4.0 WASTE DESCRIPTION

This chapter describes the type of waste that will be emplaced in the Waste Isolation Pilot Plant (WIPP) and provides an appraisal of the inventory of physical, chemical, and radionuclide components of the waste. This information supports the development of the performance assessment models that are used in predicting the long-term behavior of the repository. This chapter includes a waste description based on the inventories of existing and projected waste reported in the transuranic (TRU) Waste Baseline Inventory Report (TWBIR) (included in this application as Appendix BIR), a description of the projected waste inventory, waste limits derived from both the performance assessment and operational safety and health considerations, and methods of control to ensure compliance with the identified waste limits. In addition, this chapter provides a discussion of the applicable qualitative and quantitative waste characterization methodologies.

Title 40 of the Code of Federal Regulations (CFR) § 194.24(a) specifies that the U.S. Department of Energy (DOE) shall provide information pertaining to the chemical, radiological, and physical composition of the waste planned to be emplaced in the repository. Specifically, the criterion states

> Any compliance application shall describe the chemical, radiological and physical composition of all existing waste proposed for disposal in the disposal system. To the extent practicable, any compliance application shall also describe the chemical, radiological and physical composition of to-be-generated waste proposed for disposal in the disposal system. These descriptions shall include a list of waste components and their approximate quantities in the waste. The list may be derived from process knowledge, current non-destructive examination/assay, or other information and methods.

This waste description includes the definition, sources, types, components, and characteristics of TRU waste planned for emplacement in the WIPP. The description provided in this chapter, along with the waste characterization analysis in Appendix WCA,[1] identifies those physical, chemical, and/or radiological components of the waste that may singly or in combination affect the ability of the WIPP disposal system to meet the environmental performance standards contained in 40 CFR Part 191. This chapter is supported with several appendices. For example, waste related parameters used in performance assessment are discussed in Appendix PAR and Appendix WCA. Results of sensitivity analyses with respect to total releases used to generate the mean complementary cumulative distribution function (CCDF) in Section 6.5 are discussed in Appendix SA. The impact of waste components and characteristics on WIPP performance is discussed in Appendix WCA. Limits for waste components are discussed in Appendix WCL and summarized in this chapter. (See Table 1-4 in Chapter 1.0 for a list of appendices that provide additional information supporting this chapter.) This chapter also describes methods of control that will be employed by the DOE to ensure that only those wastes that are consistent with these descriptions are actually emplaced

[1] The waste characterization analysis detailed in Appendix WCA was peer reviewed per the criteria in 40 CFR § 194.27(a)(2). Results of this peer review are documented in Section 9.3.2 and in Appendix PEER.

in the repository. One such control is the WIPP Waste Information System (WWIS) (DOE 1995e, 1996b) database for controlling the receipt of and tracking the emplacement of waste (see Section 4.3.2).

Before the final performance assessment was designed, waste characterization analyses comprised of iterative preliminary performance assessments, related sensitivity analyses, and dedicated process studies for specific components and characteristics of the waste, were performed. A list of waste components and characteristics that were considered during these analyses, the list of and rationale for the ones retained for inclusion in the final performance assessment, and the ones not included are documented in Appendix WCA. Retained waste components are assigned fixed values in the final performance assessment (See Appendix PAR) based on information reported in the TWBIR, Revision 3 (Appendix BIR). Therefore, during the performance assessment, plausible combinations of fixed values for waste components are included in all performance assessment scenario analyses. Important imprecisely known waste characteristics are provided ranges and distributions (See Appendix SOTERM and Appendix PAR) from which values are drawn using a Latin hypercube sampling (LHS) technique that ensures that samples are taken from across the entire range of the distribution (See Section 6.1.5.2).

Since results demonstrate compliance with the quantitative containment requirements in 40 CFR § 191.13, the individual protection requirements in 40 CFR § 191.15, and the groundwater protection requirements in 40 CFR § 191.24, the fixed values used for waste components define a profile of waste suitable for disposal at WIPP. Following the final performance assessment, sensitivity analyses determined the contribution of uncertainty in individual input variables to the uncertainty in model predictions (that is, final releases). There are no waste characteristics that have a significant impact on the uncertainty about and the location of the mean CCDF reported in Figure 6-39 (See Appendix SA for a discussion of this uncertainty). Therefore, setting waste component limits is not based on performance assessment results but is based on ensuring the validity of repository conditions modelled by performance assessment (See Appendix WCL). In addition, the limits are repository-scale limits that should be met at the time of repository decommissioning. The process for demonstrating compliance with these limits is to track the waste-component quantity and the uncertainty associated with that quantity as waste is emplaced in the repository. For example, the curie content for plutonium and it's uncertainty (based on the fact that a large percentage of the waste has yet to be generated) can be accumulated as waste is emplaced throughout the operational phase. Then, at the time of decommissioning, when these repository limits apply, the total curie content for plutonium may be provided with a specified level of confidence, such as 95 percent, to demonstrate compliance with the waste component limits.

Figure 4-1 illustrates the information flow pertaining to the waste description and its relationship to other sections of this chapter as well as Chapter 6.0 and appendices to this application.

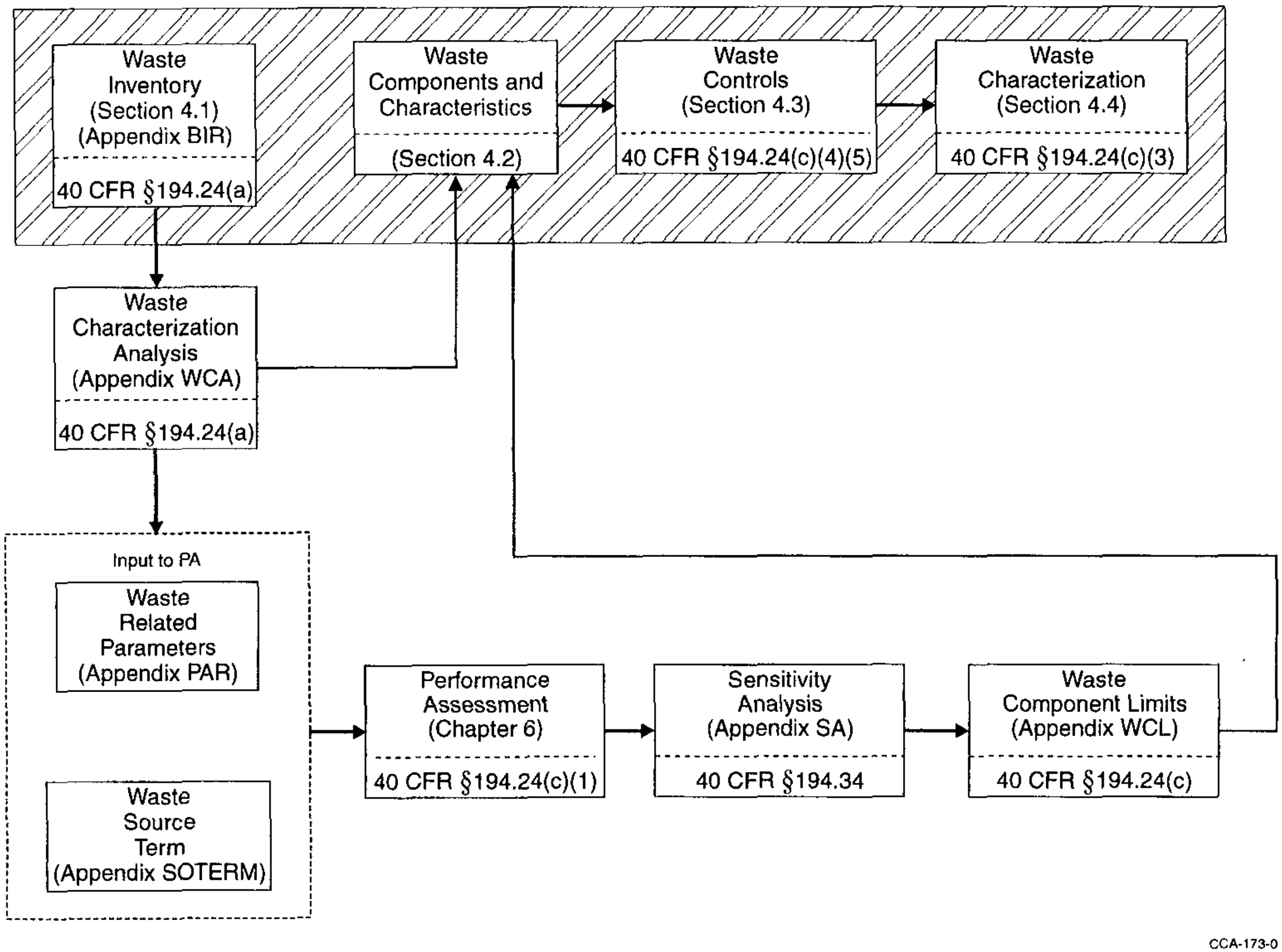

Figure 4-1. Waste Description Information Flow

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4.1 Waste Inventory

The waste inventory is defined as the quantity of waste that is anticipated to be emplaced in the WIPP. This inventory is generally characterized as the nonradionuclide inventory that consists of both physical and chemical waste constituents, generally expressed in units of density or concentration; and the radionuclide inventory, which is a tabulation, by specific isotope, of anticipated radionuclides in the waste expressed in units of curies.

The term TRU waste is defined (EPA 1993) as

> waste containing more than 100 nanocuries of alpha-emitting transuranic isotopes, with half-lives greater than twenty years, per gram of waste, except for (1) High-level radioactive wastes; (2) wastes that the Department has determined, with the concurrence of the Administrator, do not need the degree of isolation required by this part; or (3) wastes that the Commission has approved for disposal on a case-by-case basis in accordance with 10 CFR Part 61.

TRU isotopes have atomic numbers greater than uranium (92). In determining the alpha-activity concentration levels for waste classification, only the mass of the waste is used in the concentration calculation. The waste container, plus any added shielding and other packaging, is not included in the mass component of this determination.

Pre-1970 TRU waste that has been disposed of by generators in on-site, shallow landfill-type configurations is referred to as buried waste. In 1970, the U.S. Atomic Energy Commission concluded that TRU waste should have greater confinement from the environment. Thus, TRU waste generated since that date has been segregated from other waste types and placed in retrievable storage. Waste generated after the early 1970s, but before implementation of the DOE's TRU Waste Characterization Quality Assurance Program Plan (QAPP), is referred to as retrievably stored waste. Waste generated after a site's implementation of the QAPP is defined as newly generated TRU waste (DOE 1995b). Implementation of the QAPP occurs after the site's Quality Assurance Project Plans (QAPjPs) have been approved and implemented. Newly generated waste will be characterized in a similar manner to retrievably stored waste, but it will incorporate more real-time, as opposed to historical, acceptable knowledge. Approximately 65 percent of the waste to be disposed of at the WIPP is expected to be newly generated waste, as described in the TWBIR (Appendix BIR).

TRU waste is classified as either contact-handled (CH) or remote-handled (RH) based on the contact dose rate at the surface of the waste container. If the contact dose rate is less than or equal to 200 millirem per hour (2 milliSievert per hour), the waste is defined as CH-TRU (DOE 1988). If, on the other hand, the contact dose rate is greater than 200 millirem per hour (2 milliSievert per hour), the waste and its container are defined as RH-TRU (DOE 1988). Only RH-TRU waste less than or equal to 1000 rem per hour (10 Sievert per hour) is eligible for disposal at the WIPP (DOE 1996a). To meet the requirements as set forth in the WIPP Land Withdrawal Act (LWA) (U.S. Congress 1992b), the total combined volumes of CH-TRU and RH-TRU waste are not to exceed 6.2 million cubic feet (175,564 cubic meters). Moreover, the LWA also specifies that the emplaced RH-TRU waste is not to exceed a total activity of 5.1 million curies (~ 18.9×10^{16} Becquerel) and a total activity concentration of 23 curies per liter (averaged over the volume of the canister). No more than five percent of the emplaced RH-TRU waste may exhibit a dose rate in excess of 100 rem per hour (1 Sievert per hour).

The last category of waste to be defined is TRU mixed waste, that is, waste that contains both TRU radioactive components and hazardous components as defined in the New Mexico Administrative Code (see NMAC in the Bibliography). Hazardous components of TRU mixed waste to be managed at the WIPP facility are designated in Part A of the WIPP Resource Conservation and Recovery Act (RCRA) permit application. The Waste Analysis Plan (WAP) (see Appendix WAP) describes measures to ensure that the wastes received at the WIPP facility are within the scope of the Part A. As stated in Appendix WCA (Section WCA.4.1.3), only four of 60 organic compounds in the waste are expected to have an effect on actinide mobility. None of the four (acetate, citrate, oxalate, and ethylenediaminetetracetate [EDTA]) are listed in Part A of the WIPP RCRA permit application. Consequently, this component of TRU waste is omitted from further discussion in this chapter.

4.1.1 Sources of TRU Waste

The DOE's TRU waste, as described in this chapter, is derived primarily from plutonium fabrication and reprocessing, research and development (R&D), decontamination and decommissioning (D&D), and environmental restoration (ER) programs at various sites. Most TRU waste generated at the DOE sites results from specific processes and activities that are well defined and well controlled, enabling the DOE to characterize the waste on the basis of acceptable knowledge of the process, input raw materials, and output finished products. Some examples of these operations include

- Production of nuclear products. Production of nuclear products includes reactor operation, radionuclide separation and finishing, and weapons fabrication and manufacturing. The majority of the TRU waste was generated by weapons fabrication and radionuclide separation and finishing processes. More specifically, wastes typically consist of TRU-contaminated material derived from chemical processes, air and liquid filtration, casting, machining, cleaning, product quality sampling, analytical activities, and maintenance and refurbishment of equipment and facilities.

- Plutonium recovery. Plutonium recovery wastes are TRU-contaminated items and materials from the recovery of valuable plutonium, including contaminated molds, metals, glass, plastics, rags, salts used in electrorefining, precipitates, firebrick, soot, and filters.

- R&D. R&D projects include a variety of hot-cell or glove-box activities that often simulate full-scale operations described above, producing similar TRU wastes. Other types of R&D projects include metallurgical research, actinide separations, process demonstrations, and chemical and physical properties determinations.

- D&D. Facilities and equipment that are no longer needed or usable are decontaminated and decommissioned, resulting in TRU wastes consisting of scrap materials, cleaning agents, tools, piping, filters, plexiglas, gloveboxes, concrete rubble, asphalt, cinder blocks, and other building materials. This is expected to be the largest category by volume of TRU waste to be generated.

Operations carried out in glove boxes and hot cells generate both combustible and noncombustible wastes. Combustible waste contains mixtures of paper, plastics, rags, cloth clothing, and wood resulting from plutonium operations. Cloth and paper wipes are used to clean parts and glove boxes. Depending on the operations, damp combustibles are usually used and then wrung out, drained, or dried. Noncombustibles consist primarily of glass and metal. Much of this waste is laboratory equipment and glassware from R&D activities.

Filters are sometimes combinations of combustibles and non-combustibles and come from a variety of sources including high-efficiency particulate air (HEPA) filters , filter media, processed filter media, and prefilters. Prefilters and HEPA filters are used on all ventilation intake and exhaust systems associated with plutonium operations. Filter frames can be either wood, aluminum, or stainless steel; and the filter media may be paper, Fiberglass, Nomex, or similar material. Filter media are generated from splitting absolute dry box and HEPA filters apart from their frames in the plutonium process areas. Loose particulate materials that are dislodged from the filters are stabilized and packaged separately from the media. Filter media are packaged in plastic bottles or bags. Filter media may also be mixed with portland cement to neutralize any residual nitric acid.

Graphite waste is produced from molds that are broken, cleaned, or scraped in glove boxes to remove excess plutonium. Graphite is a uniform, well-defined material.

Benelex and Plexiglas are well-defined materials that are used as neutron shielding material and in glove-box construction. Benelex consists mainly of cellulose with residual amounts of the phenolic resin. Plexiglas is a polymethyl methacrylate polymer used for glove-box windows and is generated as waste during the change-out of the glove-box windows.

Inorganic process solids include residues from evaporator and other types of storage tanks, grit, firebrick fines, ash, salts, metal oxides, and filter sludge. This waste is typically solidified in portland- or gypsum-based cements.

Soil, asphalt, and sand contaminated from spills or generated from D&D activities may also be present in the waste.

To isolate the radiological and hazardous co-contaminants of these wastes from humans and the environment during handling and other life-cycle operations, a primary confinement barrier is used. Both CH-TRU and RH-TRU waste at the WIPP facility will be managed using payload containers that meet the requirements of the U.S. Department of Transportation (DOT) for Type A or equivalent containers (DOE 1995d). The term payload container in this document refers to a drum, drum overpack, canister, standard waste box, or ten-drum overpack unit. Internal to these payload containers may be other secondary layers of confinement, including rigid plastic inner liners and multiple layers of plastic bagging. Each container is vented using one or more filters.

4.1.2 TRU Waste Generator and Storage Sites

The major generator and storage sites (see Figure 4-2) that are planning to ship their TRU waste to the WIPP for disposal include

- Richland Hanford Site (HANF)

- Idaho National Engineering Laboratory (INEL)

- Lawrence Livermore National Laboratory (LLNL)

- Los Alamos National Laboratory (LANL)

- Nevada Test Site (NTS)

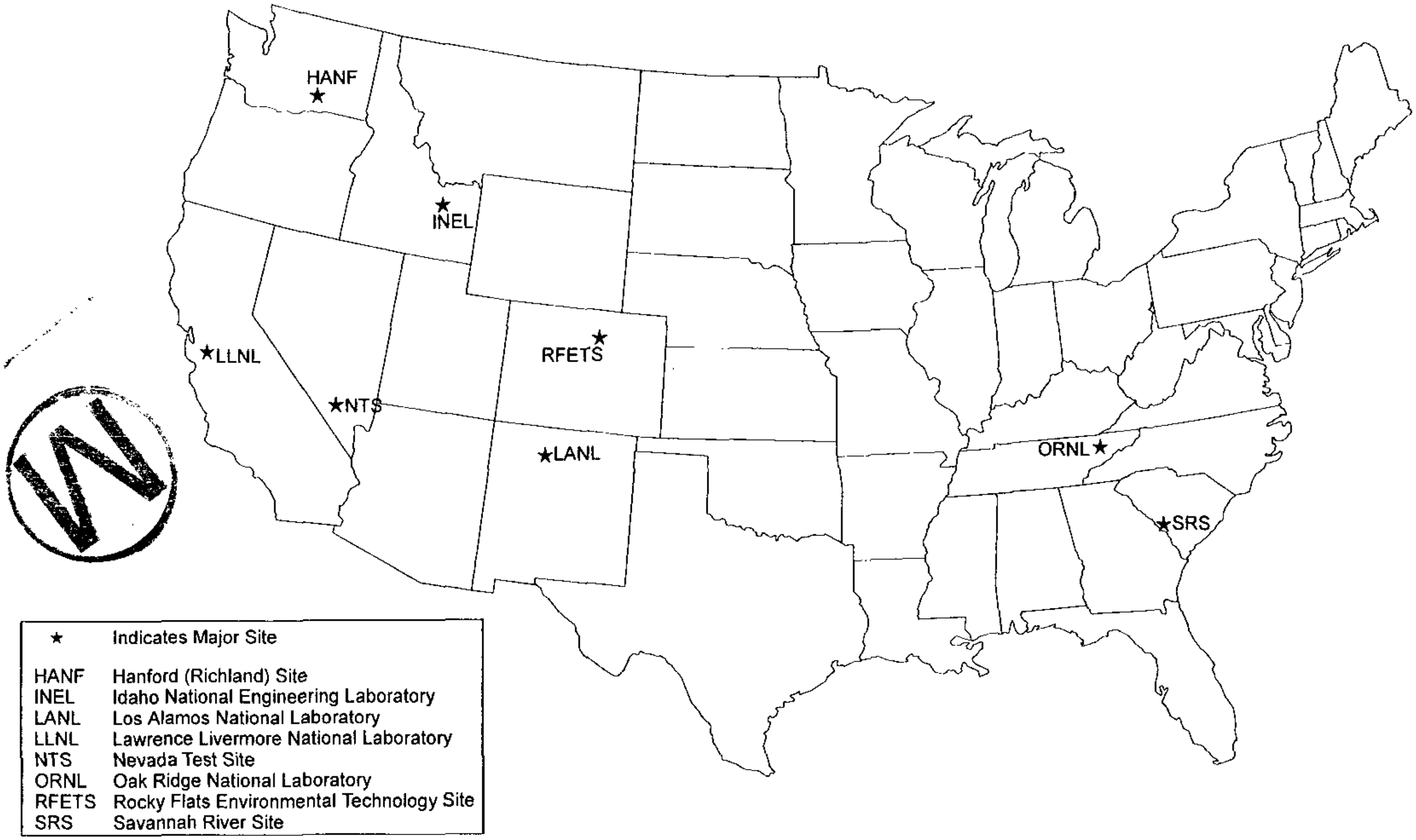
- Oak Ridge National Laboratory (ORNL)

- Rocky Flats Environmental Technology Site (RFETS)

- Savannah River Site (SRS)

The INEL, LANL, and RFETS are expected to be among the first of the major generator and storage sites to begin shipping TRU waste to the WIPP. As the other major sites develop the prerequisite certification programs required for TRU waste disposal at the WIPP, they too will commence shipping waste to the WIPP. Effective implementation by the generator and storage sites of the DOE Carlsbad Area Office (CAO) Quality Assurance Program Document (QAPD) (see Appendix QAPD) is a prerequisite for granting TRU waste certification authority to the sites. A letter granting such authority will specify the date that the subject site effectively implemented their characterization and certification program. Any limitations imposed on the certification authority will be described in the letter.

In addition to the major generator and storage sites, there are currently numerous small-quantity sites (SQSs) planning to dispose TRU waste at the WIPP. Options to facilitate disposal of the SQS waste at the WIPP include either direct shipment to the WIPP after on-site characterization and certification or shipment to an interim site for performing waste consolidation, treatment, and/or characterization and certification in accordance with WIPP requirements. The current list of SQSs includes



Note: Adapted from Figure 1-1, TWBIR Vol. 1.

CCA-078-2

Figure 4-2. U.S. DOE TRU Waste Generator and Storage Sites

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- Ames Laboratory
- Argonne National Laboratory - East
- Argonne National Laboratory - West
- Battelle Columbus Laboratories
- Bettis Atomic Power Laboratory
- Energy Technology Engineering Center
- General Electric Vallecitos Nuclear Center
- Massachusetts Institute of Technology
- Mound Plant
- National Institute of Standards and Technology
- Paducah Gaseous Diffusion Plant
- Pantex Plant
- Sandia National Laboratories/NM (SNL)
- Site A/Plot M (near Chicago, Illinois)
- Special Process Research Unit
- Teledyne Brown Engineering
- University of Missouri Research Reactor
- U.S. Army Material Command

As more SQSs are identified, they will be added to this list. Figure 4-2 shows the geographic locations of the major generator and storage sites.

4.1.3 TRU Waste Inventory

A summary of the quantity of stored and projected TRU waste and TRU waste components is contained in the TWBIR (see Appendix BIR). The TWBIR documents the total inventory of DOE TRU waste and includes both the TRU waste that is planned to be disposed at the WIPP site and the TRU waste that will not be sent to WIPP. Only the WIPP portion of the TRU waste inventory is used in performance assessment calculations that support the development of this compliance application.

Although updates are made to the TWBIR based on new information received from ongoing waste identification and characterization activities at the generator and storage sites, the TWBIR is an inventory report and not a summary of TRU waste characterization data. For waste shipped to the WIPP, waste characterization data associated with each container is entered into the WWIS for tracking purposes. A description of the WWIS is given in Section 4.3.2.

In support of performance assessment, it was necessary for the DOE to roll-up waste information on a repository scale. To this end, the TWBIR describes a process for grouping individual waste streams with similar physical and chemical properties into waste profiles, based on the waste matrix code (WMC) assigned by the DOE TRU waste generator and storage sites. Waste profiles with similar WMCs are then combined across the DOE TRU waste system to provide estimated total volumes and total waste material parameters (WMPs). WMPs and waste components (as used in 40 CFR § 194.24) are synonymous. Individual waste streams are evaluated to estimate the occurrence and quantities of nonradioactive WMPs (for example, cellulosics, plastics, iron-base metal and alloys, etc.) and are identified in Appendix WCA as having either a significant or negligible effect on the performance of the WIPP repository. See Table 4-1 for a listing of these waste components and their associated characteristics.

4.1.3.1 Inventory Terminology

Stored Inventory – The part of the TRU inventory currently in retrievable storage at the time of the last data call for inventory information is known as stored inventory. Retrievably stored waste includes waste stored since approximately 1970 in buildings or in berms with earthen cover and does not include any waste that was disposed prior to 1970.

As-Generated Waste – The chemical and physical status of waste when it is generated. The as-generated term applies to both stored and future waste.

Projected Inventory – The part of the TRU inventory that has not been generated but is currently estimated to be generated at some time in the future by the TRU waste generator and storage sites, is known as projected inventory. The projected inventory is the same as the to-be-generated waste referred to in 40 CFR §194.24(a).

Scaling – The process of adjusting, if needed, the projected inventory to the design limit (disposal inventory) is called scaling. Scaling is needed in performance assessment to model the WIPP repository at full capacity (6.2 million cubic feet by statute).

Table 4-1. Waste Characteristics and Components That are Expected to Have Significant and Negligible Effects

Characteristic	Component	Effect on Performance
Characteristics and Components Expected to Have a Significant Effect		
radioactivity in curies of each isotope	radioactivity in curies of each isotope	used in calculation for normal release
TRU radioactivity at closure	α-emitting TRU radionuclides, $t_{1/2} > 20$ years	determines waste unit factor
solubility	radionuclides	actinide mobility
colloid formation	radionuclides, cellulose, soils, plastics, rubber	actinide mobility
redox state	radionuclides	actinide mobility
redox potential	ferrous metals	actinide oxidation state; actinide mobility
gas (H_2) generation	ferrous metals	increase in H_2 pressure
microbial substrate: CH_4 generation	cellulose	increase in gas pressure
microbial substrate: CH_4 generation	plastics, rubber	increase in gas pressure
particle diameter	solid waste components	spalling release
microbial nutrients: CH_4 generation	sulfates	increase in gas pressure
microbial nutrients: CH_4 generation	nitrates	increase in gas pressure
compressibility and shear strength	solid waste components	effect on creep closure, cuttings, caving, spalling
Characteristics and Components Expected to Have a Negligible Effect		
permeability	solid waste components	negligible effect on brine movement, gas storage
porosity	solid waste components	negligible effect on brine movement
microbial nutrients, CO_2 generation	sulfates	negligible: MgO reacts with CO_2
microbial nutrients, CO_2 generation	nitrates	negligible: MgO backfill reacts with CO_2
microbial substrate: CO_2 generation	cellulose	negligible: MgO backfill reacts with CO_2
microbial substrate: CO_2 generation	plastics, rubber	negligible: MgO backfill reacts with CO_2
gas generation	water in the waste	enhances initial gas generation

Based on the inventory identified in Revision 3 of the TWBIR, the scaling factor is calculated to be 2.05 (see Appendix BIR [Revision 3, 2-3]).

Stored Inventory + Projected Inventory (2.05) = Disposal Inventory

Disposal Inventory – The inventory volume defined for WIPP emplacement to be used for performance assessment calculations is the disposal inventory. The LWA defines the total amount of TRU waste allowed for disposal in the WIPP as 6.2 million cubic feet (175,564 cubic meters) (U.S. Congress 1992b). Consistent with 40 CFR § 194.24(g), this is the maximum quantity of TRU waste which will be emplaced in the repository. The WIPP limit of RH-TRU inventory is 250,000 cubic feet (7,079 cubic meters), as set by the Consultation and Cooperation Agreement between the DOE and the state of New Mexico (DOE and state of New Mexico 1981).

WMCs – Codes developed by DOE, in response to the Federal Facility Compliance Act (U.S. Congress 1992a), as a methodology to aid in categorizing mixed waste streams in the DOE system into a series of five-digit alphanumeric codes (for example, S5400; Heterogeneous Debris) that represent different physical and chemical matrices. Using guidance prepared by the DOE (DOE 1995f), the WMC is assigned by the TRU waste generator and storage sites for all mixed waste streams and some unmixed waste streams. The TWBIR has adopted this system to remain consistent with common terminology used by the DOE waste generator and storage sites. WMCs are verified with radiographic examination (using either real-time radiography [RTR] or an equivalent methodology) and/or visual examination.

Final Waste Form – The final waste form of a waste stream consists of a series of WMCs that are grouped together, which for performance assessment purposes have similar physical and chemical properties. The final waste form applies to both stored and projected inventory. Table 4-2 presents anticipated WMCs for TRU waste and indicates the final waste form typically assigned to each WMC for the TWBIR. There are 11 final waste forms used in the TWBIR. Each of the 11 final waste forms described in Table 4-2 identify a material property common to the numerous waste streams grouped under it.

Waste Stream Profile – This is a description of a CH-TRU or RH-TRU waste stream. Examples of information included in a waste stream profile are

- waste stream description;
- waste stream source description;
- currently used identification codes, including the DOE TRU waste site matrix description;
- final waste form assigned by the TRU waste generator and storage sites;

Table 4-2. WMCs and Their Anticipated Final Waste Form

Final Waste Form	WMCs
Solidified Inorganics	L1000, L1100, L1110, L1120, L1130, L1140, L1190, 1200, L1210, L1220, L1230, L1240, L1290, S3000, S3100, S3110, S3111, S3112, S3113, S3115, S3118, S3119, S3120, S3121, S3122, S3123, S3124, S3125, S3129, S3130, S3131, S3132, S3139, S3144, S3150, S3160, S3190, S3900, X6000, X6200, X6300, X6400, X6900, X7300, X7500, X7510, X7520, X7530, X7590, L9000, Z1110, Z1190
Salt	S3000, S3140, S3141, S3142, S3143, S3149, S3900, L9000
Solidified Organics	L2000, L2100, L2110, L2120, L2190, L2200, L2210, L2220, L2290, L2900, S3000, S3114, S3200, S3210, S3211, S3212, S3219, S3220, S3221, S3222, S3223, S3229, S3230, S3290, S3900, S5340, X6000, X6100, X6190, X6900, L9000, Z1110, Z1190
Soils	S4000, S4100, S4200, S4300, S4900
Uncategorized Metal (Metal Waste Other Than Lead and/or Cadmium)	S3116, S5000, S5100, S5110, S5111, S5119, S5190, X6200, X7000, X7290, X7400, X7430, X7490, X7520, Z1140, Z1190, Z2100
Lead and Cadmium Metal	S5000, S5100, S5110, S5112, S5113, S5119, S5190, X6220, X7000, X7200, X7210, X7211, X7212, X7219, X7220, X7290, X7400, X7410, X7420, X7490, Z2100
Inorganic Nonmetal	S3117, S3118, S3160, S5000, S5100, S5120, S5121, S5122, S5123, S5124, S5125, S5126, S5129, S5190, Z1120, Z1150, Z1190
Combustible	S5000, S5300, S5310, S5311, S5312, S5313, S5319, S5320, S5330, S5390, Z1130, Z1190, Z1200
Graphite	S5000, S5126
Heterogeneous	S5000, S5100, S5400, S5420, S5440, S5450, S5460, S5490, X7520, Z2900
Filter	S5000, S5410

Source: Adapted from TWBIR, Revision 3, Table 1-2.

Legend:

L Liquids
S Solids
X Specific Waste Forms
Z Final Waste Forms

- as-generated waste form volumes and final waste form volumes:

- estimated minimum, average, and maximum weights of waste components per cubic meter of final waste form volume (for example, iron-base metal and alloys, aluminum-base metal and alloys, cellulosics, etc.);

- identification of whether the waste is CH-TRU or RH-TRU;

- final waste form radionuclide inventory (activity in curies per cubic meter); and

- comments provided by the TRU waste generator and storage sites to further explain the data provided.

Site-Specific Waste Profile – This represents a final waste form at a particular DOE TRU waste generator and storage site. That is, one or more waste stream profiles at a particular DOE TRU waste site that have been placed in the same final waste form are summarized in the site-specific waste profile. Examples of information included in a site-specific waste profile are

- DOE TRU waste generator and storage site identification;

- final waste form that the profile represents;

- listing of the waste streams (represented by waste stream profiles provided by the TRU waste generator and storage sites) that are included in the site-specific waste profile, including the waste stream identification;

- final waste form volumes (both stored and currently projected); and

- summary of minimum, average, and maximum weights of WMPs per cubic meter of final waste form volume on a site basic (for example, iron-base metal and alloys, aluminum-base metal and alloys, cellulosics, etc.).

WIPP Waste Profile – The WIPP waste profile represents a summary of TRU wastes at all DOE TRU waste generator and storage sites that have an identical final waste form. Examples of information included in a WIPP waste profile are

- the final waste form that the profile represents;

- listing of the DOE TRU waste sites (represented by the same final waste form) that are included in the WIPP waste profile, including the name of the DOE TRU waste site;

- final waste form volumes of stored and currently projected waste for each site; and

- summary of minimum, volume-weighted average, and maximum weights of WMPs per cubic meter of final waste form volume on a WIPP basis (for example, iron-base metal and alloys, aluminum-base metal and alloys, cellulosics, etc.).

WMP – This is one or more of the nonradioactive TRU waste stream constituents. The 12 WMPs have been grouped by their chemical and physical properties as shown in the following list.

Inorganics

- Iron-based metals and alloys — includes iron and steel alloys in the waste and does not include the waste container materials.

- Aluminum-based metals and alloys.

- Other metal and alloys — includes all other metals found in the waste materials (for example, copper, lead, zirconium, tantalum, etc.). The lead portion of lead rubber gloves and aprons is also included in this category.

- Other inorganic materials — includes inorganic nonmetal waste materials such as concrete, glass, firebrick, ceramics, sand, and inorganic sorbents.

- Vitrified materials — includes waste that has been melted or fused at high temperatures with glass-forming additives such as soil or silica to form a homogeneous glass-like matrix.

Organics

- Cellulosics — includes those materials generally derived from high-polymer plant carbohydrates. Examples are paper, cardboard, kimwipes, wood, cellophane, cloth, etc..

- Rubber — includes natural or synthetic elastic latex materials. Examples are Hypalon, neoprene, surgical gloves, leaded-rubber gloves (rubber part only), etc..

- Plastics — includes generally synthetic materials, often derived from petroleum feedstock. Examples are polyethylene, polyvinylchloride, Lucite, Teflon, etc..

Solidified Materials

- Inorganic matrix — includes any homogenous materials consisting of sludge or aqueous-based liquids that are solidified with cement, Envirostone, or other solidification agents. Examples are wastewater treatment sludge, cemented aqueous liquids, inorganic particulates, etc..

- Organic matrix — includes cemented organic resins, solidified organic liquids, and sludges.

- Cement — includes the cement used in solidifying liquids, particulates, and sludges.

Soils

- Soils — generally consists of naturally occurring soils that have been contaminated with inorganic radioactive waste materials.

Although not considered to be a waste component, the associated packaging materials are also listed because they also provide input to the performance assessment calculations.

Packaging Materials

- Steel — weight of the steel component of the standard container. Any necessary overpacking is included in the weight of steel.

- Plastics — weight of any standard plastic secondary confinement within the container.

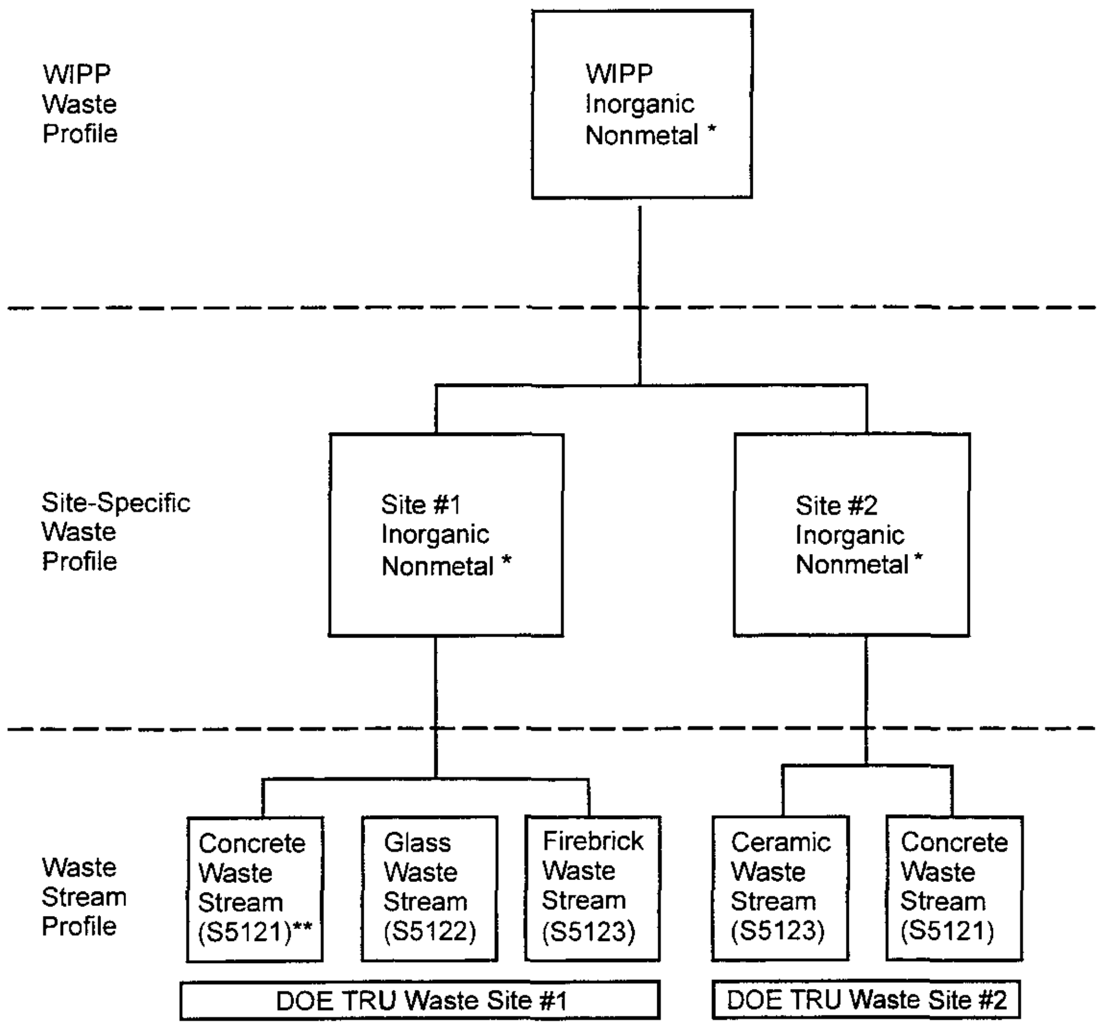
- Lead — weight of the lead shielding.

The estimated WMP information is expressed in units of kilograms per cubic meter of waste matrix. This unit facilitates scaling the material parameters to address various volumes for performance assessment calculations and sensitivity analysis.

4.1.3.2 Nonradionuclide Inventory Roll-up

The DOE uses the eleven final waste forms in the TWBIR as an intermediate step in determining the inventory of nonradioactive waste components. These final waste forms are a convenient way for the DOE to categorize waste for the purpose of waste management and waste characterization prior to shipment to the WIPP.

Waste streams at each TRU waste generator and storage site with similar WMCs are grouped together into one of the 11 final waste forms as shown in Table 4-2. An example of the methodology for grouping waste stream information is illustrated in Figure 4-3. The grouping of individual waste stream profiles into a site-specific waste profile is based on the similar physical and chemical properties of the waste streams. In the example in Figure 4-3, because of their similar properties for performance assessment modeling, concrete waste, glass waste, firebrick waste, and ceramic waste mainly influence the estimation of porosity and permeability in the waste panel region (see Figure 6-13) of the model. Therefore, the three streams within the DOE TRU Waste Site #1 and the two at DOE TRU Waste Site #2 can be



- See Table 4-2 for WMCs that can occur in each final waste form

** WMC

Note: Adapted from Figure 1-2, TWBIR, Revision 3.

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Figure 4-3. Schematic of Waste Stream Profile Methodology

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grouped together at each site based on similar physical and chemical properties and placed into the site-specific waste profile inorganic nonmetal waste, with the final waste form defined in Table 4-2.

For the DOE to consider disposal system performance at full capacity, it was necessary to scale the waste volumes in the TWBIR. This is because the TWBIR does not identify 6.2 million cubic feet (175,564 cubic meters) of existing or projected waste. The projected inventory in the TWBIR is scaled, if needed, to achieve a disposal limit equal to the design limit. For RH-TRU waste volume, the TWBIR has identified a sufficient quantity of retrievably stored waste, such that scaling is not required to meet the WIPP's RH-TRU waste disposal limit of 250,000 cubic feet (7,079 cubic meters). Estimates of the WIPP final waste-form volumes for CH-TRU and RH-TRU waste are provided in Table 4-3.

Table 4-3. Anticipated Nonradionuclide TRU Waste Inventory for the WIPP

Final Waste Forms	Stored Volumes (cubic meters)	Projected Volumes (cubic meters)	Anticipated Volumes (cubic meters)	WIPP Disposal Volumes (cubic meters)
CH Waste				
Combustible	5.8E+03	4.6E+03	1.0E+04	1.4E+04
Filter	2.2E+02	5.1E+02	7.3E+02	1.2E+03
Graphite	5.1E+02	4.8E+01	5.6E+02	6.0E+02
Heterogeneous	2.7E+04	1.3E+04	4.0E+04	5.1E+04
Inorganic Nonmetal	3.1E+03	9.4E+02	4.1E+03	4.9E+03
Lead and Cadmium Metal Waste	3.5E+01	3.3E+02	3.7E+02	6.6E+02
Salt Waste	2.1E+01	3.3E+02	3.5E+02	6.4E+02
Soils	4.1E+02	6.0E+03	6.4E+03	1.2E+04
Solidified Inorganics	9.6E+03	4.5E+03	1.4E+04	1.8E+04
Solidified Organics	9.1E+02	7.5E+01	9.8E+02	1.1E+03
Uncategorized Metal	1.1E+04	2.3E+04	3.4E+04	5.4E+04
Total CH Volumes	**5.8E+04**	**5.4E+04**	**1.1E+05**	**1.6E+05**
RH Waste				
Combustible	3.6E+01	4.9E+01	8.5E+01	
Heterogeneous	2.3E+03	5.5E+03	7.8E+03	
Inorganic Non-Metal	4.6E+01	2.1E+01	6.8E+01	
Lead and Cadmium Metal Waste	7.1E+00	6.7E+01	7.4E+01	
Solidified Inorganics	1.1E+03	2.3E+02	1.3E+03	
Solidified Organics	3.6E+00	0.0E+00	3.6E+00	
Uncategorized Metal	1.2E+02	1.7E+04	1.8E+04	
Total RH Volumes	**3.6E+03**	**2.3E+04**	**2.7E+04**	**7.1E+03**[1]
Total TRU Waste Volumes	**6.2E+04**	**7.7E+04**	**1.4E+05**	**1.7E+05**

Source: Adapted from TWBIR, Revision 3, Table 2-1.

[1] WIPP is limited to 7,079 cubic meters of RH-TRU waste.

To establish the nonradioactive waste component inventory, the DOE accumulated WMP information in the TWBIR by final waste form. This accumulation is shown as a series of tables (Tables 3-1 through 3-18 in Appendix BIR) in the TWBIR. These are further summed to determine the total WIPP waste component disposal inventory for CH-TRU and RH-TRU waste and are given in Tables 4-4 and 4-5, respectively. It should be noted that MgO is not listed in these tables. Since MgO is not a component of the waste, it is not regarded as a WMP. A discussion of the MgO backfill is contained in Chapter 3.0, Appendix BACK, and Appendix SOTERM.

Table 4-4. WIPP CH-TRU WMP Disposal Inventory

Waste Components	Average (kilograms per cubic meter)
Iron Base Metal and Alloys	170
Aluminum Base Metal and Alloys	18
Other Metal and Alloys	67
Other Inorganic Materials	31
Vitrified	55
Cellulosics	54
Rubber	10
Plastics	34
Solidified Inorganic Material	54
Solidified Organic Material	5.6
Cement (Solidified)	50
Soils	44
Container Materials - kilograms per cubic meter	
Steel	139
Plastic and Liners	26

Source: Adapted from TWBIR, Revision 3, Table 2-2.

The DOE reports the average density for WMPs because these values are used to generate the waste-related inputs for performance assessment. Section 3.4 of the TWBIR recommends use of the average value, based on the methodology used to obtain and report data. Section 3.3 of the TWBIR provides a formula for determining the average WMP densities.

With regard to the inventory of chemical components of the waste (needed for scoping calculations to determine their importance on performance), this information was requested from the generator/storage sites by the DOE subsequent to the issuance of Revision 2 of the TWBIR. The information requested by the DOE was specific to solidified waste forms destined for disposal at the WIPP and included complexing agents, nitrates, sulfates, phosphates, and cement. A summary of this supplemental information can be found in Sections 3.3.1, 3.3.2, and 3.3.3 of the TWBIR, Revision 3. Additional information addressing the impact, limits, and characterization (or noncharacterization) of these chemical components

Table 4-5. WIPP RH-TRU WMP Disposal Inventory

Waste Components	Average (kilograms per cubic meter)
Iron Base Metal and Alloys	10
Aluminum Base Metal and Alloys	7.1
Other Metal and Alloys	250
Other Inorganic Materials	64
Vitrified	4.7
Cellulosics	17
Rubber	3.3
Plastics	15
Solidified Inorganic Material	22
Solidified Organic Material	.093
Cement (Solidified)	19
Soils	1
Container Materials - kilograms per cubic meter	
Steel	446
Plastic and Liners	3.1
Lead	465
Steel Plug	2145

Source: Adapted from TWBIR, Revision 3, Table 2-3.

is provided in Appendix WCA, Appendix WCL, Section 4.4, and Tables 4-1 and 4-13. The importance of these chemical components to performance assessment is assessed in Appendix WCA.

4.1.3.3 Radionuclide Inventory Roll-up

Estimates of the radionuclide inventory are included in the TWBIR. Generators derive these estimates based on acceptable knowledge including any quantitative results that may be available. The radioactive inventory of disposed waste will be determined quantitatively prior to shipment as discussed in Section 4.2.2.

The estimates of radioactivity provided by the generator and storage sites are for stored waste only. Assuming the radionuclide distribution for projected waste to be the same as the stored waste inventory, and taking the radionuclide distribution of the stored inventory to be uniform over the stored volume, it is possible to scale the activity of the stored radionuclide inventory to the full WIPP repository. This assumption is reasonable because no new waste forms or waste generating processes are anticipated for the future and radionuclide distributions for the DOE weapons program activities are well known. The WIPP disposal radionuclide inventory has been estimated on the basis of these assumptions by first calculating the activity per unit volume (that is, curies per cubic meter) of each radionuclide that is present in the stored waste at each site. This calculation is based on all radionuclide activities decayed to the end of 1995. Radioactive decay and build-up calculations are performed annually and reported in the

TWBIR using the commercially available code ORIGEN2 (Croff 1980). The levels of radioactivity reported include contributions from both parent and daughter decay products. The curies per cubic meter calculated for each radionuclides in the stored waste at each site are then multiplied by the volume of projected waste to estimate the total curies of each radionuclide in the projected waste. The curies for the stored and the projected waste for each individual radionuclide at all sites are then added to obtain the total curies for CH-TRU and RH-TRU waste. For CH-TRU waste, the total curies for each radionuclide is divided by the CH-TRU disposal inventory to obtain a curies per cubic meter concentration for each radionuclide on a repository level. For RH-TRU waste, the total decayed WIPP curies for each radionuclide is divided by the sum of the stored and actual projected RH-TRU waste volume to obtain a radionuclide concentration in curies per cubic meter.

The WIPP disposal radionuclide inventory to be used in this application for both CH-TRU and RH-TRU wastes is shown in Table 4-6. The table shows individual radionuclide activity in curies for both CH-TRU and RH-TRU waste. Based on the total curies shown in Table 4-6 and to the extent to which each radionuclide is regulated by 40 CFR § 191.13, approximately 99.9 percent of the regulated CH-TRU activity at repository closure is contributed by ^{238}Pu, ^{239}Pu, ^{240}Pu, and ^{241}Am. Approximately 99.4 percent of the regulated RH-TRU activity at repository closure is contributed by ^{137}Cs, ^{90}Sr, ^{239}Pu, ^{240}Pu, ^{241}Am, and ^{238}P (See Appendix WCA, Section WCA.8.2). The values presented in Table 4-6 are used as input to the performance assessment calculations. A more detailed examination of the programs prepared by the DOE to collect supplemental radiological data is provided in Section 4.4.

In addition to the inventory in Table 4-6, the DOE has determined the average radionuclide inventory for each of the 569 CH-TRU and one RH-TRU waste streams in the conceptual models (see Appendix BIR, Revision 3, Appendix B-2). The distribution of waste streams is randomly sampled in the performance assessment process to determine releases due to inadvertent human intrusion. This process is discussed in Section 6.4.12.4 and assumes that each container in the waste stream has the average radionuclide inventory for that stream.

4.2 Waste Components and Characteristics

This section of the application is provided to document compliance with the provisions of 40 CFR § 194.24(b) and describes, in summary fashion,

- those components or characteristics of the waste that are most important in terms of their impact on the performance of the WIPP disposal system and

- the limits imposed by the DOE on the significant components or characteristics of the waste to ensure that future emplaced waste will behave in a manner that is consistent with the inventory assumed for the performance calculations.

Table 4-6. Important Radionuclides Considered in Performance Assesment

Radionuclide	Inventory at Closure (Curies)	EPA Units at Closure	EPA Units at 10,000 years	Release Calculations (1)		
				Cuttings, Cavings, & Spall Release	Direct Brine Release	Culebra Release
Pu238	1.94E+06	5.63E+03	1.32E-22	x	x	(2)
Pu239	7.95E+05	2.31E+03	1.73E+03	x	x	x
Am241	4.88E+05	1.42E+03	1.55E-01	x	x	x
Pu240	2.14E+05	6.23E+02	2.16E+02	x	x	c
Cs137	9.31E+04	2.71E+01	0.00E+00	x	--	--
Sr90	8.73E+04	2.54E+01	0.00E+00	x	--	--
U233	1.95E+03	5.67E+00	5.44E+00	x	x	c
U234	7.51E+02	2.18E+00	4.09E+00	x	x	x
Th230	3.06E-01	8.88E-03	3.56E+00	--	x	x
Pu242	1.17E+03	3.40E+00	3.34E+00	--	x	c
Th229	9.97E+00	2.90E-02	3.40E+00	--	x	c
Np237	6.49E+01	1.89E-01	4.82E-01	--	x	--
Cm245	1.15E+02	3.33E-01	1.48E-01	--	x	--
Ra226	1.14E+01	3.32E-02	2.77E-01	--	--	--
Pb210	8.75E+00	2.54E-02	2.77E-01	--	x	--
U238	5.01E+01	1.46E-01	1.46E-01	--	x	--
U236	6.72E-01	1.95E-03	1.16E-01	--	x	--
Am243	3.25E+01	9.45E-02	3.69E-02	--	x	--
U235	1.75E+01	5.08E-02	7.06E-02	--	x	--
Cm243	2.07E+01	6.03E-02	0.00E+00	--	x	--
U232	1.79E+01	5.21E-02	0.00E+00	--	--	--
C14	1.28E+01	3.72E-02	1.11E-02	--	--	--

Table 4-6. Important Radionuclides Considered in Performance Assesment (Continued)

Radionuclide	Inventory at Closure (Curies)	EPA Units at Closure	EPA Units at 10,000 years	Release Calculations (1)		
				Cuttings, Cavings, & Spall Release	Direct Brine Release	Culebra Release
Th232	1.01E+00	2.92E-02	2.92E-02	--	x	--
Ac227	5.05E-01	1.47E-03	1.28E-02	--	--	--
Pa231	4.67E-01	1.36E-03	1.28E-02	--	--	--
Cm248	3.72E-02	1.08E-04	1.06E-04	--	x	--
Pu244	1.51E-06	4.40E-09	1.26E-08	--	x	--
Pu241	3.94E+05	(3)	(3)	x	x	--
Cm244	7.44E+03	(3)	(3)	x	x	--
Percent of EPA Units at closure included in calculation				99.96%	99.48%	43.45%
Percent of EPA Units at 10,000 years included in calculation				99.40%	99.98%	99.92%

(1) See Section 6.3 for a discussion of scenarios analysed by performance asessment and the release pathways.
(2) Pu238 was included in the Salado transport calculations but the release to the Culebra was too low to merit calculation of its transport within the Culebra. The EPA unit percent total at closure increases to 99.47% with Pu238 added; the percent at 10,000 years is unaffected.
(3) Pu241 and Cm244 are not regulated by 40 CFR Part 191 but are included because their daughters, Am241 and Pu240 respectively, are significant to performance.
x indicates an isotope included in calculation.
c indicates isotopes that are combined for transport with isotopes having similar chracteristics.

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4.2.1 Identification and Qualification

The following text is responsive to the criterion at 40 CFR § 194.24(b).

The waste characteristics and components expected to be most significant to performance are the predominant radionuclides and their associated characteristics and components affecting actinide mobility. These are summarized in Table 4-7. The waste unit factor is the number of millions of curies of alpha-emitting TRU radionuclides with half-lives longer than 20 years (40 CFR Part 191, Appendix A). In the WIPP, 3.44 million curies of TRU waste will be in the repository at closure, so the waste unit factor is 3.44. The radionuclides that contribute to the waste unit factor are based on an analysis (see Appendix WCA.8.2) of the radionuclide

Table 4-7. Waste Characteristics and Components Expected to be Most Significant to Performance

Characteristic and Component	Reason for Significance
^{239}Pu, ^{240}Pu, ^{241}Am, ^{233}U, and ^{234}U	99 percent of EPA unit after 2,000 years
^{238}Pu	dominates EPA unit at early times
solubility of Pu and Am	large EPA unit; mobility depends on solubility
^{238}U	very low activity; dilutes higher-activity uranium isotopes for brine-based releases
iron	maintains reducing environment so that lower, less soluble oxidation states of actinides predominate
cellulose, plastic, rubber, nitrate, sulfate	microbial nutrients that are metabolized to methane and several other gases, increasing gas pressure; formation of colloids
humic materials, cellulose breakdown products	form humic colloids that sorb and transport actinides
nonferrous metals	prevent increase in actinide solubility by binding with ligands
waste shear strength	important to spalling and cavings

Source: Appendix WCA (Table WCA-12)

inventory in Revision 3 of the TWBIR (Appendix BIR) and are presented in Table 4-8 (decayed to the end of 2033). Waste characteristics and components with an insignificant impact of performance are summarized in Table 4-9.

4.2.2 Repository Limits

This following discussion is responsive to the criteria at 40 CFR § 194.24(c)(1) and 40 CFR § 194.24(c)(2).

Components are the controlling factors for the characteristics; therefore any limits imposed on the waste components necessarily serve to limit the waste characteristics. In the case where a characteristic is benign with respect to repository performance, no control of the corresponding component is necessary and no limits need be imposed on that component. Conversely, should repository performance be sensitive to a particular waste characteristic, then control of the corresponding component is mandated and limits are established to restrict the maximum or minimum amounts of that component allowed for disposal.

Table 4-10 shows the components expected to be potentially significant in as previously identified in Tables 4-1 and 4-7. Based on the performance assessment calculations and the rationale developed in Appendix WCL, Table 4-10 identifies the characteristics of the

Table 4-8. Radionuclides That Contribute to the Waste Unit Factor

Nuclide	Half-Life (years)	Inventory at Closure (curies)	Percent of Waste Unit
^{241}Am	432.7	4.88×10^{5}	1.42×10^{1}
^{243}Am	7370	3.25×10^{1}	9.45×10^{-4}
^{249}Cf	351	6.38×10^{-2}	1.85×10^{-6}
^{251}Cf	900	3.67×10^{-3}	1.07×10^{-7}
^{243}Cm	29.1	2.07×10^{1}	6.02×10^{-4}
^{245}Cm	8500	1.15×10^{2}	3.34×10^{-3}
^{246}Cm	4760	1.02×10^{-1}	2.97×10^{-6}
^{247}Cm	1.56×10^{7}	9.51×10^{-9}	2.76×10^{-13}
^{248}Cm*	3.48×10^{5}	3.72×10^{-2}	1.08×10^{-6}
^{237}Np	2.14×10^{6}	6.49×10^{1}	1.89×10^{-3}
^{238}Pu	87.7	1.94×10^{6}	5.64×10^{1}
^{239}Pu	2.41×10^{4}	7.95×10^{5}	2.31×10^{1}
^{240}Pu	6560	2.14×10^{5}	6.22
^{242}Pu	3.75×10^{5}	1.17×10^{3}	3.40×10^{-2}
^{244}Pu	8.0×10^{7}	1.51×10^{-6}	4.39×10^{-11}
TOTAL		3.44×10^{6}	

Modified (Inventory decayed to 2033) from Table WCA-5 (Appendix WCA)

* This number differs slightly from that in Appendix WCA (Section WCA.8.2) as a result of more recent information.

Table 4-9. Waste Characteristics and Components Expected to be Not Significant

Characteristics and Component	Reason for insignificant impact
radionuclides other than those in Table 4-7	EPA unit is negligible fraction of total, even with ingrowth
substances that may affect pH*	pH is buffered by MgO backfill
substances that produce CO_2 *	CO_2 is removed by reaction with MgO backfill
intrinsic and mineral fragment colloids	fraction of actinides mobilized by these colloids is insignificant
organic ligands	removed by binding with Mg and nonferrous metal
heat generated by exothermic reactions	heats of formation are small and thermal mass of repository is large so that temperature rise is negligible
fluid in the waste	negligible compared to brine volume

Source: Appendix WCA (Table WCA-13)

* These components are significant for gas generation, but not for actinide solubility.

Table 4-10. Repository-Based Emplacement Limits Related to Performance Assessment

Waste Components	Associated Waste Characteristics	Components Requiring Quantification	Emplacement Limits
radionuclides	radioactivity at closure radioactivity after closure solubility colloid formation reduction-oxidation state	^{241}Am ^{238}Pu ^{239}Pu ^{240}Pu ^{242}Pu ^{233}U ^{234}U ^{238}U ^{90}Sr ^{137}Cs	none [a]
ferrous metals (iron)	reduction-oxidation potential H_2 has generation complexing with organic ligands	none	minimum = 2×10^7 kilograms (amount from containers) [b]
cellulose, plastics, rubber	gas generation humic colloids (see below) gas generation	sum of emplaced components	maximum = 2×10^7 kilograms[c]
sulfates	gas generation	none	none[d]
nitrates	gas generation	none	none[d]
solid components	particle size effective shear resistance to erosion tensile strength	none	none
free water emplaced with waste	gas generation	none	maximum = 1684 cubic meters for CH-TRU (limit of 1 percent total waste volume as set by the WAC) [e]
humic substances	radionuclide-bearing humic colloids	none	none
nonferrous metals (metals other than iron)	bind with organic ligands and prevent increased solubility	none	minimum = 2×10^3 kilograms [f]
organic ligands	solubility	none	none [d]

Source: Appendix WCL

[a] Inventory curie content will be tracked.
[b] Minimum set to ensure sufficient reactants for reducing radionuclides to lower and less soluble oxidation states. Average density for CH-TRU container steel of 139 kilograms per cubic meter multiplied by the design basis value of 168,485 cubic meters.
[c] Maximum set to ensure sufficient MgO backfill is available to react with CO_2 produced.
[d] For the current waste generation processes that are documented in the TWBIR.
[e] 1 percent of the design basis values for CH-TRU of 168,485 cubic meters.
[f] Minimum quantity for complexing with organic ligands (see Appendix SOTERM, Section SOTERM.5).

components for which assay prior to emplacement is required. Table 4-10 also lists any applicable repository-based emplacement limit for the components. Discussions of the rationale for the proposed assaying and emplacement limits for each component are in Appendix WCL. All of the components identified in Appendix WCA were found to be insignificant to disposal system performance. Therefore, it is not necessary to establish container-based emplacement limits for these components other than those already imposed through the Waste Acceptance Criteria (WAC) (see next section).

Table 4-11 is a supplement to Table 4-10; that is, it lists the repository limits imposed by the LWA (U.S. Congress 1992b). Collectively, Tables 4-10 and 4-11 define the WIPP repository-based emplacement limits on the waste.

Table 4-11. Repository-Based Emplacement Limits Imposed by the LWA

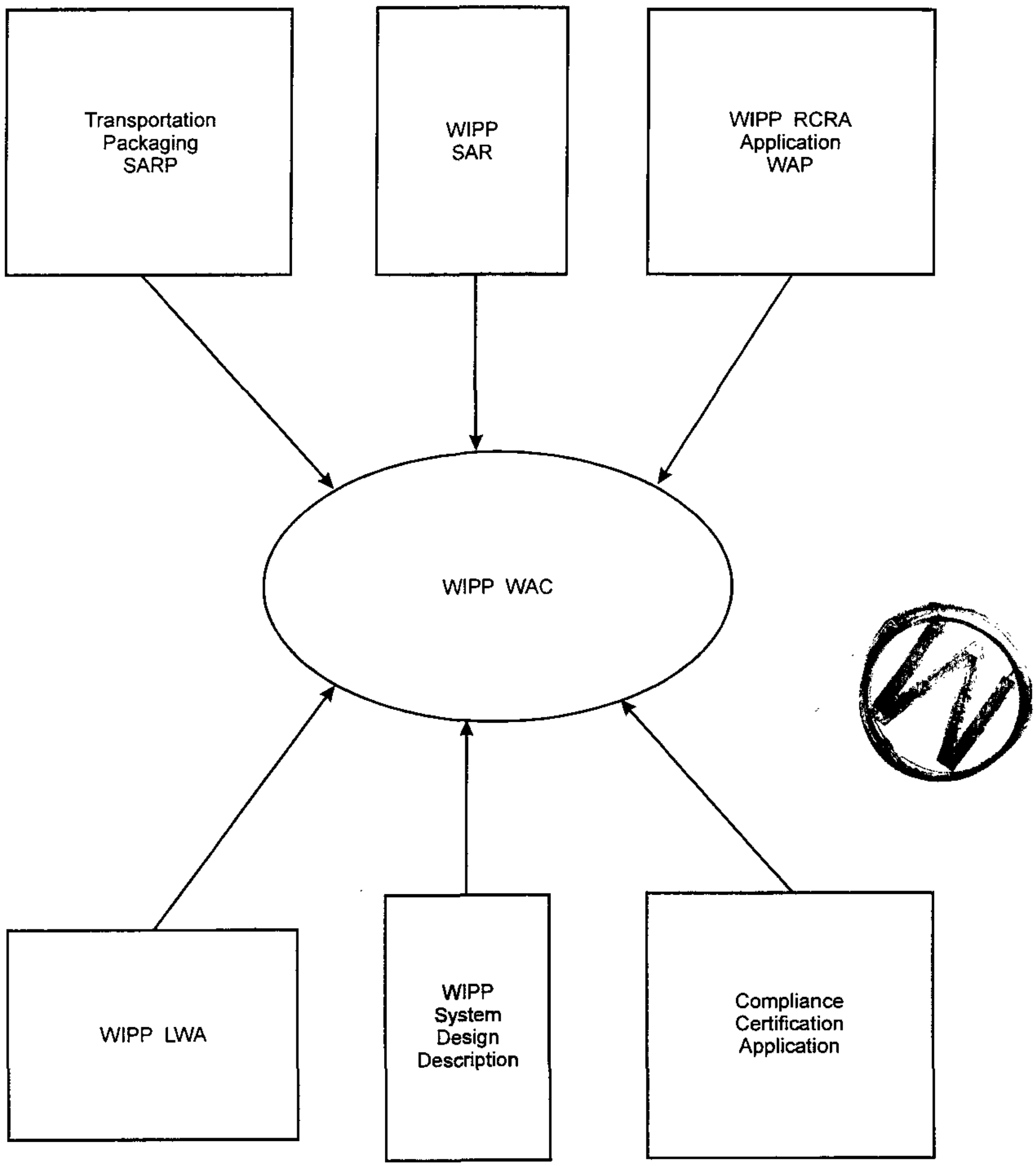
Waste Components	Emplacement Limits
Total Capacity (CH- and RH-TRU)	6.2 million cubic feet (175,564 cubic meters)
RH waste total curies	5.1 million curies (~18.9 × 10^{16} Becquerels)

4.2.3 Waste Container Limits

Waste limits have been established by the DOE as part of the WIPP's design development and by the WIPP LWA. Table 4-12 identifies waste container limits. The WAC is a compilation of criteria that restrict the physical, chemical, and radiological properties of the waste to mitigate conditions that will have adverse impacts on human health and the environment. The current WIPP WAC (DOE 1996a) does not contain restrictions associated with or driven by performance assessment results.

The WAC is founded on transportation requirements, disposal operations safety criteria as documented in the Safety Analysis Report (SAR) (DOE 1995d), regulatory compliance requirements and several other drivers (depicted in Figure 4-4) including the WAP, the Safety Analysis Report for Packaging (SARP), and this application. Only those wastes that meet established acceptance criteria and obtain waste stream profile approval from the CAO will be emplaced in the WIPP disposal system. Waste forms that do not meet these criteria will require treatment and/or repackaging prior to WIPP certification. Application of the WAC extends to both CH-TRU and RH-TRU waste proposed for disposal in the WIPP. The current WAC limits shown in Table 4-12 are on a waste container basis.

The WAC requires the generator to prepare a waste-certification program that lists the methods and techniques used to determine compliance with the WAC and the quality assurance (QA) and quality control criteria that are applied to the generator's waste certification program. Each participating site is responsible for developing and implementing



Note: Adapted from Figure 2-1, WAC Revision 5.

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Figure 4-4. Origins of the WAC

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Table 4-12. Container-Based Limits Imposed by the WAC

Waste Component or Characteristic	Limit
CH and RH waste criticality	<200 fissile gram equivalents (FGE) per 55 gallon drum <325 FGE per standard waste box (SWB)
CH and RH waste ^{239}Pu equivalent activity	Untreated Waste ≤80 plutonium equivalent curies (PE-Ci) per drum ≤130 PE-Ci per SWB ≤1800 PE-Ci per drum[1] Solidified/Vitrified Waste ≤1800 PE-Ci/55 gallon drum
CH and RH waste surface dose rate	≤200 mrem/hr (CH) ≤1000 rem/hr (RH)
RH waste thermal power	Report if 70.1 watts/cubic feet
RH waste curies per liter	≤23 curies/liter
Liquids or aqueous waste	No liquid wastes <2 liters total residual liquid per 55 gallon drum <8 liters total residual liquid per SWB <inch in the bottom of any container
Explosives	None
Compressed gases	None
Pyrophoric materials	<1% radionuclide pyrophorics No nonradionuclide pyrophorics
Polychlorinated Biphenyls	<50 ppm

[1] Overpacked in a SWB or ten-drum overpack.

site-specific TRU waste program documents (plans) that address all activities pertaining to TRU waste characterization, certification, packaging, and transportation of TRU waste to the WIPP. These plans include the TRU Waste Certification Plan and associated QA plan, the TRUPACT-II Authorized Methods for Payload Control and associated QA plans, and the TRU waste characterization QAPjP. Methods of compliance with each criterion and requirement are documented or specifically referenced and include procedural and administrative controls.

The DOE CAO Manager is responsible for granting and revoking authority to a site to certify TRU waste to the WAC. The CAO performs certification audits of the sites to assess the implementation of and compliance with the approved plans. On the basis of acceptable results of the certification audits, the DOE grants TRU waste certification authority and transportation authority to the site. Continuing oversight of participating sites is provided by the DOE through periodic audits of TRU waste characterization, certification, and transportation activities.

A waste-stream profile form (contained in the WAP) is used by generator site personnel to notify the WIPP that a waste stream has been identified and characterized. The data described on this form are used by the WIPP as the basis for acceptance of the waste characterization process identified for each container belonging to this waste stream. The WAC establishes limits for the physical, radiological, and chemical characteristics of the waste in addition to specifications for the waste packaging.

Once the DOE has obtained necessary operating permits and certifications, appropriate changes to the WAC will be published to reflect new restrictions and conditions imposed by permits and certifications. These changes will be communicated to the generator and storage sites as a change to the WAC. Those retrievably stored or newly generated waste streams that do not meet the current disposal WAC, however, may require processing (including repackaging and/or treatment) until certification can be attained. Any such processing is the responsibility of the site proposing to ship the waste to the WIPP. TRU waste that has been characterized in accordance with prior revisions of the WAC and the QAPP may be reconciled with current requirements. This reconciliation is documented and filed at the site.

4.3 Waste Controls

This section describes those processes that ensure compliance with the limits for CH-TRU and RH-TRU waste to be emplaced in the WIPP disposal system.

4.3.1 Load Management

The following discussion is responsive to the criteria at 40 CFR § 194.24(d)(f).

Load management is the process of controlling the shipment and emplacement of TRU waste in order to achieve a predetermined (that is, nonrandom) distribution of waste within the disposal system. An important reason for considering the impact of spatial distribution of waste in the repository is because of the significance of human intrusion on long-term repository performance. As described in Section 6.4.12, drilling events are assumed to be random in time and space. The location of each intrusion borehole within the waste disposal region is sampled randomly. Each intrusion borehole that penetrates waste may encounter CH-TRU waste or RH-TRU waste. For calculating direct releases to the accessible environment, containers are assumed to be placed in the WIPP from the various 569 waste streams which comprise CH-TRU waste in a random manner. In calculating direct releases resulting from a drill bit penetrating containers, each of the three stacked containers can come from different waste streams and have different activity loading. As described in Section 6.5, direct release from cuttings and cavings are the most important releases in assessing compliance with the quantitative containment requirements in 40 CFR § 191.13(a).

The CCDFs presented in Section 6.5 are constructed by estimating cumulative radionuclide releases to the accessible environment for 10,000 different possible futures. The estimated release for each future includes the randomly sampled waste streams for each of the various intruding boreholes that comprise that sampled future. A sampling of 10,000 futures is large enough that the relatively low probability combination of three of the waste streams with higher activity loading occurring in a single drilling event is captured in the CCDFs presented in Section 6.5. As described in Section 6.5, the CCDF is not impacted by sampling uncertainty so the assumption of random emplacement of containers is not important to the location of the CCDF and a load management plan is not necessary to support performance assessment assumptions.

4.3.2 WIPP Waste Information System

The following discussion is responsive to the criteria at 40 CFR § 194.24(c)(4) and 40 CFR § 194.24(c)(5) and those at 40 CFR § 194.24(e).

The WWIS is a computerized data management system used by the WIPP to gather, store, and process information pertaining to TRU waste destined for or disposed at the WIPP. The system supports those organizations who have responsibility for managing TRU waste by collecting information into one source and providing data in a uniform format that has been verified or certified as being accurate. The WWIS is used to store all information pertaining to characterization, certification, and emplacement of waste at the WIPP. Information for this system is supplied by the generator sites of TRU waste and the WIPP facility. Figure 4-5 depicts the process and flow of data from the sites to the WWIS.

The WWIS uses the Oracle (Version 7) database management system that follows American National Standards Institute (ANSI) standard query language. The database management system resides on a Digital Equipment Corporation hardware platform and is compliant with the majority of existing computer hardware throughout the DOE complex. UNIX is the operating system and supports multiuser and multitasking environments. The WWIS shall be available seven days a week, 24 hours a day except for periodic maintenance and shall support the maximum number of simultaneous users determined by the database management system license agreement and the operating system license agreement. The network communication protocol of the WWIS is Transmission Control Protocol/Internet Protocol (TCP/IP). Other features that distinguish the WWIS from its predecessor include automatic limit, range, and QA checks; automatic report generation; and compliance with QA requirements for computer software for nuclear facility applications (American Society of Mechanical Engineers [ASME], Nuclear Quality Assurance [NQA]-1, NQA-2, Part 2.7, and NQA-3 [ASME 1989a, b, and c in the Bibliography]).

The following WWIS documentation has been identified as necessary and sufficient to document the software lifecycle:

- WWIS Evaluation & Recommendation – provides an evaluation of hardware and software configurations for the WWIS and recommends an approach for implementation.

- WWIS Software Quality Assurance Plan – identifies and defines the standards and methodologies required to ensure conformance to accepted quality standards during the development, maintenance, and operation of the WWIS. This plan ensures that products conform to established technical requirements.

- WWIS Software Verification and Validation Plan – describes the criteria for verification and validation activities for the requirements, design, testing, and all necessary documentation.

- WWIS Software Requirements Specification – defines the requirements essential to the WWIS based on the WWIS Functional and Operational Requirements Document. All requirements shall be internally consistent and verifiable through demonstration, analysis, or testing.

- WWIS Software Design Description – defines the major features of the WWIS including the operating environment, databases, tables, external and internal interfaces, overall structure, sizing, modeling, and system throughput.

- WWIS Software Configuration Management Plan – describes the methods used for identifying software configuration items, controlling and implementing changes, and recording and reporting change implementation status.

- WWIS Security Plan – details the information for handling the security needs of the system (data, software, and hardware). This plan also describes password and access control procedures.

The DOE has identified more than 130 data fields for inclusion in the WWIS. An alphabetical listing and description of these data fields is found in Appendix C13 of Appendix WAP. The majority of these data fields are considered pertinent to demonstrate compliance with TRU waste transportation and disposal requirements, those data fields identified as relevant to this application include the following:

- assay characterization method

- assay date

- disposal date

- nondestructive examination

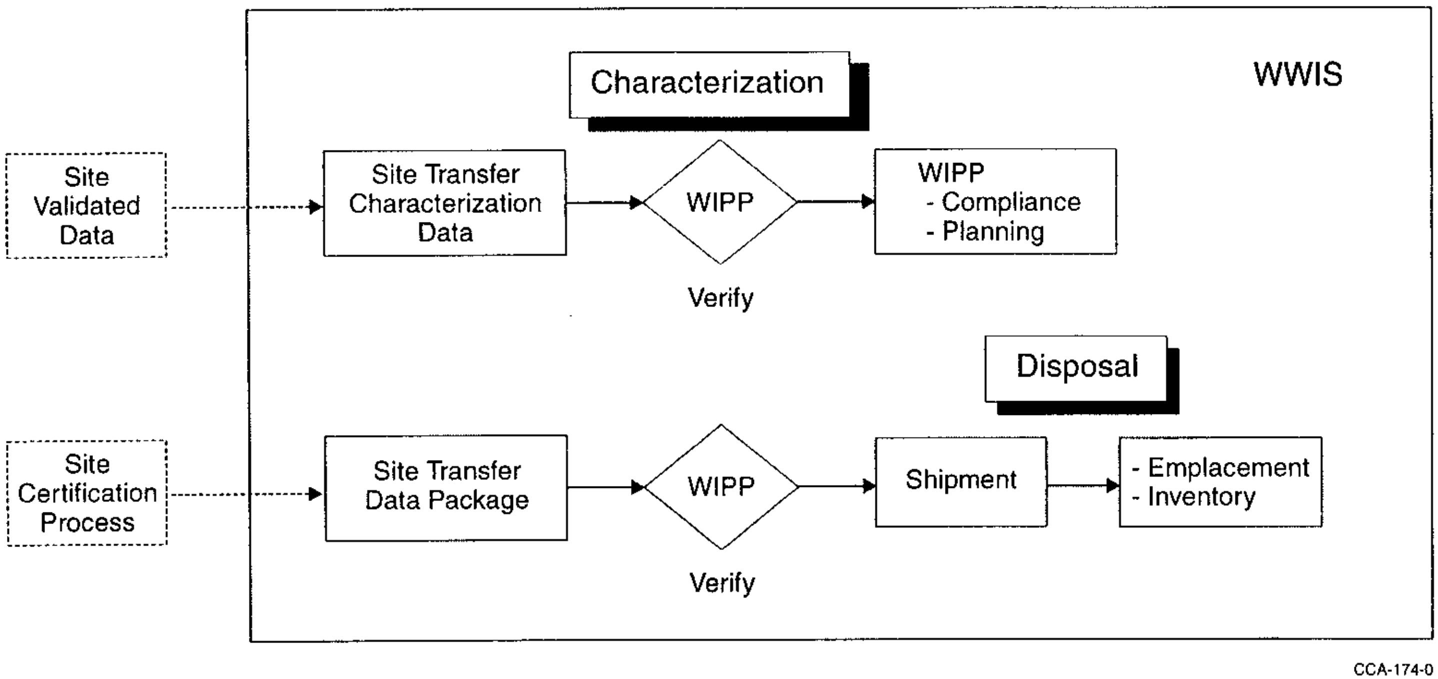

Figure 4-5. WIPP Waste Information System Process and Data Flow

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- ^{239}Pu fissile gram equivalent
- radionuclide activity
- radionuclide activity uncertainty
- radionuclide mass
- radionuclide mass uncertainty
- TRU alpha activity
- TRU alpha activity uncertainty
- verification data
- verification method
- visual examination of container
- WAC certification data
- WMPs
- WMC

To ensure compliance with the data requirements, personnel at the WIPP review the data package for completeness and adequacy before notifying the shipping site of acceptance. Thus, the WWIS becomes an integral part of the waste information screening process described in the WAP.

4.3.3 Quality Assurance

The implementation of a formal quality assurance program demonstrates the commitment of the DOE to perform all work activities and operations to the highest standards of quality. The DOE has established an effective QA program that complies with applicable sections of NQA-1, NQA-2 (Part 2.7), and NQA-3. The management controls defined by the various quality assurance plans and procedures ensure that all work is planned, documented, performed under controlled conditions, and periodically assessed to establish work item quality and process effectiveness and to promote improvement. The complexity, inherent risk, and significance of the work to the overall project and to public safety are key factors in determining applicable quality management requirements. Internal and external organizational interfaces and responsibilities are described in detail in Chapter 5.0.

The QA requirements for TRU waste characterization are contained in the DOE TRU Waste Characterization QAPP. The QAPP is applicable to all DOE TRU waste generator sites that anticipate characterizing TRU waste. Participating sites must follow acceptable analytical methods as specified in the Transuranic Waste Characterization Sampling and Analysis Methods manual (DOE 1995c). Included in the QAPP for each method is a description of the specific performance requirements. These are referred to as quality assurance objectives (QAOs). Should modifications to the approved test methods be necessary, whether for personnel protection from radiation or to implement an improved methodology, these modifications are to be fully documented and approved in accordance with the QAPP and the Sampling and Analysis Methods Manual.

The QAPjPs developed at each generator and storage site describe the characterization activities that are performed in conformance with the QA requirements specified in the QAPP. The DOE conducts annual certification audits, supplemented by surveillances to ensure that the sites comply with their approved site-specific QAPjPs. Figure 4-6 shows the quality assurance document hierarchy for waste characterization.

The QAOs for the nondestructive assay (NDA) of CH-TRU waste are listed in the QAPP and are intended to establish minimum performance requirements for the approved types of measurement systems. The QAOs include criteria for precision, accuracy, minimum detectable concentration, completeness, and total uncertainty. All measurements of activity for CH-TRU waste must have a precision bounded by the range of values in the QAOs established in the QAPP. Only those containers that can be assayed with a precision falling within these bounding values can be accepted for disposal at the WIPP.

Additional information regarding the quality assurance and quality controls used in ascertaining the waste description is given in Chapter 5.0.

4.3.3.1 Performance Demonstration Programs

The Performance Demonstration Program (PDP) plan for NDA for the TRU Waste Characterization Program (DOE 1995a) is designed to help ensure compliance with the QAOs identified in the TRU Waste Characterization QAPP for the WIPP. This plan, as well as the radioassay portion of the current revision of the QAPP, defines QAOs and measurement requirements for the characterization of alpha-emitting TRU isotopes associated with weapons-grade (WG) plutonium. WG plutonium is selected because of its predominance in an isotopic mixture within the TRU waste generated and retrievably stored across the DOE complex.

The CAO is the reviewing and approving authority for the PDP. All DOE facilities intending to dispose of their TRU waste at the WIPP must participate in the PDP and pass all individual tests within each PDP cycle. The CAO uses the PDP plan to assess, evaluate, and approve DOE facilities for waste measurement and characterization before the waste is shipped to the

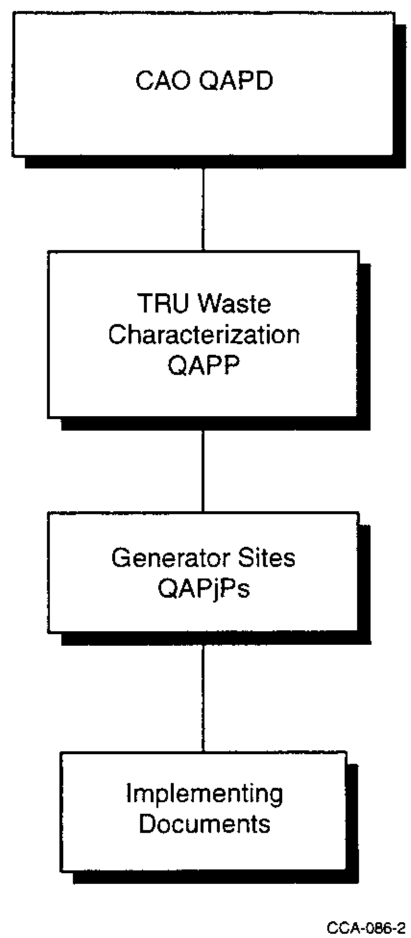

Figure 4-6. QA Document Hierarchy for Waste Characterization

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WIPP facility. This approval process also includes the evaluation of method performance data submitted by the measurement facility and the performance of QA audits.

The PDP plan describes the detailed elements that comprise the program, including the test materials and the analysis required. The PDP plan also identifies the criteria used for the evaluation of laboratory performance and the responsibilities of the program coordinator, the standard preparation team, and the participating laboratories. The radioactive source standards encompass the range of activities (masses) anticipated in actual waste characterization. The PDP sample standards address activity ranges relative to WIPP WAC limits, QAPP QAOs, and/or NDA method detection limits (DOE 1995a). The isotopes analyzed under this program plan include but are not limited to ^{238}Pu, ^{239}Pu, ^{240}Pu, and ^{241}Am.

In conjunction with the source standards, the 55-gallon drums used in the PDP also contain manufactured matrix inserts. These matrix inserts simulate waste matrix conditions and provide acceptable consistency in the sample preparation process at each measurement facility. For the first PDP cycle, the sample 55-gallon drums contain either no matrix material or a benign material.

Laboratory performance must be demonstrated by the successful analysis of blind samples by all participating measurement facilities on a semiannual basis. The blind samples (called PDP samples) are prepared twice during a calendar year at approximately six-month intervals. The PDP samples are analyzed using the methods the measurement facility anticipates using for the analysis of WIPP wastes. These methods must have been developed and approved within the specifications of the QAPP. Only the methods actually used in the PDP are considered acceptable to support the analysis of WIPP wastes. The data generated as a result of the performance demonstration indicate the appropriateness of the method used as well as the performance of the measurement facility. The program coordinator uses a set of standards that encompasses the range of WG material anticipated in actual WIPP waste.

The measurement facility analyzes the contents of each PDP sample using the procedures in the WIPP waste characterization program. The scoring system for the PDP is a pass-fail system. To pass a specific test, the measurement must fall within the specified QAOs of the QAPP. To pass the PDP cycle, the measurement must pass all individual tests. The scoring system of the PDP ensures that the QAOs are satisfied at the 95-percent confidence level.

Waste analyses may be performed only by measurement facilities that have demonstrated acceptable performance in the PDP. Measurement facility performance is used to assess general problems that may affect the facility's ability to analyze total alpha activity within a 55-gallon waste drum. Identified problems are resolved in accordance with the established QA program.

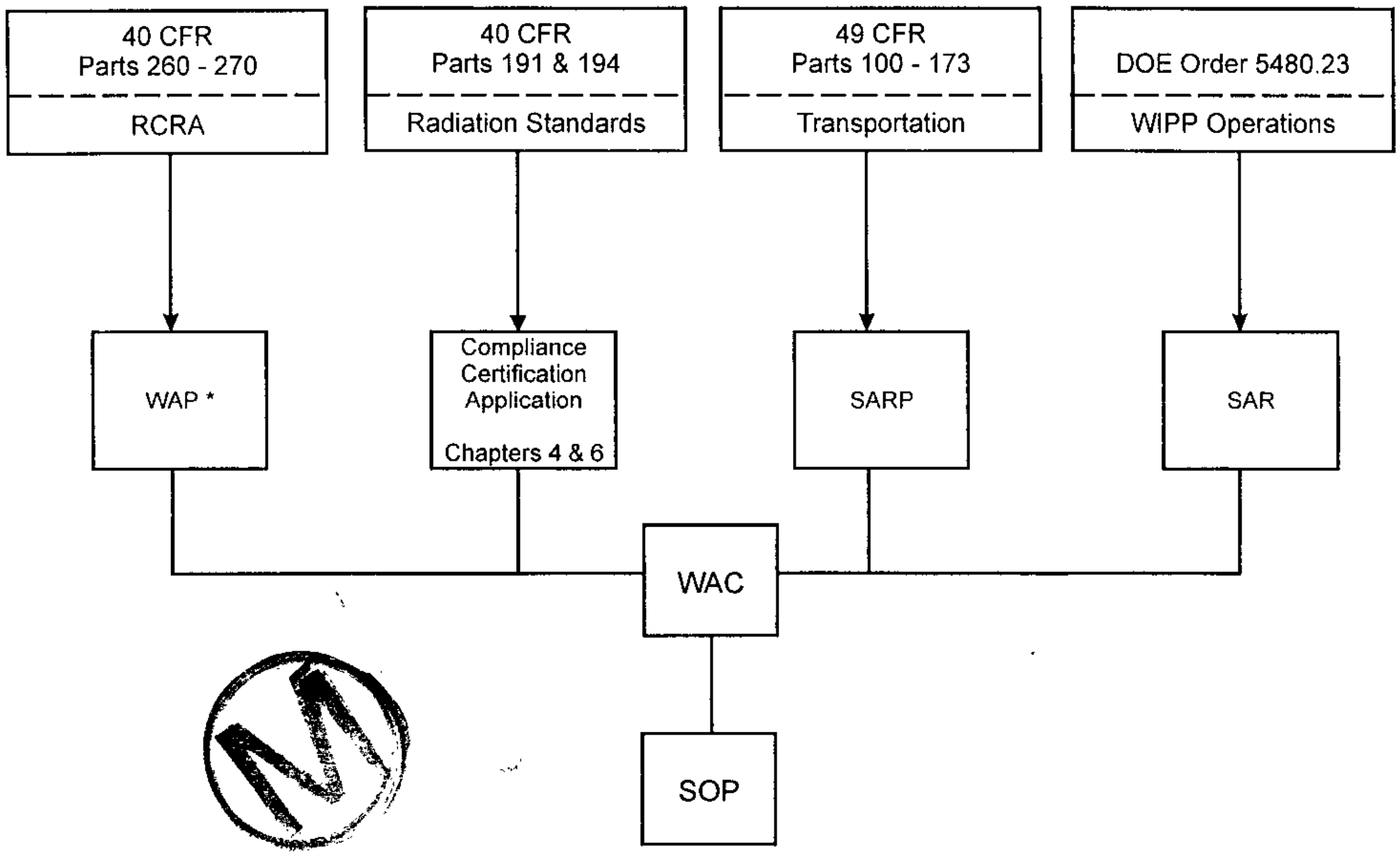
4.4 Waste Characterization

The process of waste characterization identifies the physical, chemical, and radiological properties of the waste using a variety of methodologies (DOE 1995c), including acceptable knowledge, headspace gas sampling and analysis, solid waste sampling and analysis, visual examination, NDA, and nondestructive examination (NDE). The measured waste properties obtained by the generator and storage sites are either on a waste container or waste stream basis and serve to demonstrate compliance with the limits imposed by transportation requirements (DOT) and operational safety requirements (DOE). In contrast, the waste component limits described in Appendix WCL are on a repository basis and serve as an upper bound for the accumulative waste inventory. As described in Section 4.3.2, the linkage between the collective waste inventory and the repository limits is provided by the WWIS.

Recognizing that the WAP establishes the TRU mixed-waste characterization requirements for DOE waste destined for the WIPP, it is necessary to understand the complementary role played by the radiological characterization of TRU waste. Figure 4-7 shows the requirements hierarchy governing the characterization of TRU waste for purposes of transportation, disposal, and long-term regulatory compliance. The implementation of waste characterization occurs on a waste-stream basis at the lowest tier of the diagram through the Standard Operating Procedures (SOPs). The next higher tier of Figure 4-7 includes the WAC, followed by progressively higher-tier requirements, including this application. The waste characterization requirements for compliance with the EPA's regulations pertaining to the identification of the disposed waste's hazardous and radiological components are implemented by the SOPs.

The WAP includes requirements for the determination of the physical and chemical properties of CH-TRU and RH-TRU mixed waste streams — specifically the identification and quantification of their hazardous components (see Appendix WAP). A combination of five waste characterization methodologies is employed by the WAP and includes acceptable knowledge, radiography, visual examination, headspace gas sampling and analysis, and solidified waste sampling and analysis. The capabilities and applicabilities of these five methodologies to TRU mixed waste are discussed in considerable detail in the WAP and the QAPP. Except for a brief overview of acceptable knowledge, radiography, and visual examination, a description of the five waste characterization methodologies will not be repeated in this document.

Radiological characterization of TRU waste is needed for compliance demonstrations to 40 CFR Parts 191 and 194. A quantitative determination of the radionuclides listed in Table 4-10 is driven by the need to demonstrate compliance with the release limits as specified in Appendix A to 40 CFR Part 191, Subpart B, and the RH-TRU waste curie limit established by the LWA (see Table 4-11).



* Chapter C of Part B of the WIPP RCRA Permit Application

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Figure 4-7. Requirements Hierarchy of TRU Waste Characterization for Transportation and Disposal

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Collectively, those elements of the waste characterization program that support long-term regulatory compliance include the determination of the radionuclide inventory (for purposes of normalizing radionuclide releases as required for comparison with 40 CFR § 191.13[a]), *the identification of the physical and chemical waste form inventories (if applicable)*, and the verification that no wastes are emplaced in the WIPP that exceed the disposal system's safety and/or performance limitations.

In a manner analogous to the WAP, the WIPP waste radioassay characterization program is conducted by generator and storage site personnel and is implemented in accordance with the requirements of the QAPP and the WAC. A description of the approved waste characterization methodologies and QAOs is provided in the QAPP.

Generator and storage sites may propose alternative characterization methodologies, either because of the availability of newer technologies offering enhanced performance or the modification of older technologies to facilitate meeting the QAOs. In these instances, method performance must be demonstrated and approved prior to its use in characterization TRU waste for disposal at the WIPP.

Implementation of the TRU waste characterization program at DOE sites requires that all waste characterization activities be conducted in accordance with approved documentation that describes the management, operations, and QA aspects of the program. Conformance with applicable regulatory, programmatic, and operational requirements is monitored by CAO audits and surveillances. Refer to Appendix QAPD and Sections 3.2.3 and 3.2.4 for a more detailed discussion of the CAO audit and surveillance program. The documentation requirements important to the implementation of the TRU Waste Characterization Program at each site are briefly discussed below.

- QA requirements. Implementation of individual site-specific waste certification and characterization programs must meet the QA requirements contained in the CAO QAPD, which are traceable to the applicable sections of ASME NQA-1 through NQA-3 (ASME 1989a, b, and c in the Bibliography). The QAPP describes the specific QAOs for the TRU Waste Characterization Program. The QAPP and its associated document, the TRU Waste Characterization Sampling and Analysis Methods Manual, delineate approved analytical methods for meeting regulatory requirements.

- QAPjPs. Generator sites prepare site-specific QAPjPs that describe waste characterization activities in support of the TRU waste characterization program. These documents, developed in accordance with the applicable requirements in the CAO QAPD and the QAPP, define QA management and program elements that provide for planning, implementation, and assessment of the TRU waste characterization data-collection activities.

- SOPs. The QAPP requires that each DOE site develop, implement, and control written SOPs that provide detailed descriptions of routine, standardized, or critical waste characterization activities. The SOPs serve as the basis for quality assessments of waste characterization activities at the site level because they provide detailed descriptions of required activities.

- PDPs. Analytical facilities characterizing waste for disposal at the WIPP must successfully participate in the applicable portions of the PDP. The PDP supports the determination of a facility's ability to meet the QA objectives identified in the QAPP. A more detailed description of the PDP can be found in Section 4.3.3.1.

As the generator sites complete the necessary program documentation, they commence waste characterization activities. Information derived from these activities is on a waste-stream basis and is used in preparing the site's waste-stream profile forms required for waste acceptance at the WIPP. The waste characterization data are electronically backed-up in databases at the generator sites and downloaded into the WWIS database (DOE 1996b). The WWIS is described in Section 4.3.2.

Generator and storage sites prepare documented and approved programs controlling their TRU waste characterization, certification (which includes characterization), and transportation processes. Site-specific TRU waste certification plans document how compliance with the WAC and QAPP are accomplished. Site certification shall be granted by the CAO manager contingent upon final approval of the following documentation:

1. TRU waste certification plan (including QA),

2. QAPjP(s),

3. TRU package transporter, Model 2 (TRUPACT II) Authorized Methods for Payload Compliance,

4. packaging QA plan, and

5. performance in applicable PDPs.

In addition to approval of this site-specific documentation, generator and storage sites must pass an initial site certification audit where adequate and effective implementation of these programs is assessed (see Sections 5.1.1 and 5.3.19).

Each TRU waste generator and storage site that is characterizing TRU waste to the requirements of the QAPP and the WAC is recertified by the CAO annually. A recertification consists of reviewing (if applicable)

1. site-specific program documents that are written and approved to the latest WAC,

2. program implementation as determined by a site certification audit,
3. reports from surveillances conducted during the past year,
4. performance in shipping TRU waste to the WIPP, and
5. performance in the PDPs.

To ensure that the DOE generator and storage sites comply with the WIPP TRU waste certification program, audits are conducted by the CAO. An initial audit is conducted at each generator site performing waste characterization activities prior to the formal acceptance of the waste-stream profile forms and/or any waste characterization data supplied by site personnel. This formal acceptance is referred to as site certification. Audits are performed at least annually thereafter, including the possibility of unannounced (not regularly scheduled) audits. These audits verify that the generator site has implemented a QA program for all certification activities. The accuracy of the physical waste description and the subsequent waste stream assignment are verified by a review of acceptable knowledge documentation, radiography data, and visual examination results (if applicable). Table 4-13 summarizes the characterization requirements and methods detailed in the WAC that support this application.

Table 4-13. Applicable CH- and RH-TRU Waste Component Characterization Methods

Waste Properties	Waste Components	Waste Characterization Methods
Nuclear	Radionuclides	NDA OR previous isotopic distribution from destructive radiochemistry OR previous radioassay data reconciled with WAC requirements
Physical	ferrous metals nonferrous metals cellulose plastics, rubber solid components free water humic substances	radiography with statistical selection for visual examination OR visual examination and documentation of container content at time of waste packaging for newly generated waste OR documentation and verification (random sampling) for newly generated waste
Chemical	sulfates nitrates organic ligands	No upper or lower limits apply to these chemicals; therefore no waste characterization methods are applied.

4.4.1 Qualitative Methodologies

The criteria at 40 CFR § 194.24(a) state that a description of the physical, chemical, and radiological composition of the TRU waste to be emplaced in the WIPP disposal system be provided. With regard to the waste's nonhazardous physical and chemical components (such as cellulosics), there are three qualitative methodologies, used either singularly or in combination, for verifying adherence to the compliance limits contained in Appendix WCL. These methodologies include acceptable knowledge, nonintrusive examination using penetrating radiation such as X-ray (referred to as either RTR, radiographic examination, radiometric examination, or NDE), and intrusive visual examination consisting of opening the container and recording the contents.

4.4.1.1 Acceptable Knowledge

The following discussion is responsive to the criteria at 40 CFR § 194.24(c)(3).

Acceptable knowledge is defined in the EPA Guidance Manual (EPA 1994) in the Bibliography. Acceptable knowledge includes information regarding the physical form of the waste, the base materials composing the waste, and the process that generates the waste. Waste characterization will be used to confirm acceptable knowledge information.

Consistency among DOE sites in using acceptable knowledge information to characterize TRU waste involves a three phase process: (1) compiling the minimum acceptable knowledge documentation in an auditable record, (2) confirming acceptable knowledge information, and (3) auditing acceptable knowledge records.

Appendix WAP, Figure C9-1 illustrates provides an overview of the process for assembling acceptable knowledge documentation into an auditable record. The first step is to assemble all of the mandatory acceptable knowledge information and any supplemental information regarding the materials and processes that generate a specific waste stream. DOE sites must ensure the following criteria are met in establishing acceptable knowledge records:

- Acceptable knowledge information must be compiled in an auditable record, including a road map for all applicable information.

- The overview of the facility and TRU waste management operations in the context of the facility's mission must be correlated to specific waste stream information.

- Correlations between waste streams, with regard to time of generation, waste generating processes, and site-specific facilities must be clearly described.

Acceptable knowledge documentation provides qualitative information that cannot be assessed according to specific data quality objectives that are used for analytical techniques. QAOs objectives for analytical results are described in terms of precision, accuracy, completeness, comparability, and representativeness. Analytical results will be used to confirm the characterization of wastes based on acceptable knowledge.

To ensure that the acceptable knowledge process is consistently applied, sites must comply with the following data quality indicators for acceptable knowledge documentation.

- Precision – Precision is the agreement among a set of replicate measurements without assumption of the knowledge of a true value. The qualitative determinations, such as compiling and assessing acceptable knowledge documentation, do not lend themselves to statistical evaluations of precision.

- Accuracy – Accuracy is the degree of agreement between an observed sample result and the true value. The percentage of waste containers that require reassignment to a new WMC will be reported as a measure of acceptable knowledge accuracy.

- Completeness – Completeness is an assessment of the number of waste streams or number of samples collected to the number of samples determined to be useable through the data validation process. The acceptable knowledge record must contain 100 percent of the required information (see Section C9-3 in Appendix WAP). The useability of the acceptable knowledge information will be assessed for completeness during audits.

- Comparability – Data are considered comparable when one set of data can be compared to another set of data. Comparability is ensured through sites meeting the training requirements and complying with the minimum standards outlined for procedures that are used to implement the acceptable knowledge process.

- Representativeness – Representativeness expresses the degree to which sample data accurately and precisely represent characteristics of a population. Representativeness is a qualitative parameter that will be satisfied by ensuring that the process of obtaining, evaluating, and documenting acceptable knowledge information is performed in accordance with the minimum standards listed in Section C9-4 contained in Appendix WAP. Sites also must assess and document the limitations of the acceptable knowledge information.

The acceptable knowledge process and waste stream documentation must be evaluated through internal assessments by quality assurance organizations and assessments by auditors external to the organization (that is, the CAO).

The CAO will conduct an initial audit of each generator and storage site prior to certifying the site for shipment of TRU waste to the WIPP facility (see Figure C9-2 in Appendix WAP). This initial audit will establish an approved baseline that will be reassessed annually.

Audit plans will identify the scope of the audit, requirements to be assessed, participating personnel, activities to be audited, organizations to be notified, applicable documents, and schedule. Audits will be performed in accordance with written procedures and checklists. The audit checklists will include specific items associated with the compilation and evaluation of the required acceptable knowledge information.

Audit checklists must include all of the following elements for review during the audit:

- Documentation of the process used to compile, evaluate, and record acceptable knowledge is available and implemented;

- Personnel qualifications and training are documented;

- Required acceptable knowledge documentation has been compiled in an auditable record;

- A procedure exists for resolving inconsistencies in acceptable knowledge documentation;

- A procedure exists for confirming acceptable knowledge information; and

- Results of other audits of the TRU waste characterization programs at the site are available in site records.

Members of the audit team will be knowledgeable regarding the required acceptable knowledge information regarding the use of acceptable knowledge for waste characterization. Audit team members will be independent of all TRU waste management operations at the site being audited.

Auditors will evaluate documents associated with the evaluation of the acceptable knowledge documentation for at least one debris waste stream and one solidified waste stream during the audit. For these waste streams, auditors will review procedures and associated processes developed by the site for documenting the process of compiling acceptable knowledge documentation; correlating information to specific waste inventories; and identifying, resolving, and documenting discrepancies in acceptable knowledge records. The adequacy of acceptable knowledge procedures and processes will be assessed and any deficiencies in procedures documented in the audit report.

Auditors will review the acceptable knowledge documentation for selected waste streams for logic, completeness, and defensibility. The criteria that will be used by auditors to evaluate the logic and defensibility of the acceptable knowledge documentation include completeness and traceability of the information, consistency of application of information, clarity of presentation, degree of compliance with Appendix C9 of the WAP with regard to acceptable knowledge confirmation data, nonconformance procedures, and oversight procedures.

Auditors will evaluate compliance with written site procedures for developing the acceptable knowledge record. A completeness review will evaluate the availability of the minimum required TRU waste management and TRU waste stream information. Records will be reviewed for correlation to specific waste streams. Auditors will verify that sites include all required information. All deficiencies in the acceptable knowledge documentation will be included in the audit report.

Auditors will verify and document that sites use administrative controls and follow written procedures to make waste determinations for newly generated and retrievably stored wastes. Auditors will review procedures used by the sites to confirm acceptable knowledge information.

After the audit is complete, the CAO will provide the site with preliminary results at a close-out meeting. The CAO will prepare a final audit report that includes all observations and findings identified during the audit. Sites must respond to all audit findings and identify corrective actions. Audit results will be available at CAO for review by regulatory agencies, and copies will be provided upon request. If acceptable knowledge procedures do not exist, the minimum required information is not available, or significant findings of noncompliance are identified, the CAO will not grant the site waste characterization and certification authority for the subject waste. Waste stream characterization and certification authority may be revoked or suspended if there are significant findings during subsequent annual audits.

Prior to notifying a site that a waste stream can be shipped and accepted at the WIPP facility, the CAO will review the Waste Stream Profile Forms and associated data packages. Sites must provide all of the required data associated with waste steam characterization. The data packages will be evaluated as illustrated in Figure C9-2 in Appendix WAP. The CAO will review information provided by the sites to ensure that changes to waste codes are identified and justified. If data consistently indicates discrepancies with acceptable knowledge information, the CAO will require sites to increase sampling, reassess the materials and processes that generate the waste, and resubmit waste stream profile information. Until discrepancies are resolved, shipment of the waste stream to the WIPP will be prohibited.

4.4.1.2 Nondestructive Examination

NDE is a nondestructive qualitative technique that involves X-ray interrogation of waste containers to identify and verify the contents. NDE is used to verify the absence of prohibited items and to determine the appropriate methodologies to be used for waste characterization. NDE is not required for newly generated waste because controls exist to verify compatibility of the matrix material(s) and the absence of prohibited items prior to and during waste packaging.

A typical NDE system consists of an X-ray producing device, a container handling system, and an imaging detector. X-ray generators typically used in NDE produce X-rays ranging in energy from under 100 kiloelectron volts up to approximately 450 kiloelectron volts. If higher energies are needed, either because of a high density waste matrix or the need to penetrate shielded payload containers, then the use of a linear accelerator becomes a viable approach for producing a pulsed X-ray beam with energies to 25 megaelectron volts and beyond.

The X-ray detector has the function of converting the radiation input signal into a corresponding optical or electronic output signal that ultimately is used to reconstruct an image of the payload container contents. An example of a system presently in use at many of the generator and storage sites is RTR, which gives the operator the opportunity to view events in progress (that is, in real time). In an RTR system, the imaging system typically utilizes a fluorescent screen and a low light television camera (since the light output of most screens is quite low). The resulting image is transferred to a remotely located television screen, and the operator conducts the examination by viewing the remote television screen.

Data acquired by NDE are documented as required by the QAPP. The QAOs for radiography, as listed in Section 10 of the QAPP, include precision, accuracy, completeness, and comparability. Since radiography, the primary methodology for performing NDE, is basically a qualitative determination, there is no specification for a method detection limit. The QAOs for NDE using radiography are summarized below.

Precision and Accuracy – The qualitative determinations made during radiography do not readily lend themselves to statistical evaluation of precision or accuracy. An estimate of precision and accuracy can be made, however, by comparing the results of NDE with the results of visual examination of a randomly selected statistical portion of waste containers.

Completeness – An audiotape or videotape of the radiography examination (or equivalent for other NDE methodologies) and a radiography data form, validated according to the requirements in Section 3.0 in the QAPP, must be obtained for 100 percent of the retrievably stored waste containers.

Comparability – The comparability of radiography data from different sites shall be enhanced by using standardized radiography procedures and operator qualifications in accordance with the requirements of the QAPP.

All activities required to achieve the radiography objectives must be described in site QAPjPs and SOPs. Retrievably stored containers will have this type of permanent record on file throughout the life of the WIPP project. As a quality control check on NDE, a statistically determined number of retrievably stored containers within the population subjected to NDE will be randomly selected and visually examined.

4.4.1.3 Visual Examination

The visual examination technique is used by the DOE to provide an acceptable level of confidence in NDE. There is no equivalent method in the EPA sampling and analysis guidance documents. A detailed procedure that meets the requirements of this method can be found in the WIPP Waste Characterization Program Sampling and Analysis Methods Manual (DOE 1995c). Generator site personnel develop training programs that are based on waste form and waste management operations. These training programs are used to assess operator performance. The QAPjPs and supporting SOPs specify the training requirements and other activities required to achieve the visual examination objectives. The visual examination expert must be familiar with the waste generating processes that have taken place at that site and also with the types of waste being characterized at the site. For an explanation of the hypergeometric approach used in determining the number of containers to be statistically sampled by visual examination, see Appendix A of the QAPP (DOE 1995b).

4.4.2 Quantitative Methodologies

To minimize exposure, the quantitative methodology used to determine the radionuclide inventory of the waste is NDA. The nonintrusive methodology of NDA employs radiation detection techniques for determining the waste's isotopic content and activity. This is the preferred approach because of the safety hazards involved in opening waste containers having radioactive contaminants. Although the data generated by radioassay serve many functions including the calculation of the ^{239}Pu equivalent activity, the ^{239}Pu fissile gram equivalent, and the decay heat of waste containers, the purpose of these data relative to long-term regulatory compliance with 40 CFR Part 191 is to provide corroborative data relating to the radionuclide inventory reported in the TWBIR and furnish radionuclide information on a container basis to maintain a running inventory of TRU waste emplaced in the WIPP disposal system.

TRU nuclides emit both ionizing radiation (including alpha particles, beta particles, and gamma rays) and nonionizing radiation (neutrons). Based on detection of these emissions, several technologies have been developed to measure one or more of these radiations as they emerge from the waste container. Although most of the ionizing radiation (alpha and beta particles) are not able to penetrate the walls of the waste container, both gamma rays and neutrons can penetrate the waste matrix as well as the waste container to varying degrees. Combining gamma ray measurements, other advanced particle detection techniques specific to neutrons, and acceptable knowledge provides the precision and accuracy required by the QAOs contained in the QAPP. Mass spectroscopy and radiochemistry also provide the precision and accuracy to meet the QAO requirements in the QAPP.

Special techniques, instrumentation, and detectors have been developed to measure the gamma ray energies. Because there are many different gamma rays originating from any one radionuclide with each gamma ray having a unique energy and rate of occurrence characteristic of the radionuclide from which it originated, the resulting distribution or spectrum of gamma ray energies provides a fingerprint or signature of that particular radionuclide. In practice, with the application of appropriate correction factors and the utilization of acceptable knowledge, gamma ray and neutron NDA systems provide radioisotope inventory information about the waste without the need for opening the container.

All radioassay systems must be calibrated using a variety of matrix and source standards to simulate the various waste compositions, source distributions, and interferences common to the waste streams originating from a particular generator site. By applying the resulting correction factors to the measurements, an accurate assessment of the radionuclide inventory within the waste container is feasible. NDA methods appropriate to a particular waste stream profile are used in the radionuclide analysis.

4.4.2.1 Nondestructive Assay

A variety of NDA methodologies are effective in meeting the requirements of the QAPP. Table 9-2 of the QAPP identifies a number of such systems that are in use at various DOE and/or contractor testing facilities. These instruments can be classified as belonging to one or more of the four categories listed below:

- gamma ray measurements

    - low- and high-resolution spectroscopy using a sodium iodide and intrinsic germanium detector, respectfully,
    - transmission-corrected gamma ray measurement using a segmented gamma ray scanner, and
    - transmission-corrected gamma ray measurement using a computed tomographic gamma ray scanner.

- passive neutron measurements

    - passive neutron coincidence counter,
    - advanced matrix-corrected passive neutron counter (add-a-source), and
    - shielded neutron-assay probe totals counter.

- passive and active neutron measurements

    - americium-Lithium source-driven coincident counter,
    - californium delayed-neutron counter (shuffler),
    - neutron generator differential die-away counter, and
    - combined thermal and epithermal neutron counter.

- thermal neutron capture

    - californium delayed-neutron counter,
    - neutron generator differential die-away counter, and
    - combined thermal and epithermal neutron counter.

The list is neither complete nor limiting and is meant to illustrate the breadth of choice available. QAOs may be met with the listed systems or by modifications, functionally equivalent alternatives, multiple combinations, or hybrids of the systems.

For each of the radionuclide components identified in Table 4-10 as being significant to performance assessment and requiring assay, any of the above NDA methodologies, either singularly or in combination, may be used in determining the activity and corresponding uncertainty. In the case of 100-percent sampling, these measurements are performed on a waste container basis. For the case of less than 100-percent sampling, the reported values are on a waste stream basis. Upon receipt of the waste at the WIPP, the measured activity of these significant radionuclide components, plus their associated uncertainty, are accumulated by the WWIS in order to ensure that the volume and activity limits of the repository are not exceeded.

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