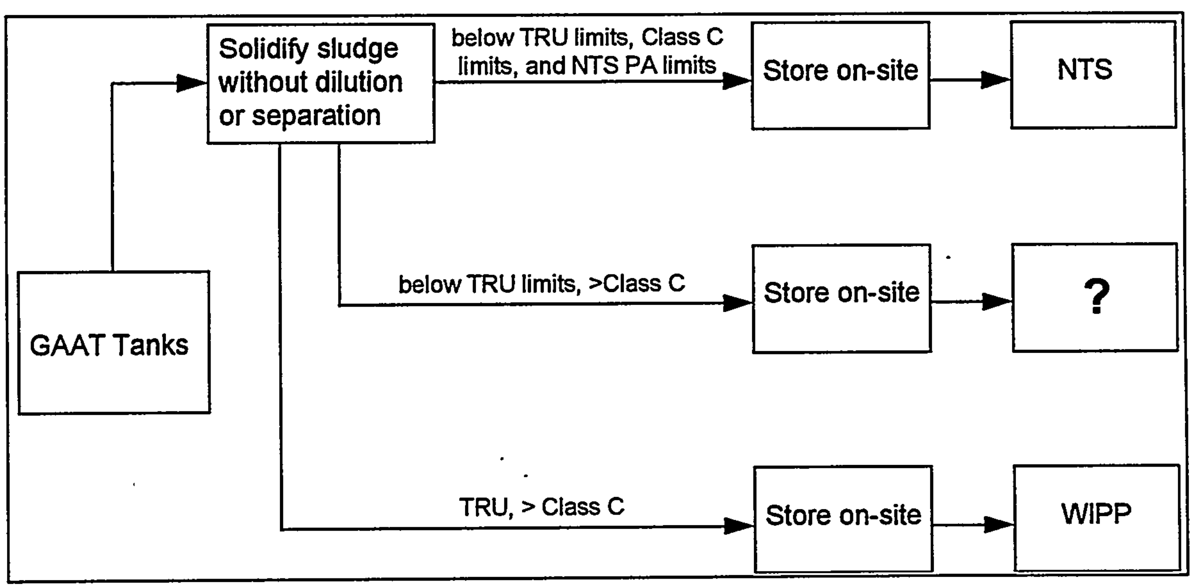


**Figure 4.3 Treatment Without Dilution or Separation - Orphan Waste**

The LLLW system is capable of concentrating the supernate and storing it in a fashion that meets the requirements of the Federal Facility Agreement. The Waste Management Remedial Action Division (WMRAD) has developed a successful program for concentrating and solidifying the MVST supernate into a cement waste form inside a shielded cask. Sending the supernate to the active LLLW system would take advantage of the treatment work that WMRAD has already accomplished. Furthermore, TS results indicate that supernate cannot be used as the sluice water because of incompatibilities with the confined sluicing equipment and potential safety concerns from the use of high pressure radioactive fluids. Therefore, the supernate cannot be used and may not be needed as a sluicing medium for sludge retrieval. After the supernate is transferred from the GAAT to the active LLLW system, it is concentrated by evaporation in Bldg. 2531. The "bottoms" from the evaporator are then transferred to the MVST for interim storage.

DOE-ORO has been authorized as a defense waste generator for the NTS. A portion of grouted MVST supernate has already met NTS approval for disposal. However, recent events (including a lawsuit by the State of Nevada against the Secretary of DOE[6])suggest that the stakeholders in Nevada are not very supportive of allowing NTS to continue receiving out-of-state radioactive waste for disposal.

## 5.2 SLUDGE

### 5.2.1 Treatment

Specific treatment technologies are identified and characterized using a number of variables, which include siting (on-site or off-site), type (thermal or nonthermal), methodology (in-situ or ex-situ), mobility (fixed or transportable systems), and dilution (the degree to which treatment includes dilution). Once the key technologies are identified, representative technologies are selected from groups of similar technologies. The Representative Treatment Technologies subheading is used to present and discuss the advantages and disadvantages of the representative technologies. The treatment subsystem variables are described individually under the subheadings below.

***Siting.*** The siting variable refers to the physical location of the treatment process. The treatment process may be located either on-site at ORNL or off the ORNL reservation (off-site). On-site treatment is further broken down in terms of the remaining variables. The GAAT sludges would be classified as Type B liquids in their current state. Approved packagings for the transportation of Type B liquids in bulk quantities over public highways do not currently exist. Approved packagings do exist for the transport of Type B solids in bulk quantities, but the sludges would have to be sufficiently dried to remove all free liquids before they could be considered "solids." **Because of the lack of approved packaging for the sludge (in its present state) and the time and high cost of developing and approving such packagings, it is assumed that off-site treatment is not feasible.**

***Type.*** The type variable distinguishes between thermal and nonthermal treatment subsystems. Thermal treatment refers to those technologies that take advantage of high temperature processes, which usually result in melting the waste and allowing it to solidify, with or without additives. Nonthermal treatment refers to those technologies for which elevated temperatures are not the primary means used to immobilize the waste.

***Methodology.*** The methodology variable distinguishes between in-situ and ex-situ treatment processes. In-situ refers to technologies implemented without the waste being removed from the tank. In-situ treatment infers in-situ disposal since treated waste would generally be much more difficult to remove from the tanks than untreated waste. **Evaluation of in-situ treatment and disposal hinges**

**largely on risk reduction that in turn requires development of risk models for each in-situ alternative identified. Risk model development is outside the scope of this document but is being pursued in support of the planned GAAT FS. Therefore, in-situ treatment and disposal alternatives will be considered, but complete evaluation cannot occur until the FS takes place.**

Ex-situ treatment refers to those technologies implemented after the waste is removed from the tanks. From a treatment perspective, it is assumed that all the waste is removed from the tanks and any further actions required to complete tank remediation (such as scabbling the tank walls to remove contaminated gunite) are identical for all ex-situ alternatives.

***Mobility.*** The mobility variable distinguishes between fixed and mobile treatment subsystems. Mobile treatment subsystems, which are temporary, can be readily set up and moved from one location to another, and may include modular skid-mounted systems. Fixed treatment refers to permanent facilities not intended to be relocated. As discussed in Sect. 5.2.1.1 , the time associated with deploying a "capital line-item type" project that would be required for a fixed treatment system can be as long as ten years. The life-cycle cost of a new fixed system for grouting RH sludge has been estimated between \$270 M for a "small" facility (177 lb/hr) to \$560 M for a "large" facility (1,831 lb/hr). Life-cycle costs for installing, operating, and maintaining RH sludge grout treatment systems in existing modified facilities have been estimated at more than \$400 M for treating 250,000 gal of waste. **Because of their significant costs and lengthy schedules, new fixed systems are removed from further consideration for processing the GAAT wastes.**

***Dilution.*** The dilution variable distinguishes between treatment that intentionally dilutes the waste to meet a regulatory requirement and treatment for which dilution does not occur or is merely a by-product of treatment process.

### 5.2.1.1 Past Work

Previous work conducted by Parallax, Inc. for Waste Management at ORNL[7] describes the technical evaluation and screening of over a dozen process technologies and waste forms that could be applied to the existing sludge and solid TRU wastes in storage at ORNL. These processes and waste forms include Aquaset, bitumen solidification, cement grouting, polymer encapsulation, fluetap concrete, molten salts, cermet, marbles in lead, the catalytic extraction process, hot pressing (Synroc and supercalcine), titanate, and various methods of vitrification.

Final selection from among these options was based on applying and evaluating specific screening criteria including estimated capital and operating costs; proven/demonstrated technology; multiple process capabilities and ability to adjust to variable characteristics of the process feed (robust systems); final characteristics of the waste form and ability to reprocess the waste; environmental, safety, and health considerations; and external (public and regulatory) confidence in the technology application. Also, several technologies were rejected on the assumption that waste form performance, as measured by meeting the WIPP WAC alone, is inadequate; the waste must also meet RCRA land disposal restrictions (LDRs), including TCLP.

As a result of this work, two technologies for processing TRU sludges were recommended to choose from: 1) Joule-heated or plasma arc vitrification or 2) cement grout solidification. The GAAT Treatment Alternatives Study Team generally agrees with the technology evaluation methods and the recommendations of the referenced study with the understanding that major modifications to the implementation approaches for use in the GAAT OU will be necessary for the near-term use of either technology.

Major modifications to the approach include the privatization of process operations with minimal capital investment by DOE (see Chap. 7, Implementation Strategies). These changes in approach are necessary to achieve deployment and start-up of an operational system in the next 2 to 5 years, as compared with the typical 7- to 10-year schedule of a capital line item project as suggested in the Parallax study.

The most likely means of enabling near-term implementation of vitrification (or grouting) treatment of GAAT wastes would be to competitively bid the treatment operations. Assuming that the most feasible arrangement is to host a private sector contractor's system as near to the gunite tanks as feasible, then the critical path activities necessary to achieve a start-up of waste processing will be the design and construction of new or modified facilities and/or interfaces to accommodate the contractor's system. This statement is supported by the experience of ORNL Waste Management in 1987 and 1988 as the MVST site was prepared with installation of new facilities to accommodate the first of a series of commercial, nuclear operations-based, 1,000-gal batch, LLLW supernate grout solidification campaigns (referred to as the Liquid Waste Solidification Project, or LWSP).

### 5.2.1.2 Waste Volume Calculations

Waste volume calculations were performed to estimate the final waste volumes for several treatment scenarios. The waste forms for which volume calculations were done include dewatered sludge, melted sludge, cement-grouted sludge (six cases), and vitrified sludge (three cases). Of these calculations, only the results for grouted and vitrified waste forms are presented here. Sample analysis results from the GAAT Phases I and II sampling campaigns were used as input to these calculations. The results from the calculations are given for the 50%-tile and 95%-tile sludge concentration statistics. In the case of water mass fraction, the minimum value was used from all samples to obtain a conservative final volume estimate. Sludge volumes are based on the sludge mapping data. The DOE definition of TRU waste is used to determine the TRU waste classification (this definition does not include $^{244}$Cm, $^{233}$U, or $^{252}$Cf).

Tables 5-1 and 5-2 show the anticipated waste volumes and key characteristics of the various final potential waste forms for the GAAT sludges based on 50%-tile and 95%-tile concentration statistics, respectively. The surface contact dose rate designations (RH/CH) in these tables are based on the results from the dose rate calculations for a 55-gal drum primary container (see Sect. 3.3). Tables 5-3 and 5-4 summarize the waste volume information in Tables 5-1 and 5-2 by presenting only the final waste form volumes for the GAAT sludges. In each table, the shaded areas indicate waste forms that are below TRU waste limits and >C and thus designated "orphan waste." The following general assumptions were used to calculate the final waste form volumes for the various waste forms studied:

1. W-3 and W-4 sludge will be combined prior to final treatment.
2. All nonwater mass remains in the final waste form (i.e., no credit is taken for removal of sludge constituents other than water).
3. Except for the grouted waste forms, all water is removed from the sludge.
4. The final waste form for vitrified waste has a density of 2.8 g/ml.
5. Grout solids used in grout mixes have a density of 3.0 g/ml.
6. For the grouted waste forms, the ratio of total water mass to total solids mass is 0.50.
7. For the grouted waste forms, the final waste volume is the sum of the individual component volumes ($V_{final} = V_{sludge} + V_{grout\ solids} + V_{added\ water}$).

**Table 5-1 Final Waste Form Volumes and Key Characteristics - 50%-tile**

| ***W-3 + W-4*** | Grout1 | Grout2 | Grout3 | Grout4 | Grout5 | Grout6 | Vit(40%) | Vit(20%) | Vit(5%) |
|---|---|---|---|---|---|---|---|---|---|
| $TRU_{final}$ (nCi/g): | 33 | 55 | 55 | 55 | 14 | 20 | 83 | 42 | 10 |
| $V_{final}$ (gal): | 4087 | 2579 | 2578 | 2578 | 9049 | 6499 | 976 | 1951 | 7805 |
| RH/CH: | RH | RH | RH | RH | RH | RH | RH | RH | CH |
| NRC Class A, B, C, or >C | C | C | C | C | C | C | C | C | C |
| ***W-5*** | Grout1 | Grout2 | Grout3 | Grout4 | Grout5 | Grout7 | Vit(40%) | Vit(20%) | Vit(5%) |
| $TRU_{final}$ (nCi/g): | 7 | 8 | 8 | 8 | 2 | 8 | 15 | 8 | 2 |
| $V_{final}$ (gal): | 5691 | 4702 | 4701 | 4701 | 16109 | 4701 | 1480 | 2961 | 11844 |
| RH/CH: | RH | RH | RH | RH | CH | RH | CH | CH | CH |
| NRC Class A, B, C, or >C | B | B | B | B | B | B | C | B | B |
| ***W-6*** | Grout1 | Grout2 | Grout3 | Grout4 | Grout5 | Grout7 | Vit(40%) | Vit(20%) | Vit(5%) |
| $TRU_{final}$ (nCi/g): | 74 | 119 | 90 | 47 | 32 | 47 | 171 | 86 | 21 |
| $V_{final}$ (gal): | 14579 | 9438 | 12181 | 22390 | 32895 | 22390 | 3829 | 7657 | 30630 |
| RH/CH: | RH | RH | RH | RH | RH | RH | RH | RH | RH |
| NRC Class A, B, C, or >C | >C | >C | >C | C | C | C | >C | >C | C |
| ***W-7*** | Grout1 | Grout2 | Grout3 | Grout4 | Grout5 | Grout7 | Vit(40%) | Vit(20%) | Vit(5%) |
| $TRU_{final}$ (nCi/g): | 28 | 55 | 55 | 24 | 14 | 10 | 72 | 36 | 9 |
| $V_{final}$ (gal): | 20887 | 11346 | 11342 | 24114 | 40719 | 57168 | 4971 | 9942 | 39769 |
| RH/CH: | RH | RH | RH | RH | RH | RH | RH | RH | RH . |
| NRC Class A, B, C, or >C | >C | >C | >C | C | C | C | >C | >C | C |
| ***W-8*** | Grout1 | Grout2 | Grout3 | Grout4 | Grout5 | Grout7 | Vit(40%) | Vit(20%) | Vit(5%) |
| $TRU_{final}$ (nCi/g): | 161 | 117 | 90 | 33 | 35 | 33 | 363 | 181 | 45 |
| $V_{final}$ (gal): | 11349 | 15349 | 19687 | 52763 | 49712 | 52763 | 3017 | 6035 | 24140 |
| RH/CH: | RH | RH | RH | RH | RH | RH | RH | RH | RH |
| NRC Class A, B, C, or >C | >C | >C | >C | C | C | C | >C | >C | >C |
| ***W-9*** | Grout1 | Grout2 | Grout3 | Grout4 | Grout5 | Grout7 | Vit(40%) | Vit(20%) | Vit(5%) |
| $TRU_{final}$ (nCi/g): | 187 | 103 | 90 | 16 | 32 | 16 | 436 | 218 | 54 |
| $V_{final}$ (gal): | 2480 | 4418 | 5061 | 28679 | 13954 | 28679 | 662 | 1324 | 5296 |
| RH/CH: | RH | RH | RH | RH | RH | RH | RH | RH | RH |
| NRC Class A, B, C, or >C | >C | >C | >C | C | >C | C | >C | >C | >C |
| ***W-10*** | Grout1 | Grout2 | Grout3 | Grout4 | Grout5 | Grout7 | Vit(40%) | Vit(20%) | Vit(5%) |
| $TRU_{final}$ (nCi/g): | 89 | 152 | 90 | 15 | 41 | 15 | 189 | 94 | 24 |
| $V_{final}$ (gal): | 20592 | 12474 | 20449 | 114915 | 43467 | 114915 | 6018 | 12037 | 48147 |
| RH/CH: | RH | RH | RH | RH | RH | RH | RH | RH | RH |
| NRC Class A, B, C, or >C | >C | >C | >C | C | >C | C | >C | >C | >C |
| ***TH-4*** | Grout1 | Grout2 | Grout3 | Grout4 | Grout5 | Grout7 | Vit(40%) | Vit(20%) | Vit(5%) |
| $TRU_{final}$ (nCi/g): | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 |
| $V_{final}$ (gal): | 22084 | 7082 | 7082 | 7082 | 23708 | 28607 | 4935 | 9869 | 39476 |
| RH/CH: | CH | CH | CH | CH | CH | CH | CH | CH | CH |
| NRC Class A, B, C, or >C | A | A | A | A | A | A | B | A | A |

**Table 5-2 Final Waste Form Volumes and Key Characteristics - 95%-tile**

| *W-3 + W-4* | Grout1 | Grout2 | Grout3 | Grout4 | Grout5 | Grout6 | Vit(40%) | Vit(20%) | Vit(5%) |
|---|---|---|---|---|---|---|---|---|---|
| $TRU_{final}$ (nCi/g): | 90 | 149 | 90 | 86 | 39 | NOT CALCUATED | NOT CALCUATED | 114 | 28 |
| $V_{final}$ (gal): | 4087 | 2579 | 4099 | 4274 | 9049 | | | 1951 | 7805 |
| RH/CH: | RH | RH | RH | RH | RH | | | RH | CH |
| NRC Class A, B, C, or >C | C | >C | >C | C | C | | | >C | C |
| *W-5* | Grout1 | Grout2 | Grout3 | Grout4 | Grout5 | | | Vit(20%) | Vit(5%) |
| $TRU_{final}$ (nCi/g): | 11 | 13 | 13 | 13 | 4 | | | 12 | 3 |
| $V_{final}$ (gal): | 5691 | 4702 | 4701 | 4701 | 16109 | | | 2961 | 11844 |
| RH/CH: | RH | RH | RH | RH | CH | | | CH | CH |
| NRC Class A, B, C, or >C | C | C | C | C | B | | | C | B |
| *W-6* | Grout1 | Grout2 | Grout3 | Grout4 | Grout5 | | | Vit(20%) | Vit(5%) |
| $TRU_{final}$ (nCi/g): | 118 | 189 | 90 | 35 | 51 | | | 136 | 34 |
| $V_{final}$ (gal): | 14579 | 9438 | 18893 | 47632 | 32895 | | | 7657 | 30630 |
| RH/CH: | RH | RH | RH | RH | RH | | | RH | RH |
| NRC Class A, B, C, or >C | >C | >C | >C | C | >C | | | >C | C |
| *W-7* | Grout1 | Grout2 | Grout3 | Grout4 | Grout5 | | | Vit(20%) | Vit(5%) |
| $TRU_{final}$ (nCi/g): | 54 | 105 | 90 | 27 | 27 | | | 68 | 17 |
| $V_{final}$ (gal): | 20887 | 11346 | 13059 | 39885 | 40719 | | | 9942 | 39769 |
| RH/CH: | RH | RH | RH | RH | RH | | | RH | RH |
| NRC Class A, B, C, or >C | >C | >C | >C | C | C | | | >C | C |
| *W-8* | Grout1 | Grout2 | Grout3 | Grout4 | Grout5 | | | Vit(20%) | Vit(5%) |
| $TRU_{final}$ (nCi/g): | 174 | 126 | 90 | 31 | 38 | | | 196 | 49 |
| $V_{final}$ (gal): | 11349 | 15349 | 21205 | 61025 | 49712 | | | 6035 | 24140 |
| RH/CH: | RH | RH | RH | RH | RH | | | RH | RH |
| NRC Class A, B, C, or >C | >C | >C | >C | C | >C | | | >C | >C |
| *W-9* | Grout1 | Grout2 | Grout3 | Grout4 | Grout5 | | | Vit(20%) | Vit(5%) |
| $TRU_{final}$ (nCi/g): | 258 | 143 | 90 | 17 | 45 | | | 301 | 75 |
| $V_{final}$ (gal): | 2480 | 4418 | 6962 | 37024 | 13954 | | | 1324 | 5296 |
| RH/CH: | RH | RH | RH | RH | RH | | | RH | RH |
| NRC Class A, B, C, or >C | >C | >C | >C | C | >C | | | >C | >C |
| *W-10* | Grout1 | Grout2 | Grout3 | Grout4 | Grout5 | | | Vit(20%) | Vit(5%) |
| $TRU_{final}$ (nCi/g): | 96 | 162 | 90 | 16 | 44 | | | 101 | 25 |
| $V_{final}$ (gal): | 20592 | 12474 | 21843 | 118536 | 43467 | | | 12037 | 48147 |
| RH/CH: | RH | RH | RH | RH | RH | | | RH | RH |
| NRC Class A, B, C, or >C | >C | >C | >C | C | >C | | | >C | >C |
| *TH-4* | Grout1 | Grout2 | Grout3 | Grout4 | Grout5 | | | Vit(20%) | Vit(5%) |
| $TRU_{final}$ (nCi/g): | 0 | 1 | 1 | 1 | 0 | | | 0 | 0 |
| $V_{final}$ (gal): | 22084 | 7082 | 7082 | 7082 | 23708 | | | 9869 | 39476 |
| RH/CH: | CH | CH | CH | CH | CH | | | CH | CH |
| NRC Class A, B, C, or >C | A | B | B | B | A | | | B | A |

### Table 5-3 Final Waste Form Volumes - 50%-tile

| TANKS | Grout1 | Grout2 | Grout3 | Grout4 | Grout5 | Grout6 | Vit(40%) | Vit(20%) | Vit(5%) |
|---|---|---|---|---|---|---|---|---|---|
| W-3 + W-4 | 4087 | 2579 | 2578 | 2578 | 9049 | 6499 | 976 | 1951 | 7805 |
| W-5 | 5691 | 4702 | 4701 | 4701 | 16109 | 4701 | 1480 | 2961 | 11844 |
| W-6 | 14579 | 9438 | 12181 | 22390 | 32895 | 22390 | 3829 | 7657 | 30630 |
| W-7 | 20887 | 11346 | 11342 | 24114 | 40719 | 57168 | 4971 | 9942 | 39769 |
| W-8 | 11349 | 15349 | 19687 | 52763 | 49712 | 52763 | 3017 | 6035 | 24140 |
| W-9 | 2480 | 4418 | 5061 | 28679 | 13954 | 28679 | 662 | 1324 | 5296 |
| W-10 | 20592 | 12474 | 20449 | 114915 | 43467 | 114915 | 6018 | 12037 | 48147 |
| TH-4 | 22084 | 7082 | 7082 | 7082 | 23708 | 28607 | 4935 | 9869 | 39476 |
| **TOTAL (gal):** | **101748** | **67388** | **83081** | **257221** | **229614** | **315722** | **25888** | **51777** | **207107** |

### Table 5-4 Final Waste Form Volumes - 95%-tile

| TANKS | Grout1 | Grout2 | Grout3 | Grout4 | Grout5 | Grout6 | Vit(40%) | Vit(20%) | Vit(5%) |
|---|---|---|---|---|---|---|---|---|---|
| W-3 + W-4 | 4087 | 2579 | 4099 | 4274 | 9049 | NOT | NOT | 1951 | 7805 |
| W-5 | 5691 | 4702 | 4701 | 4701 | 16109 | | | 2961 | 11844 |
| W-6 | 14579 | 9438 | 18893 | 47632 | 32895 | CALCU- | CALCU- | 7657 | 30630 |
| W-7 | 20887 | 11346 | 13059 | 39885 | 40719 | LATED | LATED | 9942 | 39769 |
| W-8 | 11349 | 15349 | 21205 | 61025 | 49712 | | | 6035 | 24140 |
| W-9 | 2480 | 4418 | 6962 | 37024 | 13954 | | | 1324 | 5296 |
| W-10 | 20592 | 12474 | 21843 | 118536 | 43467 | | | 12037 | 48147 |
| TH-4 | 22084 | 7082 | 7082 | 7082 | 23708 | | | 9869 | 39476 |
| **TOTAL (gal):** | **101748** | **67388** | **97844** | **320158** | **229614** | | | **51777** | **207107** |

The final waste forms studied in this assessment are further defined as follows:

- Grout 1 — (12.5% Loading) assumes a dry sludge solids loading of 12.5 % in the final waste form.
- Grout 2 — (Waste Volume Minimized) assumes no water is removed from the sludge and water is added only if necessary to meet general assumption 6 above. This case represents an attempt to minimize the final waste volume and maximize waste loading while maintaining a grout mix that will produce a monolithic final waste form with good leachability characteristics.
- Grout 3 — (Dilute to below TRU limits) assumes that the sludge is diluted until the specific activity of DOE TRU constituents is 90 nCi/g (i.e. not TRU waste). If the waste is below TRU limits as treated in Grout 2 case above, then no further dilution is required and the Grout 2 values are used.
- Grout 4 — (Dilute to Class C or Less) assumes that the sludge is diluted until the sum of fractions for the NRC Class C tables equals 0.90 (i.e. Class C or lower final waste according to the NRC definition in 10 CFR 61.55). If the waste is Class C or lower as treated in Grout 2 case above, then no further dilution is required and the Grout 2 values are used.
- Grout 5 — (Dilute by Retrieval) assumes that each gram of sludge is diluted with 2 g of process water as a result of removing the sludge from the tanks.
- Grout 6 — (NTS PA and Class C) assumes sludge dilution until the sum of fractions for either NRC Class C *or* the NTS PA equals 0.90, whichever is more restrictive. If both criteria are met as treated in Grout 2 case above, then no further dilution is required and the Grout 2 values are used.
- Vitrified (40%) — assumes that all nonwater. . . makes up 40% by mass of the vitrified waste. Glass frit makes up the remaining mass.
- Vitrified (20%) — assumes that all nonwater sludge mass forms oxides in the final waste form and that these oxides make up 20% by mass of the vitrified waste. Glass frit makes up the remaining mass.
- Vitrified (5%) — assumes that nonwater sludge mass oxides make up 5% by mass of the vitrified waste. Glass frit makes up the remaining mass.

#### 5.2.1.3 Representative Treatment Technologies

The treatment technologies below are intended to represent all of the treatment subsystems considered. Where two or more technologies are similar in function, the best demonstrated and most economical technology was chosen to represent the others. This approach is used not to eliminate technologies that will work, but to minimize redundancy.

**5.2.1.3.1 Baseline—transfer to MVST.** The baseline alternative for GAAT waste treatment is to transfer all of the waste to the active LLLW system. The GAAT supernate will first be concentrated in the Bethel Valley evaporator, then sent to the MVST, and finally solidified for disposal at NTS (see Sect. 5.2.3.1.4). The solids loading of the sludge will be diluted sufficiently to allow transfer to the MVST without causing excessive pumping pressures and to maintain sufficient fluid velocities to prevent suspended solids from falling out in the transfer line.

Over-the-road trucking of the sludge was investigated but appears to be impractical (see Appendix B: Transportation of GAAT Waste). The GAAT sludge would be combined with the existing sludge in the MVST. Mixing of the sludges is not anticipated to be a challenge, except possibly for the sludge in tank W-10, which contains PCB levels in excess of 2 ppm. A major portion of the GAAT (63%) and

MVST[†] sludges exceed the 100 ηCi/g limit used to define TRU waste. It is assumed that the combined GAAT and MVST sludges will exceed the TRU limit. Therefore, it is assumed they will be treated as part of DOE's TRU waste processing program and their eventual disposal destination will be WIPP. RCRA and PCB levels may constrain the near-term acceptance of the sludges (see Sect. 3.2.2) at the MVST.

Given the uncertainty as to whether all or a portion of the GAAT supernate can be included as part of the NTS-approved waste stream for the Oak Ridge Reservation (ORR), the best management practice may be to plan on segregating the storage of these supernates until this concern can be addressed. Segregation of GAAT supernate could be accomplished by pumping the supernate to either an existing MVST whose supernate has been removed or to one of the new, unused MVSTs associated with the Capacity Increase Project (MVST–CIP) available between 1998 and 1999—see Sect. 5.2.2.1.2)

**5.2.1.3.2 Nonshrinking cement.** Portland type cement-based immobilization (cement grouting) is chosen to represent several nonthermal immobilization technologies such as the Dow vinyl ester polymer process, polyethylene encapsulation, and sulfur polymer cementation. Details of these technologies can be found in another report. Cement grouting is chosen because of its versatility, relatively low cost, and general acceptance by near-surface disposal facilities. Cement grouting can be used for both in-situ and ex-situ immobilization processes. Cement grouting is also the technology with the most diversified, fielded, and full-scale experience base of those it represents.

Inorganic-based sludges and supernates, such as those in the GAAT tanks, are excellent candidates for immobilizing in cement-based waste forms. Of the options available for immobilizing the sludges and or supernates, cement-based grouts and concretes (grout with sand or aggregate) have the largest amount of data and fielded experience to draw from, thereby minimizing the amount of development studies required to implement the process.[8]

Supernate wastes from the ORNL MVST have been immobilized using Portland cement, fly ash, and blast furnace slag formulations over the past five years. Four immobilization campaigns have been performed, processing approximately 47,000 gal of supernate per campaign. The decanted supernate, primarily $NaNO_3$, has been solidified at a pH of 13.5. The highest nitrate concentration processed to date is 4.8 M. Batches consisting of ~800 gal of supernate are combined with the dry solid additives in a stirred, steel liner, which, upon setting, is placed in a concrete cask. The volume increase upon solidification is approximately 30 % and does not include the added increase in volume from placement in the concrete storage casks. The waste form performance criteria used to control the quality of the product grouts are primarily guided by NRC 10 *Code of Federal Regulations* (*CFR*) 61 Waste Form Performance Criteria.[9]

Grouts have been made with sludges using waste loadings from 15% to 50% based upon the weight of dry sludge, although sludge of approximately 30% filterable solids is more desirable (Conner, Jones).[10,11] Many types of cement-based formulations would be applicable to the GAAT wastes and would likely include additives such as fly ashes and various clays or pozzolans.

Grouting can be considered for in-situ or ex-situ immobilization. In-situ grouting would be an excellent way of stabilizing the GAAT tank structures. However, the major disadvantage to in-situ grouting is control of the mixing inside the limited access tanks and regulatory issues associated with

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[†] Of the MVST sludge sample data made available to the authors, only one (Sample number W31-S) was below the DOE TRU waste limit.

the on-site disposal of the wastes. Multipoint injection (MPI) of high-pressure grout has recently been tested for the immobilization of buried heterogeneous waste. Results thus far have been encouraging. Further testing is required to verify that this technology could be applied to the GAAT tanks to immobilize the sludges in-situ. However, if testing were successful and regulatory roadblocks were cleared, in-situ grouting would be a very attractive treatment option. The overall cost for TSD of the GAAT sludge would be dramatically reduced since no storage or off-site disposal would be required. The equipment required to perform the in-situ grouting is relatively inexpensive. In-situ treatment minimizes handling of the sludge and therefore drastically reduces the potential for contamination and exposure.

One significant issue related to the use of nonshrinking cement-based immobilization technology is establishment of the proper formulation ratio of waste to cement. Formulas would have to be developed for the specific wastes being processed. It is likely that different formulas would be needed for in-situ and ex-situ treatment options. Development work encompassing sample mixing, curing, and leach testing of various grout/sludge formulations would be needed using actual waste samples. Another key issue is the long-term effectiveness of cement grout immobilization. It is commonly accepted that cement grouted waste generally has less favorable long-term leaching properties than glass matrix waste forms. However, since cement-grouted waste forms are accepted routinely for disposal at near-surface disposal facilities such as NTS, there appears to be no regulatory disadvantage to using cement-grouted waste forms.

Examination of the potentially feasible, non-line-item project approaches for cement grout treatment of pumpable GAAT supernate and sludge wastes indicates that the most viable approach is use of an adaptation of a commercially proven system. This would allow DOE and LMES to provide new, modified, or temporary "host" facilities for a subcontractor-owned and operated treatment system. The host facilities would be designed and constructed with General Plant Project (GPP) or expense funds, thus avoiding the 7- to 10-year cycle for a capital line-item project.

Communication with several companies that have compiled the most extensive experience in cement grout treatment, transport, and disposal of many forms of commercial nuclear waste supports the assertion that the baseline system to provide the starting point for adaptation to specific project needs is the large steel liner, batch solidification system. This is the same type of system that has been successfully used over the past 7 years in the 4 treatment campaigns that make up the LWSP conducted at ORNL's MVST for treatment of more than 180,000 gal of concentrated radioactive supernate.

Using this system configuration as a starting point for the GAAT configuration provides several distinct advantages for timely, affordable, low-risk deployment. The first is that this system is perhaps one of the more mature, thoroughly demonstrated and proven radioactive liquid/sludge waste treatment systems in the commercial nuclear power industry. It has been proven a viable system at ORNL for treating wastes similar to the supernate in the GAAT tanks, while providing adequate protection for human health and the environment.

Second, not only do several companies operate similar systems, but they also have multiple project experience in modifying their systems to provide transfer from the large batches to 55-gal drums in a manner that shields the operators from exposures and protects the environment from spills. (This is important if it is necessary to produce a waste form suitable for disposal at WIPP).

Third, these systems have straightforward support systems and facility requirements, as demonstrated by the existing containment building adjacent to the MVST. With only a modest amount of floor space required, at most 30 ft wide by 50 ft long, perhaps the most demanding building requirement is adequate crane clearance and lifting capacity. Preliminary vendor discussions suggest a minimum of 20 ft of ground-to-hook clearance with a 5-ton lifting capacity. These requirements need further review.

These large batch solidification systems are typically documented by NRC-reviewed and -accepted topical reports, which provide sufficient process and system documentation to facilitate completion of health, safety, and environmental protection documentation. Recent cost estimates for a future LWSP campaign include the following items for processing a 60,000-gal (8,021-$ft^3$) batch of supernate.[12]

| Item | Cost in $ | Cost/$ft^3$ |
|---|---|---|
| LMES administration | 365,000 | 45.50/$ft^3$ |
| Subcontractor costs | 1,500,000 | 187.00/$ft^3$ |
| Storage casks | 15,000/1000-gal cask | 112.20/$ft^3$ |
| NTS analysis | 110,000 | 13.71/$ft^3$ |
| Transportation to NTS | 750,000 | 93.50/$ft^3$ |
| Disposal | 250,000[a] | 31.17/$ft^3$ |

[a]This NTS disposal cost agrees very closely with an estimate provided later in Sect. 5.2.3.1.4 for RH waste disposal ($31.58/$ft^3$).

***Summary of grouting immobilization.*** Grouting is a good candidate for immobilizing GAAT waste and the best alternative considered for in-situ immobilization of waste. The largest obstacle to in-situ grouting is finding a way to efficiently mix the waste with the solid additives to ensure achievement of the desired target composition. This is complicated by the limited access to the tanks and their size. However, recent developments in MPI of high pressure grout could make reliable in-situ grouting possible. Ex-situ grouting of the waste will facilitate better control of the process and certification of the waste form. Cement grouted waste is commonly accepted at near-surface disposal facilities such as NTS. It is commonly accepted that cement-grouted waste generally has less favorable long-term leaching properties than glass matrix waste forms. Ex-situ cement grouting is the immobilization technology with the most diversified, fielded, and full-scale experience base. Several companies have significant experience with cement grout immobilization of hazardous and radioactive waste.

**5.2.1.3.3 Bitumen.** The use of bitumen to immobilize GAAT wastes has not been considered in this study for two major reasons. There is presently no commercial U.S. company in the bitumen business. Most countries have abandoned the use of bitumen, with the exception of some very limited use in France. Additionally, this material, even the higher molecular weight harder bitumen, is known to flow under moderately low stress and, therefore, will provide questionable support to the tank infrastructure for in-situ treatment. Because bitumen has questionable properties and, particularly, because it is unavailable in the U.S. (resulting in unacceptably high costs), it is not considered a viable option.

**5.2.1.3.4 Dilution and separation.** Dilution during immobilization operations and chemical or physical separation processes for the GAAT sludges are considered because of the difficulty of storing and disposing of TRU waste or below the TRU limits and exceeding the NRC Class C limits. Sludge from several of the GAAT tanks is presently classified as a TRU waste and would result in a final waste form that is also a TRU waste for most types of treatment processes, including grouting and vitrification. Also, the final waste form for most of the tanks (all except TH-4 and W-5) exceeds the NRC Class C limits for disposal in or near surface disposal repositories such as NTS. And, NTS has developed draft PA limits more restrictive than the Class C limits. The NTS WAC will allow case-by-case consideration of waste exceeding its PA limits, but acceptance would be uncertain at best.

For dilution operations, the NTS PA and Class C limits are the overriding concerns because more dilution would be required to reach these limits than to reach the TRU limits. If the sludge were diluted to PA and Class C limits, the uncertainties associated with its storage and disposal would diminish significantly since disposal at NTS would become feasible. The sludge will be retrieved from the tanks using varying amounts of process water. Current estimates for the sludge removal efficiency vary considerably. It is clear that the retrieval system will be more efficient during the initial operations when primarily liquid and thin sludge is removed. It is also clear that as the more dense sludge is removed, efficiency will decrease requiring more process water to remove less sludge.

Given the current uncertainties associated with the sludge retrieval process, it reasonable to assume that it will take at least 2 gal of process water to remove each gallon of wet sludge if all the sludge is removed from the tanks. It is also reasonable to assume that ***another*** 2 gal of water will be added to each gallon of sludge to facilitate pumping the sludge through the pipelines. Assuming that the sludge is mixed uniformly with the added process water, the effective concentration of the sludge solids in the mixture is reduced. The diluted sludge may then be immobilized using excess grout to produce a waste form with desirable disposal properties. The Grout 5 case presented in Sect. 3.2.1.2 shows that using only the excess water resulting from sludge retrieval operations (2:1 dilution), the grouted sludges from all the GAAT except for W-9 and W-10 are non-TRU and Class C or less.

Separation, in the context used here, refers to separation and concentration of NRC-defined radioactive isotopes contributing to the greater-than NTS PA and Class C classification issue and of the TRU isotopes. Specific separation techniques have not been examined in this document, but it can be stated that most separation processes will generally be more expensive and more technically challenging than dilution.

Additionally, separation leaves some waste that is both TRU and greater than NTS PA and Class C and therefore does not eliminate the difficulty of storing and disposing of these types of waste. Contrary to dilution processes, properly designed separations processes should result in minimal waste volumes. However, until specific separation processes are examined in detail (including efficiencies, costs, waste types and volumes, required storage and disposal, etc.), this approach cannot be eliminated from consideration.

***Summary of dilution and separation.*** Some type of dilution or separation process for the GAAT sludge is needed to prevent the creation of an "orphan waste." The dilution process is simple but creates significantly more waste to be disposed. Dilution would allow the disposal of the solidified sludge at the NTS, which has fewer operational uncertainties than the WIPP. Disposal at the NTS is also anticipated to be less expensive than at WIPP on a unit volume of waste basis. Separation processes are more complicated and expensive and, while they reduce the volume of TRU and greater-than-Class C final waste, they do not eliminate these types of wastes. Specific information on selected separation techniques is needed.

**5.2.1.3.5 Ex-situ mobile vitrification.** Vitrification has been studied and used extensively for treating high-level radioactive waste (HLW). Relatively little research has been conducted to date on the use of vitrification for treating LLW or mixed waste. HLW waste streams typically have uniform chemical and physical characteristics. In contrast to HLW, the GAAT sludge has varying chemical and physical properties and therefore may require additional development and testing for the application of vitrification to these wastes.

The conceptual baseline system for the GAAT vitrification treatment alternative is the Transportable Vitrification System (TVS). The TVS can be described as a modular, Joule heated, melter-based vitrification system, capable of melting and vitrifying size-reduced solids and sludges/slurries that can be readily fed to the melter unit. The TVS was designed and constructed under the direction of Westinghouse-Savannah River Corp., based on lessons learned from their HLW vitrification program.

Installation of the TVS is planned for 1996 at the K-25 Site for demonstration of treatment of several low-level mixed waste (LLMW) streams stored at K-25. If this demonstration goes forward as planned and is successfully completed in 1996, it is possible that the system could be decontaminated to the extent required to move it to ORNL for a demonstration, or even complete processing of the GAAT sludges. A more likely scenario is that the operational data derived from this demonstration could be usefully applied to a modified design and fabrication of a similar unit for the GAAT (and perhaps other ORNL) sludges.

The TVS has been designed for the processing of slightly radioactive, RCRA-hazardous (mixed) wastes. Although the shielding provided by system components is probably inadequate to protect workers from the expected radiation levels of the GAAT sludges, a preliminary assessment suggests that the use of shielding around certain components and modules and the addition of an enhanced flushing and decontamination system could protect operators and allow isolated operations and essential hands-on maintenance.

Support for the conclusion that shielded operations at a distance with hands-on maintenance is feasible is found in a newly commissioned, commercial, Joule-heated, radioactive waste vitrification system, which is NRC-licensed to process wastes reading on contact up to 500 mrem/hr. This system was designed and installed by DURATEC and is being operated by Chem-Nuclear Systems, Inc. at its Barnwell, South Carolina, radioactive waste facilities. According to the Director of Chem-Nuclear Engineering, its plans are to gain operational experience with wastes at this interim radioactivity limit and then apply to the State of South Carolina (under their NRC Agreement) for a limit increase of up to several rem per hour.

***Summary of ex-situ mobile vitrification.*** Remotely operated ex-situ mobile vitrification processes with hands-on and/or limited remote maintenance features appear feasible. The resulting glass matrix waste form has superior leach-resistant properties to most other waste forms including cement grout. However, using vitrification presents some significant drawbacks. It is generally more complex than grouting systems and requires more support equipment (quencher, condenser/absorber, off-gas scrubber, precipitator, heat exchangers, ion-exchange columns, etc.). The GAAT sludge will require significant dewatering before being vitrified, thus adding to the complications.

There are at least two radioactive waste treatment facilities in the U.S. using vitrification systems that are 8-10 years behind schedule and millions of dollars over budget (Defense Waste Processing Facility at the Savannah River Site and West Valley Demonstration Project). These facilities represent large-scale fixed installation facilities that are outside the scope of the mobile vitrification system anticipated for use with the GAAT. Other smaller scale, more mobile vitrification systems have been designed, built, and operated on schedule and within budget.

**5.2.1.3.6 In-situ mobile vitrification.** A number of potential challenges have been identified with the application of in-situ vitrification (ISV) in field demonstrations including steam venting from soils and thermal damage to nearby tanks and other facilities.[13],[14] Although ISV has been successfully demonstrated on steel tanks, there is a lack of data available on the impacts of the process on other tank construction material, e.g. steel reinforced concrete. There is very little experience using ISV on tanks containing radioactive waste.

Each tank subjected to ISV will have to first be backfilled with an appropriate material for shielding and structural support. Because of subsidence of the materials inside the tanks during the vitrification process, the domes of the tanks would likely have to be removed prior to ISV to eliminate the possibility of a dome collapse and subsequent release of heated and volatilized radionuclides (especially Cs). An off-gas hood covering the tank would be needed to collect and direct off-gas from the ISV process to an off-gas treatment system. It would be difficult to guarantee that the hood would be capable of containing a sudden off-gas release as would be expected from tank dome collapse.

***Summary of in-situ mobile vitrification.*** ISV is not sufficiently developed for processing steel-reinforced concrete tanks containing radioactive wastes. Because the NTF and STF are located in a populated and well-traveled area of the ORNL site, ISV challenges have the potential to affect many people and facilities. ISV is therefore no longer considered a viable option for immobilization of the GAAT wastes on the basis of the apparent risk to human health.

### 5.2.1.4 Summary of Sludge Treatment Options

Dilution and/or separation processes are necessary to prevent some of the GAAT final waste forms from being "orphan waste." Dilution processes are generally simpler than separation processes but result in larger waste volumes to dispose of. Diluted GAAT wastes can be disposed of at NTS (less expensive per unit volume and fewer operational uncertainties than WIPP). Separation processes allow the final waste volumes of TRU and greater-than-Class-C wastes to be minimized, but will produce waste to be disposed of at WIPP.

In-situ treatment of GAAT waste precludes the need for ex-situ storage and disposal and the logistics and expense associated with them. However, there are significant regulatory uncertainties associated with in-situ treatment/disposal processes. Proving that all of the waste is immobilized is difficult. Recovering from incomplete immobilization would be extremely costly and time-consuming. However, recent developments in MPI of high pressure grout could make reliable in-situ grouting possible. Because of the uncertainties due to the lack of experience treating similar tanks and waste, ISV is not considered a viable option.

Cement grouting is a relatively simple process that has the most field experience for immobilization of hazardous and low-level radioactive wastes. Several companies with years of experience offer mobile grouting systems designed to immobilize LLW. There is significant, but less extensive, experience grouting mixed waste and sludge. Very little experience exists with grouting of HLW. Grouted waste forms meet the WAC requirements for both NTS and WIPP but has less favorable leaching properties than glass waste forms. Vitrification is a relatively complex process compared to grouting. There is a significant amount of experience using ex-situ vitrification to immobilize HLW in Europe and Asia as well as some limited experience in the U.S.

### 5.2.2 Storage

The storage subsystems are characterized by the following variables: Siting (on-site or off-site), Methodology (in-situ or ex-situ), and Physical State (liquid or solid storage). These variables are described in detail in the following paragraphs. Specific storage sites are identified and characterized in terms of these variables. Once all the key sites are identified, representative sites are selected from groups of similar sites. The advantages and disadvantages of the representative sites are then presented and discussed.

*Siting.* The siting variable refers to whether the storage occurs on-site at ORNL or off the ORNL reservation(off-site). On-site storage is further characterized in terms of the remaining variables. However, off-site storage is only broken down in terms of specific storage sites. This approach assumes that the type of storage used is irrelevant to the selection of the off-site storage technology as long as the site and its WAC are compatible with the waste characteristics.

*Methodology.* The methodology variable distinguishes between in-situ and ex-situ storage. In-situ storage means storage inside the GAAT. Ex-situ storage is storage anywhere outside of the GAAT.

*Physical State.* The physical state variable distinguishes between liquid and solid waste storage. No off-site storage sites for LLLW have been identified. Even if off-site LLLW storage sites were available, transportation of the GAAT sludge (in slurry form) would be very difficult (see Appendix B: Transportation of GAAT Waste). Therefore, the ORNL LLLW storage system is the only liquid storage site considered.

#### 5.2.2.1 Representative Storage Sites

This section describes the representative storage sites considered in this report. Where two or more storage sites are similar in function (i.e., have similar WAC), the best demonstrated and most economical storage site has been chosen to represent the others. This approach is used not to eliminate acceptable storage sites, but to prevent redundancy.

**5.2.2.1.1 In-situ Storage.** Outside of continuing current storage without treatment, in-situ storage could occur under two scenarios. The most obvious possibility for in-situ storage is in concert with in-situ treatment and in-situ disposal. In this instance, in-situ storage is a formality. It might even be argued that storage does not occur in this instance, but that there is only treatment followed immediately by disposal.

The second possibility for in-situ storage involves ex-situ treatment with storage of the treated containerized waste inside the GAAT tanks. If the tanks are left intact, without removing significant portions of the tank roofs, placement of the storage containers would require remote-handling equipment. Remote placement would be time-consuming and costly. Platform design, equipment staging, and coordination could pose significant challenges. If tank roofs are removed to allow more conventional means of access, storage in the tank cavities would be more easily accomplished. Both approaches would have to address tank stabilization and groundwater infiltration issues. Because of the uncertainties, in-situ storage should only be regarded as a "fall-back" option if other storage options are unavailable.

**5.2.2.1.2 Storage by WMRAD.** Table 5-5 summarizes the currently available and planned storage capacity at WMRAD radioactive waste storage facilities. Note that some facilities have capacities shown for more than one type of waste. This does not mean that the capacities for the different types of waste are additive, but rather that the facility can be used to store both types of waste. For drum storage facilities, capacities are based on 7 $ft^3$ of waste in each drum. Each B-25 box is assumed to contain 90 $ft^3$ of waste. Container capacities will vary depending upon treatment method, waste form, and weight restrictions. Unless otherwise noted, the information in this section has been provided by WMRAD.[15,16]

*ORNL Solid Low-Level Waste Storage.* CH solid low-level waste (SLLW) that does not exceed isotope concentration limits in the PA for the Interim Waste Management Facility (IWMF) is typically stored and disposed ofin the above-grade facility at Bldg. 7886. This facility has the capacity for 990 vaults, and each vault holds one 90-$ft^3$ container. CH SLLW that does exceed the PA limits is currently stored in B-25 boxes pending the availability of a new storage facility.

**Table 5-5 WMRAD Solid Radioactive Waste Storage Facilities and Capacities ($ft^3$)**

| Facility | Container Type | LLMW | | SLLW | | TRU | | TRU Mixed | |
|---|---|---|---|---|---|---|---|---|---|
| | | CH | RH | CH | RH | CH | RH | CH | RH |
| Bldg. 7886 | B-25 box | | | 89,100[a] | 89,100[b] | | | | |
| Bldgs. 7826 & 7834 | drums[c] | | | | | 7,000 | 7,000[d] | | |
| Bldg. 7572 (1997) | drums | | | | | | | 21,500 | |
| Bldg. 7855 bunker | drums | | | | | | | | 0[e] |
| Bldg. 7883 bunker (1997)[f] | drums | | | | | | 1,512 | | 1,512 |
| Storage wells | unknown[g] | | | | unknown | | | | |
| LWSP casks[h] | LWSP cask | | | | indef.[i] | | | | |

[a] Disposal capacity.
[b] Facility accepts RH SLLW for storage in same vaults used to dispose of CH SLLW; capacities are not additive.
[c] 55-gal stainless steel drums.
[d] Acceptance for RH TRU in these facilities depends upon the radiation levels of the containers.
[e] Facility is nearing capacity.
[f] Facility becomes available in 1997.
[g] Information not provided.
[h] These are the casks used to store the solidified waste from the LWSP campaigns.
[i] These casks can be stored outdoors, so capacity is limited only by available casks and storage laydown area.

RH SLLW is stored in above-grade and below-grade facilities. The below-grade facilities are typically 20- or 30-in. diameter wells, 15 ft deep. Above-grade storage is available using the LWSP casks or the IWMF vaults at Bldg. 7886. Each IWMF vault contains one B-25 box and has a 7-in. wall thickness. The LWSP casks are concrete and are 8 ft, 8 in. in diameter and 8 ft, 9 in. high with an internal capacity of about 1000 gal (~133 ft$^3$). The cask has a 6 ft, 6 in. inside diameter and a 6 ft, 6 in. depth. These are the casks currently being used to store solidified MVST supernate from the LWSP campaigns. These casks can be used to store waste outdoors. The current cost for a single LWSP storage cask is about $15,000. The only limits to storage capacity for the LWSP casks are laydown area and cask availability. No facility has been identified to store mixed RH SLLW.

***ORNL Solid Transuranic Waste Storage.*** On-site storage facilities are used for the storage of solid TRU wastes until the materials can be transferred to WIPP. Facilities are available for storage of both CH and RH TRU waste. The acceptance of waste packages in these facilities is primarily limited by surface dose rates. The WMRAD projections for capacity needs for both existing and future facilities do not include GAAT waste inventories. Plans for storage of TRU wastes in these facilities would have to be negotiated with WMRAD.

CH TRU is stored in either permitted above-grade facilities (RCRA or non-RCRA) or in the Bldg. 7826 and Bldg. 7834 below-grade facilities (non-RCRA only). The existing above-grade facilities are nearing capacity, and a new facility is scheduled for availability in 1997. The below-grade facilities in these buildings currently have capacity for over a thousand 55-gal drums. The new facility (Bldg. 7572) will store CH TRU with RCRA wastes and will have a capacity of 3000 drums.

RH TRU is stored in below-grade bunker 7855 or, depending on radiation levels, can be stored in below-grade bunker 7826 or 7834 (non-RCRA only). New bunker 7883 will be available in 1997 to store RH TRU with no RCRA. It will have a capacity of two hundred sixteen 55-gal drums.

***ORNL Liquid Radioactive Waste Storage.*** It is possible to transfer supernatant and slurried sludge to the ORNL Active LLLW System. Waivers from the LLLW WAC would have to be granted to allow transfer of slurry since the WAC requires that total dissolved solids and total suspended solids be minimized. The current capacity at the MVST is insufficient to accept all of the GAAT waste. The MVST–CIP) is scheduled to add 450,000 gal of usable capacity to the MVST system between late 1998 and late 1999. It is currently unclear exactly how much of this additional capacity will be available to store GAAT waste. However, since the funding of the CIP facility was justified, in part, to provide capacity for the GAAT waste, it is reasonable to assume a portion of its capacity will be available for GAAT waste. GAAT waste can be transferred to the LLLW systems using existing nearby piping systems.

All supernates meet the LLLW WAC except for isolated cases of RCRA metals. The GAAT supernates would be non-RCRA if homogenized. Transfer of the supernates from the GAAT to the LLLW system, as is (i.e., prior to any treatment steps), will most likely be possible based on preliminary assessments. As stated in the referenced letter, all discharges must comply with WMRAD-AD-108, "Procedure for Discharging Waste to the ORNL LLLW System." Such procedures for discharge include meeting the WAC for the LLLW system; submittal (in writing) of pertinent information concerning the waste to the Laboratory Certification Officer (LCO), who will obtain the further approvals as necessary for discharge; and submittal of LLLW disposal forms.

Figure 5.1 shows the anticipated available storage volume for the MVSTs and the BVESTs over the next seven years. The increase in available storage space at the end of 1999 is the addition of six new MVST-CIP storage tanks. The gray area on the graph is the region that corresponds to 420,000 to

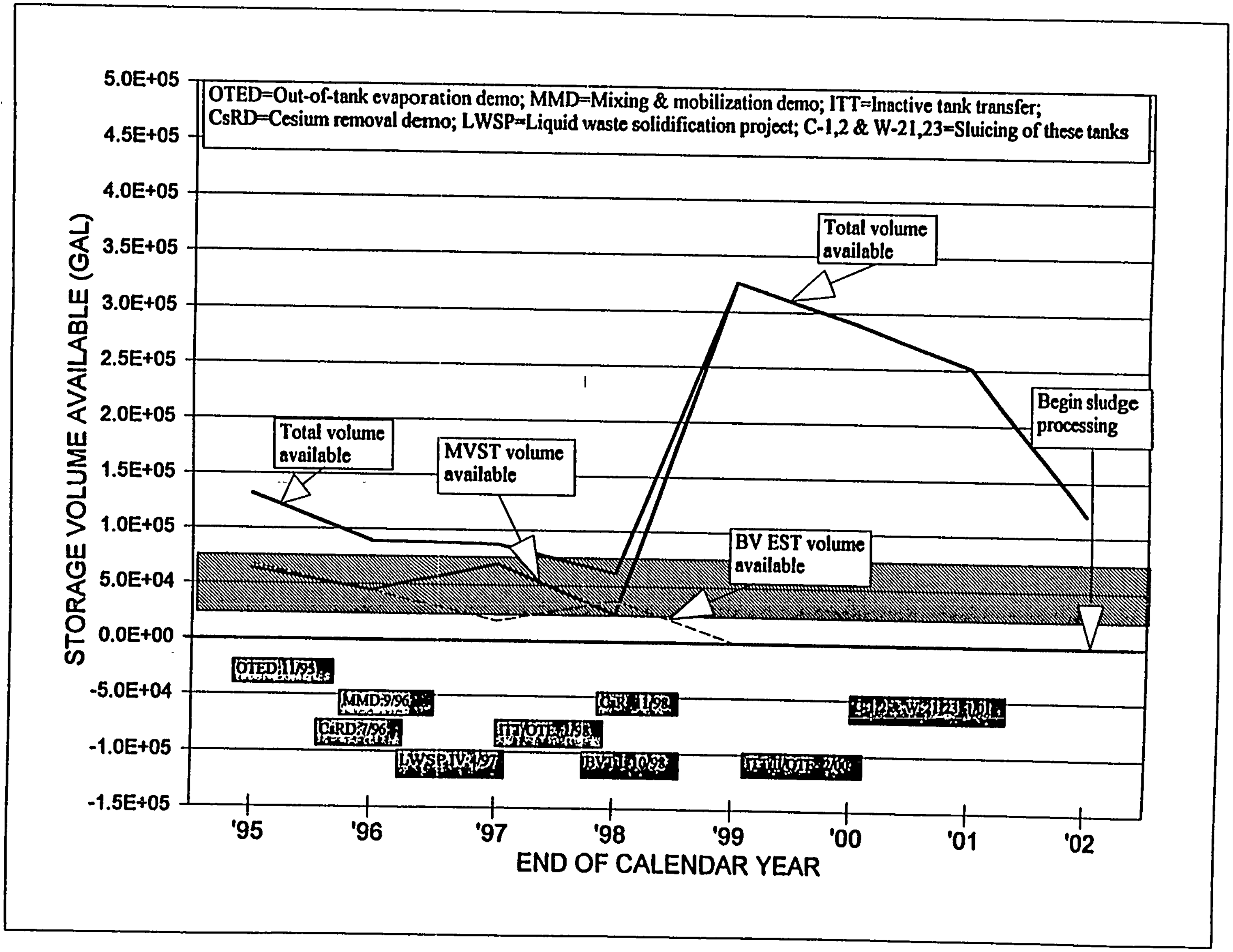


**Fig. 5-1 Planned MVST and BVEST storage capacity through 2002.**

470,000 gal of accumulated waste, or 50,000 to 100,000 gal of available storage space prior to reaching the current LLLW system Operational Safety Report (OSR) limit of 520,000 gal. In the figure, this corresponds to 25,000 to 75,000 gal available — less the 25,000 gal needed for operation of out-of-tank evaporation (OTE), cesium removal, etc. This region is known as the "Operationally Constrained Region," or the region in which operations become constrained. As the limit set by this region is approached, operation of the LLLW system becomes increasingly restricted. Obviously, to reach "zero" storage capacity would trigger shutdown of many normal operations including some research and development by ORNL divisions.

In the current scenario, as indicated in Figure 5.1, an OTE demonstration is scheduled for early 1996. A mixing and mobilization demonstration is scheduled for late 1996, parallel to the cesium removal demonstration at the MVSTs. During 1997 and 1998, two major functions are to occur at the MVSTs: a LWSP and inactive tank transfer (ITT)/OTE. These two activities can be interchanged; however, due to the volume of development work and regulatory and safety reporting that must be done prior to the transfer of inactive tank sludge and supernate to the MVSTs, it is unlikely that an ITT could be made prior to 1998.

In addition, 1998 is the latest date that an LWSP should be scheduled in order to allow for additional storage space. Thus, it is advisable to perform an LWSP campaign in 1997 to allow for ITTs in 1998. A transfer of evaporator facility (Bldg. 2531) storage tank waste to the MVSTs will be made in late 1998. The new MVST–CIP tanks are currently scheduled to be available for use by the end of 1998, and allowing for schedule changes, have been shown on the figure to be available by the end of 1999. A second ITT/OTE is shown to occur in 2000. Sludge processing is roughly set to begin in 2002.

**5.2.2.1.3 K-25 Site.** CH SLLW (<50 mR/hr, RCRA and non-RCRA) that exceeds the PA at the Bldg. 7886 storage facility may be stored at K-25 Site in Bldg. K-25 vaults. No space estimates are available, but there are claims of large capacity.

#### 5.2.2.2 Summary of Storage Options

Examination of the waste volumes and classifications in Table 5-1, in light of the available storage options, provides some valuable insight.

- No CH TRU waste is expected to be produced from GAAT sludge treatment.
- The treated TH-4 sludge is CH SLLW, regardless of treatment method.
- The treated W-7 sludge is RH SLLW, regardless of treatment method.
- Each of the treatment methods produces either two or three different classifications of waste.

Based on the items listed above, several conclusions can be reached.

1. CH SLLW and RH SLLW storage will be required.
2. If a treatment approach is used such that all waste is destined for disposal at NTS, then large RH SLLW storage capacities (as much as ~33,600 $ft^3$ for grouted waste) will be required.
3. No CH TRU storage will be required, regardless of treatment method.
4. If a treatment approach is used such that some of the waste is destined for disposal at WIPP, then some RH TRU storage (at least ~2,500 $ft^3$ for grouted waste) will be required.

LWSP cask storage is the most flexible storage option for RH SLLW because it is not bounded by current or planned storage facility capacities and availabilities. Economics, scheduling, and availability are determining factors in deciding between LWSP cask storage versus storage in Bldg. 7886. If RH-TRU waste is produced, existing and planned storage capacity is marginal even without including the existing RH TRU waste streams destined for those facilities. It may be possible to store some of the RH-TRU waste in LWSP storage casks. If this is done, the RH TRU material must be packaged in 55-gal drums first to meet WIPP requirements, and the drums then loaded into LWSP casks. Assuming 7 $ft^3$ of waste per drum, and 14 drums per cask (2 layers of seven drums), about 98 $ft^3$ of RH TRU waste could be stored in 1 LWSP cask as compared to about 133 $ft^3$ of cask capacity without using the drums. The storage cask costs become \$112.20/$ft^3$ for NTS waste and \$153.06/$ft^3$ for RH TRU waste.

### 5.2.3 Disposal

The disposal subsystems are characterized by the following variables: Siting (on-site or off-site), Methodology (in-situ or ex-situ), and Physical State (liquid or solid disposal). These variables are similar to those used to characterize the storage subsystems and are defined in detail in the following paragraphs. Specific disposal sites are then identified and characterized in terms of the variables. Once all the key sites are identified, representative sites are selected from groups of similar sites. The "Representative Disposal Sites" subheading is used to present and discuss the advantages and disadvantages of the representative sites.

***Siting.*** The siting variable refers to whether the disposal occurs on-site at ORNL or off the ORNL reservation (off-site). On-site disposal is further characterized in terms of the remaining variables. However, off-site disposal is only broken down further in terms of specific disposal sites. This approach assumes that the type of disposal used is irrelevant for identifying off-site disposal technologies as long as the selected site and its WAC are compatible with the wastes.

***Methodology.*** The methodology variable distinguishes between in-situ and ex-situ disposal. In-situ disposal means disposal inside the GAAT. **As discussed in Sect. 5.2.1, evaluation of in-situ treatment and disposal requires the development of risk models for in-situ alternatives, which is outside the scope of this document. Both in-situ and ex-situ alternatives will be identified, but only ex-situ disposal will be evaluated. In-situ disposal should be evaluated during the GAAT FS.**

***Physical states.*** The physical state variable distinguishes between liquid and solid waste storage. No off-site storage sites for LLLW have been identified. Even if off-site LLLW were available, transportation of the GAAT sludge (in slurry form) would be very difficult (see Appendix A: Annotated Bibliography of Selected Literature). Therefore, the ORNL LLLW storage system is the only liquid storage considered.

### 5.2.3.1 Representative Disposal Sites

This section describes the representative disposal sites considered in this report. Where two or more disposal sites are similar in function (i.e., have similar WAC), the best demonstrated and most economical disposal site is chosen to represent the others. This approach is used not to eliminate acceptable disposal sites, but to prevent redundancy.

**5.2.3.1.1 In-situ disposal.** Storage requirements for in-situ disposal of waste are eliminated since the waste is treated and disposed of in place. Costs and exposure potential associated with handling and transportation are reduced significantly. Before in-situ disposal is allowed, issues regarding RCRA, TRU, and greater-than-Class-C (>C) waste must be settled. GAAT waste that is not RCRA could potentially be disposed of in-situ without immobilizing the waste. However, risk drivers may well lead to immobilization requirements regardless of the RCRA status.

If RCRA is identified as an ARAR for the GAAT remediation, RCRA waste would have to be immobilized, by grouting for example, so that the final waste form passes the TCLP. A key to this approach would be proving that all of the waste in the tanks is immobilized. For the TRU or >C waste to be disposed ofin the tanks, one of two things must occur. Either disposal of TRU/>C waste or dilution of TRU/>C waste to bring it below TRU waste limits or make it Class C or less must be allowed.

**Another key requirement for in-situ disposal is risk reduction. It must be shown that in-situ disposal meets human health risk requirements in accordance with CERCLA criteria. Waste immobilization and tank stabilization are the primary methods used to achieve risk reduction. As previously discussed, issues relating to risk evaluation are not in the scope of this document and will be resolved during the FS.**

**5.2.3.1.2 Disposal in WMRAD facilities.** The IWMF is currently the only on-site alternative to in-situ disposal of GAAT waste. The IWMF is managed by the WMRAD. The IWMF accepts non-RCRA CH SLLW for disposal and does not accept mixed waste or TRU waste.

Future WAC for the Oak Ridge disposal facilities will be concentration limited based on PA results. Preliminary concentration limits for SLLW disposal on the ORR are listed in the draft PA for disposal of SLLW on the ORR.[17]

**5.2.3.1.3 Waste Isolation Pilot Plant.** The WIPP is the only facility to date identified to accept TRU waste for disposal. WIPP is expected to receive solid TRU and mixed TRU wastes by 2001. This disposal option is considered the most viable for the TRU GAAT waste. However, the probability that the WAC for WIPP will change prior to operation is quite high (preparation of a new version of the WIPP WAC is underway). Furthermore, if the LDR exemption for WIPP is not approved, then the waste would have to be stabilized to pass the TCLP tests required to certify the waste form. Certification and characterization requirements must be well known before waste is processed to the final waste form for WIPP, or Oak Ridge could end up with a legacy waste with no disposal alternative because of lack of proper documentation.

The WAC for WIPP presently requires that the waste be immobilized if >1% by weight is particulate material < 10 $\mu$m in diameter, or if >15% by weight is particulate material <200 $\mu$m in diameter. This means that the GAAT sludge would have to be immobilized for acceptance at WIPP. Residual liquid in waste containers is restricted to 1% of the internal waste container's volume. Characteristic ignitable, corrosive, or reactive wastes are unacceptable. Waste must have a specific alpha activity from TRU isotopes exceeding 100 $\eta$Ci/g, exclusive of added shielding, rigid liners, and the waste containers.

The standard packagings for CH waste at WIPP are 55-gal drums and the SWB. The SWB is a partially cylindrical metal container with two flat sides designed to fit inside of the TRU Waste Packaging and Transportation System (TRUPACT)-II (a shipping cask for TRU waste) two SWBs at a time. The SWB nominal external dimensions are 71 in. (180.3 cm) in diameter, 54-1/4 in. (137.8 cm) across the flats, and 37 in. (94.0 cm) high. The TRUPACT-II can also carry fourteen 55-gal drums at one time. Waste can be packaged directly in an SWB or in 55-gal drums, four of which can be overpacked inside an SWB.[18,19]

The costs for WIPP disposal have been estimated at $630/ft$^3$, based on life-cycle cost estimates for "cradle-to-grave" costs for WIPP disposal, including capital, and operations and maintenance costs for the WIPP facility, but not including sunk costs.[20,21]

**5.2.3.1.4 Nevada Test Site.** The NTS receives solid LLW for disposal but does not accept waste exhibiting any hazardous characteristics as defined in 40 *CFR* 261. In addition, the NTS will not accept for disposal TRU waste (defined as having a TRU waste concentration exceeding 100 ηCi/g). TRUs having half-lives of less than 20 years are excluded from the NTS TRU definition.

Given the uncertainty as to whether all or a portion of the GAAT supernate can be included as part of the NTS-approved waste stream, the best management practice may be to plan on segregating the storage of these supernates until this concern can be addressed. Segregation of GAAT supernate could be accomplished by pumping the supernate to either an existing MVST whose supernate has been removed or to one of the new, unused MVSTs associated with the CIP available between 1998 and 1999 (see Sect. 5.2.2.1.2).

NTS recently issued a draft PA that will be included as part of a new revision of the NTS WAC in late 1996. The PA limits are more restrictive than the Class C limits for some isotopes. The NTS WAC will allow case-by-case consideration of waste exceeding its performance acceptance limits, but the probability of acceptance is unknown. The NTS is believed to be an appropriate disposal site for the GAAT wastes that are below TRU waste limits and that do not exceed the NRC PA and Class C limits after treatment to remove the RCRA characteristic hazard, and/or stabilization to pass the TCLP test.

However, recent events (including a lawsuit by the State of Nevada against the Secretary of DOE[22])suggest that the stake holders in Nevada are not very supportive of allowing NTS to continue receiving out-of-state radioactive waste for disposal. The current fee for DOE generators to dispose of LLW at NTS is $12.63/ft$^3$. A multiplier of 2.5 is suggested for RH waste to be disposed ofat NTS, which brings the estimated generator waste disposal fee for RH wastes to ~$31.58/ft$^3$.[23]

**5.2.3.2 Summary of Disposal Options**

On-site disposal of GAAT waste is credible only if the TRU waste can be diluted to below TRU waste limits and to Class C or less or if in-situ disposal of TRU and >C waste is allowed. In-situ disposal is attractive from cost, schedule, and exposure (as low as reasonably achievable [ALARA]) points of view, but it will prove difficult to satisfy all of the ARARs, particularly those relating to TRU, >C, and RCRA waste for in-situ disposal. Therefore, the most viable disposal sites for the TRU and LLW GAAT wastes appear to be WIPP and NTS, respectively. There are fewer uncertainties and more experience with disposal at NTS. However, implementation of the new draft NTS PA limits in late 1996 will restrict isotope concentrations in waste sent to NTS.

# 6. TSD ALTERNATIVES—SCENARIO EVALUATIONS

All cost estimates in this section are "order-of-magnitude" estimates based on the best available information. The Parallax study and Idaho National Engineering Laboratory (INEL) reports are the basis for many of the costs in this section. These reports provided line-item type life-cycle cost estimates for new and modified facilities including escalations for work in future years. This report uses some of the costs from the previous reports and includes some scaling factors for differences in treatment facility scales and installation approaches. The scaling factors are based on "best engineering judgment"; therefore, the resulting estimates are order-of-magnitude.

More detailed estimates for some treatment alternatives are currently in progress. Preliminary treatment costs for ex-situ treatment from these estimates range from $15.5 M (for ex-situ grouting) to $41.8 M (for ex-situ vitrification). These estimates do not include removal, transfer, and pretreatment costs for the sludge. Neither do they include costs for removal, treatment, storage, or disposal of supernate. Both the ex-situ vitrification and ex-situ grouting estimates include some costs for storing and disposing of the treated sludge. The ex-situ grouting estimate does not include transportation or WIPP disposal costs but assumes that these costs are borne by WIPP.

All of the estimates in this report include $73 M for the TS and for removing and pumping the GAAT waste and stabilizing the tanks. It is recognized that there will be facility modification or new facility costs associated with each of the alternatives. The facility costs for the baseline are incorporated into the pro-rata costs for treating the sludge. Facility costs for in-situ grouting will be relatively small since they will only house nonradioactive grouting systems. The facility costs for ex-situ grouting and vitrification will be higher than for in-situ grouting because ex-situ systems will be handling radioactive materials requiring shielding and remote operations.

Facility costs for vitrification are likely to be somewhat higher than those for ex-situ grouting because of the more demanding electrical and off-gas treatment systems. A cost of approximately $4M has been estimated recently for facility modification costs to locate a vitrification system in the hot cells at Bldg. 3517. This cost is included in the ex-situ vitrification estimate in this report. Costs of $3M and $500K for ex-situ grouting and in-situ grouting respectively (based on best engineering judgment relative to the vitrification facility costs) are included in this report's estimates.

In short, it is difficult to make direct comparisons among the variety of existing estimates. One constant across all estimates appears to be that the relative costs of in-situ grouting are less than ex-situ grouting, which are in turn less than ex-situ vitrification. It is apparent that "bottom-up" cost estimates, using the same basis for each of these three treatment approaches, would be beneficial in allowing direct comparisons and increasing confidence in the bottom-line estimate results.

Each TSD alternative assumes the following common steps: 1) tank structural stabilization will be performed (see Appendix C: Tank Stabilization), 2) on-site storage of the waste form will be required for all waste types generated, 3) an interim storage/feed tank is needed for all options except in-situ stabilization, and 4) excess water removed from the sludge is treated and disposed of as supernate. It is assumed that the costs estimated to occur for the TS and the baseline transfer to MVST are also incurred by the other alternatives, the only difference being that waste is transferred to a treatment facility instead of the MVST. All cost estimates are based on final waste volumes calculated using the 50%-tile data characterization statistics summarized in Table 5-3.

## 6.1 BASELINE — TRANSFER TO MVST

This alternative consists of transferring the entire contents of the GAAT OU to the active LLLW system. The sludge transferred from the GAAT OU is stored in the MVSTs until DOE's TRU processing program comes on-line at which time the entire content of the MVSTs is processed and disposed of. It is assumed that the supernate is solidified in a fashion similar to the LWSP waste and is disposed of at NTS. All water added to the sludge to pump it to the MVSTs (45 gal of water for each gal of sludge) is assumed to be removed from the sludge after the transfer and is added to the supernate inventory. It is also assumed that the solidified sludge is a TRU waste and is disposed ofat WIPP. For the purposes of determining processing, transportation, storage, and disposal costs, final waste volumes were calculated using vitrified (20% waste oxide loading) case in Sect. 5.2.1.2.

### 6.1.1 Cost Estimate

The latest cost estimate for the baseline alternative is approximately $73 M for the TS for retrieving the waste, pumping it to MVST, and stabilizing the GAAT tanks. This estimate does not include any costs associated with handling the waste after it is sent to the MVST, such as solidification, transportation, or disposal costs. The sludge treatment costs are derived by the pro rata cost estimates for the TRU Processing Facility (TPF) and include costs for retrieving the waste from the MVST, transferring it to the TPF, analyzing the waste for WIPP disposal, and solidifying the waste. Table 6-1 summarizes the costs for this alternative.

## 6.2 IN-SITU CEMENTATION

This alternative consists of transferring the supernate to the active LLLW system for solidification with the MVST supernate. A portion of the sludge may be removed from the GAAT and transferred to the MVST in order to reduce the long term risks of exposure to the public in accordance with CERCLA requirements. The sludge that is transferred to the MVST is stored in the MVSTs until DOE's TRU processing program comes on-line, at which time the entire contents of the MVSTs are processed and disposed of.

However, since it is out of the scope of this document to determine the amount of sludge to be removed from the tanks to meet risk criteria, it is assumed for cost estimating purposes that all the sludge remains in the tanks. It is also assumed that the supernate is solidified in a fashion similar to the LWSP waste and is disposed of at NTS. The sludge is stabilized in-situ by the addition of a nonshrinking grout cement and/or aggregate for final disposal. For the purposes of determining processing, transportation, storage, and disposal costs for the supernate, final waste volumes were calculated using typical waste loadings from previous LWSP campaigns. Final waste volumes of the treated sludge are assumed to be the capacities of the tanks.

### 6.2.1 Cost Estimate

The sludge treatment costs for in-situ cementation are based on using MPI as described in a draft report written in April 1996.[24] Preliminary costs are estimated in another report,[25] and those estimates are used here. They include costs for a subcontractor to provide the MPI process, LMES supervisory costs, and analytical costs. Table 6-2 summarizes the costs for this alternative.

## 6.3 EX-SITU CEMENTATION, ALL WASTE DILUTED TO CLASS C OR LESS

This alternative transfers the supernate from the GAAT to the active LLLW system for solidification with the MVST supernate. It is assumed that the supernate is solidified in a fashion similar to the LWSP waste and is disposed ofat NTS. The sludge is removed from the GAAT and grouted. All of the waste is diluted sufficiently to bring it to the NTS PA and Class C limits to meet NTS disposal requirements. Any excess water used to remove the sludge from the tanks that is not

## Table 6-1 Cost Summary — Baseline Alternative

| | | Quantity | Retrieval Costs | | | Treatment Costs | | | Storage Costs | | | Disposal Costs | | | | | Misc. | TOTALS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Capital | O&M | | Capital | O&M | | Capital | O&M | | Capital | O&M | | Transportation | | | |
| | | (ft³) | ($) | ($/ft³ retrieved) | ($) | ($) | ($/ft³ produced) | ($) | ($) | ($/ft³) | ($) | ($) | ($/ft³) | ($) | ($/ft³) | ($) | ($) | |
| W-3+W-4 | retrieved: | 7113 | | | 0 | | 246.21 | 2189146 | | 112.2 | 997613 | | 31.58 | 280790 | 93.50 | 831344 | | $4,298,892 |
| Supernate: | produced: | 8891 | | | | | | | | | | | | | | | | |
| Sludge: | retrieved: | 259 | 7.30E+07 | | 0 | | 14827.13 | 3847521 | | 153.06 | 39949 | | 630 | 164430 | 145.44 | 37961 | | $77,089,860 |
| vit20 | produced: | 261 | | | | | | | | | | | | | | | | |
| W-5 | retrieved: | 5568 | | | 0 | | 246.21 | 1713760 | | 112.2 | 780975 | | 31.58 | 219815 | 93.50 | 650813 | | $3,365,362 |
| Supernate: | produced: | 6961 | | | | | | | | | | | | | | | | |
| Sludge: | retrieved: | 457 | | | 0 | | 14827.13 | 6783213 | | 153.06 | 60612 | | 630 | 249480 | 145.44 | 57596 | | $7,150,900 |
| vit20 | produced: | 396 | | | | | | | | | | | | | | | | |
| W-6 | retrieved: | 9308 | | | 0 | | 246.21 | 2864783 | | 112.2 | 1305506 | | 31.58 | 367450 | 93.50 | 1087922 | | $5,625,661 |
| Supernate: | produced: | 11636 | | | | | | | | | | | | | | | | |
| Sludge: | retrieved: | 941 | | | 0 | | 14827.13 | 13948997 | | 153.06 | 156733 | | 630 | 645120 | 145.44 | 148935 | | $14,899,786 |
| vit20 | produced: | 1024 | | | | | | | | | | | | | | | | |
| W-7 | retrieved: | 5189 | | | 0 | | 246.21 | 1596950 | | 112.2 | 727744 | | 31.58 | 204832 | 93.50 | 606453 | | $3,135,979 |
| Supernate: | produced: | 6486 | | | | | | | | | | | | | | | | |
| Sludge: | retrieved: | 1178 | | | 0 | | 14827.13 | 17467466 | | 153.06 | 203417 | | 630 | 837270 | 145.44 | 193296 | | $18,701,449 |
| vit20 | produced: | 1329 | | | | | | | | | | | | | | | | |
| W-8 | retrieved: | 14147 | | | 0 | | 246.21 | 4353811 | | 112.2 | 1984069 | | 31.58 | 558439 | 93.50 | 1653391 | | $8,549,709 |
| Supernate: | produced: | 17683 | | | | | | | | | | | | | | | | |
| Sludge: | retrieved: | 1378 | | | 0 | | 14827.13 | 20434874 | | 153.06 | 123519 | | 630 | 508410 | 145.44 | 117374 | | $21,184,177 |
| vit20 | produced: | 807 | | | | | | | | | | | | | | | | |
| W-9 | retrieved: | 7628 | | | 0 | | 246.21 | 2347718 | | 112.2 | 1069875 | | 31.58 | 301129 | 93.50 | 891563 | | $4,610,284 |
| Supernate: | produced: | 9535 | | | | | | | | | | | | | | | | |
| Sludge: | retrieved: | 382 | | | 0 | | 14827.13 | 5671178 | | 153.06 | 27092 | | 630 | 111510 | 145.44 | 25744 | | $5,835,523 |
| vit20 | produced: | 177 | | | | | | | | | | | | | | | | |
| W-10 | retrieved: | 19125 | | | 0 | | 246.21 | 5885834 | | 112.2 | 2682225 | | 31.58 | 754944 | 93.50 | 2235188 | | $11,558,190 |
| Supernate: | produced: | 23906 | | | | | | | | | | | | | | | | |
| Sludge: | retrieved: | 1243 | | | 0 | | 14827.13 | 18430833 | | 153.06 | 246274 | | 630 | 1013670 | 145.44 | 234020 | | $19,924,797 |
| vit20 | produced: | 1609 | | | | | | | | | | | | | | | | |
| TH-4 | retrieved: | 3639 | | | 0 | | 246.21 | 1119877 | | 112.2 | 510338 | | 31.58 | 143640 | 93.50 | 425281 | | $2,199,136 |
| Supernate: | produced: | 4548 | | | | | | | | | | | | | | | | |
| Sludge: | retrieved: | 729 | | | 0 | | 14827.13 | 10807152 | | 153.06 | 201886 | | 630 | 830970 | 145.44 | 191841 | | $12,031,850 |
| vit20 | produced: | 1319 | | | | | | | | | | | | | | | | |
| Supernate: | | | $0 | | $0 | $0 | | $22,071,879 | $0 | | $10,058,344 | $0 | | $2,831,038 | | $8,381,953 | $0 | $43,343,214 |
| Sludge: | | | $73,000,000 | | $0 | $0 | | $97,391,235 | $0 | | $1,059,481 | $0 | | $4,360,860 | | $1,006,766 | $0 | $176,818,343 |
| | | | | | | | | | | | | | | | | | | $220,161,557 |
| TOTALS: | | | $73,000,000 | | $0 | $0 | | $119,463,114 | $0 | | $11,117,825 | $0 | | $7,191,898 | | $9,388,720 | $0 | $220,161,557 |

## Table 6-2 Cost Summary— In-Situ Cementation

| | | Quantity | Retrieval Costs | | | Treatment Costs | | | Storage Costs | | | Disposal Costs | | | | | Misc. | TOTALS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Capital | O&M | | Capital | O&M | | Capital | O&M | | Capital | O&M | | Transportation | | | |
| | | (ft³) | ($) | ($/ft³ retrieved) | ($) | ($) | ($/ft³ produced) | ($) | ($) | ($/ft³) | ($) | ($) | ($/ft³) | ($) | ($/ft³) | ($) | ($) | |
| W-3+W-4 | retrieved: | 6075.13 | | | 0 | | 246.21 | 1869698.332 | | 112.2 | 852037.5 | | 31.58 | 239777.9328 | 93.5 | 710031.25 | | $3,671,545 |
| Supernate | produced: | 7593.92 | | | | | | | | | | | | | | | | |
| Sludge: | retrieved: | 0 | 7.30E+07 | | 0 | 1352667 | | 0 | | 0 | 0 | | 0 | 0 | 0 | 0 | | $74,352,667 |
| | produced: | 85000 | | | | | | | | | | | | | | | | |
| W-5 | retrieved: | 3738.5 | | | 0 | | 246.21 | 1150570.929 | | 112.2 | 524325 | | 31.58 | 147554.0274 | 93.5 | 436937.5 | | $2,259,387 |
| Supernate | produced: | 4673.13 | | | | | | | | | | | | | | | | |
| Sludge: | retrieved: | 0 | | | 0 | 676333 | | 0 | | 0 | 0 | | 0 | 0 | 0 | 0 | | $676,333 |
| | produced: | 170000 | | | | | | | | | | | | | | | | |
| W-6 | retrieved: | 5545.32 | | | 0 | | 246.21 | 1706641.81 | | 112.2 | 777731.25 | | 31.58 | 218866.8825 | 93.5 | 648109.375 | | $3,351,349 |
| Supernate | produced: | 6931.65 | | | | | | | | | | | | | | | | |
| Sludge: | retrieved: | 0 | | | 0 | 676333 | | 0 | | 0 | 0 | | 0 | 0 | 0 | 0 | | $676,333 |
| | produced: | 170000 | | | | | | | | | | | | | | | | |
| W-7 | retrieved: | 476.604 | | | 0 | | 246.21 | 146680.9241 | | 112.2 | 66843.75 | | 31.58 | 18810.9751 | 93.5 | 55703.125 | | $288,039 |
| Supernate | produced: | 595.755 | | | | | | | | | | | | | | | | |
| Sludge: | retrieved: | 0 | | | 0 | 676333 | | 0 | | 0 | 0 | | 0 | 0 | 0 | 0 | | $676,333 |
| | produced: | 3873 | | | | | | | | | | | | | | | | |
| W-8 | retrieved: | 8633.82 | | | 0 | | 246.21 | 2657167.114 | | 112.2 | 1210893.75 | | 31.58 | 340766.2224 | 93.5 | 1009078.125 | | $5,217,905 |
| Supernate | produced: | 10792.3 | | | | | | | | | | | | | | | | |
| Sludge: | retrieved: | 0 | | | 0 | 676333 | | 0 | | 0 | 0 | | 0 | 0 | 0 | 0 | | $676,333 |
| | produced: | 170000 | | | | | | | | | | | | | | | | |
| W-9 | retrieved: | 6098.4 | | | 0 | | 246.21 | 1876857.513 | | 112.2 | 855300 | | 31.58 | 240696.0561 | 93.5 | 712750 | | $3,685,604 |
| Supernate | produced: | 7622.99 | | | | | | | | | | | | | | | | |
| Sludge: | retrieved: | 0 | | | 0 | 676333 | | 0 | | 0 | 0 | | 0 | 0 | 0 | 0 | | $676,333 |
| | produced: | 170000 | | | | | | | | | | | | | | | | |
| W-10 | retrieved: | 14152.4 | | | 0 | | 246.21 | 4355579.98 | | 112.2 | 1984875 | | 31.58 | 558577.7908 | 93.5 | 1654062.5 | | $8,553,095 |
| Supernate | produced: | 17690.5 | | | | | | | | | | | | | | | | |
| Sludge: | retrieved: | 0 | | | 0 | 676333 | | 0 | | 0 | 0 | | 0 | 0 | 0 | 0 | | $676,333 |
| | produced: | 170000 | | | | | | | | | | | | | | | | |
| TH-4 | retrieved: | 723.262 | | | 0 | | 246.21 | 222592.9311 | | 112.2 | 101437.5 | | 31.58 | 28546.24833 | 93.5 | 84531.25 | | $437,108 |
| Supernate | produced: | 904.078 | | | | | | | | | | | | | | | | |
| Sludge: | retrieved: | 0 | | | 0 | 676333 | | 0 | | 0 | 0 | | 0 | 0 | 0 | 0 | | $676,333 |
| | produced: | 14000 | | | | | | | | | | | | | | | | |
| Supernate: | | | $0 | | $0 | $0 | | $13,985,790 | $0 | | $6,373,444 | $0 | | $1,793,596 | | $5,311,203 | $0 | $27,464,033 |
| Sludge: | | | $73,000,000 | | $0 | $6,087,000 | | $0 | $0 | | $0 | $0 | | $0 | | $0 | $0 | $79,087,000 |
| | | | | | | | | | | | | | | | | | | $106,551,033 |
| TOTALS: | | | $73,000,000 | | $0 | $6,087,000 | | $13,985,790 | $0 | | $6,373,444 | $0 | | $1,793,596 | | $5,311,203 | $0 | $106,551,033 |

necessary to grout the sludge is added to the supernate inventory. The grouted waste is stored on-site until it can be shipped to the disposal site. The grouted waste is disposed of at NTS. For the purposes of determining processing, transportation, storage, and disposal costs for the sludge, final waste volumes were calculated using the Grout 6 case (NTS PA and Class C) in Sect. 5.2.1.2.

### 6.3.1 Cost Estimate

The costs for treating the supernate are based on recent estimates for a future LWSP campaign. The LWSP estimates are converted to dollars per cubic foot and then applied to the amount of waste produced by the supernate solidification. The estimate includes LMES administration, a competitively bid solidification subcontractor, and product analysis for disposal at NTS. Storage and transportation costs also come from the LWSP estimates. Storage is assumed to be similar to current LWSP cask storage (outdoors and uncovered, but segregated) and includes the cost of the storage cask on a dollar-per-cubic-foot basis. Transportation costs are based on disposal at NTS. The NTS disposal costs are based on the latest generator fees for that facility multiplied by 2.5, since most of the waste sent to NTS is likely to be RH.[26,27]

The sludge treatment costs are derived from a combination of information from a Rocky Flats report[28,29] and an INEL report[30] and include equipment and installation costs for a grout solidification system, electrical and controls, radiation monitoring, and decontamination and decommissioning. The solidification equipment and decontamination and decommissioning costs come from the Rocky Flats report on the solidification of low level Pu contaminated solar pond sludges. The Rocky Flats costs are multiplied by a factor of two to account for difficulties associated with the increased radioactivity of the GAAT waste.

The electrical and controls and radiation monitoring costs come from the INEL report and are based on estimates for a vitrification facility. The electrical and controls costs are divided by a factor of two since it is assumed that those requirements would be significantly less for a grout facility. It is assumed that an existing or new facility near the GAAT OU will be used to house the treatment system and that there will be some modification and construction costs. The treatment facility operation and maintenance (O&M) costs are based on the following assumptions: two 8-hour shifts per day, ten full-time equivalents (FTEs) per shift, $200,000 per FTE per year, and 3 years of operation.

There are no storage, transportation, or disposal costs for this alternative. It is assumed that the sludge interim storage, transportation, and disposal costs are the same as for the supernate.Table 6-3 summarizes the costs for this alternative.

## 6.4 EX-SITU CEMENTATION, WASTE VOLUME MINIMIZED

This alternative transfers the supernate from the GAAT to the active LLLW system for solidification with the MVST supernate. It is assumed that the supernate is solidified in a fashion similar to the LWSP waste and is disposed ofat NTS. The sludge is removed from the GAAT and grouted ex-situ. Any excess water used to remove the sludge from the tanks that is not necessary to grout the sludge is added to the supernate inventory. The undiluted sludge/grout solution from each tank is evaluated separately (except for W-3 and W-4, which are combined prior to evaluation). Solutions below TRU waste and NTS PA limits and Class C or less are disposed ofat NTS (Tanks W-3 and W-4 combined, W-5 and TH-4).

# Table 6-3 Cost Summary — Ex-Situ Cementation, All Waste Diluted to Class C or Less

| | | Quantity | Retrieval Costs | | | Treatment Costs | | | Storage Costs | | | Disposal Costs | | | | | Misc. | TOTALS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Capital | O&M | | Capital | O&M | | Capital | O&M | | Capital | O&M | | Transportation | | | |
| | | ($ft^3$) | ($) | ($/$ft^3$ retrieved) | ($) | ($) | ($/$ft^3$ produced) | ($) | ($) | ($/$ft^3$) | ($) | ($) | ($/$ft^3$) | ($) | ($/$ft^3$) | ($) | ($) | |
| W-3+W-4 | retrieved: | 7113 | | | 0 | | 246.21 | 2189155.807 | | 112.2 | 997617 | | 31.58 | 280746.4953 | 93.5 | 831347.5 | | $4,298,867 |
| Supernate: | produced: | 8891 | | | | | | | | | | | | | | | | |
| Sludge: | retrieved: | 259 | 7.30E+07 | | 0 | 9208000 | 851.97 | 293929.4649 | | 153.06 | 52805.7 | | 31.58 | 10893.375 | 93.5 | 32257.5 | | $82,597,886 |
| grout2 | produced: | 345 | | | | | | | | | | | | | | | | |
| W-5 | retrieved: | 5569 | | | 0 | | 246.21 | 1713776.304 | | 112.2 | 780982.5 | | 31.58 | 219781.8399 | 93.5 | 650818.75 | | $3,365,359 |
| Supernate: | produced: | 6961 | | | | | | | | | | | | | | | | |
| Sludge: | retrieved: | 457 | | | 0 | | 246.21 | 154866.09 | | 112.2 | 70573.8 | | 31.58 | 19860.675 | 93.5 | 58811.5 | | $304,112 |
| grout2 | produced: | 629 | | | | | | | | | | | | | | | | |
| W-6 | retrieved: | 9308 | | | 0 | | 246.21 | 2864752.097 | | 112.2 | 1305492 | | 31.58 | 367387.7888 | 93.5 | 1087910 | | $5,625,542 |
| Supernate: | produced: | 11635 | | | | | | | | | | | | | | | | |
| Sludge: | retrieved: | 941 | | | 0 | | 851.97 | 1075185.463 | | 153.06 | 193161.72 | | 630 | 795060 | 93.5 | 117997 | | $2,181,404 |
| grout2 | produced: | 1262 | | | | | | | | | | | | | | | | |
| W-7 | retrieved: | 5189 | | | 0 | | 246.21 | 1596857.824 | | 112.2 | 727701.75 | | 31.58 | 204787.7251 | 93.5 | 606418.125 | | $3,135,765 |
| Supernate: | produced: | 6486 | | | | | | | | | | | | | | | | |
| Sludge: | retrieved: | 1178 | | | 0 | | 246.21 | 1881783.03 | | 112.2 | 857544.6 | | 31.58 | 241327.725 | 93.5 | 714620.5 | | $3,695,276 |
| grout6 | produced: | 7643 | | | | | | | | | | | | | | | | |
| W-8 | retrieved: | 14147 | | | 0 | | 246.21 | 4353861.776 | | 112.2 | 1984092 | | 31.58 | 558357.4412 | 93.5 | 1653410 | | $8,549,721 |
| Supernate: | produced: | 17684 | | | | | | | | | | | | | | | | |
| Sludge: | retrieved: | 1378 | | | 0 | | 851.97 | 1748241.339 | | 153.06 | 314079.12 | | 630 | 1292760 | 93.5 | 191862 | | $3,546,942 |
| grout2 | produced: | 2052 | | | | | | | | | | | | | | | | |
| W-9 | retrieved: | 7628 | | | 0 | | 246.21 | 2347734.138 | | 112.2 | 1069882.5 | | 31.58 | 301083.2436 | 93.5 | 891568.75 | | $4,610,269 |
| Supernate: | produced: | 9535 | | | | | | | | | | | | | | | | |
| Sludge: | retrieved: | 382 | | | 0 | | 851.97 | 503513.953 | | 153.06 | 90458.46 | | 630 | 372330 | 93.5 | 55258.5 | | $1,021,561 |
| grout2 | produced: | 591 | | | | | | | | | | | | | | | | |
| W-10 | retrieved: | 19124 | | | 0 | | 246.21 | 5885775.13 | | 112.2 | 2682198 | | 31.58 | 754816.4158 | 93.5 | 2235165 | | $11,557,955 |
| Supernate: | produced: | 23906 | | | | | | | | | | | | | | | | |
| Sludge: | retrieved: | 1243 | | | 0 | | 851.97 | 1421085.065 | | 153.06 | 255304.08 | | 630 | 1050840 | 93.5 | 155958 | | $2,883,187 |
| grout2 | produced: | 1668 | | | | | | | | | | | | | | | | |
| TH-4 | retrieved: | 3515 | | | 0 | | 246.21 | 1081865.831 | | 112.2 | 493015.5 | | 31.58 | 138742.9983 | 93.5 | 410846.25 | | $2,124,471 |
| Supernate: | produced: | 4394 | | | | | | | | | | | | | | | | |
| Sludge: | retrieved: | 729 | | | 0 | | 246.21 | 233160.87 | | 112.2 | 106253.4 | | 31.58 | 29901.525 | 93.5 | 88544.5 | | $457,860 |
| grout2 | produced: | 947 | | | | | | | | | | | | | | | | |
| Supernate: | | | $0 | | $0 | $0 | | $22,033,779 | $0 | | $10,040,981 | $0 | | $2,825,704 | | $8,367,484 | $0 | $43,267,948 |
| Sludge: | | | $73,000,000 | | $0 | $9,208,000 | | $7,311,765 | $0 | | $1,940,181 | $0 | | $3,812,973 | | $1,415,310 | $0 | $96,688,229 |
| | | | | | | | | | | | | | | | | | | $139,956,177 |
| TOTALS: | | | $73,000,000 | | $0 | $9,208,000 | | $29,345,544 | $0 | | $11,981,162 | $0 | | $6,638,677 | | $9,782,794 | $0 | $139,956,177 |

Solutions that are TRU are disposed of at WIPP (W-6, W-8, W-9, and W-10). If the solution is below TRU waste limits but greater than NTS PA limits or Class C, it meets neither the WIPP nor NTS WAC and has no disposal options (i.e., orphan waste). This "orphan waste" is diluted until it becomes below NTS PA limits and Class C and then disposed of at NTS (tank W-7). The grouted waste is stored on-site until it can be shipped to the disposal sites. For the purposes of determining processing, transportation, storage, and disposal costs, final waste volumes were calculated using the Grout 2 case (Waste Volume Minimized) in Sect. 5.2.1.2 with the exception of tank W-7 sludge. Tank W-7 sludge final waste volume is calculated using the Grout 6 case (NTS PA limits and Class C).

### 6.4.1 Cost Estimate

The supernate and sludge treatment costs for this option are the same as for the treatment costs for the ex-situ cementation (all waste diluted to NTS PA limits and Class C or less) option (refer to Sect. 6.3.1) with the following exceptions:

1. Unit transportation costs are based on disposal at NTS and, for this document, are assumed to be the same for NTS and WIPP.
2. The unit costs for disposal at WIPP include capital and O&M expenditures expected to occur from 1996 on, divided by total WIPP capacity in cubic feet.[31],[32] WIPP disposal costs do not include sunk costs prior to 1996.

Table 6-4 summarizes the costs for this alternative.

## 6.5 EX-SITU VITRIFICATION, WASTE VOLUME MINIMIZED

This alternative transfers the supernate from the GAAT to the active LLLW system for solidification with the MVST supernate. It is assumed that the supernate is solidified in a fashion similar to the LWSP waste and is disposed of at NTS. The sludge is removed from the GAAT, dewatered, and vitrified. Any water used to remove the sludge from the tanks is addd to the supernate inventory. The waste is vitrified with a 20% waste oxide loading (tanks W-3 and W-4 combined, W-5, W-8, W-9, W-10, and TH-4), unless the resulting waste form is determined to be below TRU waste limits and >C ("orphan waste"). This potential "orphan waste" is vitrified with a 5% waste oxide loading to make the final waste form Class C (W-6 and W-7). All waste below TRU waste limits is disposed of at NTS (tanks W-3 and W-4 combined, W-5, W-6, W-7, W-10, and TH-4) and all TRU waste (tanks W-8 and W-9) is disposed ofat WIPP.

For the purposes of determining processing, transportation, storage, and disposal costs, final waste volumes were calculated using the vitrification 20% case (20% waste oxide loading—dry basis) in Sect. 5.2.1.2 with the exception of tanks W-6, W-7, and W-10 sludge. Tanks W-6, W-7, and W-10 sludge final waste volumes are calculated using the vitrification 5% case (5% waste oxide loading—dry basis). It should be noted that the W-10 sludge final waste at 5% waste oxide loading is still slightly above the Class C limit (sum of ratios is 1.37 compared to <1.0 needed to be Class C or less). However, the 5% loading volume is used here for W-10 sludge for simplification.

# Table 6-4 Cost Summary — Ex-Situ Cementation, Waste Volume Minimized

| | | Quantity | Retrieval Costs | | | Treatment Costs | | | Storage Costs | | | Disposal Costs | | | | | Misc. | TOTALS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Capital | O&M | | Capital | O&M | | Capital | O&M | | Capital | O&M | | Transportation | | | |
| | | (ft³) | ($) | ($/ft³ retrieved) | ($) | ($) | ($/ft³ produced) | ($) | ($) | ($/ft³) | ($) | ($) | ($/ft³) | ($) | ($/ft³) | ($) | ($) | |
| W-3+W-4 | retrieved: | 6799 | | | 0 | | 246.21 | 2092518 | | 112.2 | 953579 | | 31.58 | 268353 | 93.5 | 794649 | | $4,109,099 |
| Supernate: | produced: | 8499 | | | | | | | | | | | | | | | | |
| Sludge: | retrieved: | 259 | 7.30E+07 | | 0 | 9208000 | 343.52 | 298516 | | 112.2 | 97502 | | 31.58 | 27439 | 93.5 | 81252 | | $82,712,708 |
| | produced: | 869 | | | | | | | | | | | | | | | | |
| W-5 | retrieved: | 5569 | | | 0 | | 246.21 | 1713776 | | 112.2 | 780983 | | 31.58 | 219782 | 93.5 | 650819 | | $3,365,359 |
| Supernate: | produced: | 6961 | | | | | | | | | | | | | | | | |
| Sludge: | retrieved: | 457 | | | 0 | | 343.52 | 215728 | | 112.2 | 70462 | | 31.58 | 19829 | 93.5 | 58718 | | $364,737 |
| | produced: | 628 | | | | | | | | | | | | | | | | |
| W-6 | retrieved: | 8271 | | | 0 | | 246.21 | 2545602 | | 112.2 | 1160053 | | 31.58 | 326459 | 93.5 | 966711 | | $4,998,824 |
| Supernate: | produced: | 10339 | | | | | | | | | | | | | | | | |
| Sludge: | retrieved: | 941 | | | 0 | | 343.52 | 1028144 | | 112.2 | 335815 | | 31.58 | 94504 | 93.5 | 279846 | | $1,738,308 |
| | produced: | 2993 | | | | | | | | | | | | | | | | |
| W-7 | retrieved: | 1517 | | | 0 | | 246.21 | 466754 | | 112.2 | 212704 | | 31.58 | 59858 | 93.5 | 177253 | | $916,569 |
| Supernate: | produced: | 1896 | | | | | | | | | | | | | | | | |
| Sludge: | retrieved: | 1178 | | | 0 | | 343.52 | 2625495 | | 112.2 | 857545 | | 31.58 | 241328 | 93.5 | 714621 | | $4,438,988 |
| | produced: | 7643 | | | | | | | | | | | | | | | | |
| W-8 | retrieved: | 11149 | | | 0 | | 246.21 | 3431190 | | 112.2 | 1563623 | | 31.58 | 440030 | 93.5 | 1303019 | | $6,737,861 |
| Supernate: | produced: | 13936 | | | | | | | | | | | | | | | | |
| Sludge: | retrieved: | 1378 | | | 0 | | 343.52 | 2423164 | | 112.2 | 791459 | | 31.58 | 222730 | 93.5 | 659549 | | $4,096,902 |
| | produced: | 7054 | | | | | | | | | | | | | | | | |
| W-9 | retrieved: | 6098 | | | 0 | | 246.21 | 1876858 | | 112.2 | 855300 | | 31.58 | 240696 | 93.5 | 712750 | | $3,685,604 |
| Supernate: | produced: | 7623 | | | | | | | | | | | | | | | | |
| Sludge: | retrieved: | 382 | | | 0 | | 343.52 | 1317041 | | 112.2 | 430175 | | 31.58 | 121059 | 93.5 | 358479 | | $2,226,754 |
| | produced: | 3834 | | | | | | | | | | | | | | | | |
| W-10 | retrieved: | 14152 | | | 0 | | 246.21 | 4355580 | | 112.2 | 1984875 | | 31.58 | 558578 | 93.5 | 1654063 | | $8,553,095 |
| Supernate: | produced: | 17691 | | | | | | | | | | | | | | | | |
| Sludge: | retrieved: | 1243 | | | 0 | | 343.52 | 5277441 | | 112.2 | 1723729 | | 31.58 | 485087 | 93.5 | 1436441 | | $8,922,697 |
| | produced: | 15363 | | | | | | | | | | | | | | | | |
| TH-4 | retrieved: | 1790 | | | 0 | | 246.21 | 550976 | | 112.2 | 251084 | | 31.58 | 70659 | 93.5 | 209237 | | $1,081,956 |
| Supernate: | produced: | 2238 | | | | | | | | | | | | | | | | |
| Sludge: | retrieved: | 729 | | | 0 | | 343.52 | 1313606 | | 112.2 | 429053 | | 31.58 | 120743 | 93.5 | 357544 | | $2,220,946 |
| | produced: | 3824 | | | | | | | | | | | | | | | | |
| Supernate: | | | $0 | | $0 | $0 | | $17,033,254 | $0 | | $7,762,199 | $0 | | $2,184,416 | | $6,468,499 | $0 | $33,448,368 |
| Sludge: | | | $73,000,000 | | $0 | $9,208,000 | | $14,499,136 | $0 | | $4,735,738 | $0 | | $1,332,718 | | $3,946,448 | $0 | $106,722,039 |
| | | | | | | | | | | | | | | | | | | $140,170,407 |
| TOTALS: | | | $73,000,000 | | $0 | $9,208,000 | | $31,532,389 | $0 | | $12,497,937 | $0 | | $3,517,133 | | $10,414,947 | $0 | $140,170,407 |

### 6.5.1 Cost Estimate

The supernate unit treatment costs for this option are the same as for the treatment costs for the ex-situ cementation (all waste diluted to NTS PA limits and Class C or less) option (refer to Sect. 6.2.1).

The sludge treatment costs are derived from an INEL report[33] and include equipment and installation costs for a melter system, a dryer system, a cooling and packaging system, an electrical system and controls, and radiation monitoring. It is assumed that an existing building near the GAAT OU will be used to house the treatment system and that the facility will require minimal modifications to support treatment operations. The treatment facility O&M costs are based on the following assumptions: two 8-hour shifts per day; 10 FTEs per shift; $200,000 per FTE per year; and 3 years of operation.

The unit storage costs for treated sludge are assumed to be the same as those for treated supernate. The unit transportation costs for treated sludge are adjusted for the difference in densities between grouted waste and vitrified waste since transportation costs are weight-dependent. The unit costs for disposal at WIPP include capital and O&M expenditures expected to occur from 1996 on, divided by total WIPP capacity in cubic feet.[34,35] WIPP disposal costs do not include sunk costs prior to 1996. The NTS unit disposal costs for treated sludge are the same as for treated supernate. Table 6-5 summarizes the costs for this alternative.

# 7. IMPLEMENTATION STRATEGIES

Implementation of proposed TSD options can be accomplished in a variety of ways. Implementation methods range from complete privatization to conduct by on-site managing and operating (M&O) labor forces. This chapter will present the various implementation options and attempt to describe the major advantages and disadvantages for each option. Each of the following implementation strategies can result in the TSD of the GAAT wastes. The primary differences between the strategies lie in the cost, risk of failure, and ability to push the available technology. A similar evaluation was presented in the TRU Waste Processing FS. The current evaluation, however, provides information on implementation strategies for smaller scale processing options that could be useful in proof-of-principles demonstrations to support the processing of the balance of the on-site TRU wastes.

## 7.1 TOTAL PRIVATIZATION

The total privatization option results in turning over all GAAT TSD activities to a private sector subcontractor. Under this option, DOE and the site M&O contractor would not be involved in the performance of any of the TSD activities and would function only to monitor the performance of the subcontractor. The subcontractor would be responsible for all processes, equipment, safety, regulatory compliance, operations, and transportation of the waste. Because the GAAT are inactive tanks and therefore no longer receive waste from the Oak Ridge Complex, total privatization of the TSD of the wastes in the tanks may be a feasible approach. This option assumes that the necessary disposal facilities are available for placement of the wastes. However, it is likely that an interim storage facility will be needed prior to disposal of the wastes. It would be the responsibility of the private sector subcontractor to arrange for the storage of the waste and its later disposal.

## Table 6-5 Cost Summary — Ex-Situ Vitrification, Waste Volume Minimized

| | | Quantity | Retrieval Costs | | | Treatment Costs | | | Storage Costs | | | Disposal Costs | | | | | Misc. | TOTALS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Capital | O&M | | Capital | O&M | | Capital | O&M | | Capital | O&M | | Transportation | | | |
| | | (ft³) | ($) | ($/ft³ retrieved) | ($) | ($) | ($/ft³ produced) | ($) | ($) | ($/ft³) | ($) | ($) | ($/ft³) | ($) | ($/ft³) | ($) | ($) | |
| W-3+W-4 | retrieved: | 7113 | | | 0 | | 246.21 | 2189146 | | 112.2 | 997613 | | 31.58 | 280745 | 93.50 | 831344 | | $4,298,847 |
| Supernate: | produced: | 8891 | | | | | | | | | | | | | | | | |
| Sludge: | retrieved: | 259 | 7.30E+07 | | 0 | 15757000 | 917.52 | 239472 | | 112.2 | 29284 | | 630 | 164430 | 145.44 | 37961 | | $89,228,147 |
| vit20 | produced: | 261 | | | | | | | | | | | | | | | | |
| W-5 | retrieved: | 5568 | | | 0 | | 246.21 | 1713760 | | 112.2 | 780975 | | 31.58 | 219780 | 93.50 | 650813 | | $3,365,327 |
| Supernate: | produced: | 6961 | | | | | | | | | | | | | | | | |
| Sludge: | retrieved: | 457 | | | 0 | | 917.52 | 363337 | | 112.2 | 44431 | | 31.58 | 12504 | 145.44 | 57596 | | $477,868 |
| vit20 | produced: | 396 | | | | | | | | | | | | | | | | |
| W-6 | retrieved: | 9308 | | | 0 | | 246.21 | 2864783 | | 112.2 | 1305506 | | 31.58 | 367392 | 93.50 | 1087922 | | $5,625,603 |
| Supernate: | produced: | 11636 | | | | | | | | | | | | | | | | |
| Sludge: | retrieved: | 941 | | | 0 | | 917.52 | 3757235 | | 112.2 | 459459 | | 630 | 2579850 | 145.44 | 595595 | | $7,392,139 |
| vit5 | produced: | 4095 | | | | | | | | | | | | | | | | |
| W-7 | retrieved: | 5189 | | | 0 | | 246.21 | 1596950 | | 112.2 | 727744 | | 31.58 | 204800 | 93.50 | 606453 | | $3,135,946 |
| Supernate: | produced: | 6486 | | | | | | | | | | | | | | | | |
| Sludge: | retrieved: | 1178 | | | 0 | | 917.52 | 4878442 | | 112.2 | 596567 | | 31.58 | 167884 | 145.44 | 773328 | | $6,416,221 |
| vit5 | produced: | 5317 | | | | | | | | | | | | | | | | |
| W-8 | retrieved: | 14147 | | | 0 | | 246.21 | 4353811 | | 112.2 | 1984069 | | 31.58 | 558351 | 93.50 | 1653391 | | $8,549,621 |
| Supernate: | produced: | 17683 | | | | | | | | | | | | | | | | |
| Sludge: | retrieved: | 1378 | | | 0 | | 917.52 | 740437 | | 153.06 | 123519 | | 630 | 508410 | 145.44 | 117374 | | $1,489,740 |
| vit20 | produced: | 807 | | | | | | | | | | | | | | | | |
| W-9 | retrieved: | 7628 | | | 0 | | 246.21 | 2347718 | | 112.2 | 1069875 | | 31.58 | 301081 | 93.50 | 891563 | | $4,610,236 |
| Supernate: | produced: | 9535 | | | | | | | | | | | | | | | | |
| Sludge: | retrieved: | 382 | | | 0 | | 917.52 | 162401 | | 153.06 | 27092 | | 630 | 111510 | 145.44 | 25744 | | $326,746 |
| vit20 | produced: | 177 | | | | | | | | | | | | | | | | |
| W-10 | retrieved: | 19125 | | | 0 | | 246.21 | 5885834 | | 112.2 | 2682225 | | 31.58 | 754824 | 93.50 | 2235188 | | $11,558,071 |
| Supernate: | produced: | 23906 | | | | | | | | | | | | | | | | |
| Sludge: | retrieved: | 1243 | | | 0 | | 917.52 | 1476286 | | 153.06 | 246274 | | 630 | 1013670 | 145.44 | 234020 | | $2,970,250 |
| vit20 | produced: | 1609 | | | | | | | | | | | | | | | | |
| TH-4 | retrieved: | 3639 | | | 0 | | 246.21 | 1119877 | | 112.2 | 510338 | | 31.58 | 143618 | 93.50 | 425281 | | $2,199,113 |
| Supernate: | produced: | 4548 | | | | | | | | | | | | | | | | |
| Sludge: | retrieved: | 729 | | | 0 | | 917.52 | 1210206 | | 112.2 | 147992 | | 31.58 | 41647 | 145.44 | 191841 | | $1,591,686 |
| vit20 | produced: | 1319 | | | | | | | | | | | | | | | | |
| Supernate: | | | $0 | | $0 | $0 | | $22,071,879 | $0 | | $10,058,344 | $0 | | $2,830,590 | | $8,381,953 | $0 | $43,342,766 |
| Sludge: | | | $73,000,000 | | $0 | $15,757,000 | | $12,827,815 | $0 | | $1,674,618 | $0 | | $4,599,905 | | $2,033,459 | $0 | $109,892,797 |
| | | | | | | | | | | | | | | | | | | $153,235,563 |
| TOTALS: | | | $73,000,000 | | $0 | $15,757,000 | | $34,899,694 | $0 | | $11,732,962 | $0 | | $7,430,495 | | $10,415,412 | $0 | $153,235,563 |

### 7.1.1 Advantages

Total privatization would have the following advantages:

1. It is reasonable to assume that a private sector subcontractor with expertise with a particular TSD option could come on-site, set up the necessary equipment, process the waste, store the waste, remove/dispose of the equipment, and transport the waste to a disposal site at an equal or lower cost than on-site M&O forces.

2. The private sector subcontractor costs are expected to be lower than the M&O contractor if they can be exempted from DOE orders. If an operations area near the gunite tanks can be isolated and turned over to the private sector subcontractor, only state and federal laws and NRC requirements would apply to the subcontractor.

### 7.1.2 Disadvantages

Total privatization would have the following disadvantages:

1. The likelihood of locating a private sector subcontractor with the required expertise for this type of job is low. Most private sector subcontractors are unfamiliar with the regulatory and procedural operating requirements to perform work on DOE property. However, it is reasonable to assume that the subcontractor may be exempted from DOE orders.

2. Assuming that a fixed-price contract payable upon production of an acceptable product is let for this effort, the pressure to make a profit would likely compromise regulatory compliance.

3. It will be difficult to locate a company willing to put up all the "up-front" money to process the small quantity of waste in the GAAT OU. If such a company is located it is likely that the costs will be excessive without DOE assurances for follow-on processing actions with high potential pay-off.

4. The type of procurement necessary for this work requires major expenditures in the years that the subcontractor produces an acceptable product. The level of funding needed for the entire project may not be possible in today's budget climate. Existing regulations require the funding to be in the budget in the year the contract is let and that the funding be spent in that year. In order to fund this type of multi-year project either 1) the present financial rules would have to be changed, 2) a phased procurement would have be to done, or 3) multiple contracts would have to be let.

5. The risks and ultimately the costs evolved in total privatization of the TSD of the wastes in these tanks are related to the level of liability assumed by the private sector. DOE and the site M&O contractor must accept the responsibility for the wastes processed on site. In order to remain competitive and at the same time boost profits, inadequate proof-of-principles testing and/or waste form development may be done by the private sector subcontractor. Without adequate independent testing and waste form validation, the permanence and acceptability of the waste form produced is questionable. At a minimum, the private sector subcontractor should be required to perform treatability studies on simulants and actual waste. However, many vendors do not have the capability to perform hot tests and may need assistance from the M&O contractor. Independent validation of the performance of the private sector's process and waste form durability is desirable. These types of tests tend to diminish the attractiveness of a total privatization approach to TSD of tank wastes.

6. If the private sector fails, the M&O contractor could end up with a much more expensive clean-up effort and will miss the project's CERCLA regulatory commitments. The same effects occur if the bid process takes 2 years or more and there are no successful bidders.

## 7.2 COLLABORATION WITH THE PRIVATE SECTOR

This option permits the site M&O contractor to collaborate with the private sector and actively participate in the TSD of the GAAT wastes. In this option, the private sector subcontractor would perform a major portion of the TSD activities. DOE would assist in the division of labor between the private sector and the site M&O contractor. DOE and the site M&O contractor will select the private sector subcontractor based on the demonstrated ability of the subcontractor to provide the necessary processes and equipment for the TSD of the GAAT wastes. The site M&O contractor will assist the private sector subcontractor in equipment and process selection, support facilities operation, formula development, proof-of-principles experiments, regulatory compliance, interim waste storage, waste transportation/disposal, and other activities as needed to ensure project success. The site M&O contractor will provide management oversight for the private sector subcontractor operations for DOE.

### 7.2.1 Advantages

Collaboration with the private sector would have the following advantages:

1. Since the M&O contractor has a proactive role in the selection of the TSD technology supplier and the technologies to be employed and can participate with the private sector subcontractor, the likelihood of success is higher.
2. The M&O contractor has control over the private sector subcontractor to ensure compliance with applicable regulations and product quality specifications.
3. Since the M&O contractor and DOE have oversight and approval of each step of the subcontractor's operation, phased payments could be made to the subcontractor to avoid the financial complications described for total privatization.

### 7.2.2 Disadvantages

Collaboration with the private sector would have the following disadvantages:

1. Oversight by the M&O contractor may result in delays and cost overruns by the private sector subcontractor compared to total privatization.
2. The proactive role of the M&O contractor increases the liability of the M&O contractor in the event that something goes wrong.
3. The private sector subcontractor would fall under DOE orders and drive up the costs, unless necessary and sufficient rules can be implemented by the M&O contractor in lieu of certain cumbersome DOE orders.

## 7.3 TECHNOLOGY DEMONSTRATIONS

This option gives the site M&O contractor the flexibility to perform a significant portion of the TSD activities through the use of technology demonstrations if necessary to ensure successful full-scale operation. The private sector may also be involved in these demonstrations by providing specialized processes and equipment capable of demonstrating advanced technologies for the TSD of tank wastes. Once an acceptable process is obtained, operation of the systems could be either contracted to the private sector or continue to be operated by the M&O contractor under the technology demonstration umbrella until all the GAAT wastes are processed.

### 7.3.1 Advantages

Technology demonstrations would have the following advantages:

1. Technology demonstrations prior to full-scale implementation will increase the chances of success and decrease costs (as seen by the present GAAT TS) for treating GAAT wastes.
2. Technology demonstrations result in a phased approach to treating wastes, which has the potential advantages of being implemented more quickly than the previous options and to meeting required treatment dates.
3. Leveraged funding with EM-50 can reduce local EM-40 budget requirements.
4. Information and data collected from the technology demonstrations would be useful in reducing the costs of other TSD activities, both on-site and at other DOE sites.

### 7.3.2 Disadvantages

Technology demonstrations would have the following disadvantages:

1. Demonstration of new technologies or new applications of existing technologies will require greater proof-of-principle testing than for previously demonstrated/proven technologies. The longer test phases and greater emphasis on data collection may result in slightly longer schedules and greater initial costs.
2. Demonstration of new technologies or new applications of existing technologies may have a greater risk of failure than the use of previously demonstrated/proven technologies. However, these risks can be minimized by 1) selecting technologies with envelopes of application near the range of the selected TSD problem and 2) using focused small scale proof-of-principles testing.
3. Collaborative efforts with EM-50 may require the collection of either diverse or additional data to meet technology development needs. These needs may not necessarily be required to meet the needs of EM-40. Stakeholders may interpret these data collection actions in a negative light and assume that the M&O contractor is performing unnecessary studies and not striving to solve the waste disposal challenge.

## 7.4 TECHNOLOGY DEVELOPMENT

This option is primarily directed at basic research and development of novel processes for the TSD of tank wastes by the site M&O contractor. The processes and equipment developed should have applicability to other DOE Complex wastes. This option would require minor assistance from the private sector for the purchase of equipment and services. This option would establish the GAAT OU as a test-bed for the development of advanced technology and would continue until all the GAAT waste is processed.

### 7.4.1 Advantages

Technology development would have the following advantages:

1. Valuable research based information would be gained on the performance of novel technology options. This information will be of use to the entire DOE Complex in the selection of the most appropriate technology for TSD of tank wastes.
2. Collaboration between technology users and technology developers would serve to focus the available resources on specific TSD tasks, which would result in the development of better solutions for tank waste challenges.
3. Information and data collected from the technology development activities would be useful in reducing the costs of other TSD activities, both on-site and at other DOE sites.
4. Opportunities for technology development would bring in additional funding from EM-50.

### 7.4.2 Disadvantages

Technology development would have the following disadvantages:

1. Since new technologies are to be developed with this option a significant level of proof-of-principle testing is needed. The longer test phases and greater emphasis on data collection will result in significantly longer remediation schedules and potentially greater costs.
2. Development of new technologies has a greater risk of failure than the use of previously demonstrated/proven technologies. However, these risks can be managed by use of focused small scale proof-of-principles tests to develop the technology. Any failures encountered in these small scale tests would provide additional data with minimal equipment costs.
3. The use of multiple technology development activities to process the GAAT wastes may result in larger quantities of secondary waste streams from equipment decontamination and failed process operations.
4. As a result of technology development activities and collaborative efforts with EM-50, the collection of diverse and/or additional data will likely be required. These efforts may not be required to met the needs of EM-40. Stakeholders may interpret technology development data collection actions in a negative light and assume that the M&O contractor is performing unnecessary studies and not striving to solve the waste disposal challenge.

# 8. RECOMMENDATIONS AND CONCLUSIONS

## 8.1 GENERAL

After removal of the necessary quantities of the waste, the GAAT tanks should be stabilized to prevent groundwater intrusion and collapse by the use of a nonshrinking concrete or aggregate material.

## 8.2 TREATMENT

Vitrification and grouting demonstrations should be pursued as a means of 1) demonstrating and comparing immobilization technologies, 2) establishing disposal pathways for ORNL waste streams, and 3) demonstrating cost effective methods of establishing waste treatment facilities for long term use by the Oak Ridge Complex. There is extensive experience using vitrification for treating HLW but very little experience for treating LLW. Grouting systems are less complex and generally have been applied more widely in similar waste immobilization operations than vitrification. In addition, several companies exist that are capable of providing mobile equipment for grouting LLW.

There is more fielded experience using grouting technology to treat LLW than with vitrification. In general, properly formed vitrified waste has superior long-term leaching properties when compared with grouted waste forms. However, both waste forms generally meet the most recent versions of the WAC for NTS and WIPP. Special care must be taken to avoid creating a final waste form that cannot be accepted at any of the identified disposal sites (orphan waste). In particular, no final waste form should be created that exceeds NRC Class C limits (unfit for near-surface disposal facilities) but is below TRU waste limits (unfit for disposal at WIPP). This is primarily a concern for the GAAT sludge.

## 8.3 STORAGE AND DISPOSAL

Current on-site storage facilities have marginal capacity to contain the GAAT wastes. New TRU storage facilities are due for completion in 1997, but with the largest capacity increase being for CH TRU storage, they will not help alleviate much of the GAAT storage capacity crunch. It would be more attractive from a cost and schedule standpoint to store immobilized GAAT waste outdoors in individual storage containers or casks similar to those used to store the LWSP waste. A variety of off-site disposal sites exist; however, the availability of all of these sites in a time frame compatible with the GAAT project schedule is uncertain. The disposal site with the fewest uncertainties is NTS. Its generator fees are inexpensive and it is currently accepting LLW. WIPP is the only disposal alternative identified for TRU waste disposal other than in-situ disposal (assuming stakeholder acceptance). The estimated cost for WIPP disposal (including all O&M costs but no sunk costs or transportation costs) is a factor of 20 higher than NTS disposal per cubic foot of waste. There are also numerous uncertainties associated with WIPP disposal including schedule for waste acceptance and WAC requirements. In-situ disposal is attractive from the point of view that it requires no transportation and there are no storage or disposal fees. Recent developments in in-situ grouting using MPI techniques deserve more attention due to the financial and ALARA advantages of in-situ treatment and disposal. If this approach can be proven to produce homogeneous waste with desirable properties under conditions similar to the GAAT sludge, then in-situ grouting could gain wider acceptance among the stakeholders.

## 8.4 TSD ALTERNATIVES

In-situ cementation (Sect. 6.2) is the least expensive of all the identified alternatives. It does not require disposal of waste at WIPP but does require in-situ disposal. In-situ stabilization and immobilization of the wastes in the GAAT appear technically feasible, but require further regulatory approval and scrutiny prior to implementation. There are significant uncertainties associated with regulatory approval of in-situ disposal. Risk reduction is a key parameter in evaluating in-situ disposal but is not within the scope of this document.

The ex-situ cementation, waste volume minimized alternative (Sect. 6.4) is the least expensive of the identified ex-situ alternatives (see Tables 8-1, 8-2, and 8-3) because it generates the least amount of waste for disposal and its treatment costs are generally smaller. However, this alternative along with the alternatives described in Sect. 6.1 (Baseline - Transfer to MVST) and Sect. 6.5 (Ex-Situ Vitrification, Waste Volume Minimized) include disposal of at least a portion of the waste as RH TRU waste at WIPP.

The uncertainties continue over when WIPP will begin receiving waste, what changes might occur to the WAC, and even whether WIPP will ever receive TRU waste for disposal. Because of these uncertainties, there is a larger degree of confidence in the success of alternatives that do not require disposal of waste at WIPP. The ex-situ cementation, all waste diluted to NTS PA limits and Class C or less alternative (Sect. 6.3) requires neither in-situ disposal nor disposal at WIPP. Waste from this alternative is disposed of at NTS, which has been and is currently accepting DOE waste for disposal. Because of the lack of uncertainties associated with disposal at WIPP, there is a higher degree of confidence that the alternative in Sect. 6.3 could be successfully accomplished.

**Table 8-1. TSD Alternatives Order-of Magnitude Cost Comparison—Supernate Only**

| *Supernate only* | Quantity | Retrieval Costs | | Treatment Costs | | Storage Costs | | Disposal Costs | | | Misc. | TOTALS | TSD minus retrieval |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Capital | O&M | Capital | O&M | Capital | O&M | Capital | O&M | Transportation | | | |
| | ($ft^3$) | ($) | ($) | ($) | ($) | ($) | ($) | ($) | ($) | ($) | ($) | | |
| Baseline | 89647 | $0 | $0 | $0 | $22,071,879 | $0 | $10,058,344 | $0 | $2,831,038 | $8,381,953 | $0 | $43,343,214 | $43,343,214 |
| In-situ Grout | 56804 | $0 | $0 | $0 | $13,985,790 | $0 | $6,373,444 | $0 | $1,793,596 | $5,311,203 | $0 | $27,464,033 | $27,464,033 |
| Grout (min. volume) | 89492 | $0 | $0 | $0 | $22,033,779 | $0 | $10,040,981 | $0 | $2,825,704 | $8,367,484 | $0 | $43,267,948 | $43,267,948 |
| Grout6 (NTS PA and Class C) | 69182 | $0 | $0 | $0 | $17,033,254 | $0 | $7,762,199 | $0 | $2,184,416 | $6,468,499 | $0 | $33,448,368 | $33,448,368 |
| Vit. (min. volume) | 89647 | $0 | $0 | $0 | $22,071,879 | $0 | $10,058,344 | $0 | $2,830,590 | $8,381,953 | $0 | $43,342,766 | $43,342,766 |

**Table 8-2. TSD Alternatives Order-of Magnitude Cost Comparison—Sludge Only**

| *Sludge only* | Quantity | Retrieval Costs | | Treatment Costs | | Storage Costs | | Disposal Costs | | | Misc. | TOTALS | TSD minus retrieval |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Capital | O&M | Capital | O&M | Capital | O&M | Capital | O&M | Transportation | | | |
| | ($ft^3$) | ($) | ($) | ($) | ($) | ($) | ($) | ($) | ($) | ($) | ($) | | |
| Baseline | 6922 | $73,000,000 | $0 | $0 | $97,391,235 | $0 | $1,059,481 | $0 | $4,360,860 | $1,006,766 | $0 | $176,818,343 | $103,818,343 |
| In-situ Grout | 952873 | $73,000,000 | $0 | $6,087,000 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $79,087,000 | $6,087,000 |
| Grout (min. volume) | 15137 | $73,000,000 | $0 | $9,208,000 | $7,311,765 | $0 | $1,940,181 | $0 | $3,812,973 | $1,415,310 | $0 | $96,688,229 | $23,688,229 |
| Grout6 (NTS PA and Class C) | 42208 | $73,000,000 | $0 | $9,208,000 | $14,499,136 | $0 | $4,735,738 | $0 | $1,332,718 | $3,946,448 | $0 | $106,722,039 | $33,722,039 |
| Vit. (min. volume) | 13981 | $73,000,000 | $0 | $15,757,000 | $12,827,815 | $0 | $1,674,618 | $0 | $4,599,905 | $2,033,459 | $0 | $109,892,797 | $36,892,797 |

**Table 8-3. TSD Alternatives Order-of Magnitude Cost Comparison—Sludge and Supernate**

| *Sludge + Supernate* | Quantity | Retrieval Costs | | Treatment Costs | | Storage Costs | | Disposal Costs | | | Misc. | TOTALS | TSD minus retrieval |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Capital | O&M | Capital | O&M | Capital | O&M | Capital | O&M | Transportation | | | |
| | ($ft^3$) | ($) | ($) | ($) | ($) | ($) | ($) | ($) | ($) | ($) | ($) | | |
| Baseline | 96569 | $73,000,000 | $0 | $0 | $119,463,114 | $0 | $11,117,825 | $0 | $7,191,898 | $9,388,720 | $0 | $220,161,557 | $147,161,557 |
| In-situ Grout | 1009677 | $73,000,000 | $0 | $6,087,000 | $13,985,790 | $0 | $6,373,444 | $0 | $1,793,596 | $5,311,203 | $0 | $106,551,033 | $33,551,033 |
| Grout (min. volume) | 104629 | $73,000,000 | $0 | $9,208,000 | $29,345,544 | $0 | $11,981,162 | $0 | $6,638,677 | $9,782,794 | $0 | $139,956,177 | $66,956,177 |
| Grout6 (NTS PA and Class C) | 111390 | $73,000,000 | $0 | $9,208,000 | $31,532,389 | $0 | $12,497,937 | $0 | $3,517,133 | $10,414,947 | $0 | $140,170,407 | $67,170,407 |
| Vit. (min. volume) | 103628 | $73,000,000 | $0 | $15,757,000 | $34,899,694 | $0 | $11,732,962 | $0 | $7,430,495 | $10,415,412 | $0 | $153,235,563 | $80,235,563 |

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# APPENDIX A: ANNOTATED BIBLIOGRAPHY OF SELECTED LITERATURE

Various key literature was reviewed to provide input to this report. An annotated bibliography of selected literature used in this report follows.

1. Lee Wan & Associates, Inc., *Feasibility Study of the Modification of ORNL Facilities to Serve as a Transuranic Waste Handling Pilot Plant (WHPP)*, Goldsmith, W.A. et al., July 1987.

   Of the existing ORNL hot cell facilities capable of safely handling TRU waste, this study recommended Bldg. 7930, the Thorium-Uranium Recycle Facility (TURF), as the best candidate facility for modification to function as the ORNL WHPP, at a cost of $63 to $78 million (estimate escalated to 1995).

2. Lockheed Martin Energy Systems, Inc. September 1995. *Feasibility Study for Processing ORNL Transuranic Waste in Existing and Modified Facilities, Management Summary*. Project Order No. 107-004.

   The Management Summary is a brief- stand alone document that provides an overview of the project, its methods, and its conclusions. Volume I of the FS is a technical summary and includes an introduction providing the purpose and scope , background information, a summary of approach, and conclusions. Descriptions of candidate TRU waste processes and how they were selected follows. Important features of existing facilities evaluated by the study are then presented, including interfaces with site infrastructure. Alternatives for installation of processes into facilities are shown and preliminary assessments are made. Methods of accomplishment are addressed, including business methods that may provide significant cost savings. An overall assessment of processes, facilities, and compliance issues is made leading to selected strategies. Selected strategies for processing and disposing of TRU waste are detailed with schedules, cost estimates, life-cycle cost estimates, uncertainties, and a summary of risks. Conclusions, both financial and for business models, are then drawn. Volumes II through V are building-specific for Bldgs. 3517, 3525, 7860, and 7930, respectively, and provide the details to support Vol. I. Bldg. 7877 (LLW Solidification Facility) was added to the scope of work in August 1995 as a special case for in-liner solidification and is described in Vol. I and its appendix. (NOTE: This summary was paraphrased from the Forward to the Management Summary. The TRU Waste FS Project Team included Parallax, Inc., Delta-21 Resources, and Foster Wheeler Environmental Corp.)

3. Lockheed Martin Energy Systems, Inc. June 1995. *Research, Development, and Demonstration Permit Application for the Transportable Vitrification System (TVS) for the Oak Ridge K-25 Site*. K/EM-131.

   The purpose of this project is to demonstrate vitrification of low-level mixed waste (LLMW) on a larger scale than previously demonstrated and to perform this demonstration on both simulated and actual radioactive waste. Another purpose is to profile the operational and rate of production impacts of chemical composition and water content variability. Current plans are to move the TVS to the K-25 Site, at a location between the K-31 Bldg. and Poplar Creek, between November 1995 to March 1996 and begin set-up, check-out, and testing. Sludge waste streams planned for testing include the West End Treatment Facility, the Central Neutralization Facility, Bldg. K-1232, the Central Pollution Control Facility, and the Pond Waste Management Project (B & C Ponds). Glass-forming additives will be supplemented or replaced by wastes such as crushed fluorescent bulbs, sand sludge, and sandblast residue.

4. Martin Marietta Energy Systems, Inc. "TRU Waste LDR Treatment Increment Task," Stellern, J.L. and Moore, J.W. for Monk, T.H., May 16, 1995.

The WMRAD TRU Program tasked Central Engineering Services to determine the incremental costs of treating ORNL's TRU waste to LDR standards, relative to a baseline, minimal process that only meets the WIPP–WAC. The difference in cost, or increment, is expressed as a factor, to be used to adjust minimal treatment process options cost estimates.

5. Martin Marietta Energy Systems, Inc., September 1994. *Waste Certification Program Plan for the Oak Ridge Reservation*. ES/WM-6.

   In compliance with DOE Order 5820.2A, "Radioactive Waste Management," requirement that generators shall certify that (their)wastes meet the WAC for the receiving TSDF, this program plan was developed to provide a structured process for waste stream certification on the ORR. References are made to ES/WM-10 and EP-710 (documented below) as the framework for accomplishing this process.

6. Martin Marietta Energy Systems, Inc. February, 1995. *Waste Acceptance Criteria for the Oak Ridge Reservation*. ES/WM-10, Rev. 1.

   This document supersedes all prior WAC at each of the Oak Ridge sites for those wastes accepted at Energy Systems Waste Management Organization (ESWMO) facilities which are covered by the Waste Certification Program. Effective March 1, 1995, all transfers of waste to ESWMO or (transfers) within the reservation boundary by ESWMO shall meet the characterization requirements of ES/WM-10 (Rev. 1), which shall be documented on form UCN -2109 (Attachments A-G). Certification of wastes to ES/WM-10 shall be made by those organizations with approved Waste Certification Procedures (WCPs) in accordance with the site schedules for WCP implementation.

7. Martin Marietta Energy Systems, Inc. April 1995. "Waste Certification Requirements for Energy Systems Waste Management Organization (ESWMO)." Energy Systems Procedure EP-710.

   This procedure provides the required actions for certifying wastes to be managed by ESWMO against the requirements of ES/WM-10, *Waste Acceptance Criteria for the Oak Ridge Reservation. ORNL Office of Waste Management and Remedial Actions*, July 1991. Waste Management Operations–Waste Management Coordination Office, WAC for the Liquid Waste Treatment Systems at ORNL. This document should be used as a guide by liquid waste generators to determine the proper means of treatment/storage for routine wastewater streams. If the characteristics of a specific waste stream fall outside the guidelines presented in these criteria, the generator shall consult the Liquid Waste Laboratory Certification Officer (LCO). The Liquid Waste LCO does not dictate waste acceptance policy, but provides a single point of contact for all liquid waste generators on all matters concerning their liquid waste challenges. The LCO will contact appropriate Waste Management and Environmental Compliance personnel for policy determination and/or interpretation. As of the issuance of this document, John R. Parrott, Jr. (Bldg. 3017, M/S 6044, phone 574-6595) was the Liquid Waste LCO.

7. *ORNL Final Waste Forms Project: Performance Criteria for Phase I Treatability Studies.* Gilliam, T. M. et al, June 1994, ORNL /TM-12759

   The purpose of this document is to define the product performance criteria that was used in Phase I of the Final Waste Forms Project, as required by the Federal Facility Compliance Agreement for conducting TSs and treatment methods development for those ORR mixed wastes listed in Appendix B to the Agreement. The Final Waste Forms Project gave priority to the traditional

stabilization/solidification processes, but did not exclude other technologies such as filtration, drying, etc. The waste form types considered by this project were grout, glass, and organic binders. Leachate-concentration-based standards discussed in this report were derived from the Environmental Protection Toxicity Characteristic Leaching Procedure (EP Tox), although the leach test procedure has been replaced by the more rigorous TCLP. This combination is presumed to give a more conservative performance criteria.

8. State of Tennessee Department of Environment and Conservation. (TDEC) September 1995. "Commissioner's Order for DOE Compliance with a Site Treatment Plan (STP) for Land Disposal Restricted (LDR) Mixed Wastes on the U.S. DOE Oak Ridge Reservation." TDEC Division of Solid Waste Management Case No. 95-0514.

   In accordance with 3021(b) of RCRA, 42 U.S.C. 6939(c), as amended by the Federal Facility Compliance Act and Tennessee Code Annotated Sect. 68-212-111, DOE is ordered to implement the amended STP, as stated in the attachment to the order. All previous orders and agreements (e.g., the Federal Facility Agreement) remain in effect. Sect. 4.1, "Transuranic Wastes Expected to Go to the Waste Isolation Pilot Plant," lists five milestones between November 1995 and June 1998 for the FS/Conceptual Design of the proposed TRU Processing Facility, including determination of the feasibility of private sector treatment. June 30, 2002, is the target date for initiating treatment of RH-TRU sludges. Sect. 4.3, "Mixed Low-Level Waste Associated with the Mixed Transuranic Program (Remotely Handled Supernatants)," requires the completion of the LWSPs for supernatant stabilization by December 31, 1995, and December 31, 1997, to maintain MVST capacity. (NOTE: LWSP III was completed on or about 9/30/95 and satisfies the first of these milestones.)

9. U.S. Department of Energy. August 1995. *Draft Waste Management Programmatic Environmental Impact Statement for Managing Treatment, Storage, and Disposal of Radioactive and Hazardous Waste. Summary.* DOE/EIS-0200-D.

   Paraphrased from the introductory letter by Thomas P. Grumbly, DOE Assistant Secretary for EM: Summary of the Draft Waste Management PEIS, prepared in accordance with National Environmental Policy Act to evaluate management and siting alternatives for the TSD of radioactive and/or hazardous wastes, including LLW, LLMW (with hazardous components), TRU waste, HLW, and hazardous waste. The alternatives were evaluated for waste stored, buried, or to be generated from future operations over the next 20 years at 54 sites (including ORNL). For each waste type, the analyses in this document examined the potential health and environmental impacts of integrated waste management program alternatives involving multiple sites, as well as the potential cumulative impacts. DOE plans to issue the final environmental impact statement in the summer of 1996. No decisions will be made until the final document is issued and a 30-day waiting period has elapsed.

10. U.S. Environmental Protection Agency. April 1994. *Waste Analysis at Facilities that Generate, Treat, Store, and Dispose of Hazardous Wastes. A Guidance Manual.* PB94-963603.

   Part One provides guidance on determining individual waste analysis responsibilities and how to meet these responsibilities. Part Two provides facility-specific procedures for conducting waste analysis and developing a Waste Analysis Plan (WAP). Part Three provides a checklist to ensure that all relevant waste analysis responsibilities at individual facilities have been addressed. Part Four provides facility-specific (i.e., generator, disposal, and on- and off-site treatment facilities) model WAPs to be used as guidance for development of site-specific WAPs.

11. U. S. Department of Energy. December 1991. *Waste Acceptance Criteria for the Waste Isolation Pilot Plant.* WIPP-DOE-069, Rev. 4.0, UC-70.

This document identifies and consolidates existing criteria and requirements that regulate the safe handling and preparation of TRU waste packages for transportation to and emplacement in the WIPP. This revision specifies the requirements (in force at the time of issuance) imposed by the RCRA for waste emplacement in the WIPP. The WIPP Project will comply with all applicable federal and state requirements and regulations, including those in *CFR* Titles 10, 40, and 49 as they apply to CH TRU and RH TRU waste forms. These criteria and requirements will be reviewed and revised based on new technical or regulatory requirements. DOE Headquarters Office of Environmental Restoration and Waste Management (DOE/EM), along with the DOE WIPP Project Integration Office and the DOE WIPP Project Site Office, is responsible for the final approval of the WAC, the QA Program Plan for the WIPP Experimental Waste Characterization Program, and any subsequent revisions of these documents.

# APPENDIX B: TRANSPORTATION OF GAAT WASTE

On-site transport at ORNL, that is, transfers made when access control measures (gates and/or guards; signs will not suffice) are in place to restrict access by the public, is governed by the ORNL On-site Transportation Operations Manual. The purpose of this manual is to establish a level of safety equivalent to that established by DOT regulations. In the DOT regulations, the primary instrument of safety is the packaging. For on-site shipments, it is oftentimes impossible to get the packaging that would be required by DOT. In these cases, administrative controls (i.e., reduced speed limits, restricted times/routes, escorts) are put in place to minimize the possibility of any credible accident scenario. A transportation plan detailing the nature of the material to be transported, the proposed packaging configuration, and administrative controls is submitted to the ORNL Installation Transportation Safety Manager, who will convene the ORNL Transportation Safety Committee to review the plan for approval/amendment or disapproval.

ORNL Waste Management is currently capable of transporting LLLW on-site via a 1,000-gal truck-mounted tank. The tank truck is certified to transport LLLW on-site that does not exceed the Low Specific Activity (LSA) limits as given in the LLLW WAC. Under special circumstances, LSA limits may be exceeded provided certain waivers are obtained. A new 1,000-gal LLLW waste tanker for ORNL, called the LR-56, should be available for transporting waste by April 1996. Its DOT certification will be for exclusive use to transport liquids up to the DOT A2 limits on public roads. For the LR-56 to be used as a Type B packaging on-site (for liquids exceeding the A2 limits), a plan would have to be submitted to the ORNL Transportation Safety Committee for approval.

The new tanker design is certified by the International Atomic Energy Agency as Type B (U) packaging in France, where it is being built, and has passed all applicable DOT tests for Type B packaging. DOT certification of the tanker as Type B is possible without further testing. However, the effort to obtain DOT Type B certification has been deemed excessive and unnecessary to this point. If enough specific needs are identified for a Type B liquids tanker, certification could be pursued. However, since no DOT-certified bulk Type B liquid packaging currently exists, the political difficulties of certifying the first one are likely to be significant and the cost and time implications uncertain. Neither tanker will accept sludge, and total dissolved solids and total suspended solids must be eliminated to the maximum extent possible. The WAC for the ORR (Rev. 1), limits the surface radiation dose rate to 200 mR/hr for the existing LLLW tanker. The LR-56 allowable surface dose rates will be 1,000 mR/hr at the tank surface and 200 mR/hr at the trailer surface, which totally encloses the tank. The LR-56 tank will have 2-in. lead-equivalent shielding.

LMES does not currently have the capability to transport bulk quantities of radioactive sludge similar to the GAAT sludge in accordance with DOT regulations. Sludge from each GAAT tank, except TH-4, exceeds the DOT LSA limits for at least one isotope (most commonly $^{137}Cs$ and $^{90}Sr$). The GAAT sludge also has activity high enough so that in most cases, the maximum quantity of sludge that could be carried without exceeding the DOT A2 limits (for type A packaging) would be less than 2 gal. TH-4 sludge can be transported in quantities of up to 50 gal without exceeding the A2 limits. Type B packaging for the transport of bulk quantities of radioactive liquids exceeding the A2 limits are not currently available. Untreated sludge is considered a liquid by DOT. Dewatered sludge that passes a paint filter test and contains no free liquids is considered a solid and can be transported in Type B bulk packaging.

Other limitations, such as surface radiation dose, must be considered prior to selecting a packaging. LMES is commissioning a study by the manufacturer of the new LLLW tanker to examine design changes necessary to allow transport of radioactive sludge. Design changes would likely include reduction of internal baffles and the addition of an internal recirculation system to maintain suspension of solids during transportation. It is unlikely that funding will be available to purchase a sludge tanker (approximately $3 million dollars would be required) in the near future. If funding were available, it would take about 18 months to design, build, and deliver the new tanker. The sludge tanker would likely have the same certification as the new LLLW tanker.

Bulk quantities of dewatered and immobilized GAAT sludge, again with the exception of TH-4 sludge, have activities exceeding the A2 limits and, therefore, cannot be transported in Type A packaging. Type B packaging is required, and while not plentiful, these types of packagings are available. TH-4 stabilized sludge can be transported in quantities approaching 300 gal without exceeding the A2 limits. Immobilized sludge could be packaged directly in a Type B packaging with a liner. An alternative is to overpack Type A primary containers full of immobilized sludge (such as 55-gal drums) inside of a Type B packaging. Both approaches have been used in the past. There are members of the packaging staff within ORNL Transportation Department who can assist the GAAT project in obtaining the necessary containers. Several factors will need to be considered in finding the appropriate packaging, including the WAC of the storage and/or disposal facility and the gram quantities of fissile radionuclides in the waste. Of course, these factors are likely to limit the number of packages that may be utilized.

# APPENDIX C: TANK STABILIZATION

A report[1] commissioned to examine the current stability of the Gunite Tanks concludes that, based on a preliminary design review and the videotape records available, "the Gunite tanks are generally sound and can comfortably carry the currently imposed loads for many more years. The only tanks of substantial concern are tanks W-5 and W-6. Additional data must be collected to determine the reserve structural capacity of these tanks."

The additional data referred to above for the determination of the structural integrity of tanks W-5 and W-6 is listed in the report as follows.

- "The remaining wall thicknesses in the areas of severe deterioration."
- "The compressive strength of the shotcrete (gunite) in the wall(s) at these areas."
- "A more thorough visual inspection to discover the extent of severe attack of the shotcrete."

The report goes on to describe the core sampling and nondestructive testing recommended for determination of the compressive strength of the W-5 and W-6 tank walls.

The results of dome and wall structural calculations are reassuring. The report states: "The results show that these domes, if built to the thicknesses shown on the drawings and meeting the rest of the assumptions, are much thicker than they need to be to resist buckling. The lowest additional (safety) factor is 8 on tanks W-3 and W-4." Similarly, evaluation of wall compressive stresses on the 12 Gunite Tanks suggests that the lowest extra factor of safety is 3 for tanks W-5 through W-10, given the reasonable engineering estimates ("assumptions") used to make the calculations. These assumptions include maximum earth cover depth, shotcrete strength after initial curing, allowable compressive strength, live (snow) load maximum, earth fill unit weight, and loss of original prestress compressive strength.

In fact, except for the need to confirm that the chemical attack and concrete spalling (on the walls of W-5 and W-6) is not strength-threatening, this report suggests that these gunite tanks may be in sufficiently good condition to remain stable for decades to come. This possibility should be kept in mind when considering options for post-treatment stabilization of the gunite tanks.

One of the main concerns for long term stabilization of remaining tank structures, (especially where contaminated concrete and other materials will be entombed), is prevention of the migration of contaminants from the structures into the adjoining groundwater. A potential mechanism for transport that warrants consideration is the inleakage of groundwater when the groundwater is high followed by the outleakage of the same water with leached contaminants when the surrounding groundwater is low. This phenomenon, known as the bathtub effect, has been documented as a challenge encountered in many LLW disposal trenches at ORNL. This is not meant to imply that this is necessarily a significant challenge for the gunite tanks, but, given the ORNL experience with highly cyclical shallow groundwater at other sites, it is worth reviewing.

Relating this concern to the referenced report, it is noted that "If water is kept available to the concrete throughout the life of the structure, the concrete will swell slightly and shrinkage stresses may be eliminated." Furthermore, the report observes "The Gunite tanks appear to have had some liquid in them since first being put in service. This should have helped the floor and the submerged wall surfaces to experience minimal shrinkage stresses. This would have resulted in minimal if any cracking of these sections due to shrinkage stresses in the concrete. Overall, continually submerged concrete should crack less than concrete experiencing wetting and drying cycles or even a completely dry concrete."

This suggests the possibility that some nominal amount of process water should be maintained in the bottoms of the gunite tanks, even after the removal of supernate and sludges, until such time as the GAAT Project is prepared to support the final entombment of the tanks in a manner that will stabilize remaining contamination and exclude the intrusion of surface and groundwater.

The options available for final stabilization of the gunite tanks include a wide range of combinations of removal and/or fixation of remaining contamination on the tanks' floors and walls followed by structural stabilization of the tanks to prevent future collapse. The most straight forward method to accomplish this may be to fill the tanks with a cement grout, formulated to adhere to the gunite tank surfaces and isolate the residual contaminants. A variation of this might be to apply a new layer of shotcrete-type cement, followed by filling the tanks with aggregate that will provide the required structural stability. Determination of the optimal stabilization method is a matter of using best estimates of risk associated with the calculated final contamination inventory to develop a set of long term performance criteria which will form the basis for the final stabilization design.

# APPENDIX D: TSD DESCRIPTION CRITERIA

## Table D-1. TSD Description Criteria

| ID | Description Category and Description Variable | Explanation |
|---|---|---|
| | | |
| H | **Overall Protection of Human Health** | |
| H1 | Human Health Risk at White Oak Creek | Risk models required, outside the scope of this document |
| H2 | Dose Rate to Radiological Workers | Assumes all alternatives will be designed and operated to meet ORNL requirements |
| R | **Compliance with ARARs** | |
| R1 | WAC Requirements | Alternative meets storage facility or disposal facility WAC requirements |
| R2 | TRU Waiver Requirements | Identification if no waiver for WAC is required based on TRU |
| R3 | Disposal Facility RCRA Part B Permit | Alternative meets disposal facility RCRA Part B requirements |
| R4 | Regulatory Complexity for Cost | A decreased ARARs impact (relative to the Baseline) occurs on the cost of the alternative |
| R5 | Regulatory Complexity for Schedule | A decreased ARARs impact (relative to the Baseline) occurs on the schedule of the alternative |
| E | **Long Term Effectiveness** | |
| E1 | Permanence | Number of years that alternative will store or isolate waste |
| V | **Toxicity/Mobility and Volume Reduction** | |
| V1 | Volume Reduction | Ratio of initial volume at GAAT to final volume of waste that the alternative supplies to storage or disposal facility |
| V2 | Toxicity/Mobility Reduction | Toxicity and mobility of waste is less than or equal to baseline |
| S | **Short Term Effectiveness** | |
| S1 | Human Health Risk Reduction Rate at GAAT OU | Risk models required, outside the scope of this document |
| S2 | Functional Interface Requirements | Unique functional interfaces required |
| I | **Implementability** | |
| I1 | Impact on GAAT Operations Schedule | Increase or decrease in GAAT operations schedule |
| I2 | System Maturity | Maturity of treatment, storage, or disposal system |
| I3 | Capacity at Receiving Facility | Available capacity at storage or disposal facility is greater than GAAT waste volume shipped to that storage or disposal facility |
| I4 | Organization Interface Requirements | Unique organizational interfaces required (DOE, LMES, DOT, EPA, TDEC, etc.) |
| C | **Cost** | |
| C1 | Capital Cost | Discounted capital cost of materials and equipment for alternative |
| C2 | O&M Cost | Discounted operations and maintenance cost for alternative |
| C3 | Source of Funds | One or more DOE organizations can provide funding for cost-sharing or leveraging of cost |
| A | **State and Community Acceptance** | |
| A1 | Public Acceptance | Alternative has Public Acceptance |
| A2 | Off-site transport of supernate and wet sludge required | Off-site transport of DOT Type B liquids is extremely difficult and increases potential for public exposure |
| A3 | Demonstration Opportunity | A favorable technology demonstration is identified |

[1] Charles S Hanskat. P.E., Gunite and Associated Tanks (GAAT) Operable Unit "Evaluation of Dome and Wall Strength under Current Loading", for AST, Inc., June 1995.

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