Buried Transuranic-Contaminated Waste Information for U.S. Department of Energy Facilities

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Buried Transuranic-Contaminated Waste Information for U.S. Department of Energy Facilities

Abstract

Radioactive wastes meeting the current definition of transuranic (TRU) wastes were disposed of by shallow land burial and other techniques at a number of sites owned and operated by the federal government in support of the nuclear weapons program from the 1940s through 1970s. Following the identification of TRU wastes as a separate category of radioactive wastes (as distinct from low-level wastes) in 1970 by the U.S. Atomic Energy Commission, such wastes were generally segregated and placed in retrievable storage pending the availability of a geologic repository. This geologic repository, the Waste Isolation Pilot Plant located near Carlsbad, New Mexico, began accepting wastes in 1999. Data on buried TRU-contaminated wastes have been included in a number of documents, such as various revisions of the Integrated Data Base report. In response to questions raised by the Institute for Energy and Environmental Research, the U.S. Department of Energy (DOE) collected and analyzed information on buried TRU-contaminated wastes. The DOE sought to establish a consistently derived set of data developed through the application of uniform guidance to support future decisions on how to manage these buried TRU-contaminated wastes. This report summarizes the approach used to develop this information and presents the key results. The total volume of buried TRU wastes at DOE sites is approximately 126,000 m^3 with a much smaller volume (about 11,000 m^3) disposed of at intermediate depths. These previously disposed of wastes contain about 755,000 curies of TRU activity (745,000 curies in buried wastes and 10,000 curies in wastes disposed of at intermediate depths). Although these new volume data are not significantly different, in sum, from previously reported amounts of buried TRU wastes, the new activity data are higher than DOE previously has reported in official data sources. Finally, although Field Offices indicated that the level of confidence associated with these data were generally low to medium, these new data represent a major improvement in the quality of the inventory information because of the methods used to collect the data.

Summary and Results in Context

Radioactive wastes meeting the current definition of transuranic (TRU) wastes were managed in a manner similar to low-level wastes (LLW) at a number of sites owned and operated by the federal government from the 1940s through 1970s. These wastes were generally disposed of by shallow land burial and other similar techniques. Data on these buried TRU-contaminated wastes have been included in a number of documents. In response to questions raised by the Institute for Energy and Environmental Research (IEER), the U.S. Department of Energy (DOE) Carlsbad Area Office (CAO) and Headquarters Office of Environmental Management (EM) requested updated information on buried TRU-contaminated wastes and environmental media from the DOE Field Offices in January 1999. This data update was to include a complete accounting of all previously disposed of wastes and contaminated environmental media containing TRU radionuclides in concentrations greater than 10 nCi/g (considered to be "TRU-contaminated" materials) for which DOE has responsibility. "TRU-contaminated" materials were to be divided into "TRU" materials, i.e., those having TRU radionuclide concentrations greater than 100 nCi/g, and "αLLW" ("alpha low-level waste") materials, i.e., those having TRU radionuclide concentrations between 10 and 100 nCi/g. These terms were used solely to categorize these wastes and environmental media in a consistent manner in this data collection activity.

The overall objective of this data collection effort was to develop a single, comprehensive source of buried TRU-contaminated waste information to support strategic planning and to meet various reporting requirements. A single, up-to-date source for this information allows for more accurate evaluations and assessments, and improves consistency in reporting of this information to various stakeholders, including the IEER. The IEER issued a report in late 1997 asserting, among other things, that DOE's publicly-reported data on buried TRU-contaminated wastes were inconsistent and unreliable, and raised questions about DOE's waste management practices (Fioravanti and Makhijani 1997). The information obtained by this data collection effort appears to address many of the site-by-site concerns raised by IEER relative to buried TRU-contaminated waste volumes and inventories.

The Field Office responses to this data request were reviewed by CAO and EM Headquarters during the summer of 1999 for completeness, accuracy and consistency, and upon resolution of all questions and issues, the data were entered into the *Buried Transuranic-Contaminated Waste and Related Materials Database.* This database was completed on December 15, 1999, and serves as the current source for information on buried TRU-contaminated wastes and environmental media within the DOE complex. This information was developed using uniform guidance for all DOE sites and updates information provided in other document sources such as various revisions of the Integrated Data Base (IDB) report and is being incorporated into DOE's Central Internet Database (www.em.doe.gov/cid).

The results of this data collection activity are summarized in Table 1 which shows the total volume of buried TRU waste at DOE sites as approximately 126,000 m^3. A much smaller volume of TRU waste (about 11,000 m^3) has been disposed of at intermediate depths. These volumes are not significantly different from the total estimated buried TRU waste volume of 140,000 m^3 given in the most recent IDB report (DOE 1997a). However, the site-by-site totals are different than previously reported in some cases. Although the Field Offices noted that the level of confidence associated with these data was generally low to medium, these new data represent a significant improvement over previous estimates because of the methods used to collect the data. The volume of previously disposed of αLLW is significantly larger than the buried TRU waste volume, in excess of 317,000 m^3. Essentially all of this αLLW is buried waste; only 3,200 m^3 of this total is waste disposed of at intermediate depths.

A total of 755,000 curies of TRU activity was reported for these previously disposed of wastes (745,000 curies in buried wastes and 10,000 curies in wastes disposed of at intermediate depths). This curie value is greater than reported in a number of previous documents and provides a better estimate of the TRU activity associated with these wastes. The 755,000 curies figure is about 30 percent of the radioactivity in retrievably stored TRU waste; previous DOE estimates put this value at only 3 percent. The decay-corrected activity (to 2006) is about 406,000 curies. For additional perspective, this TRU activity will decrease to 301,000 curies in an additional 100 years (the year 2106) and 175,000 curies in 1,000 years (the year 3006).

While there are a number of uncertainties associated with the TRU-contaminated soil estimates, the volumes and TRU activities for contaminated soil appear to be significantly smaller than for previously disposed of wastes. The TRU-contaminated soil can arise from three general sources: previous liquid discharges (such as associated with cribs, reverse wells, absorption beds and seepage pits), releases from waste containers in burial trenches and pits (with subsequent migration of radioactivity to the surrounding soil), and above-ground safety and nuclear weapons tests. While the Field Offices were able to provide some estimates of the volumes of TRU-contaminated soil associated with liquid releases and above-ground safety and nuclear weapons tests, no such estimates were provided for contaminated soil associated with releases from waste containers in burial trenches and pits due to data limitations. While TRU-contaminated soil is likely present in proximity to buried wastes, it is very difficult to estimate the volumes of such soil due to the heterogeneity of the wastes and the difficulty in estimating the release and movement of contaminants from intact or degraded waste containers located beneath any engineered covers that might be present. It is

somewhat easier to determine (either by direct measurements or modeling) the volume of contaminated soil resulting from liquid discharges and above-ground safety and nuclear weapons tests. The TRU-contaminated soil volumes given in this report are therefore likely to be only partial estimates of the total volume of soil contaminated with TRU radionuclides above 10 nCi/g.

The reported volume of TRU-contaminated soil is about 32,000 m^3 (essentially all of which is associated with liquid discharges at the Hanford Site) and the reported volume of αLLW soil is about 12,000 m^3. These two volumes do not include the contribution of contaminated soil at Oak Ridge National Laboratory (which was reported as being unknown) nor contaminated soil proximate to buried wastes (which is likely present, but their volumes cannot be reasonably estimated). The TRU activity in this contaminated soil was reported as 26,000 curies. In addition to this soil contaminated by previous liquid discharges and aboveground safety and nuclear weapons tests, subsurface environmental media (rock and debris) became contaminated with TRU radionuclides as a result of underground nuclear weapons tests. A total of 295,000 curies of TRU activity was reported for this subsurface TRU-contaminated rock and debris, which would represent an additional 40 percent if it were included with the inventory of buried and intermediate-depth disposed of TRU waste.

The volumes and TRU activity of DOE radioactive wastes and their dispositions (by degree of isolation) are shown graphically in Figures 1 and 2. As shown in Figure 1, only a very small fraction of the volume of DOE radioactive waste (less than one percent) will be disposed of in geologic repositories or is associated with intermediate depth disposed of TRU wastes. Most of the DOE radioactive waste (by volume) will be disposed of by shallow land burial techniques. However, the waste targeted for geologic disposal contains most (about 98 percent) of the TRU activity (Figure 2). Less than one percent of the radioactivity contained in DOE TRU-contaminated waste and soil is projected to remain in shallow land burial or intermediate depth disposal. (The remaining one percent of TRU activity is associated with subsurface nuclear weapons testing activities.) Even though only a very small fraction of the TRU activity will remain in shallow land burial sites, this activity is potentially more available for environmental transport, and will require careful monitoring over the long term if it is not exhumed.

Most of the radioactivity in LLW disposed of by shallow land burial will decay over time periods on the order of 200 to 300 years, as the half-lives for many of the radionuclides in this waste are 30 years or less. The principal radionuclides in LLW are typically neutron activation products (such as cobalt-60 and iron-55), fission products (such as cesium-137 and strontium-90), and other generally short-lived isotopes. In contrast, the TRU activity (largely associated with plutonium isotopes and americium-241) is much longer lived and will persist over long periods of time. For stored TRU wastes, about 40 percent of the total activity has half-lives less than 50 years, 46 percent has half-lives between 50 and 500 years, and 14 percent has half-lives greater than 500 years (DOE 1997b). Hence, much of the radioactivity in TRU waste will remain in 50 years, whereas much of the radioactivity will have decayed from LLW. While such a profile is not available for previously disposed of TRU waste due to data limitations, this information for stored TRU wastes provides perspective on the general persistence of radioactivity in TRU wastes over time.

DOE's current approach for managing buried TRU-contaminated wastes and environmental media is to address them in the same manner as other environmental restoration issues, i.e., on a site-specific basis working with federal, state, and local regulatory agencies and other stakeholders. This approach is consistent with the Comprehensive Environmental Response, Compensation and Liability Act and other regulatory processes governing contaminated waste sites. The appropriate action to take at each TRU-contaminated waste site will depend on several factors including the technical situation, current and future risks, land-use plans for the facility and nearby area, availability of cost-effective technologies, and other local concerns. The priority afforded to buried TRU-contaminated waste sites is considered in the context of the overall site priorities, which have been negotiated with regulators and stakeholders generally over a multi-year period.

The DOE believes that the current approach for managing buried TRU-contaminated waste sites on a site-specific basis is appropriate, and DOE will continue to work with regulators and local citizens in reaching consensus plans for each of these sites.

Insert Figure 1 here.

Insert Figure 2 here.

Background

Radioactive waste contaminated with transuranic (TRU) radionuclides was first generated by early plutonium chemistry experiments in 1940 at the University of California under the direction of Dr. Glenn Seaborg. The volume of such waste increased significantly during World War II from the operation of plutonium production reactors and chemical processing plants under the Manhattan Project. The nuclear weapons complex grew rapidly in the early 1950s as the country entered into the Cold War with the Soviet Union and the need for special nuclear materials for defense purposes expanded. Descriptions of the early history of nuclear research activities in this country and the development of the nuclear weapons complex and resulting environmental legacy are provided in two recent reports of the U.S. Department of Energy (DOE): *Closing the Circle on the Splitting of the Atom* (DOE 1996a) and *Linking Legacies* (DOE 1997b).

The U.S. Atomic Energy Commission (AEC) first identified TRU waste as a separate category of radioactive waste in 1970, and it was later defined by AEC in 1973 as waste containing greater than 10 nCi/g of TRU alpha-emitting radionuclides. This waste was felt to warrant more stringent handling and disposal considerations than low-level waste (LLW) due to the hazards associated with the increased concentrations of long-lived alpha-emitting radionuclides. Before 1970, such waste was handled in a manner similar to LLW and was generally disposed of by shallow land burial or other similar disposal techniques. The DOE revised the definition of TRU waste in 1982, increasing the lower limit of TRU alpha-emitting radionuclides with half-lives greater than 20 years from 10 to 100 nCi/g. Around this same time period, the U.S. Nuclear Regulatory Commission (NRC) revised its classification of LLW, specifically noting that LLW containing more than 100 nCi/g of TRU radionuclides was not suitable for disposal by shallow land burial. The DOE Field Offices were given flexibility to manage certain other radioactive wastes containing non-TRU alpha-emitting radionuclides (such as uranium-233 and radium-226), TRU alpha-emitting radionuclides with half-lives less than 20 years (such as curium-244 and californium-252), or TRU non-alpha-emitting radionuclides (such as plutonium-241) as TRU wastes.

According to the Immediate Action Directive issued by AEC in 1970, all TRU wastes generated after that date were to be segregated from LLW and placed in retrievable storage pending shipment to and disposal in an approved geologic repository. Several sites, specifically Los Alamos National Laboratory (LANL), Oak Ridge National Laboratory (ORNL) and Savannah River Site (SRS), continued to bury some TRU wastes well into the 1970s. While the intent of these burials may have been retrievable storage at that time, most of these wastes are currently believed to be essentially irretrievably buried. Other than the waste burials at these three sites in the 1970s, all TRU wastes generated since 1970 have been placed in retrievable storage. Some wastes managed by shallow land burial or placed in retrievable storage between 1970 and 1982 as TRU wastes are now considered LLW because they contain TRU alpha-emitting radionuclides in concentrations between 10 and 100 nCi/g.

As used in this report, the term "TRU-contaminated" generally refers to materials (wastes and environmental media) containing TRU alpha-emitting radionuclides in concentrations greater than 10 nCi/g. These materials are divided into two categories: "TRU" materials which have concentrations of TRU alpha-emitting radionuclides in excess of 100 nCi/g and "αLLW" ("alpha low-level waste") materials which have concentrations of TRU alpha-emitting radionuclides between 10 and 100 nCi/g. These definitions are used solely for the purpose of summarizing buried TRU-contaminated waste information in this report. The identification of the category of αLLW for LLW containing TRU alpha-emitting radionuclides in concentrations between 10 and 100 nCi/g does not imply that this is or should be a separate category of LLW having specific management requirements.

The DOE recently issued updated requirements for management of its radioactive wastes in DOE Order 435.1, *Radioactive Waste Management*. This Order defines TRU waste as waste containing more than

100 nCi/g of TRU alpha-emitting radionuclides with half-lives greater than 20 years except for high-level waste (HLW); waste that DOE has determined, with the concurrence of the U.S. Environmental Protection Agency (EPA), does not need the degree of isolation required by 40 CFR 191; or waste that the NRC has approved for disposal on a case-by-case basis in accordance with 10 CFR 61. This definition of TRU waste is the same as that given in the Waste Isolation Pilot Plant (WIPP) Land Withdrawal Act (LWA). The flexibility previously given to Field Offices to manage certain other radioactive wastes as TRU wastes was eliminated in DOE Order 435.1.

Certain radioactive wastes disposed of by shallow land burial (generally prior to 1970) meet the current definition of TRU waste. These wastes are considered to be buried TRU wastes. For this report, buried wastes are those that have been previously (mostly before 1970) disposed of by shallow land burial generally within the top 30 m (100 ft) of the earth's surface, consistent with NRC guidance for near-surface disposal of LLW given in 10 CFR 61 (guidance that mirrored then-existing government and commercial waste disposal practices). In addition to these buried TRU wastes, certain radioactive wastes meeting the current definition of TRU waste were previously disposed of by means that provide greater waste-isolation potential than shallow land burial, e.g., by hydrofracture disposal at ORNL and placement in shafts at LANL and Nevada Test Site (NTS) at depths generally between 30 m (100 ft) and 300 m (1,000 ft) of the earth's surface. These wastes are not considered buried TRU wastes in a strict sense. However, an accounting of such TRU wastes disposed of at intermediate depths, along with previously disposed of αLLW (as defined above), was included in this recently completed data collection effort for completeness. While the intent of this data collection activity was to obtain as complete an accounting of previously disposed of TRU-contaminated wastes as reasonably possible, it is acknowledged that certain TRU-contaminated wastes are not covered in this report, such as those associated with previous atmospheric nuclear tests in the Marshall Islands, sites where ocean dumping took place from 1946 through 1970, and any TRU-contaminated wastes disposed of at the six original commercial LLW disposal sites.

In addition to previously disposed of TRU-contaminated wastes, some soils have become contaminated with TRU radionuclides in concentrations exceeding 10 nCi/g, and in some cases 100 nCi/g, as a result of past discharges of liquid wastes onto the ground, spills of liquid wastes, and surface and subsurface nuclear weapons tests. Also, a largely unknown volume of soil in the vicinity of burial sites (generally interstitial soil between waste containers) may have become contaminated with TRU radionuclides as a result of past management practices such as crushing drums after placement and radionuclide migration from the wastes. These soils contaminated by previous liquid and solid waste management activities could also be considered αLLW or TRU wastes, depending on the level of contamination. Further, certain additional special test projects, e.g., criticality experiments and safety testing of nuclear devices, resulted in contamination of soil with TRU radionuclides in excess of 10 and possibly 100 nCi/g.

Past estimates of buried TRU-contaminated wastes have varied from year to year and from one data source to another. The reasons for these differences include limited historical records, the changing definition of what constitutes TRU waste, different methods for managing certain materials from one site to another, and differing objectives for estimating inventories, as it was not always clear what materials should be reported. For example, contaminated soil resulting from past nuclear weapons testing and research is commonly considered contaminated environmental media rather than waste because it does not meet the regulatory definition for waste generation (which involves removing contaminated material for subsequent treatment and disposal). Also, TRU wastes disposed of by hydrofracture techniques were sometimes included in estimates of buried TRU wastes, even though the disposal method was not shallow land burial.

Summary of Data Collection Process

To improve consistency of buried TRU-contaminated waste information, the DOE Carlsbad Area Office (CAO) and Headquarters Office of Environmental Management (EM) jointly requested updated information by issuing a "data call" to the DOE Field Offices on January 15, 1999 (DOE 1999a). The data call was developed in a tiered format (from general to more specific) to allow for the reporting of as much information on buried TRU-contaminated waste as was available at the various sites. The data call package consisted of detailed guidance on the information to be provided, forms (which could be completed either by hard-copy or electronically), and additional narrative describing the need for more complete information and identifying past problems with the reporting of buried TRU-contaminated waste information. (A copy of the data call guidance and forms is included as Appendix A to this report.) This information request was discussed with the Field Offices at the Transuranic Waste Steering Committee meeting in Scottsdale, Arizona, in January 1999, and in a conference call in early March. Additional discussions were held with individuals responding to the data call to address site-specific questions and to ensure that the data provided was as complete as possible.

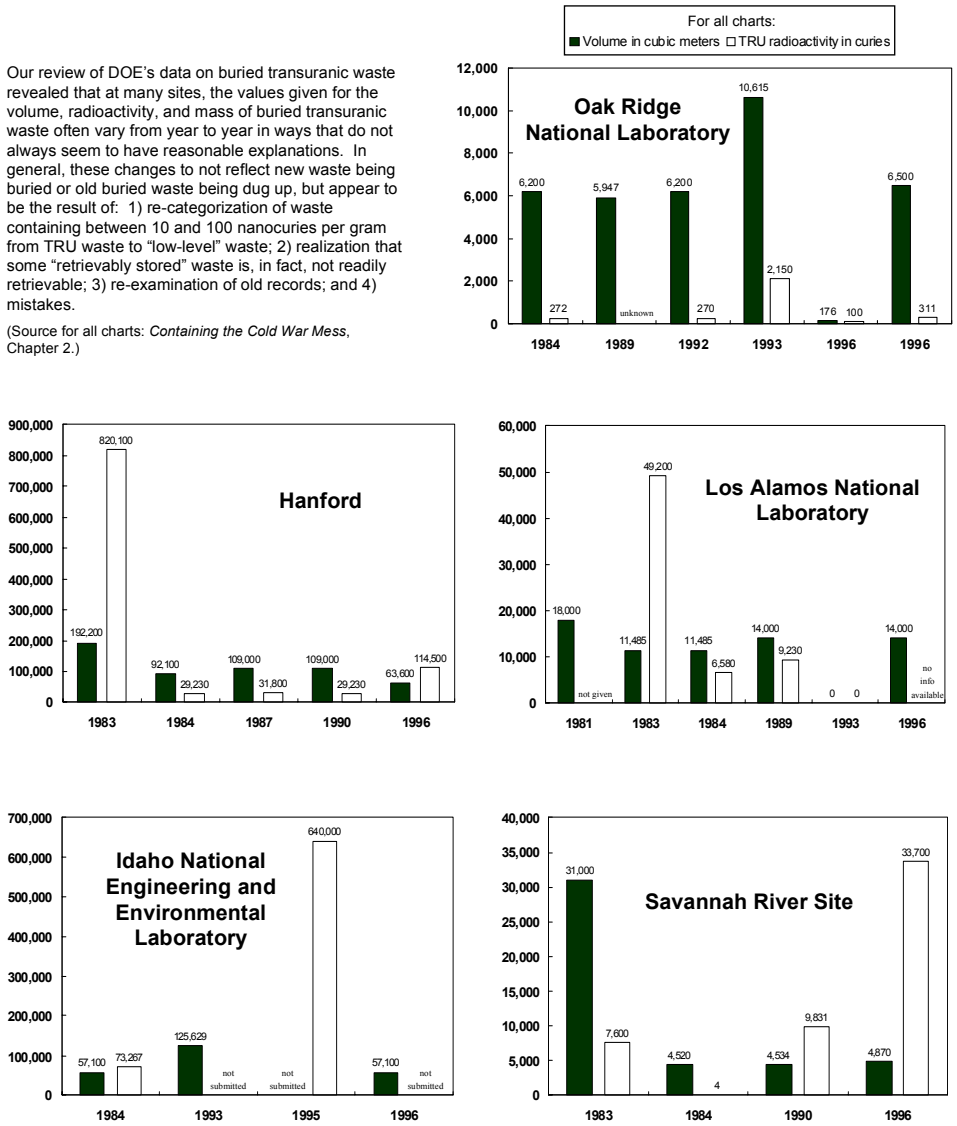
The purpose of the data call was to develop a single, comprehensive source of buried TRU-contaminated waste information to support strategic planning and to meet various reporting requirements. A single, up-to-date source for this information would allow for more accurate evaluations and assessments, and improve consistency in reporting of this information to various stakeholders, including the Institute for Energy and Environmental Research (IEER). The IEER issued a report in late 1997 asserting, among other things, that DOE's publicly-reported data on buried TRU-contaminated wastes were inconsistent and unreliable, and raised questions about DOE's waste management practices (Fioravanti and Makhijani 1997). The buried TRU waste information compiled by IEER for their 1997 report was shown graphically in another publication of IEER (Makhijani and Fioravanti 1999) and this graphic is reproduced here as Figure 3. The data call supporting this report was issued in part to respond to this concern and also to ensure a full accounting of previously disposed of TRU-contaminated waste. The results will also assist in future programmatic decisions for managing DOE TRU wastes.

The scope of the data call included all previously disposed of waste having concentrations of TRU radionuclides in excess of 10 nCi/g. The Field Offices were requested to partition (as a percentage) the volume greater than 100 nCi/g (and thus meeting the current definition of TRU waste) and the volume between 10 and 100 nCi/g (considered to be αLLW), if possible. In addition, the data call requested estimates of all soil, rock and other materials that may be contaminated with TRU radionuclides to a level greater than 10 nCi/g, apportioned as percentages into the same two categories as for previously disposed of waste. Any additional previously disposed of materials that could be considered TRU-contaminated wastes were also to be reported. For example, certain Field Offices managed wastes containing uranium-233, radium-226, curium-244, californium-252 and plutonium-241 as TRU wastes. These wastes and any TRU-contaminated wastes disposed of by means other than shallow land burial, e.g, hydrofracture disposal of certain radioactive sludges at ORNL and environmental media that may be contaminated with TRU radionuclides in concentrations greater than 10 nCi/g, were to be included in the data call response. That is, the data call requested a complete accounting of all previously disposed of TRU-contaminated waste and environmental media for which DOE has responsibility regardless of regulatory definition (waste or environmental media), DOE organization responsible for managing this material (EM or non-EM), time of disposal (before or after 1970), and definition of TRU waste at the time of disposal (before or after 1982).

While the data call focused on waste and media volumes, additional information on contaminants, physical form and projected management plans was requested to the extent it was available. Historical data on contaminants and physical forms are lacking for much of the previously disposed of waste, especially for that disposed of in the 1940s and 1950s. Also, characterization of waste burial grounds and contaminated soil

has not been completed at most sites, and management plans are still being developed. Thus, it was recognized *a priori* that it would be difficult to provide all of the requested information. Field Offices were requested to use best professional judgement and be as complete as possible. All major assumptions and calculations (including reference to previously completed analyses and field studies for buried TRU-contaminated wastes) were to be documented to ensure traceability of the information.

Figure 3. Graphical Representation of Historic DOE Estimates of Buried TRU Waste as Compiled by IEER and Reproduced from Makhijani and Fioravanti (1999)



Buried TRU-contaminated waste information was provided to DOE CAO for six DOE sites in the spring of 1999: Hanford Site (Hanford), Idaho National Engineering and Environmental Laboratory (INEEL), LANL, NTS, ORNL, and SRS. The information provided by the various DOE Field Offices was entered into a database for use by CAO and EM Headquarters. This information was reviewed for completeness and consistency with previously reported buried TRU-contaminated waste information. Written comments were provided to the Field Offices in July 1999 (DOE 1999b), highlighting areas that were felt to warrant

additional investigation. Follow-up conference calls were held with Field Office representatives to discuss these comments and to address any outstanding issues. Updated information was provided by each of these Field Offices and the Rocky Flats Environmental Technology Site (RFETS) shortly thereafter.

All of the updated information was again reviewed and any outstanding issues and concerns were addressed via telephone calls. Upon resolution of all issues, the information was updated in the database. The *Buried Transuranic-Contaminated Waste and Related Materials Database* was finalized on December 15, 1999.

Inventory of Previously Disposed of TRU-Contaminated Wastes

The inventories of previously disposed of TRU-contaminated wastes are summarized in Tables 2 and 3. Two types of volumes are presented in these tables: a TRU volume (which represents the volume of waste having a TRU-radionuclide concentration in excess of 100 nCi/g) and an αLLW volume (which represents the volume of waste having a TRU-radionuclide concentration between 10 and 100 nCi/g). In addition, two values of the TRU-radionuclide activities are given for each location: the reported activity (in curies) and a decay-corrected activity to 2006. The year 2006 was selected as the time for presenting decay-corrected TRU activities because this is the earliest year in which these materials could be scheduled for disposal at WIPP, should this option be the selected remedy for any of these materials at the individual sites. The decay-corrected activities include the contribution of TRU radionuclides resulting from the radioactive decay process. For example, plutonium-241 decays with a 14.4 year half-life by the emission of a beta particle to americium-241, an alpha-emitting radionuclide having a 432-year half-life. The activity contribution from americium-241 resulting from the radioactive decay of plutonium-241 is included in the decay-corrected activities. As a note, the maximum in-growth activity of americium-241 is about three percent of the initial activity of plutonium-241, and this peak activity occurs 73 years in the future.

The total volume of buried TRU waste at DOE sites is approximately 126,000 m^3. A much smaller volume of TRU waste (about 11,000 m^3) has been disposed of at intermediate depths. The volume of previously disposed of αLLW is significantly larger than the buried TRU waste volume, in excess of 317,000 m^3. Essentially all of this αLLW is buried waste; only 3,200 m^3 of this total is waste disposed of at intermediate depths. A total of 755,000 curies of TRU activity was reported for these previously disposed of wastes (745,000 curies in buried wastes and 10,000 curies in wastes disposed of at intermediate depths). The decay-corrected activity (to 2006) is about 406,000 curies.

Buried TRU-Contaminated Wastes

The buried TRU-contaminated wastes are given in Table 2. As can be seen in this table, Hanford has the largest volume of buried TRU waste of the six sites, with a total of 75,800 m^3 containing 67,800 curies of TRU activity (1995 value). The decayed activity (to year 2006) for the buried TRU wastes is 60,000 curies. The waste volume reported for Hanford is limited to wastes containing TRU radionuclides in concentrations greater than 100 nCi/g. Separate estimates of waste containing TRU radionuclides in concentrations between 10 and 100 nCi/g, i.e., αLLW, are not available for this site. Most of the materials are currently planned to be managed by in-situ containment. The alternative selected in the National Environmental Policy Act Record of Decision for Burial Ground 618-11 was to proceed with removal and processing of waste (DOE 1988b). By analogy, the same remedy is being considered for Burial Ground 618-10 subject to public comment.

The INEEL has the next largest volume of buried TRU waste and the largest curie inventory by far, with a total of 36,800 m^3 containing 634,000 curies of TRU activity (63% of which is plutonium-241, a non-alpha-emitting radionuclide with a 14.4-year half-life). This reported activity represents the initial

emplaced curies. The decayed activity (297,000 curies in year 2006) is less than half of the curie content initially emplaced, largely due to radioactive decay of plutonium-241. The contribution of the alpha-emitting decay product americium-241 is included in this decayed value. The volume reported for INEEL represents wastes having a concentration of TRU radionuclides in excess of 10 nCi/g, i.e., it represents the sum of the buried TRU wastes and αLLW at this site. Separate estimates of the fraction of this waste containing more than 100 nCi/g are not available. This waste is located in the Subsurface Disposal Area of the INEEL Radioactive Waste Management Complex (RWMC). Although a decision has not yet been made, the current planning assumption is that about 10% of this volume, i.e., the wastes in Trenches 1-10, will to be managed by in-situ containment and the remainder will be excavated and treated with the resultant TRU waste transferred to WIPP for disposal. The wastes in Trenches 1-10 are assumed to contain about 10% of the total TRU activity, i.e., in direct proportion to the volume of TRU waste in these trenches. Estimates of the TRU curies associated with various disposal areas in the INEEL RWMC are not available. In addition to excavation, various in-situ based technologies are also under consideration. The remaining LLW that has a concentration of TRU radionuclides below 10 nCi/g will be disposed of on-site.

The LANL and NTS contain lesser amounts of buried TRU wastes, 8,620 m^3 and 21 m^3, respectively. The LANL also contains a large volume of αLLW (313,400 m^3) in four burial grounds at the laboratory. The total TRU activities are 21,000 curies for the LANL wastes and 229 curies for the NTS wastes. Both values represent initial emplaced curies. The decayed activities (to year 2006) for the LANL wastes are essentially unchanged because most of the reported activity is plutonium-239 which decays quite slowly due to its long half-life of 24,000 years. The decayed activity of the NTS wastes is lower (152 curies) largely due to radioactive decay of plutonium-241. In-situ containment of most of these materials is currently planned.

Volume estimates are not available for many of the TRU-contaminated wastes previously disposed of at ORNL and SRS, although an estimate is available for TRU wastes in the Old Radioactive Waste Burial Ground at SRS (4,530 m^3) and for several areas at ORNL. A reasonably good estimate of the TRU activity associated with the buried TRU-contaminated wastes at the three locations at SRS is available; the total reported value of 21,900 curies corresponds to 18,500 curies in 2006. The activity associated with TRU-contaminated wastes at ORNL is generally unknown. While in-situ containment is generally the preferred option for these wastes, especially for SRS, the DOE may excavate certain buried TRU-contaminated wastes within Solid Waste Storage Area (SWSA) 5 North at ORNL. Based on the results of this pilot excavation, additional buried TRU-contaminated wastes within SWSA 5 may also be excavated. These remedial plans are considered preliminary and are subject to change. Much more information on recently completed efforts to compile and reconcile past estimates of buried TRU-contaminated wastes at ORNL and identify current data gaps is given in Trabalka (1997). The buried TRU-contaminated waste volume at SRS has not been examined in detail in recent years since the current plan is to contain the previously disposed of wastes in place.

TRU-Contaminated Wastes Disposed of at Intermediate Depths

The TRU-contaminated wastes that have been disposed of at intermediate depths, e.g,. in shafts, boreholes and by hydrofracture techniques, are given in Table 3. As can be seen, TRU-contaminated wastes were disposed of by these techniques at three sites: LANL, NTS and ORNL. About 11,000 m^3 of TRU waste (or less than 10% of the total volume of TRU waste disposed of by shallow land burial) has been disposed of by such techniques at the three sites with an additional 3,200 m^3 of αLLW being present at LANL and ORNL in the same disposal units. The largest volume of previously disposed of TRU waste is associated with the New Hydrofracture Facility at ORNL, which accounts for two-thirds of this total. Most of the rest is attributable to wastes in shafts in Material Disposal Areas (MDAs) C, G and T at LANL, with NTS greater confinement disposal (GCD) Shafts 1, 2, 3, 4 and 7 contributing the remainder. About 10,000 curies of TRU

activity are associated with these wastes. All of these wastes previously disposed of at intermediate depths are expected to be managed in place.

Two sites contain TRU-contaminated rock and debris as a result of previous nuclear weapons tests: LANL and NTS. While these materials are not officially defined as "TRU-contaminated wastes" and were not emplaced for the primary purpose of disposal, they do represent materials that have similar radiological characteristics to such wastes and are reported here for completeness. A total of 4,400 m^3 containing 2,480 curies of TRU radionuclides is attributable to underground experiments involving special nuclear material conducted in multiple shafts and chambers at LANL's MDA AB. This material will be managed by in-situ containment. Although a volume estimate is not available for the amount of material associated with subsurface nuclear weapons tests at NTS, this material is estimated to contain a total of 292,000 curies (1996 value) of TRU radionuclides. This activity will be reduced to 217,000 curies by year 2006. Land use controls will limit access to this large volume of subsurface contaminated rock.

An additional small volume (76 m^3) of TRU waste is located in several underground storage tanks at Hanford. This sludge, which contains 10,300 curies of TRU activity (initial emplaced value) and may be more correctly considered "stored" rather than "disposed of" waste, is included in this report for completeness as it was provided in the data call response for Hanford. The decay-corrected activity in this sludge (to year 2006) is estimated to be 7,720 curies. Access/institutional controls are the current management plan for this material.

Inventory of TRU-Contaminated Soil at the Five Major Sites

The volumes and activities of TRU-contaminated soil are summarized in Table 4. The information included in this table is the same as that described earlier for previously disposed of TRU-contaminated wastes. Two general types of TRU-contaminated soil volumes have been reported in the past for the five major sites, i.e., Hanford, INEEL, LANL, ORNL and SRS: soil contaminated by previous liquid discharges and contaminated soil in proximity to solid wastes. The following text discusses each of these two categories separately for consistency with previously reported information. Text describing additional TRU-contaminated soil and waste volumes at other sites is provided in the next section. The volume of TRU soil is about 32,000 m^3 and the volume of αLLW soil is about 12,000 m^3. A total of 26,000 curies of TRU activity was reported for this contaminated soil.

TRU-Contaminated Soil Associated with Liquid Discharges

As shown in Table 4, a total of 38,600 m^3 of soil has been contaminated by liquid discharges at three sites: Hanford, LANL and ORNL. Hanford contains the largest volume of contaminated soil (31,600 m^3) largely associated with cribs, ditches and trenches. This contaminated soil contains a total of 25,400 curies of TRU activity. The reported activity is given for year 2020, the time at which a decision on management of these units is currently planned. The "decay-corrected" value is somewhat larger (32,400 curies) as it represents the activity in year 2006. As for buried TRU-contaminated wastes at Hanford, information is limited to soil containing TRU radionuclides in concentrations exceeding 100 nCi/g, i.e., TRU soil. No estimates of αLLW soil are available for Hanford. These contaminated soil sites are expected to be managed by in-situ containment.

The TRU-contaminated soil volumes and TRU activities for LANL and ORNL are significantly lower, although specific estimates are generally lacking for ORNL. The volume of TRU soil at LANL is 162 m^3 and the volume of αLLW soil is 6,840 m^3; this soil (absorption beds) contains about 10 curies of TRU activity. The absorption beds in MDAs T and V are generally expected to be managed by in-situ

containment, although other alternatives are being considered. The TRU-contaminated soil in seepage beds and trenches at ORNL contains a total of 53 curies of TRU activity. Immobilization of the high-activity fission product residues in the seepage beds and trenches is currently planned. This process would also permanently immobilize any TRU-contaminated residues within the treatment zone.

TRU-Contaminated Soil Proximate to Solid Wastes

While the Field Offices in some instances were able to provide estimates of the volumes of TRU-contaminated soil associated with liquid releases, they were not able to provide such estimates for contaminated soil in proximity to buried wastes. The general lack of TRU-contaminated soil estimates associated with solid wastes was noted in the comments provided by CAO and EM Headquarters staff to Field Office staff following the initial submittals. In response, Field Office staff maintained that such estimates were simply not available due to data limitations. Hanford staff did note that the reported buried TRU waste volume included the volume of proximity soil (interstitial soil between waste containers), but did not provide any data to support the assumption that this soil was indeed contaminated and if contaminated, to what extent.

It is somewhat easier to develop estimates of the TRU-contaminated soil volumes associated with liquid releases than for solid wastes because the radionuclide inventories in the released liquids are reasonably well known, so a volume estimate can be developed by measuring or modeling the extent to which these released contaminants have migrated in the soil. Depending upon the complexities of the site, such analyses may be readily performed, while in other cases it may be more difficult. Similar evaluations for solid buried wastes are more difficult because of the heterogeneity of the wastes and because it requires estimating the release and movement of contaminants from intact or degraded waste containers located beneath any engineered covers that might be present.

Previous documents, including various revisions of the Integrated Data Base (IDB) report, have reported estimates of the volumes of TRU-contaminated soil in proximity to buried wastes. Some of these volumes were noted by the IEER as having wide variations over the years (see Figure 3). One possible reason for this wide variation was the lack of guidance by CAO and EM Headquarters staff to Field Office staff for determining when soil should be considered "TRU-contaminated." The data call issued to the Field Offices addressed this concern by specifically identifying TRU soil as soil having a concentration of TRU radionuclides greater than 100 nCi/g and αLLW soil as soil having a concentration of TRU radionuclides between 10 and 100 nCi/g. When definitive thresholds are defined, as they were in this data call, the Field Offices stated that it was not possible to give quantitative estimates of TRU-contaminated soil associated with solid wastes. This has probably always been the case.

The "best" historical estimates of TRU-contaminated soil volumes associated with buried TRU wastes are probably those given in DOE (1988a) as follows: Hanford (40,000 m^3); INEEL (56,600-156,600 m^3); LANL (1,000 m^3); ORNL (12,000-60,000 m^3); and SRS (38,000 m^3). These values are more than 10 years old and were generally derived by reviewing historical disposal records or from pit/trench dimensions rather than from field characterization activities. It was strongly suggested by CAO and EM Headquarters staff in comments to Field Office staff that these estimates be considered in developing comprehensive buried TRU-contaminated waste information as part of this data collection activity. In all cases the Field Offices declined to validate these estimates since they were not able to determine the basis for them. These volumes were developed solely for the purpose of supporting early disposal or remedial planning activities for waste sites containing TRU-contaminated materials. It is more appropriate to refer to the volume of contaminated soil associated with solid waste as being "unknown" rather than propagate the use of values that have no firm scientific basis. While contaminated soil proximate to buried solid wastes could well be present, their volumes cannot be reasonably estimated. It is noted, however, that in the few instances where

characterization work has specifically looked for contamination around the buried wastes, very little has been found.

Additional TRU-Contaminated Waste and Soil

The RFETS reported that although it did not contain any buried TRU wastes, it did contain a large volume of soil (in excess of 100,000 m^3) contaminated with low concentrations of TRU radionuclides (generally less than 10 nCi/g) that would be ultimately managed as waste. However, none of this soil is expected to require management as TRU waste, because the concentrations of TRU radionuclides are expected to be significantly less than 100 nCi/g (and likely 10 nCi/g). Although some on-site areas may contain isolated "hot spots" having TRU-radionuclide contamination in excess of 100 nCi/g, e.g., 903 Pad, when remediated, the concentrations of TRU radionuclides in the resultant wastes would be significantly less than 100 nCi/g (and likely 10 nCi/g) and would thus be managed as LLW. Also, aboveground safety and nuclear weapons tests at NTS have resulted in contaminated soil covering an area of 6 ha (15 acres) to an average depth of 8 cm (3 in). The volume of this αLLW soil is estimated to be 4,800 m^3 containing 86 curies of TRU activity. These values represent soil contaminated with TRU radionuclides in excess of 10 nCi/g. This soil is scheduled for excavation and disposal as LLW at NTS. Two of the five main locations have been excavated and resulted in the generation of less than 1 m^3 of TRU waste.

Buried TRU-contaminated waste and soil information has been developed for DOE sites, and this information is available in an electronic database (*Buried Transuranic-Contaminated Waste and Related Materials Database*) for use by CAO and EM Headquarters. In addition to the sites addressed in this database, buried TRU wastes and soil have been reported for three additional sites in previous IDB reports and other documents including the *Linking Legacies* report (DOE 1997b). A discussion of these three sites is provided here to complete the picture for previously reported information on buried TRU-contaminated wastes and soil.

A very small amount of buried TRU waste was previously reported for Sandia National Laboratories in New Mexico (about one cubic meter). This waste is currently in storage at the site and will be transferred to LANL in the near future for treatment and storage prior to disposal. In addition, a relatively small volume of buried TRU waste has been reported for a commercial site in western New York (the West Valley Site). This site is the subject of an ongoing project to solidify stored HLW by vitrification and manage the associated facilities and wastes generated by this project. The West Valley Site is estimated to contain 1,350 m^3 of buried TRU waste (DOE 1997a).

Finally, soil in the Miami-Erie Canal at the Mound Environmental Management Project in Miamisburg, Ohio, was contaminated with plutonium-238 as a result of an accident in which liquid wastes were released to the canal in 1969. The volume of TRU-contaminated soil was estimated as 288 m^3 in 1992 (DOE 1992). The Miami-Erie Canal has recently been remediated (the removal action was completed in May 1998). The selected remedy consisted of removing soil to a specified cleanup level that was developed in consultation with stakeholders (75 pCi/g or 0.075 nCi/g) and disposing of it off-site as LLW, as the average plutonium concentration in this soil was well below 100 nCi/g. A total of about 29,000 m^3 of soil was removed from the canal area. Included in this excavated soil was the amount previously identified as being TRU-contaminated.

Risk Estimates for Buried TRU Wastes: Summary of WIPP SEIS II Analysis

A number of risk analyses for the buried TRU-contaminated waste sites have been prepared over the years. Most recently, the Final Supplemental Environmental Impact Statement II (SEIS II) prepared for WIPP (DOE 1997c and Buck et al. 1997) contained a "no action" assessment of the health risks associated with leaving in place the buried TRU wastes at the five major sites: Hanford, INEEL, LANL, ORNL and SRS. To support this assessment, estimates were made of the volumes and radionuclide inventories associated with the buried TRU wastes at these five sites, using inventory information intended to bound the impacts from these wastes. The total volume of buried TRU waste at these five sites was estimated to be about 140,000 m^3 in SEIS II. Most of this waste was identified as being contact-handled waste (with a dose rate less than 200 mrem/hr). Only a few percent (by volume) of the buried TRU waste was considered to be remote-handled waste (with a dose rate above 200 mrem/hr).

In the SEIS II analysis, it was assumed that the buried TRU wastes had the same radionuclide profiles as for the stored and newly generated waste. This was done since detailed characterization information for buried TRU waste is generally lacking. The most recent IDB report notes that the radionuclide concentrations in buried TRU wastes are significantly less than for stored contact-handled waste (see Table A.1 of DOE [1997a]). A comparison was made of the volumes and radionuclide inventories used for buried TRU wastes in the SEIS II assessment with those reported by the Field Offices in response to this data call to determine the degree of conservatism associated with this "no action" assessment. (See Appendix A of DOE [1997c] and Buck et al. [1997] for an description of these volumes and inventories.)

The buried waste volumes are generally in good agreement, but the radionuclide concentrations (and hence radionuclide inventories) used in the SEIS II analyses were conservative (higher) by factors ranging from 20% (for INEEL) to more than 20 (for SRS). The degree of conservatism varied by site, but in no case were the values used in the SEIS II assessment lower than the corresponding inventories associated with the recently compiled buried TRU-contaminated waste information included in this report. That is, using the radionuclide profiles for stored and newly generated TRU wastes for buried TRU wastes (as was done in SEIS II) results in an overestimate of the actual risk associated with the buried waste.

In the SEIS II, the potential health impacts from exposure to radionuclides and hazardous chemicals were evaluated with a DOE-developed computer code. The code was used to calculate contaminant fluxes from the source, environmental fate and transport to the receptor point, and toxicological impacts and carcinogenic risks from the hazardous chemicals and radionuclides. Two analyses were conducted by Buck et al. (1997). The first addressed the impacts of human intrusion at or near the buried TRU waste sites under each of four hypothetical exposure scenarios. The second analysis addressed long-term (10,000-year) lifetime exposures to individuals and populations following the assumed loss of institutional controls.

The SEIS II estimates that a total of 13 latent cancer fatalities may be attributable to buried TRU wastes over a period of 10,000 years, largely due to exposures at INEEL and LANL. As noted previously, the radionuclide inventories used in the SEIS II calculations are conservative. As such, the "true" estimate is lower, less than ten latent cancer fatalities over 10,000 years (assuming no intrusion into the burial grounds), all other parameters being the same. In comparison to all benchmarks of acceptable risks known to DOE, such risks would be considered very low.

Buried TRU-Contaminated Waste and Soil Sites Not Addressed in This Report

As noted previously, there are other TRU-contaminated wastes and soil at sites that are not the responsibility of or are not being managed by DOE. Radioactive wastes were disposed of at six commercial facilities

beginning in the early 1960s. These six facilities are located at Barnwell, South Carolina; Richland, Washington; Beatty, Nevada; Maxey Flats, Kentucky; Sheffield, Illinois; and West Valley, New York. Only the first two sites in this list are currently accepting wastes for disposal. Some LLW disposed of at these six sites could be classified as TRU waste, since disposal operations at these commercial sites were initiated prior to TRU waste being identified as a separate category of radioactive waste in 1970. (The estimated volume of buried TRU waste at the West Valley Site was given previously.) The DOE is not responsible for addressing any buried TRU-contaminated wastes that may be present at these sites, other than participating as a "potentially responsible party" for the remedial action conducted under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) at Maxey Flats, Kentucky. The locations and volumes of wastes disposed of at these six LLW disposal sites are given in DOE (1997a).

A number of sites in the Pacific Ocean (mostly in the Marshall Islands) were contaminated by previous surface tests of nuclear devices. The government of the United States reached a settlement with citizens and nationals of the Marshall Islands on all claims, past, present and future, which were in any way related to previous nuclear weapons tests conducted in the Marshall Islands (48 USC Sec. 1901 et. seq.). Also, radioactive wastes were disposed of at a number of sites in the Pacific and Atlantic Oceans from 1946 through 1970 (NACOA 1984; DOE 1997a). These sites are the responsibility of the National Oceanic and Atmospheric Administration and EPA. The wastes disposed of in the oceans are irretrievable under any realistic set of conditions.

In addition to the sites listed above as not being covered in this report, there are undoubtedly some additional sites which contain buried TRU-contaminated wastes and soil. For example, it is possible that some soil beneath HLW storage tanks at Hanford could be contaminated with plutonium and other TRU radionuclides in excess of 10 or 100 nCi/g as a result of previous leaks from certain single-shell HLW storage tanks. Detailed characterization of such soil has not yet been completed. Also, some wastes and experimental test sites at NTS that are still classified for security reasons contain TRU material. However, the classified inventories of TRU material associated with these classified activities are relatively small compared to the unclassified inventories for the underground test areas given in Table 3 of this report. This report also does not address TRU-contaminated waste that will continue to be generated as a result of plutonium stabilization and management activities, environmental restoration (including remediation of some sites where TRU waste was previously buried), decontamination and decommissioning, waste management, and testing and research activities. While it is not possible to guarantee a 100 percent accounting of all buried TRU-contaminated waste and soil sites, this data-collection activity has provided as complete an accounting as reasonably possible.

Summary of Buried TRU-Contaminated Waste Information

A summary of the information given previously in Tables 2, 3 and 4 is provided in Table 5. This summary table presents information at a high (facility) level to allow for easy inter-site comparisons on the extent of the buried TRU-contaminated waste and soil issue across the DOE complex. Table 5 does not include the sludge reported by Hanford in underground storage tanks (76 m^3) nor the volumes and activities associated with contaminated rock and debris from subsurface testing activities at LANL and NTS. (These volumes were given in Table 3.)

As can be seen in Table 5, the total volume of buried TRU waste at DOE sites is approximately 126,000 m^3. A much smaller volume of TRU waste (about 11,000 m^3) has been disposed of at intermediate depths. The volume of previously disposed of αLLW is significantly larger than the buried TRU waste volume, in excess of 317,000 m^3. Essentially all of this αLLW is buried waste; only 3,200 m^3 of this total is waste disposed of at intermediate depths. A total of 755,000 curies of TRU activity was reported for these previously

disposed of wastes (745,000 curies in buried wastes and 10,000 curies in wastes disposed of at intermediate depths). The decay-corrected activity (to 2006) is about 406,000 curies. The TRU activity associated with the αLLW is less than 10% of that in the buried TRU waste.

The volume of TRU soil is about 32,000 m^3 (essentially all of which is associated with liquid discharges at Hanford) and the volume of αLLW soil is about 12,000 m^3. These two volumes do not include the contribution of contaminated soil at ORNL which was reported as being unknown. The TRU-contaminated soil volume contains a total of about 26,000 curies of TRU activity (reported value); the decay-corrected activity (to 2006) is somewhat higher (33,000 curies) as the reported activity for Hanford reflects values in 2020. As noted previously, contaminated soil proximate to buried wastes is likely present, but their volumes cannot be reasonably estimated.

To place these volumes and TRU activities in perspective, the disposal capacity of WIPP is about 175,600 m^3. Of this total, no more than above 7,080 m^3 can be remote-handled waste, i.e., having a contact dose rate in excess of 200 mrem/yr. The remaining volume capacity is for contact-handled TRU waste. In addition, the WIPP LWA limits the total remote-handled TRU waste curie content to 5,100,000 curies. The total activity of TRU radionuclides in the waste currently targeted for disposal at WIPP is about 5,800,000 curies. Of this total, less than 1 million curies is associated with remote-handled waste (DOE 1997c). A total of 117,000 m^3 containing 2,510,000 curies of TRU activity was in retrievable storage at the end of 1998. Thus, even though the *untreated* volume of previously disposed of TRU waste (137,000 m^3) is comparable to the disposal capacity of WIPP, this waste only contains about 10 percent of the TRU activity in the wastes ultimately planned for disposal at WIPP. This is consistent with the previous discussion of the analyses performed in the WIPP SEIS II for the buried TRU waste sites and supports the conservatism of that analysis. If the currently existing TRU activities in the buried TRU wastes and retrievably stored TRU wastes are compared, it is seen that buried TRU waste contains about 30 percent of the activity of the stored TRU waste. This percentage of buried TRU waste compared to stored TRU waste is much larger than the three percent estimate given in the 1987 DOE report on buried TRU wastes (DOE 1987).

For additional perspective, it is useful to compare buried TRU activities with those expected to be disposed of in deep geologic repositories. The volume of solidified DOE HLW currently planned for disposal in a geologic repository is estimated to be about 21,000 m^3. This waste is estimated to contain about 7,600,000 curies of TRU activity. The volume of spent nuclear fuel targeted for disposal in a geologic repository is estimated to be about 1,900 m^3 and contain approximately 16,000,000 curies of TRU activity (DOE 1999d). The total amount of DOE TRU activity scheduled for disposal in geologic repositories (WIPP and Yucca Mountain) is thus about 29,000,000 curies. The activity associated with the previously disposed of TRU waste (755,000 curies) is seen to represent between 2 and 3% of the total TRU activity in these wastes.

About one-third of the buried TRU waste is planned for excavation, treatment and disposal at WIPP. Most of this waste is located at the INEEL RWMC; about 90% of the buried TRU waste in the RWMC is currently scheduled for excavation. The TRU waste planned for excavation is estimated to contain about 571,000 curies, or about 75 percent of the total TRU activity. (This curie estimate assumes that the activity associated with the excavated wastes at INEEL is linearly proportional to the volume of waste excavated.) Hence, the amount of activity in the TRU wastes projected to remain in shallow land burial or intermediate depth disposal sites is estimated to be about 184,000 curies, or about 0.6% of the total amount of DOE TRU activity. As stated earlier, the health risks associated with buried TRU waste sites are very low, even if the total inventory was assumed to be left in place. Even so, the buried TRU activity is potentially more available for environmental transport, and will require careful monitoring over the long-term if it is not exhumed.

Comparison with Estimates Reported by IEER

A comparison of the results given in this report for TRU wastes and soil with those presented by IEER (Fioravanti and Makhijani 1997) is given in Table 6. As can be seen in this table, the overall volumes are in reasonable agreement other than the contaminated soil volume associated with solid waste, which is currently reported as being unknown. "Unknown" should *not* be interpreted as meaning zero; it simply means that it is not possible to provide reasonable estimates at this time. As suggested by IEER, the current activity estimates of buried TRU wastes are higher than previous DOE estimates.

The IEER noted that there have been wide variations in the volumes of buried TRU-contaminated wastes and soil reported by DOE over the past several years. One reason for this variation was uncertainty by Field Office staff over what volumes were to be reported, i.e., container volumes, soil volumes, and trench/pit volumes were often confused and interchanged. The data call for this report addressed this issue by clearly articulating which volumes were to be reported, although Field Offices were sometimes not able to completely comply with the information requests. This analysis of the data provided by the Field Offices has resulted in greater confidence in estimates of buried TRU-contaminated wastes and soil than in the past. In almost all cases, significant additional (intrusive) characterization of the buried TRU-contaminated waste sites would be necessary to provide more detailed information. Whether the effort to obtain such information is worth the costs and potential health and safety risks is evaluated by DOE and regulatory agencies on a site-specific basis.

Conclusions and Recommendations

In this report, DOE sought to provide a complete accounting of previously disposed of TRU-contaminated wastes and environmental media to the extent that information is currently available at the various Field Offices. This information updates that provided in other documents such as various revisions of the IDB report and was developed using uniform guidance for all DOE sites. The reported inventories of buried TRU wastes (volumes and activities) developed in response to this data call are similar to previously reported values. The total volume of buried TRU waste is approximately 126,000 m^3 and the volume of TRU waste disposed of at intermediate depths is 11,000 m^3. These new estimates are not significantly different from the total estimated buried TRU waste volume of 140,000 m^3 given in WIPP SEIS II (DOE 1997c) and most recent IDB report (DOE 1997a). However, the site-by-site totals are different than previously reported in some cases. In addition, radioactivity totals are higher than previously reported. Although process knowledge and back-extrapolations can help reconstruct site inventories, no amount of detailed guidance or directions on collecting information associated with buried TRU-contaminated wastes and environmental media can compensate for the lack of historical disposal records and waste characteristics data. This is especially true for wastes disposed of in the early years of the operation of the nuclear weapons complex from about 1943 through 1965.

In responding to the data call, Field Offices used all available information to develop as complete a response as was possible. While information within a site response is consistent, it was not always possible to obtain complete consistency among sites. For example, Hanford was not able to provide separate estimates for the volumes of αLLW. In contrast, INEEL could only provide estimates for the waste volumes having TRU radionuclide concentrations in excess of 10 nCi/g, without dividing this estimate into the fraction greater than 100 nCi/g and that between 10 and 100 nCi/g. The inability to provide finely discriminating volume estimates based on the concentrations of TRU radionuclides is not surprising in view of the way in which TRU waste thresholds were defined, i.e., as "floors." The *Buried Transuranic-Contaminated Waste and Related Materials Database* includes entries in narrative fields to fully document the bases of the estimates.

The responses to the data call were compiled by the DOE Field Office project engineers having responsibility for managing the buried TRU-contaminated waste sites, using input from DOE and contractor staff familiar with past waste management practices and historical waste data compilations. To obtain a sense of the quality of information being reported, the data call requested that a "level of confidence," i.e., low, medium, or high, be identified for the waste and contaminated media data. The level of confidence was generally reported as being low or medium; no data were identified as having a high level of confidence.

Although the data call focused on volumes and radioactive contaminants, information was requested on management plans and additional contaminant information, particularly hazardous contaminants as regulated under the Resource Conservation and Recovery Act (RCRA) and Toxic Substances Control Act (TSCA). While this was not a major focus of the data call, this information was requested, as available, to update remedial action plans and to complete the contaminant profiles for these materials. Little hazardous contaminant information was reported, which reflects the lack of definitive characterization information for these wastes and environmental media. Such information gaps are understood to introduce uncertainties into predictions of fate and transport of radionuclides, and are considered by the regulatory authorities in making final remedy decisions for these sites.

The priority afforded to buried TRU-contaminated waste sites is considered in the context of the overall site priorities, which have been negotiated with regulators and stakeholders generally over a multi-year period. Detailed inventory reports on buried TRU-contaminated waste sites are prepared once remedial action decisions for such sites are ripe for consideration, as negotiated with the regulatory agencies. For example, ORNL prepared a detailed report reconciling past estimates of buried TRU-contaminated wastes to support remedial action planning for the Melton Valley Watershed (DOE 1999c and Trabalka 1997).

DOE's current approach for managing buried TRU-contaminated wastes and environmental media is to address them in the same manner as other environmental restoration issues, i.e., on a site-specific basis under CERCLA, RCRA, or applicable state statute incorporating input from impacted stakeholders. The appropriate action to take at each TRU-contaminated waste site is determined at the local level based on regulator decisions and community input, and will depend on several factors including the technical situation, current and future risks, land-use plans for the facility and nearby area, availability of cost-effective technologies, and other local concerns. Some facilities, such as SRS, have been able to reach consensus decisions with regulators and other stakeholders on the appropriate course of action to take at buried TRU-contaminated waste sites without having definitive estimates of the exact volumes of previously disposed of waste, provided good (bounding) estimates of the activities (curies) associated with the buried wastes are available and modeling of the movement of these contaminants in the local environment can demonstrate no significant risks to nearby human and ecological receptors. Current remedial action plans indicate that in-situ remedies are still the preferred approach for much of the buried TRU-contaminated wastes, although about one-third of this waste may be exhumed, treated and disposed of at WIPP. The DOE believes that the current approach for managing buried TRU-contaminated waste sites on a site-specific basis is appropriate, and DOE will continue to work with regulators and local citizens in reaching consensus plans for each of these sites.

TABLE 1 Summary of Buried TRU-Contaminated Waste and Soil Within the DOE Complex[a]

	Buried Waste				Waste Disposed of at Intermediate Depths				Contaminated Soil[b]			
	Volume (m^3)[c]		TRU Activity (Ci)[d]		Volume (m^3)[c]		TRU Activity (Ci)[d]		Volume (m^3)[c]		TRU Activity (Ci)[d]	
Facility[e]	TRU	αLLW	Reported	Decay-Corrected	TRU	αLLW	Reported	Decay-Corrected	TRU	αLLW	Reported	Decay-Corrected
Hanford	75,800	NA	67,800	60,000	-	-	-	-	31,600	NA	25,400	32,400
INEEL	36,800	NA	634,000	297,000	-	-	-	-	-	-	-	-
LANL	8,620	313,400	21,000	21,000	3,690	1,300	7,690	7,470	162	6,840	10	10
NTS	21	0	229	152	95	0	343	341	0	4,800	86	86
ORNL	570	NA	6	6	6,880	1,940	2,100	1,960	NA	NA	53	53
SRS	4,530	NA	21,900	18,500	-	-	-	-	-	-	-	-
	126,000	>313,000	745,000	397,000	11,000	3,200	10,000	9,800	>32,000	>12,000	26,000	33,000

[a] Totals have been rounded to two or three significant figures. Several totals are given as ">" values to accommodate volumes reported as not available or unknown. Buried wastes are those wastes generally disposed of within the top 30 m (100 ft) of the earth's surface and wastes disposed of at intermediate depths are those wastes generally disposed of between 30 m (100 ft) and 300 m (1,000 ft) of the earth's surface. NA = not available and dashed line means not applicable for that site.

[b] Soil contaminated as a result of liquid discharges and aboveground safety and nuclear weapons tests. Contaminated soil proximate to solid buried wastes could well be present, but their volumes cannot be reasonably estimated. An additional 295,000 curies of transuranic (TRU) activity (reported value) is associated with rock and debris contaminated by subsurface nuclear weapons tests. This activity will decay to 219,000 curies by 2006.

[c] LLW = low-level waste. The TRU volume represents the volume of material having a concentration of TRU radionuclides greater than 100 nCi/g, and the αLLW volume represents the volume of material having a concentration of TRU radionuclides between 10 and 100 nCi/g.

[d] The reported TRU activity represents the sum of the activities of alpha-emitting TRU radionuclides having half-lives in excess of 20 years as identified in the Field Office submittals (see Tables 2, 3, and 4). Also included in this total are the reported activities of uranium isotopes, plutonium-241 (which has a half-life of 14.4 years and decays by emission of a beta particle), and curium-244 (which has a half-life of 18.1 years). The decay-corrected values represent the estimated activities in the year 2006, the earliest year in which any of these materials could reasonably be scheduled for disposal at the Waste Isolation Pilot Plant. The decay-corrected TRU activity (to 2006) for contaminated soil at Hanford is somewhat higher than the reported value as the reported activity reflects values in 2020, the time at which a decision on management of these units is currently planned.

[e] Hanford = Hanford Site, INEEL = Idaho National Engineering and Environmental Laboratory, LANL = Los Alamos National Laboratory, NTS = Nevada Test Site, ORNL = Oak Ridge National Laboratory, SRS = Savannah River Site.

TABLE 2 Buried TRU-Contaminated Waste Sites[a]

Facility[b]	Location	Site	TRU Volume (m^3)[c]	αLLW Volume (m^3)[d]	TRU Activity (Ci)[e] Reported	TRU Activity (Ci)[e] Decay-Corrected
Hanford	600 Area	618-10	8.4	NA[f]	140	120
Hanford	600 Area	618-11	10,200	NA	680	600
Hanford	200 West Area	218-W-1	7,200	NA	13,000	11,400
Hanford	200 West Area	218-W-2	8,200	NA	18,100	16,000
Hanford	200 West Area	218-W-3	11,000	NA	29,700	26,100
Hanford	200 West Area	218-W-4A	18,000	NA	3,550	3,530
Hanford	200 West Area	218-W-4B	6,200	NA	1,090	960
Hanford	200 East Area	218-E-12A	15,000	NA	1,510	1,330
			75,800		67,800	60,000
INEEL[g]	RWMC	Pits 1-6, 9, 10; Trenches 1-10	36,800	NA	634,000	297,000
LANL[h]	TA-21	MDA A pits	700	13,300	25	25
LANL	TA-21	MDA B pits	525	20,500	6	6
LANL	TA-50	MDA C pits	2,600	100,400	196	186
LANL	TA-54	MDA G pits	4,790	179,200	20,800	20,800
			8,620	313,400	21,000	21,000
NTS[i,j]	RWMS Area 5	Trench T04C	21	0	229	152
ORNL[k,j]	Melton Valley	SWSA 4	NA	NA	NA	NA
ORNL	Melton Valley	SWSA 5 North	400	NA	6	6
ORNL	Melton Valley	SWSA 5 South	170	NA	NA	NA
			570		6	6
SRS[l]	ORWBG	643-G	4,530	NA	18,300	17,100
SRS	LLRWDF	643-7G	NA	NA	98	38
SRS	MWMF	643-28G	NA	NA	3,540	1,390
			4,530		21,900	18,500

[a] Information is limited to sites having transuranic (TRU)-contaminated wastes buried generally within the top 30 m (100 ft) of the earth's surface. Some values have been rounded. Table excludes sites in the Marshall Islands created from past atmospheric nuclear weapons tests, sites where ocean dumping took place from 1946 through 1970, and the six original commercial low-level waste (LLW) disposal sites.

[b] Hanford = Hanford Site, INEEL = Idaho National Engineering and Environmental Laboratory, LANL = Los Alamos National Laboratory, NTS = Nevada Test Site, ORNL = Oak Ridge National Laboratory, SRS = Savannah River Site.

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TABLE 2 (Cont.)

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[c] These waste volumes refer to previously disposed of radioactive wastes having a concentration of TRU radionuclides in excess of 100 nCi/g. They may include some wastes that contain hazardous constituents regulated under the Resource Conservation and Recovery Act (RCRA) and Toxic Substances Control Act (TSCA), i.e., mixed waste.

[d] αLLW refers to previously disposed of radioactive wastes having a concentration of TRU radionuclides between 10 and 100 nCi/g. They may include some wastes that contain hazardous constituents regulated under RCRA and TSCA, i.e., mixed waste.

[e] The reported TRU activity represents the sum of the activities of alpha-emitting TRU radionuclides having half-lives in excess of 20 years as identified in the Field Office submittals. Also included in this total are the reported activities of uranium isotopes, plutonium-241 (which has a half-life of 14.4 years and decays by emission of a beta particle), and curium-244 (which has a half-life of 18.1 years). All of the reported activities represent initial emplaced values except for the burial grounds at Hanford (which represent 1995 values) and the ORWBG at SRS (which represents 1997 values). The decay-corrected values represent the estimated activities in 2006, the earliest year in which any of these materials could reasonably be scheduled for disposal at the Waste Isolation Pilot Plant.

[f] NA = not available. The waste volumes reported for Hanford are limited to those wastes containing TRU radionuclides in concentrations in excess of 100 nCi/g. Materials having TRU radionuclides in concentrations between 10 and 100 nCi/g are classified as LLW, consistent with the 1984 definition of TRU waste. Separate estimates of the volumes of LLW containing TRU radionuclides in concentrations between 10 and 100 nCi/g are not available. These materials are included in LLW environmental media and waste volume estimates maintained for the site. The TRU activities for these wastes were calculated from the mass of reported TRU radionuclides.

[g] RWMC = Radioactive Waste Management Complex at INEEL. The TRU waste volume reported for INEEL includes all wastes having a TRU radionuclide concentration in excess of 10 nCi/g. Sufficient information is not available to divide this volume into that containing more than 100 nCi/g and that between 10 and 100 nCi/g.

[h] TA = Technical Area and MDA = Material Disposal Area at LANL.

[I] RWMS = Radioactive Waste Management Site at NTS.

[j] The buried waste volumes reported for NTS and ORNL are for disposal site locations where definitive estimates are available and were provided in response to the data call.

[k] SWSA = Solid Waste Storage Area at ORNL. The reported TRU volumes are for SWSA 5 North (4-Trench Disposal Area) and SWSA 5 South (1970 through 1972). The buried TRU-contaminated waste volumes in other disposal areas at the site and percentages of wastes having concentrations of TRU radionuclides in excess of 100 nCi/g and between 10 and 100 nCi/g are not known. Detailed information on recently completed efforts to compile and reconcile past estimates of buried TRU-contaminated wastes at ORNL and identify current data gaps is given in Trabalka (1997).

[l] ORWBG = Old Radioactive Waste Burial Ground, LLRWDF = Low-Level Radioactive Waste Disposal Facility, and MWMF = Mixed Waste Management Facility at SRS.

TABLE 3 TRU-Contaminated Waste Disposed of at Intermediate Depths[a]

Facility[b]	Location	Site	Type of Disposal	TRU Volume (m^3)[c]	αLLW Volume (m^3)[d]	TRU Activity (Ci)[e] Reported	TRU Activity (Ci)[e] Decay-Corrected
Hanford	200 West	241-Z-361	Underground tank storage	76[f]	NA[g]	10,200	7,720
LANL[h]	TA-50	MDA C shafts	Shafts	70	70	57	57
LANL	TA-54	MDA G shafts	Shafts	6	1,040	3,630	3,630
LANL	TA-21	MDA T shafts	Shafts	3,610	190	4,000	3,780
				3,690	1,300	7,690	7,470
LANL	TA-49	MDA AB	Hydronuclear tests	4,400	0	2,480[i]	2,480
NTS[j]	RWMS Area 5	Boreholes 1, 2, 3, 4, 7	GCD boreholes	95	0	343	341
NTS	NTS	Subsurface rock	Underground weapons tests	NA[k]	NA	292,000[l]	217,000
ORNL	Melton Valley	New Hydrofracture Facility[m]	Hydrofracture	6,880	1,940	2,100	1,960

[a] Information is limited to sites having transuranic (TRU)-contaminated wastes (and similar materials) generally disposed of at depths between 30 m (100 ft) and 300 m (1,000 ft) of the earth's surface. Some values have been rounded.

[b] Hanford = Hanford Site, LANL = Los Alamos National Laboratory, NTS = Nevada Test Site, ORNL = Oak Ridge National Laboratory.

[c] These waste volumes refer to previously disposed of radioactive wastes having a concentration of TRU radionuclides in excess of 100 nCi/g. They may include some wastes that contain hazardous constituents regulated under the Resource Conservation and Recovery Act (RCRA) and Toxic Substances Control Act (TSCA), i.e., mixed waste.

[d] LLW = low-level waste. αLLW refers to previously disposed of radioactive wastes having a concentration of TRU radionuclides between 10 and 100 nCi/g. They may include some wastes that contain hazardous constituents regulated under RCRA and TSCA, i.e., mixed waste.

[e] The reported TRU activity represents the sum of the activities of alpha-emitting TRU radionuclides having half-lives in excess of 20 years, as identified in the Field Office submittals. Also included in this total are the reported activities of uranium isotopes, plutonium-241 (which has a half-life of 14.4 years and decays by emission of a beta particle), and curium-244 (which has a half-life of 18.1 years). All of the reported activities represent initial emplaced values except for the underground tests at NTS (which represent 1996 values). The decay-corrected values represent the estimated activities in 2006, the earliest year in which any of these materials could reasonably be scheduled for disposal at the Waste Isolation Pilot Plant.

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TABLE 3 (Cont.)

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[f] While this waste volume does not represent previously disposed of waste, it was identified in the Field Office submittal and is included here for completeness. The TRU activity for this waste was calculated from the mass of reported TRU radionuclides. This waste volume does not include the volume of TRU-contaminated material included with high-level waste contained in single-shell and double-shell underground storage tanks at the site.

[g] NA = not available. The waste volumes reported for Hanford are limited to those wastes containing TRU radionuclides in concentrations in excess of 100 nCi/g. Materials having TRU radionuclides in concentrations between 10 and 100 nCi/g are classified as LLW, consistent with the 1984 definition of TRU waste. Separate estimates of the volumes of LLW containing TRU radionuclides in concentrations between 10 and 100 nCi/g are not available. These materials are included in LLW environmental media and waste volume estimates maintained for the site.

[h] TA = Technical Area and MDA = Material Disposal Area at LANL.

[I] This estimate is based on the specific activity of plutonium-239 for the reported mass of plutonium isotopes associated with contaminated rock and debris.

[j] RWMS = Radioactive Waste Management Site at NTS.

[k] The volumes of TRU-contaminated rock and debris associated with previous underground nuclear weapons tests at NTS having concentrations in excess of 100 nCi/g or between 10 and 100 nCi/g are not known. Approximately 800 tests were conducted in shafts and tunnels at Yucca Flats, Pahute Mesa, Ranier Mesa and Frenchman Flats. Excluded from this table are certain experimental test locations at NTS that remain classified for security purposes. The volumes also do not include contaminated rock and debris associated with previous nuclear detonations at off-site locations at Amchitka Island and Project Chariot Sites in Alaska, Rio Blanco and Rulison Sites in Colorado, Gnome-Coach and Gasbuggy Sites in New Mexico, Salmon Site in Mississippi, and Shoal and Central Nevada Test Sites in Nevada.

[l] The TRU activity of contaminated rock and debris associated with previous underground nuclear weapon tests at NTS, as derived from Table 4-27 of DOE (1996b).

[m] Liquid radioactive wastes and sludges were mixed with grout and disposed of in two separate hydrofracture facilities at ORNL. The Old Hydrofracture Facility was used for the disposal of liquid LLW from 1966 through 1979 and the New Hydrofracture Facility was used for the disposal of TRU waste sludges (along with some liquid LLW) from 1982 through 1984. While the wastes disposed of in the Old Hydrofracture Facility at ORNL had some small amount of TRU radionuclides in them, the concentrations are well below 100 nCi/g (and likely 10 nCi/g) and are considered to be LLW (Trabalka 1997, 1999).

TABLE 4 TRU-Contaminated Soil Sites[a]

Facility[b]	Location	Site	Description	TRU Volume (m^3)[c]	αLLW Volume (m^3)[d]	TRU Activity (Ci)[e] Reported	TRU Activity (Ci)[e] Decay-Corrected
Hanford	200 West Area	241-T-361	Settling tank	180	NA[f]	272	348
Hanford	200 West Area	216-T-6	Crib	290	NA	53	68
Hanford	200 West Area	216-S-1, -2	Crib	1,700	NA	163	209
Hanford	200 West Area	216-T-18	Crib	590	NA	245	313
Hanford	200 West Area	216-T-3	Reverse well	3	NA	177	226
Hanford	200 West Area	216-T-32	Crib	460	NA	436	557
Hanford	200 West Area	216-Z-1	Ditch	38	NA	19	24
Hanford	200 West Area	216-Z-1, -2-TF	Crib	8,300	NA	8,720	11,100
Hanford	200 West Area	216-Z-3	Crib	1,500	NA	777	993
Hanford	200 West Area	216-Z-5	Crib	210	NA	46	59
Hanford	200 West Area	216-Z-7	Crib	590	NA	273	348
Hanford	200 West Area	216-Z-8	French drain	6	NA	7	8
Hanford	200 West Area	216-Z-9	Trench	5,100	NA	5,170	6,610
Hanford	200 West Area	216-Z-10	Reverse well	0.2	NA	7	9
Hanford	200 West Area	216-Z-11	Ditch	550	NA	1,100	1,410
Hanford	200 West Area	216-Z-12	Crib	5,400	NA	3,410	4,360
Hanford	200 West Area	216-Z-18	Crib	5,700	NA	3,130	4,010
Hanford	200 West Area	216-Z-19	Ditch	73	NA	19	24
Hanford	200 East Area	216-B-5	Reverse well	64	NA	232	296
Hanford	200 East Area	216-B-361	Settling tank	180	NA	354	453
Hanford	200 East Area	216-B-7A, -B	Crib	430	NA	586	749
Hanford	200 East Area	216-E-15	Unplanned release	260	NA	163	209
Hanford	200 East Area	216-B-53A	Trench	24	NA	14	17
				31,600		25,400	32,400
LANL[g]	TA-21	MDA T	Absorption beds	162	2,540	10	10
LANL	TA-21	MDA V	Absorption beds	0	4,300	0.1	0.1
				162	6,840	10	10
NTS	NTS	Surface soil	Aboveground safety/weapons tests	0	4,800[h]	86[i]	86
ORNL	Melton Valley	Seepage Pits 2, 3, 4; Trenches 5, 7	Seepage pits and trenches	NA[j]	NA	53	53

[a] Information is limited to sites having soil contaminated with transuranic (TRU) radionuclides as a result of liquid discharges and previous weapons testing activities. Contaminated soil volumes proximate to solid buried wastes could well be present, but their volumes cannot be reasonably estimated. All sites except the surface soil at NTS were contaminated by previous liquid discharges. Some values have been rounded.

[b] Hanford = Hanford Site, LANL = Los Alamos National Laboratory, NTS = Nevada Test Site, ORNL = Oak Ridge National Laboratory. In addition to the sites listed here, the Rocky Flats Environmental Technology Site (RFETS) has a large volume of soil (in excess of 100,000 m^3) containing low concentrations of TRU radionuclides (generally less than 10 nCi/g) that will be managed as low-level waste (LLW). Although some areas at RFETS may contain isolated "hot spots" of TRU-radionuclide contamination in concentrations exceeding 100 nCi/g, e.g., 903 Pad, when remediated, the concentrations of TRU radionuclides in the resultant wastes are expected to be significantly lower than 100 nCi/g (and likely 10 nCi/g) and will be managed as LLW.

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TABLE 4 (Cont.)

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[c] These soil volumes refer to soil having a concentration of TRU radionuclides in excess of 100 nCi/g. They may include some soil that contains hazardous constituents regulated under the Resource Conservation and Recovery Act (RCRA) and Toxic Substances Control Act (TSCA), i.e., mixed waste.

[d] αLLW soil refers to soil having a concentration of TRU radionuclides between 10 and 100 nCi/g. The volumes may include some soil that contains hazardous constituents regulated under RCRA and TSCA, i.e., mixed waste.

[e] The reported TRU activity represents the sum of the activities of alpha-emitting TRU radionuclides having half-lives in excess of 20 years as identified in the Field Office submittals. Also included in this total are the reported activities of uranium isotopes, plutonium-241 (which has a half-life of 14.4 years and decays by emission of a beta particle), and curium-244 (which has a half-life of 18.1 years). The reported activities for contaminated soil sites at Hanford represent year 2020 values and the activities for LANL and ORNL represent initial emplaced values. The decay-corrected values represent the estimated activities in 2006, the earliest year in which any of these materials could reasonably be scheduled for disposal at the Waste Isolation Pilot Plant.

[f] NA = not available. The soil volumes reported for Hanford are limited to those containing TRU radionuclides in concentrations in excess of 100 nCi/g. Materials having TRU radionuclides in concentrations between 10 and 100 nCi/g are classified as LLW, consistent with the 1984 definition of TRU waste. Separate estimates of the volumes of LLW containing TRU radionuclides in concentrations between 10 and 100 nCi/g are not available. These materials are included in LLW environmental media and waste volume estimates maintained for the site. The TRU activities for these contaminated soil volumes were calculated from the mass of reported TRU radionuclides.

[g] TA = Technical Area and MDA = Material Disposal Area at LANL.

[h] Estimated extent of contamination is 6 ha (15 acres) to an average depth of 8 cm (3 in), as given in DOE (1995).

[I] The TRU activity is based on the estimated soil volume of 4,800 m^3, an average soil density of 1.8 g/cm^3, and a TRU radionuclide concentration of 10 nCi/g.

[j] The volumes of contaminated soil having TRU-radionuclide concentrations in excess of 100 nCi/g and between 10 and 100 nCi/g are not known. Detailed information on recently completed efforts to compile and reconcile past estimates of buried TRU-contaminated wastes and soil at ORNL and identify current data gaps is given in Trabalka (1997).

TABLE 5 Complex-Wide Summary of Buried TRU-Contaminated Waste and Soil[a]

	Buried Waste[b]				Waste Disposed of at Intermediate Depths[c]				Contaminated Soil[d]			
	Volume (m^3)[e]		TRU Activity (Ci)[f]		Volume (m^3)[e]		TRU Activity (Ci)[f]		Volume (m^3)[e]		TRU Activity (Ci)[f]	
Facility[g]	TRU	αLLW	Reported	Decay-Corrected	TRU	αLLW	Reported	Decay-Corrected	TRU	αLLW	Reported	Decay-Corrected
Hanford[h]	75,800	NA[i]	67,800	60,000	-[j]	-	-	-	31,600	NA	25,400	32,400
INEEL[k]	36,800	NA	634,000	297,000	-	-	-	-	-	-	-	-
LANL	8,620	313,400	21,000	21,000	3,690	1,300	7,690	7,470	162	6,840	10	10
NTS[l]	21	0	229	152	95	0	343	341	0	4,800	86	86
ORNL[l]	570	NA	6	6	6,880	1,940	2,100	1,960	NA	NA	53	53
SRS	4,530	NA	21,900	18,500	-	-	-	-	-	-	-	-
	126,000	>313,000	745,000	397,000	11,000	3,200	10,000	9,800	>32,000	>12,000	26,000	33,000

[a] Information summarized in this table was extracted from Tables 2, 3, and 4. These previous three tables can be referenced for a more detailed description of these data. Totals have been rounded to two or three significant figures. Several totals are given as ">" values to accommodate volumes reported as not available or unknown.

[b] Wastes generally disposed of within the top 30 m (100 ft) of the earth's surface.

[c] Wastes generally disposed of between 30 m (100 ft) and 300 m (1,000 ft) of the earth's surface. Not included in this table are sludges in underground storage tanks at Hanford, and contaminated rock and debris at LANL and NTS associated with subsurface testing activities. See Table 3 for the volumes and activities associated with these materials.

[d] Soil contaminated as a result of liquid discharges and aboveground safety and nuclear weapons tests. Contaminated soil proximate to solid buried wastes could well be present, but their volumes cannot be reasonably estimated. In addition to the contaminated soil volumes given here, the Rocky Flats Environmental Technology Site has a large volume of soil (in excess of 100,000 m^3) containing low concentrations of transuranic (TRU) radionuclides (generally less than 10 nCi/g) that will be managed as low-level waste (LLW).

[e] The TRU volume represents the volume of material having a concentration of TRU radionuclides greater than 100 nCi/g, and the αLLW volume represents the volume of material having a concentration of TRU radionuclides between 10 and 100 nCi/g.

[f] The reported TRU activity represents the sum of the activities of alpha-emitting TRU radionuclides having half-lives in excess of 20 years as identified in the Field Office submittals (see Tables 2, 3, and 4). Also included in this total are the reported activities of uranium isotopes, plutonium-241 (which has a half-life of 14.4 years and decays by emission of a beta particle), and curium-244 (which has a half-life of 18.1 years). The decay-corrected values represent the estimated activities in the year 2006.

[g] Hanford = Hanford Site, INEEL = Idaho National Engineering and Environmental Laboratory, LANL = Los Alamos National Laboratory, NTS = Nevada Test Site, ORNL = Oak Ridge National Laboratory, SRS = Savannah River Site.

[h] Waste and soil volumes reported for Hanford represent material containing TRU radionuclides in concentrations greater than 100 nCi/g.

[I] NA = not available.

[j] Dashed line means not applicable for that site.

[k] Waste and soil volumes reported for INEEL represent material containing TRU radionuclides in concentrations greater than 10 nCi/g.

[l] Waste and soil volumes reported for NTS and ORNL are for disposal site locations where definitive estimates are available and were provided in response to the data call.

TABLE 6 Comparison of Current Estimated Volumes (m^3) of Buried TRU-Contaminated Waste and Soil with Those Reported by IEER[a]

Facility[b]	Buried Waste[c]	Waste Disposed of at Intermediate Depths[d]	Contaminated Soil Associated with[e]	
			Solid Waste	Liquid Waste
Hanford	75,800/63,000	-[f]	Unknown/45,400	31,600/32,000
INEEL	36,800/57,000	-	Unknown/56,000-156,000	0/No estimates
LANL	8,620/14,000	3,690	Unknown/1,000	162/140
NTS	21/0	95	4,800/6,000[g]	0/No value
ORNL	570/6,600	6,880	Unknown/12,000-60,000	NA/1,000-35,000
SRS	4,530/4,900	-	Unknown/38,000	0/No estimates

[a] For each entry, the first value represents the current estimate as extracted from information contained in the *Buried Transuranic-Contaminated Waste and Related Materials Database* and the second value represents the corresponding estimate as given in Table 9 of Fioravanti and Makhijani (1997). The current estimates are for wastes and soil having a concentration of transuranic (TRU) radionuclides greater than 100 nCi/g except for INEEL, which represents materials having a concentration of TRU radionuclides greater than 10 nCi/g.

[b] Hanford = Hanford Site, INEEL = Idaho National Engineering and Environmental Laboratory, LANL = Los Alamos National Laboratory, NTS = Nevada Test Site, ORNL = Oak Ridge National Laboratory, SRS = Savannah River Site.

[c] Wastes generally disposed of within the top 30 m (100 ft) of the earth's surface.

[d] Wastes generally disposed of between 30 m (100 ft) and 300 m (1,000 ft) of the earth's surface. Not included in this table are sludges in underground storage tanks at Hanford, and contaminated rock and debris at LANL and NTS associated with subsurface testing activities. See Table 3 for the volumes and activities associated with these materials. There are no corresponding values in Fioravanti and Makhijani (1997) for wastes disposed of at intermediate depths.

[e] Soil contaminated as a result of liquid discharges and previous nuclear weapons tests. Contaminated soils proximate to solid buried wastes could well be present, but their volumes cannot be reasonably estimated; these volumes are reported as "Unknown" in this table. In addition to the contaminated soil volumes given here, the Rocky Flats Environmental Technology Site has a large volume of soil (in excess of 100,000 m^3) containing low concentrations of TRU radionuclides (generally less than 10 nCi/g) that will be managed as low-level waste. The two "No estimates" entries reflect the corresponding information given in Table 9 of Fioravanti and Makhijani (1997), i.e., the values are given as "No estimates" in this table. The "No value" entry means that no information is provided for this field in Table 9 of Fioravanti and Makhijani (1997). NA= not available.

[f] Dashed line means not applicable for that site.

[g] Contaminated soil having a concentration of TRU radionuclides greater than 10 nCi/g from previous aboveground safety/weapons tests.

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APPENDIX A

Guidance and Form Used to Collect Information on Buried Transuranic-Contaminated Wastes and Related Materials

Guidance for Reporting Information on Buried Transuranic Waste and Related Materials

Background

Transuranic (TRU) waste was first defined in 1970 by the U.S. Atomic Energy Commission (AEC) as waste containing greater than 10 nCi/g of alpha-emitting transuranic radionuclides. Transuranic radionuclides are those with an atomic number higher than uranium, i.e., higher than 92. This waste was felt to warrant different handling and disposal considerations than low-level waste (LLW) due to the hazards posed by the long-lived alpha-emitting radionuclides. Prior to 1970, such waste was handled in a manner similar to LLW and was generally disposed of by shallow land burial or other similar techniques. The definition of TRU waste was revised in 1984, increasing the lower limit of alpha-emitting transuranic radionuclides with half-lives greater than 20 years from 10 to 100 nCi/g. Field Offices were given the flexibility to manage certain other non-transuranic alpha-emitting radionuclides, such as uranium-233 and radium-226, as TRU radionuclides.

All TRU waste generated after 1970 was to be segregated from LLW and placed in retrievable storage pending shipment to and disposal in an approved geologic repository, the Waste Isolation Pilot Plant (WIPP) near Carlsbad, New Mexico. Retrievably stored waste has been contained in a variety of packagings (metal drums, wooden and metal boxes) and has been stored in buildings, earth-mounded berms, concrete culverts, and other types of engineered facilities.

Certain radioactive wastes disposed of prior to 1970 meet the current definition of TRU waste. These wastes are considered to be "buried" TRU waste, as distinct from "stored" TRU waste. However, the difference between buried and stored TRU waste is not always clear because in some cases the method of retrievable storage, such as beneath an earthen berm, is similar to the method used to bury wastes. In addition, certain formerly TRU waste placed into storage between 1970 and 1984 is now considered LLW that contains alpha-emitting transuranic radionuclides (referred to here as αLLW), due to the 1984 redefinition of TRU waste.
In addition to these original emplaced wastes, some soils have become contaminated with transuranic radionuclides in concentrations exceeding 10 nCi/g, and in some cases 100 nCi/g, as a result of past discharges of liquid TRU waste onto the ground, above-ground nuclear tests, leaks from underground tanks, and migration of transuranic radionuclides from buried TRU wastes. These soils could also be considered αLLW or TRU waste, depending on the level of contamination. Further, certain activities conducted below ground (e.g., criticality experiments and testing of nuclear weapons) resulted in subsurface contamination of materials with transuranic radionuclides in excess of 10 and possibly 100 nCi/g.

Past estimates of buried TRU waste have varied from year to year and from one data source to another, e.g., from the Integrated Data Base reports to the TRU Baseline Inventory reports. The reasons for these differences include limited historical records, the changing definition of what constitutes TRU waste, different methods for managing certain materials from one site to another, and differing objectives for estimating the inventories, as it was not always clear what materials should be reported. Various groups who have reviewed existing data on TRU waste have noted inconsistencies and requested more comprehensive information, notably to address TRU-contaminated materials that do not meet the definition of buried TRU waste. For example, the contaminated soil resulting from past nuclear weapons testing and research is commonly considered contaminated environmental media rather than "waste" because it does not meet the regulatory definition for waste generation (which involves removing contaminated material for subsequent management). Thus, this soil was typically considered outside the scope of earlier requests for data on

"buried TRU waste." Additional discussion on past problems associated with reporting buried TRU waste information is provided in Attachment 1.

Because uniform guidance for reporting information on TRU materials across programs and conditions has not previously been available, past efforts relied on site-specific interpretations of data requests at the time of reporting. Results have varied due to different individual interpretations. With the expectation that WIPP will open in the near future and in light of increased interest in how DOE plans to manage all TRU-contaminated materials, it is important to have a complete, consistent inventory of these materials to support appropriate management plans. Toward that end, this guidance has been developed to provide a consistent framework for reporting comprehensive information about buried TRU wastes and related materials.

This guidance integrates key program needs, as it has been jointly developed by the Carlsbad Area Office to support its Comprehensive Disposal Recommendations (CDR) and the Office of Environmental Management Headquarters to support its data needs. Through this combined approach, the Office of Environmental Management aims to establish a comprehensive framework for TRU information that will support essential complex-wide analyses.

General Guidelines for Providing Data

It is requested that two primary guidelines be followed in completing the attached data form:

1. Six "type of placement" categories have been identified for the waste and soil (Section I.A.2), and a separate form needs to be filled out for each one that is applicable to a given site. As used in this guidance, soil includes sediment, rock and other similar naturally occurring earthen materials.

2. Information should be reported separately for different areas within a site that have a distinct history and are being addressed in a distinct manner, whereas those with a common history that are being addressed in the same manner (typically adjacent areas) can be grouped for reporting. (For example, if different types of TRU waste were emplaced in two separate burial grounds, a separate form would be used for each, while individual trenches within a given burial ground would be grouped for reporting on a single form if they received similar types of materials and are being addressed by a common approach, such as capping.)

Recognizing that data on TRU-contaminated materials are limited, it is important that this information be compiled in a consistent and defensible manner to meet several reporting requirements. The basis for all estimates should be documented and included in the response package to allow for future traceability.

Description of the Data Elements

The TRU data form is tiered to provide a format for collecting as much information as is available, starting with summary-level data (Section I), moving to more specific information on waste volumes (Section II) and response plans (Section III), and closing with additional supporting information on contaminants, response plans, and the status of environmental management activities (Section IV). The following text tracks to the letter/number designations on the accompanying form. Please be as specific as possible in completing the form, adhering to the two guidelines given above.

Section I: Summary Estimates

A. Original Material (*Emplaced Wastes*)

1a. Site/area name & location

Provide the physical location of the TRU waste or TRU-contaminated material. If the information is being provided for a smaller area within a site, please provide the name of that subarea (e.g., "Storage Area 3").

1b. Origin

List the origin of the wastes identified in **1a** — e.g., the specific facility and activity generating this waste — if known. It is especially important to note the origin of off-site wastes (for example, "origin" for Pit 9 at the Idaho National Engineering and Environmental Laboratory would include the Rocky Flats Plant).

2. Type of placement

Identify (check) which of the six general categories is most appropriate to the material. Only one category can be checked for each data form. (Thus, if two types of placement had occurred at a given area, two forms would be completed for that area.) If none of the listed categories are appropriate, please check "Other *(pls specify)*"and provide a description of the type of placement under *Remarks.* The six categories are:

Trench/pit burial: Wastes buried in a manner similar to that used to dispose of LLW, i.e., in shallow trenches and/or pits. Most of this waste was buried prior to 1970, generally with no intent of retrieval.

Greater confinement disposal (GCD): Wastes placed in boreholes drilled into bedrock and backfilled with sand, soil, rock and/or cement. (Wastes disposed of in a similar manner would also be reported in this category.) Please note the specific type of disposal in the *Remarks*, where possible.

Underground injection - Wastes (liquids and/or sludges) injected underground for disposal.

Surface discharge (or spill) - Liquid wastes accidentally spilled or intentionally discharged onto the ground, which subsequently contaminated the soil with TRU radionuclides.

Surface testing - Soil (and any associated debris) contaminated by above-ground nuclear testing.

Underground testing - Soil and rock (and any associated debris) contaminated by underground testing.

3. Total volume of waste emplaced

The total volume of waste originally emplaced should be reported here. This entry should be filled out only if category **a, b, c,** or **d** were checked in **A.2,** to identify the amount buried or discharged. (The volume to be reported in **2d** is the initial amount of liquid spilled or discharged. The volume of soil that has been contaminated by subsequent migration from burial or other placement areas, spills or discharges, or past testing should be reported in **B.1**, not here.) The volume reported in **A.3** should include all waste material with a concentration of TRU radionuclides exceeding 10 nCi/g.

For packaged waste, the total volume of waste itself — not including the container — is to be reported in **A.3a**. (This actual waste volume is the preferred information.) For example, if wastes were placed in

55 gallon drums (internal volume of 0.208 m^3) for burial and the drums only averaged half full, then the total volume of waste emplaced would be estimated based on 0.104 m^3 per drum. If only the total volume of containers is known, this would be reported in **A.3b** (e.g., based on 0.208 m^3 per drum, regardless of the amount of waste in each.) Please provide any additional narrative that would help in interpreting the data in the *Remarks* (such as the range or representative percent filled and total number of drums, if only the container volume is reported). If both the waste and total container volume can be estimated, both can be provided (in **A.3a** and **A.3b**).

4. Type of material

Identify (check) the major physical matrix of the emplaced waste. For homogeneous solids, it would be helpful to identify the primary form (particulates, sludges or soil), if possible. Please provide any additional narrative that would assist in interpreting this information in the accompanying *Remarks*.

5. Waste percentages

Provide the percent of the volume in **A.3** containing TRU radionuclides above 100 nCi/g (current definition of TRU waste) and the percent containing between 10-100 nCi/g. If available, for the volume with TRU radionuclides above 100 nCi/g, please indicate in the *Remarks* the percent that would be considered remote handled (i.e., with a contact dose rate above 200 mrem/hr).

6. Amount of TRU radionuclides

Provide the total amount of TRU radionuclides in the emplaced waste identified in **A.3**. For the purpose of this effort, TRU radionuclides are considered to be alpha-emitting radionuclides with an atomic number greater than 92 and a half-life in excess of 20 years *and* any additional radionuclides managed by the site in the same manner as TRU radionuclides. It is important to indicate whether the units are *kg* or *Ci*.

7. Percent component key radionuclides

Provide the percent of each key TRU radionuclide in the waste identified in **A.3,** and indicate whether the units are *kg* or *Ci*. These units need to be the same as those used in **A.6**. Additional radionuclides (beyond those identified here) can be provided in the *Other* entries. If common areas have been grouped for reporting on a single form, please provide a representative value and/or range.

8. Radionuclide basis

Indicate whether the values given in **A.6** and **A.7** are for the material initially emplaced or whether they reflect decay of the TRU radionuclides since emplacement. If decay has been assumed, please indicate to what date.

9. Waste information basis

Provide the basis of the waste volumes and radionuclide data provided in **A**. This can include narrative, calculational work sheets, reference to published reports, and any other data that helps establish traceability.

10. Level of confidence

Indicate the general level of confidence in the waste information provided in **A**, i.e., low, medium or high. Only one level should be indicated.

B. Contaminated Soil (*if applicable*)

1. Total volume of contaminated soil

Provide the total volume of soil contaminated with TRU radionuclides as a result of previous waste emplacement; injection; discharges or spills of liquids or sludges; or nuclear testing activities. The volume reported in **B.1** should be for soil contaminated in excess of 10 nCi/g. Please provide any additional narrative that would assist with interpreting the information in the accompanying *Remarks*.

2. Waste percentages

Provide the percentage of the soil volume reported in **B.1** that exceeds 100 nCi/g (thus meeting the current definition of TRU waste) and also give that between 10-100 nCi/g.

3. Soil information basis

Provide the basis of the soil information provided in **B.1** and **B.2** (as described for waste information in **A.9**).

4. Level of confidence

Indicate the general level of confidence in the information provided in **B** (as described in **A.10**).

Section II. Supporting Volume Detail

1. Volume matrix

To the extent possible, please provide additional information in this matrix on the volumes of emplaced wastes (**I.A.3**) and contaminated soil (**I.B.1**). It is recognized that this level of detail may not be available for many sites. However, please make every effort to provide as much information as possible.

For emplaced wastes, please provide the total, combined volume in the first (shaded) row; this volume should be the same as that reported in **I.A.3**. If available, individual estimates for the component material types are to be reported in the subsequent rows. For both the combined totals and individual material categories, also provide estimates for the indicated "waste type" breakouts as available: TRU waste, mixed TRU waste, αLLW, and mixed αLLW. (TRU waste contains TRU radionuclides at a concentration greater than 100 nCi/g, and αLLW [or alpha-contaminated LLW] contains TRU radionuclides at a concentration between 10-100 nCi/g). Mixed wastes are radioactive wastes that also contain hazardous substances as regulated under the Resource Conservation and Recovery Act. (Any asbestos- or PCB-contaminated materials regulated under the Toxic Substances Control Act should be reported as TRU waste or αLLW, not mixed waste; these contributions should be discussed in **IV.2**)

For contaminated soil, please provide the best estimate of the volume in the shaded row; this volume should be the same as that reported in **I.B.1**. If possible and as appropriate, also indicate the minimum and

maximum volume estimates. (This range is intended to accommodate uncertainty in estimating the affected soil volume.) As for emplaced wastes, please apportion the total volume of contaminated soil into the four indicated categories for TRU and αLLW material.

2. Waste or container basis

Please indicate whether the volumes given in this table are actual waste volumes (from **I.A.3a**) or container volumes (from **I.A.3b**).

Section III. Anticipated Response Plans

Please identify the anticipated management plans for the TRU-contaminated materials by indicating the volumes targeted for the given responses. This information is to be consistent with existing baselines and reflect current regulatory agreements and commitments. Please provide the projected response information separately for emplaced waste and contaminated soil, as indicated. If more detailed information is available for lower level groupings (i.e., TRU/MTRU and αLLW/αMLLW), please provide the data in the additional rows of the table.

Section IV. Additional Supporting Information

This section should be used to provide additional supporting information on response plans (**IV.1**), contaminant information (**IV.2**), and the status of environmental management activities (**IV.3**). Of particular interest would be any agreements with regulatory agencies, major planned near-term investigations and milestones, and contaminant information (particularly the possible presence of hazardous chemicals) that could influence future management decisions for these materials. Reference should be provided to major environmental compliance documents, i.e., records of decision or similar documents, that dictate the manner in which these materials are expected to be managed, as available.

Supplemental Data for Buried TRU Waste

I. Summary Estimates

A. Original Material *(Emplaced Waste)*

1a. Site/area name & location: _____ 1b.Origin: _____

2. Type of placement: ___a. Trench/pit burial ___c. Underground injection ___e. Surface testing ___g. Other
(check only one) ___b. Greater confinement disposal (GCD) ___d. Spill or surface discharge ___f. Underground testing *(pls specify)*
Remarks:
_____

3a. Total volume of actual waste emplaced (not including packaging): _____ m^3
3b. Total volume of containers emplaced (including packaging): _____ m^3
This applies to 2a-d waste; soil contaminated from 2d-f would be reported in B.1 below. Actual waste volume is preferred over container volume.
Please indicate how volumes were estimated & provide source citation(s) / report reference(s) in A.9 below.
Remarks:
_____

4. Type of material *(for 1a-d)*: _____ Liquid _____ Homogeneous solids *(if available, as*: ___ particulates; ____ sludges; ____ soil)
_____ Heterogeneous debris _____ Other *(please specify)*:_____
Remarks:
_____

5. Of the total volume reported in 3 above: Estimated percent exceeding 100 nCi/g: _____% Estimated percent between 10-100 nCi/g: _____%

6. Total amount of TRU radionuclides in the original material: _____ kg *or* _____ Ci ***(These units must be the same as those used in 7 below.)***

7. Percent component key radionuclide(s): ***Please identify units used*:** ☛ _____ weight % *or* _____ Ci % ***(Must be the same as those used in 6 above.)***

Am-241	Pu-238	Pu-239	Pu-240	Pu-241	Pu-242	U-233	Cm-244	Ra-226	Cf-252	*Other:*	*Other:*	*Other:*	*Other:*	*Other:*

8. Estimates provided in Sections 6 and 7 above are based on: ___ Initial (emplaced) values *or* ___ Decayed values. If decayed, to what date? _____

9. Basis for waste information, notably **how TRU values were estimated** for 6 & 7 and **how volumes were calculated** for 3.
(Please provide here or attach.)

10. General level of confidence in the waste information: _____ Low _____ Medium _____ High

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B. <u>Contaminated Soil</u> *(if applicable)*

1. Estimated total volume of soil contaminated by the emplaced waste (solid or liquid) or by past testing: _____ m^3

   Please indicate how volumes were estimated & provide source citation(s) / report reference(s) in B.3 below.

   Remarks:

   _____

2. Of this total volume of contaminated soil: Estimated percent exceeding 100 nCi/g: _____% Estimated percent between 10-100 nCi/g: _____%

3. Basis for the soil information, including supporting **volume calculations** and the report **reference(s)/citation(s)**: *(Please provide here or attach.)*

4. General level of confidence in the soil information: _____ Low _____ Medium _____ High

II. Supporting Volume Detail

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1. Please provide for the initial waste (report combined volume within dark lines) and contaminated soil, with additional breakouts as can be provided.

	Total Volume	**Volume with >100 nCi/g *(m^3)***		**Volume with 10-100 nCi/g *(m^3)***	
		TRU	**MTRU**	**αLLW**	**αMLLW**
Emplaced Waste *(combined)*					
Liquids					
Homogeneous Solids					
Heterogeneous Solids					
Other (please specify)					
Contaminated Soil *(best est.)*					
Minimum estimate					
Maximum estimate					

2. The volume(s) of "waste emplaced" in this table represent: ____ Volume of actual waste *(I.A.3.a) or* ____ Volume of container(s) *(I.A.3.b)*

III. Anticipated Response Plans *Per baselines, as can be provided — e.g., only for the total initial waste and associated soil (within dark lines), &/or for further breakouts.*

	In-Place Management						Removal for Further Management					
	No Action	Access/Instnl Controls	In-Situ Containment	*Containment Type*	In-Situ Treatment	*Treatment Type*	Collection & Treatment	*Treatment Type*	Collection & Storage	*Storage Type & Location*	Collection & Disposal	*Disposal Location*
Emplaced Waste												
TRU / MTRU												
αLLW / αMLLW												
Contaminated Soil												
TRU / MTRU												
αLLW / αMLLW												

(Response plans are often similar for mixed/non-mixed materials, so they have been combined above. Please use a "/" to separate entries where response plans differ, or provide additional information in IV below.)

IV. Additional Supporting Information

1. Further supporting detail on response plans, as needed, including references or agreements that have resulted in the responses indicated above.

2. Additional information about contaminants (e.g., further detail about those identified in I.A.7, or other radionuclides not yet discussed), including nonradiological content (e.g., hazardous chemicals), as appropriate.

3. Additional status of environmental management activities — e.g., ongoing/planned investigations, major milestones, and any additional notes on response plans.

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ATTACHMENT 1

Additional Discussion on Past Problems with Reporting Information about Buried TRU Waste

Following is additional discussion on reasons for past discrepancies in estimates of buried TRU waste, as identified in recent reports by the Institute for Energy and Environmental Research (Fioravanti and Makhijani 1997) and Oak Ridge National Laboratory (Trabalka 1997). It is hoped that by reviewing these past problems, the current data update can be made more accurate and consistent from site to site. Preferred approaches for addressing these problems, for purposes of this data update, are noted within the following discussion.

1. Past TRU waste reporting efforts have been hampered by poor historical records and the lack of formal waste-reporting requirements for waste generators. The unavailability of detailed documentation is a primary source of uncertainty in estimates of buried TRU waste, especially for the early years of operating the nuclear weapons complex. While this problem is difficult to rectify, information from process knowledge and back-calculations can be provided. The basis for the estimates must be documented and the underlying assumptions clearly articulated.

2. The change in the definition of TRU waste makes it unclear as to what information should be reported as TRU waste. There are at least three sub-issues with respect to this definition. First, between 1970 and 1984 the concentration threshold was 10 nCi/g, and since 1984 the defining concentration has been 100 nCi/g. In prior waste inventory updates, sites have generally modified their waste inventories to be consistent with the current 100 nCi/g definition. Indeed, many of the previous "discrepancies" in waste volumes can be attributed to this significant change. To address this issue, the current data form includes separate estimates for TRU waste and αLLW (as percentages). Field Offices should confirm that waste volumes reported in response to this data call distinguish between these two waste types, although we understand that there may be data limitations in this regard. It is also recognized that differentiating between these levels will be difficult given inventory records, which again underscores the importance of documenting all assumptions.

   Second, DOE Order 5820.2A gave Field Offices the flexibility to count radionuclides in their TRU inventories that don't strictly meet the 20-year half-life requirement in the definition of TRU waste but have nonetheless been managed at the site as TRU waste. Examples include curium-244 and californium-252. Field Offices should continue to report such radionuclides in their inventories, but clearly identify them in their response.

   Third, and similar to the second item, Field Offices have often reported radionuclides as "transuranic" even though strictly speaking they do not have atomic numbers greater than 92 (uranium), e.g., uranium-233. Again Field Offices should continue to maintain such flexibility in which radionuclides to report, but should clearly identify such radionuclides in their response.

3. Previous disposal practices sometimes included mixing of non-alpha contaminated waste with TRU waste. The TRU waste that is inextricably intermixed with LLW should be identified as such *if possible* (e.g., pre-1970 TRU waste containers placed in the same pit or trench with LLW without any attempt to segregate). It is also important to explain the basis for any areal averaging assumptions, especially if this causes the waste to fall below the 10 or 100 nCi/g level.

4. There have been different interpretations as to what constitutes "buried TRU waste." Since the TRU waste category was created in 1970, there has been confusion over which TRU wastes are "buried" versus which are "stored." Indeed, the distinction is difficult because much of the "stored" waste is

effectively "buried" with a soil cover. Notwithstanding, the intent is to use the following definition for buried TRU waste *(taken from pg. 2 of Trabalka 1997, with reference to Everette et al. 1988)*, with the clarifications noted beneath the general definition.

> Buried TRU waste is waste disposed of prior to the decision to retrievably store such waste, which may contain TRU radionuclides in concentrations above 10 or 100 nCi/g. This waste is primarily in two forms: buried solid waste and contaminated soil. Contaminated soil falls into two categories: soil contaminated by being in contact with solid waste and soil contaminated by liquid waste injection.

- The phrase "waste disposed of" means waste originally emplaced in the ground with no intention of later retrieval except by extraordinary means. For example, some wastes were placed under a soil cover and then several feet of concrete, making them for practical purposes irretrievable and thus eligible for inclusion as buried TRU waste.

- The phrase "prior to the decision to retrievably store such waste" refers to the AEC Immediate Action Directive of 1970 that required segregation of LLW from the newly created category of TRU waste. However, no time cutoff should be interpreted for the purposes of reporting volumes of buried TRU waste. This recognizes that several sites continued to bury TRU waste after the 1970 date, just as some sites segregated TRU waste from LLW before the action directive was issued.

- The phrase "primarily in two forms" should be interpreted literally in the sense that there may be other forms of contaminated soil besides the two identified above that might meet the intent of the definition.

In summary, given these broad definitions, it is clear that Field Offices will continue to need to exercise their best professional judgement in making estimates of buried TRU wastes. It is important that assumptions be clearly documented so the logic of how volumes were estimated can be followed, consistent with the broad guidelines for this update.

5. A number of special types of waste and media contaminated with transuranic radionuclides may have sometimes been temporarily included as TRU waste when responding to certain data calls. For example, certain types of materials that might well qualify as buried TRU waste may not have been initially reported as such, but were later added in only to be dropped again (and so on) when responding to updates of various databases. Several types of materials can be identified that might fall into this "odds and ends" category:

   - hydrofracturing waste (Oak Ridge National Laboratory),
   - hydronuclear test/weapons residue wastes (Los Alamos National Laboratory and Nevada Test Site),
   - greater confinement disposal wastes (Nevada Test Site),
   - classified wastes (multiple sites), and
   - nuclear weapons testing/accident residues (Nevada Test Site and Savannah River Site).

   There are likely other types of materials not listed above that might qualify as well. These wastes have some of the attributes defined above for buried TRU wastes; for example, some of them were disposed of by shallow land burial with no intention of later retrieval, and they can have concentrations of transuranic isotopes above the 10 or 100 nCi/g threshold. Yet there are some differences with much of the more "traditional" buried TRU waste that was put in drums, boxes, and plastic and randomly dumped into pits and trenches before about 1970. For completeness, please include all such materials in the response to this data request, and include sufficient information to allow for future traceability.

6. There have been some past reporting errors in responding to data updates. For example, a number of contradictory accounting discrepancies, transcription errors, and unexplained changes in either volumes or radioactivity content have been identified. It has been reported that some submissions to the Integrated Data Base report contained inventories of TRU elements whose mass and radioactivity varied independently of one another, with large changes in one and no corresponding change in the other. A number of significant typographical errors in input data have also been reported. In certain cases, considerable volume changes were reported with no explanation (e.g., dropping to zero and then returning to earlier estimates in subsequent years). Clearly these kinds of problems should be avoided, and Field Offices are asked to carefully review their volume estimates for TRU waste and TRU-contaminated materials prior to submission to Headquarters.

7. Inconsistent ways of expressing waste volumes have been used in the past, resulting in different volume estimates reported over time and between sites. For example, waste volumes have been reported as the container volume (regardless of the amount of waste contained), number of waste containers emplaced, portion of a trench or pit in which wastes from a specific disposal campaign were placed or dumped, and entire volume of a trench or pit in which such wastes were placed or dumped, possibly including all or a portion of the volume of the (uncontaminated) soil cover placed over the wastes.

   It is appreciated that such variations reflect in part site-specific TRU waste management practices at the time and that, in many instances, lack of original historical information and records forced Field Offices to use such surrogate measures. Notwithstanding these complexities, Field Offices are asked to use best professional judgement in responding to this data update, and to clearly identify which volumes are being reported and the basis for the estimates.

   Recognizing the special difficulties involved in estimating volumes of soil contaminated above the threshold concentration due to limited characterization data for most buried TRU waste sites, if Field Offices consider the uncertainties so great that not even a range of volume estimates can be given, then "unknown" would be an acceptable (though not preferred) response.

References

Everette, S.E., et al., *Comprehensive Implementation Plan for the DOE Defense Buried TRU-Contaminated Waste Program*, DOE-TRU TECH-001, U.S. Department of Energy, Albuquerque, New Mexico (1988).

Fioravanti, M., and A. Makhijani, *Containing the Cold War Mess: Restructuring the Environmental Management of the U.S. Nuclear Weapons Complex*, Institute for Energy and Environmental Research, Washington, D.C. (October 1997).

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Glossary of Terms

As used in this report, the following terms have the meanings indicated. Other related terms are defined in other reports prepared by the U.S. Department of Energy (DOE) including *Closing the Circle on the Splitting of the Atom* (DOE 1996a) and *Linking Legacies* (DOE 1997b).

11e(2) byproduct material: Tailings or waste produced by the extraction or concentration of uranium or thorium from any ore processed primarily for its source material content. The term derives its name from the fact that it is defined in Section 11e(2) of the Atomic Energy Act of 1954, as amended.

Absorption bed: Underground structure composed of aggregate materials used at Los Alamos National Laboratory to receive liquid discharges containing low levels of transuranic isotopes. Similar in concept to a french drain or septic tank and leach field system.

Activity: The rate at which radioactive material emits radiation, stated in terms of the number of nuclear disintegrations per unit time; the common unit of radioactivity is the curie (Ci).

Alpha low-level waste: Low-level waste containing, at the time of assay, concentrations of at least 10 but less than 100 nCi/g of waste of alpha-emitting transuranic radionuclides (i.e, having an atomic number greater than 92) with half-lives greater than 20 years. Certain additional redionuclides are included in this waste category to reflect past waste management practices at various sites. See also explanations for transuranic activity and transuranic waste.

Alpha low-level-waste contaminated soil or environmental media: Soil or other environmental media (e.g., sediment, rock) contaminated with transuranic radionuclides above 10 nCi/g but below 100 nCi/g. See also explanations of alpha low-level waste and transuranic-contaminated soil or environmental media.

Alpha-contaminated waste: Synonymous with buried transuranic-contaminated waste.

Alpha-emitting radionuclides: A radioactive substance that decays by releasing an alpha particle, which is a positively charged particle identical to a helium nucleus.

Buried transuranic waste: Synonymous with buried transuranic-contaminated waste.

Buried transuranic-contaminated materials: A slightly broader term than "buried transuranic-contaminated waste" that includes, in addition to the waste itself, environmental media such as soil contaminated above 10 nCi/g with transuranic isotopes by contact with solid waste or by liquid discharges.

Buried transuranic-contaminated waste: Waste disposed of by shallow land burial with no intent of later retrieval except by extraordinary means prior to the 1970 directive to retrievably store such wastes, and which is suspected of containing transuranic isotopes in concentrations above 10 or 100 nCi/g. Before 1970, transuranic-contaminated waste was not distinguished from other low-level waste, and was physically intermingled with low-level waste in the same containers and disposal locations. Transuranic waste generated after 1970 was usually, but not

always, segregated in a retrievable manner for later disposal in a geologic repository (see retrievably stored TRU waste).

For consistency with definitions of other types of radioactive waste (e.g., LLW) as distinct from contaminated media, soil contaminated from contact with either solid waste or liquid discharges is **NOT** considered "waste" but rather is considered contaminated "environmental media." Transuranic wastes (or low-level or low-level mixed waste) are created when remediation strategies involve excavation or removal of materials that require disposal in specially-engineered disposal facilities, i.e., waste generation.

Over the three decades that the final disposition of this special type of waste has been at issue, several other terms besides "buried transuranic-contaminated waste" have been used to describe the same entity, including "pre-1970 buried suspect transuranic waste," "alpha contaminated waste," "pre-1970 transuranic waste," "pre-1970 defense buried wastes," and just "buried transuranic waste" for short. The latter term is perhaps most common, but is somewhat misleading in that, to qualify as a *transuranic waste* by today's standards, the buried waste would need to be exhumed and radioactively assayed to show that it exceeds the current 100 nCi/g limit, among other factors. See text for additional discussion of complicating factors.

Central Internet Database: A database of information on waste, contaminated media (e.g., water, soil, sediment), facilities, and waste transfers required as part of a Settlement Agreement between DOE, the National Resources Defense Council, and plaintiffs on the Waste Management Programmatic Environmental Impact Statement lawsuit. The current report on buried transuranic-contaminated waste will be added to this database, which can be found at http://cid.em.doe.gov.

Classified Waste: Waste that includes weapons components and assemblies designated by the U.S. Government, pursuant to Executive Order, statute, or regulation, that require protection against unauthorized information or material disclosure for reasons of national security. Additional security and safeguards activities are required in the handling of these materials.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA): A federal law, enacted in 1980, that governs the cleanup of hazardous, toxic, and radioactive substances. The Act and its amendments created a trust fund, commonly known as Superfund, to finance the investigation and cleanup of abandoned and uncontrolled hazardous waste sites.

Contact-handled waste: Packaged waste whose external surface dose rate does not exceed 200 millirem per hour.

Crib: Underground structure designed to receive liquid wastes that percolate into the soil directly or after traveling through a connected tile field. This is similar in concept to a septic tank system.

Criticality: A term describing the conditions necessary for a sustained nuclear chain reaction.

Curie: The amount of radioactivity in 1 gram of the isotope radium-226. One curie is 37 billion radioactive decays per second.

Decay (radioactive): Spontaneous disintegration of the nucleus of an unstable atom, resulting in the emission of particles and energy. See also Table G-1.

Decay product: The isotope that results from the decay of an unstable atom.

Decommissioning: Retirement of a nuclear facility, including decontamination and/or dismantlement.

Decontamination: Removal of unwanted radioactive or hazardous contamination by a chemical or mechanical process.

Disposal: Emplacement of waste in a manner that ensures protection of the public, workers, and the environment with no intent of retrieval and that requires deliberate action to regain access to the waste.

Dose: A specific amount of ionizing radiation or toxic substance absorbed by a living being. Radiation dose is commonly expressed in terms of millirem. A dose of one millirem is about equal to the dose received from a one-day exposure to natural background radiation.

Environmental Restoration: Often described broadly as "cleanup," this function encompasses a wide range of activities, such as characterizing contaminated waste sites through drilling and sampling test holes; stabilizing contaminated soil; treating groundwater; decommissioning process buildings, nuclear reactors, chemical separations plants, and many other facilities; and exhuming sludge and buried drums of waste.

Fission products: The large variety of smaller atoms, including cesium and strontium, left over by the splitting of uranium and plutonium. Most of these atoms are radioactive, and they decay into other isotopes. There are more than 200 isotopes of 35 elements in this category. Most of the fission products in the United States are found in spent nuclear fuel and high-level waste.

Geologic repository: A place to dispose of radioactive waste deep beneath the earth's surface. A geologic repository for defense transuranic waste, known as the Waste Isolation Pilot Plant, is currently in operation near Carlsbad, New Mexico. A geologic repository for high-level waste and spent nuclear fuel is currently under evaluation for its suitability at Yucca Mountain, Nevada. Such specially sited and designed facilities are believed to provide the greatest degree of isolation of radioactive wastes from humans and the environment.

Greater confinement disposal (GCD): A disposal option adopted by DOE that involved the placement of wastes in intermediate depth boreholes (20 to 36 meters [70-120 feet]) with backfill at Area 5 of the Nevada Test Site for certain wastes not suitable for shallow land burial. The 13 GCD boreholes (four of which are currently empty) may contain one or more of the following waste types: mixed low-level waste; low-level waste; waste similar to greater-than-Class-C low-level waste; high specific-activity low-level waste; transuranic waste; and some classified wastes.

Greater-than-Class-C low-level waste: Low-level radioactive waste from commercial sources that exceeds U.S. Nuclear Regulatory Commission concentration limits specified in 10 CFR Part 61. Such wastes are not generally suitable for near-surface disposal. The Low-Level Waste Policy Act made DOE responsible for the disposal of greater-than-Class-C low-level waste.

Half-life: The time it takes for one-half of any given number of unstable atoms to decay. Each isotope has its own characteristic half-life. They range from small fractions of a second to billions of years. For the convenience of the reader, the half lives of the major radionuclides discussed in this report are listed in Table G-1 at the end of this glossary.

High-level waste: The highly radioactive waste material resulting from the reprocessing of spent nuclear fuel, including liquid waste produced directly in reprocessing and any solid material derived from such liquid waste that contains fission products in sufficient concentrations; and other highly radioactive material that is determined, consistent with existing law, to require permanent isolation.

Hydrofracture: An underground injection disposal process used in the past at Oak Ridge National Laboratory to dispose of certain radioactive wastes in which liquid waste and/or sludges were mixed with grout before injecting them into shale formations to a depth of about 300 meters (1,000 feet) below the surface. It was intended as a form of greater confinement disposal, as compared with shallow land burial.

Institutional controls: Long-term actions or restrictions including monitoring, periodic sampling, access controls, and land use restrictions designed to mitigate any risks posed by contamination following remediation.

Integrated Data Base (IDB) reports: A series of annual reports prepared between 1984 and 1997 by DOE compiling historic data on inventories and characteristics of both commercial and DOE spent nuclear fuel and commercial and U.S. government-owned radioactive wastes.

Intermediate depth disposal: As used in this report, disposal of certain special case wastes at depths "intermediate" between shallow land burial and deep geologic disposal. Disposal was generally between 30 and 300 meters (100 to 1,000 feet) but may be deeper.

Isotopes: Any of two or more variations of an element in which the nuclei have the same number of protons (i.e., the same atomic number) but different numbers of neutrons so that their atomic masses differ. Isotopes of a single element possess almost identical chemical properties, but often different physical properties (e.g., carbon-12 and 13 are stable, carbon-14 is radioactive).

Latent cancer fatality: Death from cancer resulting from, and occurring some years after, exposure to ionizing radiation or other carcinogens.

Low-level waste: Radioactive waste that is not high-level waste, spent nuclear fuel, transuranic waste, byproduct material (as defined in Section 11e(2) of the Atomic Energy Act of 1954, as amended), or naturally occurring radioactive material.

Mixed low-level waste: Low-level radioactive waste that contains a chemically hazardous component subject to the Resource Conservation and Recovery Act.

nCi/g: Abbreviation for nanocurie per gram, a term often used to describe the concentration of transuranic materials. A nanocurie is equal to one billionth of a curie.

Pre-1970 buried suspect transuranic waste: Synonymous with buried transuranic-contaminated waste.

Pre-1970 transuranic waste: Synonymous with buried transuranic-contaminated waste.

Previously disposed of waste: As used in this report, buried transuranic-contaminated waste and intermediate-depth disposed of waste. Excludes contaminated soil and other environmental media such as rock contaminated by underground nuclear tests conducted at the Nevada Test Site and off-site test locations.

Process knowledge: The set of information that is used by trained and qualified individuals who are cognizant of the origin, use, and location of waste-generating materials and processes in sufficient detail so as to certify the content of the waste.

Radioactive waste: Any garbage, refuse, sludges, and other discarded material, including solid, liquid, semi-solid, or contained gaseous material that must be managed for its radioactive content.

Record: A completed document or other medium that provides objective evidence of an item, service, or process.

Release: Any discharging, dumping, emitting, emptying, escaping, injecting, leaching, leaking, pouring, pumping, spilling of radioactive substances into the environment, including abandoning any type of receptacle containing radioactive substances, but not including disposal in a permitted disposal facility.

Remote-handled waste: Packaged waste whose external surface dose rate exceeds 200 millirem per hour.

Resource Conservation and Recovery Act (RCRA): A Federal law enacted in 1976 to address the treatment, storage, and disposal of hazardous waste.

Retrievably stored transuranic waste: Temporary storage of transuranic waste in a manner designed for recovery without a loss of control or release of radioactivity. Starting in the 1970s, the Atomic Energy Commission (now DOE) began storing waste that was suspected of being contaminated with transuranic isotopes at a concentration greater than 10 nCi/g of waste (this limit was later changed to 100 nCi/g) with the intent of retrieving this waste at a later time for final disposal in a geologic repository (i.e., a facility recognized today as the Waste Isolation Pilot Plant). To implement the directive to retrievably store suspect transuranic waste, the DOE Field sites used a wide variety of waste containers (e.g., 55-gallon drums, fiberglass-reinforced plywood or metal boxes) and storage configurations (e.g., below-grade storage in earthen-covered lined or unlined trenches, pits, pads, culverts, caissons, concrete casks, vaults, shafts, etc., or above-grade storage on asphalt pads with covers, or storage in modern RCRA-compliant buildings or fabric domes, or storage of waste containers outside in the open, depending on the expected length of time storage was to be maintained). While DOE has substantial waste characteristic data for many of the waste containers stored after 1970, there are some waste containers for which very little content information is available. Therefore, except for differences in emplacement dates, it may be difficult to distinguish some of the post-1970 stored transuranic waste from the pre-1970 buried transuranic waste since both came from the same waste generators, were packaged in the same manner, and are covered with soil. There are a few instances where waste originally intended to be maintained in a retrievably stored condition may now be irretrievably disposed of, due, for

example, to a total loss of integrity of the waste containers. Generally, such situations would be managed pursuant to the CERCLA/RCRA regulations.

Reverse well: Process in which solutes are injected in an underlying geologic formation through wells. During the early years of Hanford operations, waste solutions were pumped into reverse wells as a method of waste disposal.

Safety tests: Chemical explosion tests of mostly plutonium-bearing materials conducted between 1954 and 1963 on portions of the Nevada Test Site, Nellis Air Force Range Complex, and the Tonopah Test Range. The immediate effects of the tests included the dispersal of plutonium and uranium over significant surface areas. Many tests were conducted to determine whether nuclear yields could be produced from accidental detonations, which is the reason for the term "safety tests."

Shallow land burial: As used in this report, disposal of radioactive waste generally within the top 30 meters (100 feet) of the earth's surface.

Source material: Uranium or thorium, or any combination thereof, in any physical or chemical form, or ores which contain by weight one-twentieth of one percent (0.05%) or more of (a) uranium, thorium or any combination thereof. Source material does not include special nuclear material.

Special case waste: Waste that is not high-level or transuranic waste, but requires greater confinement than shallow land burial.

Special nuclear material: Plutonium, uranium enriched in the isotope 233 or in the isotope 235, and any other material which is determined, pursuant to the provisions of Section 51 [of the Atomic Energy Act of 1954, as amended], to be special nuclear material, but does not include source material; or any material artificially enriched by any of the foregoing, but does not include source material.

Spent nuclear fuel: Fuel that has been withdrawn from a nuclear reactor following irradiation, the constituent elements of which have not been separated by reprocessing. Test specimens of fissionable material irradiated for research and development only, and not production of power or plutonium, may be classified and managed as waste when it is technically infeasible, cost prohibitive, or would increase worker exposure to separate the remaining test specimens from other contaminated material.

Storage: The holding of radioactive waste for a temporary period, at the end of which the waste is treated, disposed of, or stored elsewhere.

Toxic Substances Control Act (TSCA): A federal law enacted in 1976 to protect human health and the environment from unreasonable risk caused by manufacturing, distribution, use, disposal of, or exposure to, substances containing toxic chemicals, such as asbestos and polychlorinated biphenyls.

Transuranic activity: As used in this report, radioactivity reported in curies due to any of the following isotopes: americium-241; plutonium-238, plutonium-239, plutonium-240, plutonium-241, or plutonium-242; uranium-233, uranium-234, uranium-235, or uranium-238; curium-244; radium-226; neptunium-237; californium-252; and possibly others. Note that several of these isotopes would not be categorized as "transuranic" by today's standards. See also explanation for "transuranic waste."

Transuranic waste: The official, operating definition as taken from federal legislation is as follows: Radioactive waste containing more than 100 nanocuries (3700 becquerels) of alpha-emitting transuranic isotopes per gram of waste, with half-lives greater than 20 years, except for: (1) high-level radioactive waste; (2) waste that the Secretary of Energy has determined, with the concurrence of the Administrator of the Environmental Protection Agency, does not need the degree of isolation required by the 40 CFR Part 191 disposal regulations; or (3) waste that the Nuclear Regulatory Commission has approved for disposal on a case-by-case basis in accordance with 10 CFR Part 61.

To reflect past Atomic Energy Commission radioactive waste disposal practices before the 1970s involving transuranic-contaminated materials, which is the subject of this report, this definition must be expanded to include certain other isotopes that would **not** by today's definition qualify as transuranic wastes. In particular, for the purposes of this report, radioactive wastes containing non-transuranic alpha-emitting isotopes (such as uranium-233 and radium-226), transuranic alpha-emitting isotopes with half-lives less than 20 years (such as curium-244 and californium-252), or transuranic non-alpha-emitting isotopes (such as plutonium-241) are treated as though they were transuranic wastes. Such an expansion is necessary to reflect the reality of diverse site-specific past practices and flexibility given to Field Offices to manage certain other radioactive wastes as transuranic wastes. See also Table G-1.

Transuranic-contaminated soil or environmental media: Soil or other environmental media (e.g., sediment, rock) contaminated with transuranic radionuclides above 100 nCi/g. This report does not consider contaminated environmental media as waste when the media are addressed through in-situ containment or treatment remediation strategies. The categorization of a material as a "waste" or "contaminated media" is made for discussion purposes only, and has no bearing on the regulatory status of the material.

Treatment: Any method, technique, or process designed to change the physical or chemical character of waste to render it less hazardous, safer to transport, store, or dispose of, or reduce its volume.

Vitrification: A process by which waste is transformed from a liquid or sludge into an immobile solid that traps radionuclides and prevents waste from contaminating soil, groundwater, and surface water. The DOE has selected vitrification processes to solidify and stabilize certain forms of radioactive and hazardous waste. This process does not reduce radioactivity.

Waste container: A receptacle for waste, including any liner, shielding, or material that is intended to accompany the waste in disposal.

Waste Isolation Pilot Plant (WIPP): A DOE facility designed and authorized to permanently dispose of transuranic radioactive waste in a mined underground facility in deep geologic salt beds. It is located in southeastern New Mexico, 42 km (26 miles) east of the city of Carlsbad.

Table G-1. Half-life and Main Mode of Radioactive Decay of the Major Radionuclides Considered in this Report[a]

Radionuclide	Half-life (Years)	Main Mode of Radioactive Decay
Radium-226	1,600	alpha
Uranium-233	159,000	alpha
Uranium-234	245,000	alpha
Uranium-235	704,000,000	alpha
Uranium-238	4,470,000,000	alpha
Neptunium-237	2,140,000	alpha
Plutonium-238	87.7	alpha
Plutonium-239	24,100	alpha
Plutonium-240	6,540	alpha
Plutonium-241	14.4	beta
Plutonium-242	376,000	alpha
Americium-241	432	alpha
Curium-244	18.1	alpha
Californium-252	2.64	alpha

[a]The radionuclides listed above are those included in the data call issued to the Field Offices in January 1999, and in the Field Office responses as provided in the *Buried Transuranic-Contaminated Waste and Related Materials Database*. The half-lives and main modes of radioactive decay were obtained from the most recent edition of *The Health Physics and Radiological Health Handbook*. The half-lives are given to three significant figures.