HANFORD SITE 300 AREA 618-4 BURIAL GROUND TECHNOLOGY BASELINE FOR TREATMENT AND DISPOSAL OF DEPLETED URANIUM WITH RCRA AND TSCA CONSTRAINTS

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ABSTRACT

During remediation activities at a Hanford Site burial ground, a large cache of drummed waste was unexpectedly encountered. Most of the drums contained depleted uranium metal chips submerged in oil. A combination of attributes including multiple phases, pyrophoriticy, toxicity, and radioactivity presented complex and costly treatment/disposal issues that were not addressed through any established Hanford Site processes. A safe, environmentally responsible, and cost-effective path forward for treatment of the drums that had been, and would be, excavated from the 618-4 Burial Ground was needed.

To establish the framework for investigation of potential treatment and disposal options, a preliminary waste designation was prepared. Because there was a potential for separation of the phases prior to treatment, the preliminary designation considered the individual liquid and solid phases as well as the combined phases of the whole drum. An analysis of applicable regulatory issues was then performed to help determine the performance criteria for treatment/disposal methods.

A technology alternatives baseline was prepared as a starting point for identification of potential treatment options. Discussions were also held with representatives from other sites within the U.S. Department of Energy complex that faced similar problems with treatment and disposal of depleted uranium waste. After the initial screening, there were no established/proven processes identified that were absent of technical and/or regulatory limitations and issues based on the preliminary waste designation. Treatment methods that were determined to have a potential to be made into viable options were evaluated using criteria typically used for remedial investigations and feasibility studies. It was concluded that combinations of individual-phase treatment methods were not cost-competitive with whole drum methods. Solidification processes provided the lowest cost, but required variances to authorize land-disposal and treatability tests to show that the methods could be environmentally responsible. Vitrification methods provided the best technical performance among the alternatives that were evaluated.

In December 1999, a decision was made to prepare a request for proposal (RFP) for solicitation of bids to treat the drummed waste from the 618-4 Burial Ground. It is anticipated that an RFP will be issued in March 2000. An award decision is expected during the spring of 2000. Treatment of the drummed waste is scheduled begin in fiscal year 2001.

INTRODUCTION

Background

The Hanford Site is a 1,517-km^2 (586-mi^2) federal facility located in southeastern Washington State along the Columbia River. From 1943 to 1990, the primary mission of the Hanford Site was the production of nuclear materials for national defense. In July 1989, the Hanford Site was placed on the National Priorities List (NPL) pursuant to the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) (1). The Hanford Site includes four NPL sites consisting of the 100 Area, the 200 Area, the 300 Area, and the 1100 Area.

The 300 Area is located along the Columbia River north of the Richland city limits. It was constructed and operated as the reactor fuel fabrication and laboratory complex. In 1989, it was placed on the NPL because of soil and groundwater contamination that resulted from past operations, and the focus shifted to environmental restoration and waste management. The primary contaminant in the 300 Area is uranium from the fuel fabrication processes. The 300 Area consists of three operable units (OUs). 300-FF-1 and 300-FF-2 are both source OUs, and 300-FF-5 is a groundwater OU.

The 300-FF-1 OU is a source unit that includes the major 300 Area liquid/process waste disposal sites, the 618-4 Burial Ground, and three small landfills. Remediation of the 618-4 Burial Ground was initiated in fiscal year (FY) 1998 as a remove/treat/dispose operation. There was no evidence of liquid waste disposal at the 618-4 Burial Ground based on historical records and previous investigations that were performed as part of remedial investigation activities for the 300-FF-1 OU. Routine processes were established to excavate and ship contaminated soil and debris to the Environmental Restoration Disposal Facility (ERDF), a large landfill located in the Hanford Site 200 West Area.

In March 1998, an area of drummed waste was unexpectedly discovered in a central location of the 618-4 Burial Ground. Most of the drums were intact, 113.5 L (30 gal) in size, and had a D38 marking on the side (Figure 1). There were also 208-L (55-gal) drums unearthed from the same area that were suspected to be secondary containers for inner drums. Based on the observation of contents from damaged drums, there was evidence that layers of fine sediments and/or metal cuttings were present in the bottom of the drums. A thin oil material was observed in drums that contained the fine sediments/metal cuttings. The excavated drums posed an immediate issue with the routine disposal process because free liquids are not permitted by the ERDF waste acceptance criteria. Initial sample results from four of the drums with accessible contents suggested the potential for additional disposal issues associated with the presence of heavy metals, polychlorinated biphenyls (PCBs), and volatile organic compounds in the oil.

In parallel with the excavation process, investigations were conducted to determine the meaning of the D38 markings and locate information that documented disposal of the drummed waste at the 618-4 Burial Ground. Through an interview with a Hanford Site retiree, it was learned that the D38 term was commonly used within the U.S. Department of Energy (DOE) complex to identify depleted uranium. Oil was typically used to stabilize chips from milling operations due to the pyrophoric property of uranium metal, which presented another disposal issue at the

ERDF. Information from the interview prompted the suspension of drummed waste excavation activities at the 618-4 Burial Ground on April 2, 1998.

Between March 12 and April 2, 1998, 338 drums had been excavated from the central area of the waste site and staged within the 618-4 Burial Ground area of contamination (AOC). In mid-April 1998, a stabilization operation was implemented for excavated drums that were determined to have lost all or a significant portion of the original oil content. Through the process, 149 drums considered to be at risk were safely overpacked and filled with mineral oil to stabilize the uranium metal.

On April 24, 1998, a decision was made to postpone excavation of the 618-4 Burial Ground and begin operations at a liquid waste disposal site within the 300-FF-1 OU. The decision was made, in part, to permit development of plans for the safe and efficient excavation, treatment, and disposal of drummed waste. Based on field observations of multiple drum layers (two, possibly three as shown in Figure 2) and review of geophysical survey data that show a large magnetic anomaly at the approximate location where the drums were found, it was estimated that 1,200 additional drums may be buried in the area.

Extensive searches of historical records and interviews with Hanford Site retirees yielded no information on the original source of the buried drums. It is possible that the drummed waste was generated offsite and shipped to the Hanford Site for disposal. The lack of available historical records does not preclude the possibility that classified historical documents exist that have not yet been declassified.

Figure 1. Typical "D-38" Drums within the 618-4 Burial Ground Staging Area.

Figure 2. Exposed Excavation Face within the 618-4 Burial Ground Showing Multiple Layers.

In August 1998, samples were collected from 50 of the excavated drums as part of an effort to characterize the contents. Field observations and results from the characterization effort confirmed the presence of depleted uranium metal chips and oil material in all of the intact 113.5-L (30-gal) drums that were sampled. The 208-L (55-gal) drums that were sampled were confirmed to be original overpacks for 113.5-L (30-gal) inner drums that contained depleted uranium oxide powder (dry).

Problem Definition

A large number of drums had been excavated from the 618-4 Burial Ground. It was estimated that up to 1,200 drums remained to be excavated when remediation operations at the 618-4 Burial Ground were postponed. Drums that contained depleted uranium metal chips submerged in oil presented complex (technical and regulatory) and potentially costly waste disposal issues that were not addressed through any routine and/or established Hanford Site processes. These disposal issues resulted from a combination of attributes that were exhibited by the drum contents, including the following:

- Multiple phases - Drums contained solid material and free liquids.
- Pyrophoricity - Uranium metal is pyrophoric under certain conditions.
- Toxicity - Heavy metals, organic compounds, and PCBs were present in the oil at concentrations that exceed regulatory thresholds.
- Radioactivity - Contents required management as low-level radioactive material.

The applicable treatment/disposal requirements for the drum contents varied depending on whether the waste was considered as combined or individual phases. An acceptable method and process for treatment and disposal of this waste was needed before remediation operations at the 618-4 Burial Ground could be resumed.

Scope and Objective

The scope of the technical investigation was limited to treatment and disposal methods for drums that contained depleted uranium metal chips submerged in oil. The total number of drums estimated to contain this material was 1,184 based on extrapolation of information from the excavated drum population. Established 300-FF-1 OU procedures and processes were in place to manage treatment and/or disposal of drums that contain material other than uranium metal chips submerged in oil (e.g., dry uranium oxide powder).

The objective of the investigation was to identify a safe, environmentally responsible, and cost-effective path forward for treatment of the drums that had, and would be, excavated from the 618-4 Burial Ground. To accomplish this objective, analyses of the waste stream, regulatory issues, treatment/disposal alternatives, and technical and cost performance were addressed in the investigation. When the investigation was initiated in late 1998, it was recognized that few, if any, straightforward paths existed for treatment and disposal of the drummed waste from the 618-4 Burial Ground. As a result, any applicable regulatory and/or process issues associated with proposed methods that were otherwise considered to be viable were included in the investigation.

Schedule

At the time of the investigation, treatment of the drummed waste from the 618-4 Burial Ground was scheduled to begin in July 2000 in accordance with the FY 1999 multi-year detailed work plan (DWP) for the 300-FF-1 OU. Since completion of the investigation, the schedule has been updated as part of the FY 2000 DWP, and treatment of the drummed waste is not currently anticipated to begin until FY 2001.

WASTE STREAM ANALYSIS

Characterization of the drummed waste that had been excavated from the 618-4 Burial Ground was completed in September 1998. Of the 260 excavated drums that are suspected to contain uranium metal chips/oil, 32 were sampled. Results for the referenced sample population are summarized as follows.

- Uranium was in a depleted state in all of the solid samples.
- The solid material was confirmed not to require management as transuranic waste.
- Free liquids (oil) were present in each drum.
- Heavy metals, PCBs, and volatile organic compounds were present in the oil material at concentrations that exceeded regulatory thresholds.

Based on the characterization information, a preliminary waste designation was prepared by waste management personnel for use in the development of the treatment and disposal plan. For designation purposes, all of the drums that contained solid depleted uranium immersed in oil were considered to be a single waste stream. Because it was unknown if the liquid and solid portion of the drum contents would be separated as part of the treatment and disposal process, a preliminary designation was prepared for the individual and combined phases, as summarized in Table I.

Table I. Preliminary Waste Designation Summary.

Criteria	Combined Phase[b]	Solid Phase[c]	Liquid Phase
TSCA[a]	PCBs	PCBs	PCBs
Characteristics (RCRA)	Lead (D008) Benzene (D018) Chloroform (D022) PCE (D039) TCE (D040)	Not regulated[d]	Barium (D005) Lead (D008) Mercury (D009) Benzene (D018) Chloroform (D022) PCE (D039) TCE (D040)
UHCs	PCBs Barium Mercury Selenium Methyl ethyl ketone Methylene chloride Toluene Ethyl benzene Xylenes Pyrene Naphthalene di-n-octyl phthalate bis(2-ethylhexyl)phthalate	N/A	PCBs Selenium Methyl ethyl ketone Methylene chloride Toluene Ethyl benzene Xylenes Pyrene Naphthalene di-n-octyl phthalate bis(2-ethylhexyl)phthalate
Washington State	Persistent (WP01)[e]	Not regulated	Persistent (WP01)[e]
DOE	Low-level radioactive	Low-level radioactive	Low-level radioactive

[a] All phases of the waste are regulated by TSCA due to an oil source with PCB concentrations that exceed 50 ppm. A few drums contained oil with PCB concentrations that exceeded 500 ppm.
[b] A 2 to 1 ratio (by weight) of liquid to solid material was utilized for the evaluation based on characterization results.
[c] Residual oil must be <0.25% or additional waste codes and UHCs may apply.
[d] Although the uranium metal is pyrophoric under certain conditions, the waste is not designated as dangerous/hazardous by the characteristic of ignitability because uranium is excluded from regulation under the federal RCRA program.
[e] Persistent waste consists of organic compounds that retain more than half of their initial concentration after one year.

REGULATORY ANALYSIS

An evaluation of the applicable regulatory issues was performed based on the preliminary waste designation to help determine the performance criteria for treatment/disposal methods.

A number of complex issues were identified through the evaluation with respect to the CERCLA, *Resource Conservation and Recovery Act of 1976* (RCRA) (2), *Toxic Substances Control Act* (TSCA) (3), and transportation regulations.

CERCLA Issues

Applicable or Relevant and Appropriate Requirements. The primary applicable or relevant and appropriate requirements (ARARs) that drove the need for treatment of the drummed waste included the State of Washington Dangerous Waste Regulations (4), RCRA Land Disposal Restrictions (LDRs), and the TSCA. It was recognized that the previously mentioned ARARs were not all inclusive and that all remediation activities associated with the 618-4 Burial Ground waste, including treatment and disposal, were subject to the ARARs identified in *Record of Decision for the U.S. Department of Energy Hanford 300-FF-1 and 300-FF-5 Operable Units* (5).

CERCLA Documentation. A review of the 300-FF-1 OU Record of Decision (ROD) was performed to identify any revisions needed to properly authorize treatment and disposal of the 618-4 Burial Ground drummed waste. The LDR "Phase IV" final rule and the PCB "Mega Rule" were two significant regulatory changes that had occurred since issuance of the 300-FF-1 OU ROD. Based on protectiveness of the selected remedy, it was determined that the two rule changes did not surpass the threshold for reevaluation of the ROD. It was recognized that revisions or amendments to the ROD made for other reasons could invoke new ARARs, even if the new standards did not challenge the protectiveness of the original remedy.

A review of the 300-FF-1 OU ROD indicated that drummed waste discovered in the 618-4 Burial Ground was different than what was anticipated at the time of ROD signature. It was determined that because the differences could still be addressed using the general remedy that was selected (e.g., excavate, treat to meet disposal facility acceptance criteria, and dispose in ERDF or at another regulated landfill), an explanation of significant difference (ESD) would be an appropriate method to document the differences. This conclusion was viewed as rather easy to support for "soft-landing" treatment technologies (e.g., simple solidification). More complicated treatment techniques (e.g., in situ vitrification followed by disposal in ERDF) could approach the threshold of a fundamental change to the ROD. The pursuit of an ESD with an opportunity for public comment was identified as an alternative approach between an ESD and a ROD amendment. A final determination of the type of documentation necessary to identify changes to the 300-FF-1 OU ROD (5) was identified as a subject for consideration by the Tri-Parties.

Area of Contamination. The AOC was an important consideration with respect to management of the 618-4 Burial Ground waste for two reasons. Because waste managed within the AOC is not subject to RCRA substantive standards, it was desirable to stage all of the waste within the AOC. In situ or land-based treatment options must be performed within the AOC, otherwise LDR treatment standards would have to be met before placement of waste in the land-based treatment unit.

RCRA Issues

Waste Designation. Because waste generation process knowledge was unavailable, a need to confirm acceptability of the designation as a single waste stream was identified. It was recognized that some periodic verification analyses might be necessary during the cleanup process to confirm that drum contents remain within the established designation profile. In addition to verification analyses, a method of identifying any grossly anomalous waste (e.g., a visual inspection) would likely be required.

Land Disposal Restrictions. Significant issues associated with treatment and disposal of the 618-4 Burial Ground drummed waste were identified. A variety of solidification technologies had proven successful in meeting the LDR treatment standards for metals, but were not acceptable for treatment of organic constituents because standards are based almost exclusively on total concentration, not leachability. In addition, the LDR dilution prohibition precluded use of technologies that merely diluted a constituent to levels that are below the treatment standard. Destruction technologies were the most common treatment methods for organic compounds. Achieving the LDR treatment standard was further complicated by the fact that compliance is based on analysis of individual grab samples rather than a statistical evaluation of the entire waste stream (i.e., the treatment standard cannot be exceeded in a single grab sample taken from any part of the waste).

Another issue involves the treatment of PCBs as Underlying Hazardous Constituents (UHCs). The LDR treatment standards for PCBs (as UHCs) are more stringent than the corresponding TSCA requirements and would require treatment to a concentration below 10 ppm. Compliance with this standard must be attained using a technology that does not merely dilute or immobilize the PCB compounds. In contrast, TSCA regulations for PCB-bearing liquids would allow wastes containing less than 500 ppm PCB to be solidified and disposed of in the ERDF. There was no parallel in TSCA that required treatment to less than 10 ppm using a technology other than dilution.

Waiver of the federal LDR standards could be obtained from the U.S. Environmental Protection Agency (EPA) through provision of a treatability variance in situations where "treatment to the specified level or by the specified method is technically inappropriate" or where treatment "is environmentally inappropriate because it would discourage aggressive remediation." It was determined that either of the variance provisions could be used to request a variance in conjunction with the drummed waste at the 618-4 Burial Ground. An ESD with public comment would be required to justify a need and obtain approval for a variance.

TSCA Issues

Under the applicable PCB regulations based on the dates of ROD signatures, the majority of the oil-bearing drums from the 618-4 Burial Ground could be stabilized and disposed of in the ERDF. However, there were a few drums containing PCB liquids at concentrations that exceeded the 500-ppm limit for landfill disposal. Mixing liquids that have PCB concentrations in excess of 500 ppm with lower concentration oils would typically result in the entire mixture being considered a "greater than 500 ppm" waste (regardless of the actual concentration that resulted). Depending on the treatment process, combining the oil from various drums into a single vessel was viewed as potentially desirable from a process optimization and waste minimization perspective. To accommodate such an approach without invoking a requirement to incinerate the resultant mixture, an "interpretive" determination (with no formal variance or exemption required) would be needed from the EPA.

Although the recently promulgated PCB rule was not invoked for the 300-FF-1 OU or the ERDF based on signature dates of the applicable RODs, there was flexibility available in the new Mega-rule that could benefit the 618-4 Burial Ground remediation effort. The rule generically prohibits disposal of liquid PCB-bearing wastes with PCB concentrations that exceed 50 ppm, but it also contained special allowances for dealing with PCB remediation wastes. Specifically, a new provision allowed the EPA to approve a risk-based disposal approach for remediation waste. This approval authority was broad and accommodates the use of any disposal approach with a provision that "the method will not pose an unreasonable risk of injury to health or the environment." If an interpretative approach to address the liquid PCB waste was rejected by the EPA, the new regulations could be applied to the 618-4 Burial Ground effort to use the new remediation waste flexibility accordingly.

Transportation

The primary transportation issue was the pyrophoric property of uranium metal and the associated U.S. Department of Energy (DOT) packaging requirements for movements of drummed waste on public roadways. Relief from the DOT transportation and packaging regulations could be obtained by conducting the movements on roadways that have been closed to the public. Depending on the treatment process that is selected and the location of associated facilities with respect to the 300-FF-1 OU, road closures or transportation on non-public roadways were identified as options worth investigating.

TREATMENT/DISPOSAL OPTIONS

Support from the Technology Applications organization was solicited to investigate potential treatment/disposal options that could be applied to the 618-4 Burial Ground drummed waste. Results of the investigation were published in the *Technology Alternatives Baseline - 618-4-Burial Ground Drum Treatment and Disposal Project* (6) and provided to the 300-FF-1 OU project team. The technology baseline was used as the starting point in the investigation to identify potential treatment and disposal options. Discussions were also held with representatives from other sites within the DOE complex that faced similar problems with treatment and disposal of depleted uranium waste.

After an initial screening and discussion with Technology Applications personnel, there were no established/proven processes that were absent of technical and/or regulatory limitations and issues based on the preliminary waste designation. Several options were immediately rejected from further consideration based on technical qualifications and/or other factors, as summarized in Table II.

Table II. Treatment Methods Rejected After Initial Screen.

Category	Method	Comments
Whole drum	Mobile ex situ melter	Under construction. Larger fixed facility available within 3 km (2 mi) of the site.
Whole drum	Undetermined	Broad spectrum contract RCRA/TSCA permitted facility. No treatment processes developed. Space could be used for other treatment methods.
Whole drum or liquids	Solvated Electron Technology	Will not oxidize uranium. Not applicable to RCRA organic compounds.
Solids	Steam Reformer	Incineration preferred over steam reforming; similar cost and treatment result.
Solids	Sulfur polymer cement, polyethylene, thermal setting resins	Process in early development stage for uranium encapsulation.
Solids	Phosphate-bonded ceramics	Not commercialized. Similar to commercialized calcination/binder process.
Solids	Chemical oxidation	Pilot system not tested and requires significant startup investment.

Treatment/disposal alternatives that were determined to have a potential to be made into viable options are presented with a summary of the associated limitations and/or issues in Tables III through VI. An integrated logic diagram of the potential treatment/disposal alternatives, including whole drum and individual phase methods, is presented in Figure 3. For each treatment alternative presented, it was assumed that the treated waste product would be disposed of in the ERDF unless otherwise specified.

Table III. Potential Whole Drum Treatment/Disposal Alternatives.

Methodology	Description
Staged vitrification	Excavated drums would be put into a lined pit, crushed, mixed with soil, and then vitrified. Product is a glass material that immobilizes the uranium and RCRA metals. Organic constituents (including PCBs) would be thermally destroyed. After being broken into pieces, the solid glass material would be acceptable for shipment and disposal in the ERDF. Process would be performed onsite within the AOC under CERCLA treatment provisions such that permits are not required.
Gasification/ vitrification	Excavated drums would be transported offsite to a commercial facility for vitrification. Product would be a glass material that immobilizes uranium and RCRA metals. Organic constituents (including PCBs) would be thermally destroyed. Glass material could be produced in multiple forms (e.g., chips, monolith) and would be suitable for disposal in the ERDF. If needed, waste could be stored at the facility under a RCRA/TSCA mixed waste permit for a period of up to 1 year prior to treatment. Process anticipated to be available mid-summer 2000.
Pyrolysis	Excavated drums would be put into a reaction vessel containing molten aluminum that provides the energy for pyrolysis of the organic compounds (including PCBs). Chloride ions that are released during the process bond to the aluminum to form aluminum chloride. Uranium and RCRA metals are absorbed into the aluminum bath. Product is an aluminum monolith that would encapsulate the uranium and RCRA metals. Organic constituents (including PCBs) would be thermally destroyed. Solid product would be suitable for disposal at the ERDF. Proof-of-concept treatability test would be required.
Category D broad spectrum treatment	Subcontracts for treatment of mixed waste through specific vendors made available to DOE sites (without additional contracting costs) as part of a DOE initiative to consolidate procurement activities. Drummed uranium waste from the 618-4 Burial Ground would be designated as Category D. In June 1998, the contract for treatment of Category D waste was awarded to the East Tennessee Materials and Energy Company (ETMEC). Treatment for Category D waste expected to be available by August 1999. Five basic treatment methodologies currently planned, including direct chemical oxidation, solidification, aqueous waste treatment (e.g., filtration, precipitation, ion exchange, adsorption), reactive waste treatment (e.g., cyanide, sulfides, and oxidizers), and mercury amalgamation. Waste could be stored at the facility under a RCRA/TSCA mixed waste permit for a period of up to 1 year.
Petroset	Solidification technology would be used onsite within the AOC. Technology is based on the addition of a chemical to a mixture of waste material and oil to form a stiff petroleum putty that contains the uranium, RCRA metals, and organic compounds. Process would require an exemption from LDR treatment standards prior to disposal of waste in the ERDF. May also require EPA approval of a risk-based PCB disposal alternative under TSCA. Before implementation, a proof-of-concept treatability test would be required.
Cementation	Process would be performed onsite within the AOC. Product would be a concrete monolith that encapsulates the uranium metal and oil (including RCRA metals and organic compounds/PCBs contained in the oil). Process would require an exemption from LDR treatment standards prior to ERDF disposal. May also require EPA approval of a TSCA risk-based PCB disposal alternative. Proof-of-concept treatability test would be required.
Hanford storage (Central Waste Complex)	Permitted Hanford Site mixed waste storage facility provides interim storage of the mixed waste. Actual treatment and/or disposal of the waste is deferred. Waste would be subjected to a suitable treatment/disposal process in the future based on characterization information that is submitted to the CWC with the waste. If mixed waste treatment capacity exists elsewhere, long-term storage may not satisfy the LDR storage prohibition rules. Requires repackaging.

Table IV. Potential Phase Separation Alternatives.

Methodology	Description
Decanting	Oil would be drained, pumped, or poured from the drums to the extent possible. Process would not achieve degree of separation needed to remove all of the RCRA hazardous waste codes from the solid phase. Regardless of separation efficiency, process is not approved method for removal of PCBs. Would be appropriate for subsequent solid treatment technologies that do not have restrictions (e.g., able to accept pyrophoric, radioactive, RCRA/TSCA waste) and liquid alternatives for mixed waste (e.g., low-level radioactive, RCRA/TSCA).
Washing	Oil would be separated from the solid material using a solvent extraction method approved by the EPA for solids contaminated with PCBs and volatile/semivolatile organic compounds. Products would be uranium metal solids free of RCRA/TSCA hazardous waste codes, the retrieved oil, and the spent solvent solution. Process could be performed onsite within the AOC or offsite at a facility selected for subsequent treatment of solid material. Depending on subsequent movement or treatment plans, uranium solid material may require stabilization (e.g., addition of clean oil) after process. Retrieved oil would be suitable for any liquid alternatives that could accept mixed waste (e.g., low-level radioactive, RCRA/TSCA).
Filtration	Radioactive suspended solids would be separated from the oil material onsite within the AOC using a filter process to the extent that the oil would no longer be considered mixed waste. Would allow treatment/disposal of the oil using any RCRA/TSCA permitted facility or process. Filter cake material would be combined with the other uranium solid material for treatment and disposal. Free-release of the filtered liquid as nonradioactive material could be an issue.

Table V. Potential Liquid Phase Treatment/Disposal Alternatives.

Methodology	Description
Incineration (RCRA/TSCA, rad)	Liquid phase would be incinerated at a RCRA/TSCA, low-level radioactive permitted facility in Oak Ridge. Organic compounds, including PCBs, would be thermally destroyed. Product would be incinerator ash containing uranium and RCRA metals. Permission to treat Hanford Site waste would be required from the state of Tennessee. Ash returned to the Hanford Site could be mixture of ash from the Hanford Site waste and other unknown waste streams. Ash would require supplemental treatment to reduce the mobility of RCRA metals to meet LDR standards prior to disposal at ERDF.
Thermal destruction/ vitrification	Organic compounds, including PCBs, would be thermally destroyed at local facility. Product would be ash containing uranium and RCRA metals. Ash could be vitrified at same facility and disposed of at the ERDF. Facility expected to be operational during summer of 2000. Waste could be stored at the facility under a RCRA/TSCA mixed waste permit for a period of up to 1 year prior to treatment.
Petroset	After phase separation, oil would be subjected to the solidification process using Petroset product onsite within the AOC. Product is a stiff petroleum putty containing RCRA metals and organic compounds. Process would require an exemption from LDR treatment standards prior to disposal of waste in the ERDF. May also require EPA approval of a risk-based PCB disposal alternative under TSCA.
Incineration (RCRA/TSCA, nonrad)	Oil would be incinerated at a commercial RCRA/TSCA incinerator restricted to acceptance of nonradioactive waste. Oil would have to be filtered to remove radioactive particulate material and a free-release would have to be obtained before shipment. Product is ash containing RCRA metals. Disposal of the ash would likely be done through the commercial incineration contractor. If returned, ash would require supplemental treatment to reduce the mobility of RCRA metals to meet LDR standards prior to disposal at ERDF.

Table VI. Potential Solid Phase Treatment/Disposal Alternatives.

Methodology	Description
Vitrification	After phase separation, drums containing the uranium metal would be transported offsite to a local facility for vitrification. Addition of clean oil would be required to stabilize uranium metal during transportation. Glass material could be produced in multiple forms (e.g., chips, monolith) and would be suitable for disposal in the ERDF. If needed, waste could be stored at the facility under a RCRA/TSCA mixed waste permit for a period of up to 1 year prior to treatment. Process is anticipated to be available by mid-summer 2000.
Petroset	After separation of the contaminated oil, chemical activator and clean oil would be mixed with the uranium metal to form a stiff petroleum putty. Contaminated oil would need to be *completely* removed (using a washing process approved for PCBs) to eliminate need for variance from LDR treatment standards, otherwise RCRA waste codes and UHCs would apply. Stability of the petroleum putty material for ERDF disposal may need to be evaluated if drums containing the material must be crushed and mixed with soil prior to burial at the facility.
Cementation	After phase separation, uranium metal would be encapsulated in a concrete monolith onsite within the AOC. Contaminated oil would need to be *completely* removed (using a washing process approved for PCBs) to eliminate the need for a variance from LDR treatment standards, otherwise RCRA waste codes and UHCs would apply. Proof-of-concept treatability test would be required to verify that the method is viable due to potential reaction of the uranium metal with water in the cement.
Calcination/ Binder	Uranium metal would be calcined, mixed with a binder, and pressed into bricks at a commercial offsite facility. Products would be high-density uranium oxide bricks suitable for disposal at ERDF. Facility could not accept waste that is regulated by RCRA or TSCA; contaminated oil must be *completely* separated (using a washing process approved for PCBs) from solid phase. After separation, addition of clean oil would be required to stabilize uranium metal during transportation. Treated material could be used as a product if user identified.
Chip oxidation	Chip oxidizer would be used to oxidize uranium metal at a commercial facility. Product is uranium oxide that would be suitable for disposal in the ERDF. Facility could not accept waste that is regulated by RCRA or TSCA; contaminated oil must be *completely* separated (using a washing process approved for PCBs) from solid phase. After separation, addition of an inerting material that is acceptable for oxidation processing (process requires no oil present for burn control) may be required to stabilize the uranium metal during transportation.

ALTERNATIVES ANALYSIS

The initial evaluation was performed using criteria prescribed in *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (7), including:

- Overall Protection of Human Health and the Environment
- Compliance with ARARs
- Long-Term Effectiveness and Permanence
- Reduction of Toxicity, Mobility, and Volume through Treatment
- Short-Term Effectiveness
- Implementability
- Cost
- State Acceptance
- Community Acceptance.

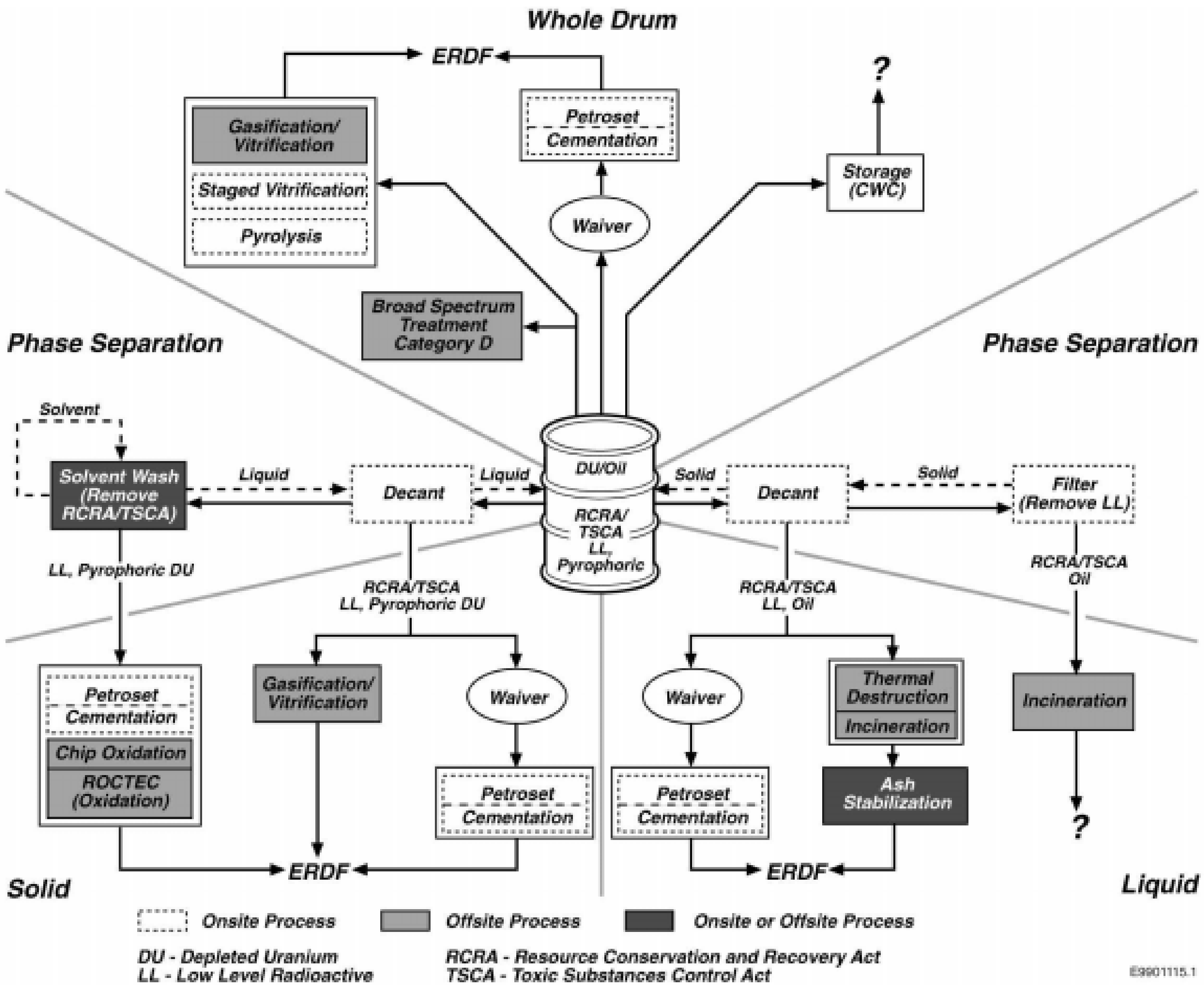

Figure 3. Integrated Logic Diagram for Potential Treatment/Disposal Methods.

Cost information for each treatment/disposal methodology was obtained through the Technology Applications organization. Rough order of magnitude (ROM) cost estimates (including applicable material, labor, and subcontract costs for treatability testing, construction, treatment, transportation, disposal, and project management) were developed using common assumptions based on field observations and characterization results as summarized in Table VII.

Table VII. Treatment/Disposal Alternatives Cost Summary.

Category	Methodology	Cost ($M)	Adjusted Cost ($M)[a]	Comments
Whole drum	Staged vitrification	4.07	N/A	Onsite within AOC
	Gasification/vitrification	4.25	N/A	Not yet permitted
	Pyrolysis	5.92	N/A	Offsite within AOC
	Category D broad spectrum treatment	6.61	N/A	Method TBD
	Petroset	1.72	N/A	Requires variance
	Cementation	0.99	N/A	Requires variance
	Hanford storage (Central Waste Complex)	1.71	N/A	Defers disposal cost and may not met LDR storage prohibition
Phase separation	Decanting	0.48	N/A	
	Washing	1.9	N/A	
	Filtration	0.57	N/A	
Liquid[b]	Incineration (RCRA/TSCA, rad)	0.49	1.47 – 3.93	Must be complete by FY 2001[c]
	Thermal destruction/ vitrification	2.81	3.79 – 6.25	Not yet permitted
	Petroset	0.6	1.58 – 4.04	Requires variance
	Incineration (RCRA/TSCA, nonrad)	0.53	2.08 – 4.54	Requires filter to remove radioactivity
Solid[b]	Vitrification	1.49	2.46 – 4.78	Not yet permitted
	Petroset	1.07	2.04 – 6.26	Requires decant and wash or variance
	Cementation	0.5	1.47 – 5.69	Requires decant and wash or variance
	Calcination/binder	1.06	3.93 – 6.25	Requires decant and wash
	Chip oxidation	0.59	3.46 – 5.78	Requires decant and wash

[a] Includes combined cost ranges for phase separation, liquid treatment, and solid treatment for a given liquid/solid treatment method. A treatment variance may be required for some treatment combinations to achieve the minimum cost.
[b] All liquid/solid treatment alternatives require some degree of phase separation with decanting as the minimum.
[c] Incineration cost provided for permitted facility in Oak Ridge. If treatment is complete by FY 2001, there is no cost for the actual incineration process (beginning in FY 2001, the treatment cost is anticipated to be at least twice the listed estimate of $0.49 million). The listed cost is based on packaging and transportation to the facility, and supplemental treatment and disposal of the incinerator ash.

Information is provided in the Adjusted Cost column of Table VII to identify the minimum/maximum cost range for treatment of the entire drum contents using individual liquid and solid treatment methods. Each adjusted cost range value consists of phase separation, liquid treatment, and solid treatment components. Using the cementation treatment method for solids as an example, the minimum adjusted cost includes decanting ($0.48 million), cementation of the solids via a variance ($0.5 million), and incineration at Oak Ridge prior to FY 2001 ($0.49 million). This scenario results in a minimum adjusted cost of $1.47 million for the cementation treatment method for solids. Conversely, the maximum adjusted cost for cementation of the solid material includes decanting ($0.48 million) followed by washing to remove the RCRA/TSCA designation from the solid material ($1.9 million), cementation of the solids ($0.5 million), and thermal destruction/ vitrification of the liquid ($2.81million) for a total of $5.69 million. For evaluation of total cost, the values for individual liquid treatment and solid treatment methods in the Adjusted Cost column should be compared with values for whole drum treatment methods in the Cost column of Table VII.

TECHNICAL AND COST PERFORMANCE SUMMARY

An integrated review of technical and cost information was performed with the objective of narrowing the list of candidate alternatives to those treatment/disposal methods that represented the best combination of technical responsiveness and value given the properties of the waste stream. After review of technical and cost performance information, the following general conclusions were evident.

- Vitrification was a proven treatment technology that appeared to provide the best technical performance among the alternatives that were evaluated.

- With successful proof-of-concept treatability testing and issuance of a variance to permit disposal at the ERDF, solidification processes would provide the lowest cost among the alternatives that were evaluated.

- When evaluated against comparable (e.g., pathways that require regulatory variances are not considered comparable to pathways that do not require variances) whole drum treatment/disposal alternatives, combinations of individual treatment/disposal methods (e.g., phase separation, solid treatment, liquid treatment) were not cost-competitive.

Based on the aforementioned conclusions, two whole-drum vitrification processes and two whole-drum solidification processes were put onto a short list of treatment/disposal alternatives, as follows:

- Gasification/vitrification at a commercial offsite facility with an estimated cost of $4.25 million
- Staged vitrification performed onsite, with an estimated cost of $4.07 million
- Petroset performed onsite, with an estimated cost of $1.72 million
- Cementation performed onsite, with an estimated cost of $0.99 million.

The treated waste product would be disposed of in the ERDF for each of the listed treatment alternatives. The Petroset and cementation processes will require issuance of a variance before disposal. A summary of the rationale that was used to eliminate the other treatment/disposal alternatives from further consideration is presented in Table VIII.

Table VIII. Rationale Used to Eliminate Treatment/Disposal Alternatives.

Class	Methodology	Elimination Rationale
Whole drum	Pyrolysis	High cost with respect to vitrification processes. Unproven technology would require significant treatability testing.
	Category D broad spectrum treatment	High cost with respect to vitrification processes. Mechanism to access contract is in place, but treatment methods have not been developed.
	Hanford storage – Central Waste Complex	Interim storage only pending determination and availability of treatment/disposal method. Actual cost of deferred treatment/disposal unknown. Long-term storage may not satisfy LDR storage prohibition.
Liquid[a]	Incineration (RCRA, TSCA, radioactive)	No plans to accept out-of-state waste in foreseeable future. Significant increase in cost anticipated in FY 2001 (current incineration cost is $0).
	Thermal destruction/ vitrification	Minimum adjusted cost scenario involves cementation of solid material via treatment variance. Whole-drum cementation process is available as a preferred alternative at lower cost. Other adjusted cost scenarios greater than cost for whole-drum vitrification alternatives.
	Petroset	Minimum adjusted cost scenario involves cementation of solid material via treatment variance at comparable/greater cost than preferred whole-drum solidification processes (e.g., cementation, Petroset).
	Incineration (RCRA, TSCA, nonradioactive)	Free release of filtered liquid expected to be difficult. Minimum adjusted cost scenario involves cementation of solid material via treatment variance at comparable/greater cost than preferred whole-drum solidification processes (e.g., cementation, Petroset).
Solid[a]	Vitrification	Minimum adjusted cost scenario involves incineration at Oak Ridge (see entry under liquid class). Other adjusted cost scenarios involve Petroset (via variance) at a higher cost than preferred whole-drum solidification processes.
	Petroset	Minimum adjusted cost scenario involves incineration at Oak Ridge (see entry under liquid class) at greater cost than preferred whole-drum solidification processes.
	Cementation	Minimum adjusted cost scenario involves incineration at Oak Ridge (see entry under liquid class) at greater cost than preferred whole-drum cementation process.
	Calcination/binder	Minimum adjusted cost scenario involves incineration at Oak Ridge (see entry under liquid class) at greater cost than preferred whole-drum solidification processes and at a comparable cost to preferred whole-drum vitrification processes.
	Chip oxidation	Minimum adjusted cost scenario involves incineration at Oak Ridge (see entry under liquid class). Other adjusted cost scenarios involve methods that are available as preferred whole-drum alternatives at lower cost.

[a] All liquid/solid treatment alternatives require some degree of phase separation, with decanting as a minimum.

COMPARATIVE ANALYSIS OF PREFERRED ALTERNATIVES

A comparative analysis of preferred alternatives was performed with respect to each other, the technical evaluation criteria, and cost. Results of the analysis reinforced the general technical strength/high cost of vitrification methods and the comparative technical weakness/low cost of the solidification methods. A summary of strengths and weaknesses for the preferred alternatives is presented in Table IX.

Table IX. Summary of Preferred Alternative Strengths and Weaknesses.

Alternative	Strengths	Weaknesses
Gasification/Vitrification (offsite)	• Proven technology • Compliance with ARARS • Low residual risk • Irreversibility • Reduction of toxicity and mobility • Waste reduction (decrease in weight/volume)	• Facility not yet permitted • Cost
Staged Vitrification (onsite)	• Proven technology • Compliance with ARARS • Low residual risk • Irreversibility • Reduction of toxicity and mobility	• AOC space limitation • Waste reduction (significant increase in weight/volume) • Cost • May require ROD amendment
Petroset (onsite)	• Cost	• Compliance with ARARS • Requires variance • Long-term stability of treated waste uncertain – requires proof-of-concept treatability test
Cementation (onsite)	• Cost	• Compliance with ARARS • Requires variance • Waste reduction (significant increase in waste/volume) • Major concerns with near- and long-term stability of treated waste (phase separation, reaction with water) – requires proof-of-concept treatability test

TREATMENT STRATEGY RECOMMENDATION

Based on the comparative analysis, Petroset was identified as the recommended treatment method when the treatment plan was issued in March 1999 (8). When compared with the vitrification methods, both of the solidification methods were attractive from a cost standpoint, but required proof-of-concept treatability tests and significant coordination with the EPA to obtain the necessary regulatory variances. The cementation alternative was considered technically suspect because of the potential for phase separation of the oil and reaction of the uranium metal and water within the cement matrix. With the Petroset product, it was believed that there was a good chance for a treatability test to verify production of a treated waste form that could be disposed of in the ERDF in a manner that was environmentally responsible. In comparison with cementation, the Petroset alternative would result in only a minimal increase in the amount of waste by weight/volume and is the better choice with respect to waste minimization. Initial discussions with EPA representatives indicated that the agency might be willing to consider the issuance of regulatory variances for a solidification product such as Petroset.

Because there was a chance for treatability test failure and/or complications with issuance of regulatory variances, some parallel path activities were performed associated with the vitrification processes to ensure that a viable treatment method was available to support the project schedule. Of the two vitrification methods, offsite treatment at a local commercial facility was preferred. Transportation of the waste offsite would facilitate closeout/regrading of the site during the treatment process and address concerns with the availability of space within the 618-4 Burial Ground AOC for onsite processes. The treatment process would also support waste minimization initiatives by reducing the amount of waste (both weight and volume). The staged vitrification alternative is also available if the permit process for the commercial facility stalls or collapses.

To meet the July 2000 start date that was identified in the FY 1999 DWP, an implementation schedule was developed for Petroset as the recommended treatment method. The schedule included a critical path item that coincided with the then-anticipated restart of excavation operations at the 618-4 Burial Ground. If a successful Petroset treatability test had not been completed and/or the necessary regulatory variances were not issued/progressing by October 1999, a decision would be made to potentially delay the start of treatment activities or begin implementation of a vitrification treatment method. It was recognized that solicitation of services and subsequent placement of any commercial contracts to support treatment and/or disposal of 618-4 Burial Ground waste would be performed within all applicable federal procurement regulations.

FISCAL YEAR 2000 UPDATE

A schedule change has taken place since issuance of the treatment plan in February 1999. Under the original schedule, excavation of the 618-4 Burial Ground was to be completed prior to starting the drummed waste treatment operation in July 2000. During the multi-year planning process, a decision was made to defer continuation of excavation operations at the 618-4 Burial Ground until FY 2001. The schedule and budget were established to allow treatment of the drums to be initiated concurrent with excavation operations.

In accordance with the implementation strategy developed in the treatment plan (8), discussions were held with the EPA during the spring of 1999 to further investigate the likelihood of obtaining a variance that would authorize disposal of solidified (e.g., Petroset) waste at the ERDF. The discussions were based on the premise that a subsequent treatability test would reduce the leachability and produce a stable waste form such that disposal at the ERDF could be viewed as environmentally responsible. Feedback was received that EPA Region 10 would not support a variance. Consequently, a treatability test was not performed and efforts were shifted to the vitrification path.

A public hearing was held in April 1999 for information and comments regarding the permit application for thermal treatment at the commercial gasification/vitrification facility. Approval of the thermal treatment permit application was received in June 1999. The commercial facility is now in the construction and demonstration phase of the permit process. It is anticipated that the facility will be operational for commercial thermal treatment of waste in the summer of 2000.

During the spring of 1999, an unsolicited proposal was received to perform a no-cost treatability test for the staged vitrification process. The test was completed in August 1999 at the 618-4 Burial Ground and successfully melted a 3.8-L (1-gal) can containing uranium chips and oil to produce a glass monolith. Sample results from the glass showed that the treated waste form was suitable for disposal at the ERDF. Information collected from the treatability test is being used to help optimize the design and refine cost for the process. The information is also being shared with interested representatives from other DOE sites where there is potential for application of this type of treatment technology.

A second unsolicited proposal was received during the spring of 1999 that suggested use of a thermal desorption/polymer based immobilization treatment technology for drummed waste from the 618-4 Burial Ground. This proposed approach would involve distillation of the oil and other organics at reduced pressure in the presence of an inert gas such as helium, followed by combustion in a high-efficiency burner. The uranium metal would then be cooled in the helium atmosphere and immobilized in a radiation-proof polymer system. The product would consist of a stable, uranium metal/polymer matrix suitable for disposal at the ERDF. The process could be performed onsite within the AOC or at an offsite facility. The estimated cost for implementation of this approach onsite is $5.3 million using the same assumptions used to prepare the estimates provided in Table VII.

In December 1999, a decision was made to prepare a request for proposal (RFP) for solicitation of bids to treat the drummed waste from the 618-4 Burial Ground. It is anticipated that an RFP will be issued in March 2000. An award decision is expected during the spring of 2000.

REFERENCES

1. *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*, 42 U.S.C. 9601, et seq.

2. *Resource Conservation and Recovery Act of 1976*, 42 U.S.C. 6901, et seq.

3. *Toxic Substances Control Act of 1976*, 15 U.S.C. 2601, et seq.

4. WAC 173-303, "Dangerous Waste Regulations," *Washington Administrative Code*, as amended.

5. *Record of Decision for the U.S. Department of Energy Hanford 300-FF-1 and 300-FF-5 Operable Units*, U.S. Environmental Protection Agency, Region 10, Richland, Washington (1996).

6. *Technology Alternatives Baseline – 618-4 Burial Ground Drum Treatment and Disposal Project*, BHI-01275, Bechtel Hanford, Inc., Richland, Washington (1999).

7. *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA*, EPA/540/G-89/004, U.S. Environmental Protection Agency, Washington, D.C. (1988).

8. *Treatment/Disposal Plan for Drummed Waste from the 300-FF-1 Operable Unit, 618-4 Burial Ground*, BHI-01264, Bechtel Hanford, Inc., Richland, Washington (1999).