THE WASTE ISOLATION PILOT PLANT: THE SUCCESSFUL NATIONAL SOLUTION TO THE U.S. NUCLEAR WEAPONS COMPLEX TRANSURANIC WASTE LEGACY

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ABSTRACT

Transuranic radioactive waste (TRUW) is a long-lived radioactive waste/material (LLRM). In the United States of America (USA), by law, (1-4) all LLRMs must be safely managed by the generator and, eventually, disposed in deep geological repositories by the United States (U.S.) Department of Energy (DOE). At the end of the year 2001, more than 100,000 cubic meters (m^3) of TRUW is presently safely stored at 23 nuclear weapons complex sites (Fig. 1) managed by the DOE Office of the Assistant Secretary for Environmental Management (EM-1) in compliance with stringent national and international safeguards. The management of the Nation's TRUW involves several EM offices, of which, the Carlsbad Field Office (CBFO) is responsible for the development and safe operation of a regulator-certified, state-permitted TRUW repository at the Waste Isolation Pilot Plant (WIPP) site in New Mexico, USA (Fig. 1).

On March 26, 1999, the WIPP site received the first shipment of TRUW from Los Alamos National Laboratory (LANL) for safe disposal. (5) At the end of the year 2001, the WIPP TRUW site/repository had received nearly 500 shipments of TRUW from five of the nation's 23 TRUW generator and storage sites (Fig. 1). In 1998, EM designed an accelerated schedule for removal of all TRUW from 17 sites by the year 2006, and from the remaining six sites by the year 2034. (6) Hence, the opening and continued safe operation of the WIPP TRUW repository fulfill the following national missions and imperatives:

1. The WIPP repository provides a *very safe solution to the disposition of the nation's TRUW legacy.* Conservatively projected post-closure doses and radionuclide releases from the WIPP repository are less than 10 percent (%) of applicable regulatory limits and 0.15 % of the average natural background radiation in the USA.
2. The WIPP repository provides *a considerable national risk reduction* in that it allows the TRUW to be moved from current surface and near-surface storage locations, i.e., from within approximately 10 meters (m) below the surface, to more than 650 m below the surface at the WIPP site. More than 50 million people currently reside within an 80-kilometer (km) radius of the nation's 23 TRUW-generator and -storage sites, whereas only 30 people live within a 16-km radius of the WIPP site. (5)
3. The accelerated EM-schedule for removing all TRUW from the nation's 23 nuclear weapons complex sites by the year 2034 (6) *reduces the national mortgage for the nation's TRUW legacy,* i.e., the period and cost involved in maintaining strict safeguards at these sites.

Fig. 1. U.S. map showing the locations of the WIPP and the nations 23 TRUW generator and storage sites, and TRUW transportation routes. (NOTE: By the end of the year 2001, only the five sites indicated by squares had shipped TRUW to the WIPP site.)

INTRODUCTION

In the USA, the accumulation of nuclear waste from the nation's nuclear-weapons program/complex started in the 1940s. At the end of the year 2001, the DOE faces the daunting challenge to safely:

- Deactivate, decontaminate, and decommission more than 700 facilities;
- Clean approximately 80 million m^3 of contaminated soil and 6.8 billion m^3 of contaminated groundwater; and
- Dispose approximately 380,000 m^3 of highly radioactive waste, 220,000 m^3 of TRUW (includes both existing and projected TRUW of which some will be repackaged and some may not be acceptable at WIPP), and 3.3 million m^3 of low-level radioactive waste (LLW). (7)

This legacy, which is managed by EM-1, is significant in terms of the volumes, efforts, time, and cost involved, and the many sophisticated solutions required for its mitigation.

Pursuant to current laws, (1-4) the DOE is responsible for the development and safe disposal of the Nation's LLRMs in deep geological repositories. To meet these statutory mandates, the DOE established:

1. The Office of Civilian Radioactive Waste Management (OCRWM) with a mission to site, develop, operate, and close the deep geological repositories required for safe disposal of the nation's spent nuclear fuel and other high-level radioactive waste (HLW). (NOTE: *As illustrated in Fig. 2, EM does not manage the OCRWM).*
2. The CBFO has a similar mission for TRUW that also includes the National TRU Program (NTP), which entails the characterization and preparation for shipment of TRUW to WIPP from the nation's 23 nuclear weapons complex sites (Fig. 1). The CBFO is managed by EM, as are two other DOE offices actively involved in resolving the safe disposition of the nation's TRUW legacy: the Office of Integration and Disposition (EM-20) and the DOE Headquarters WIPP Office (EM-23) (Fig. 3).

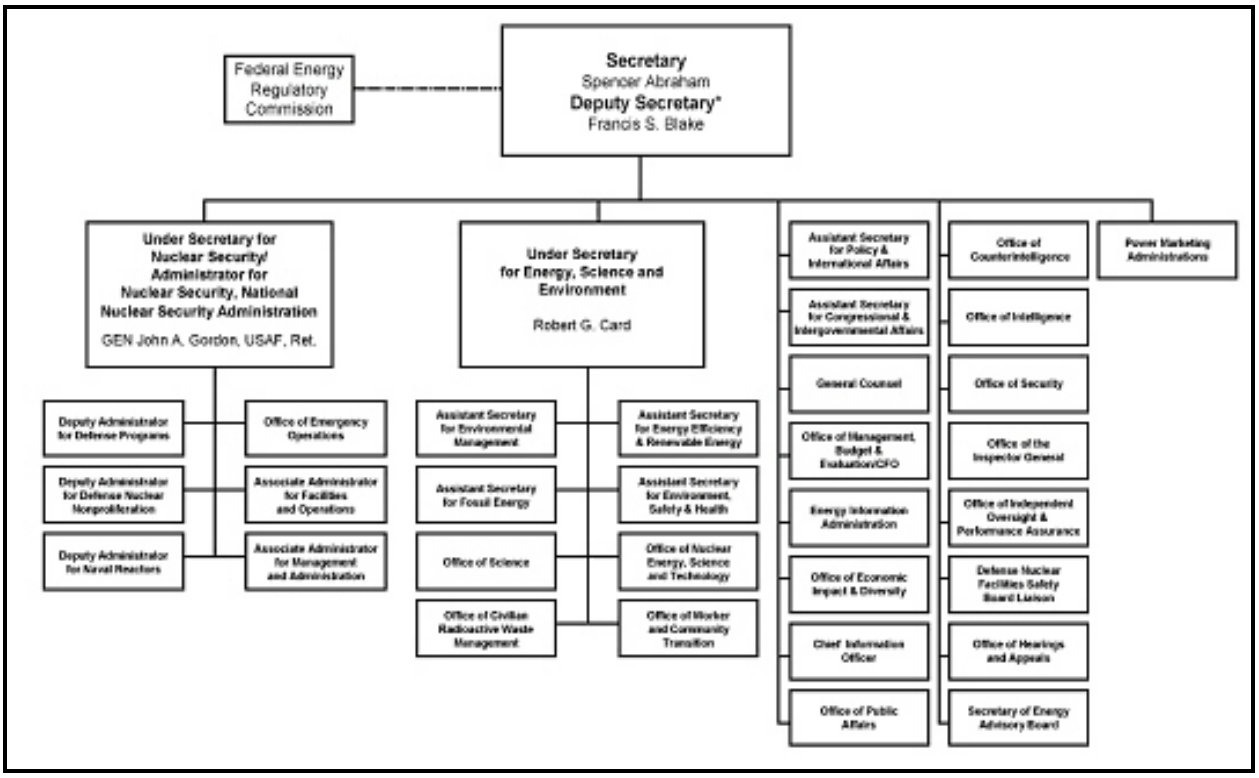

Fig. 2. DOE organization chart.

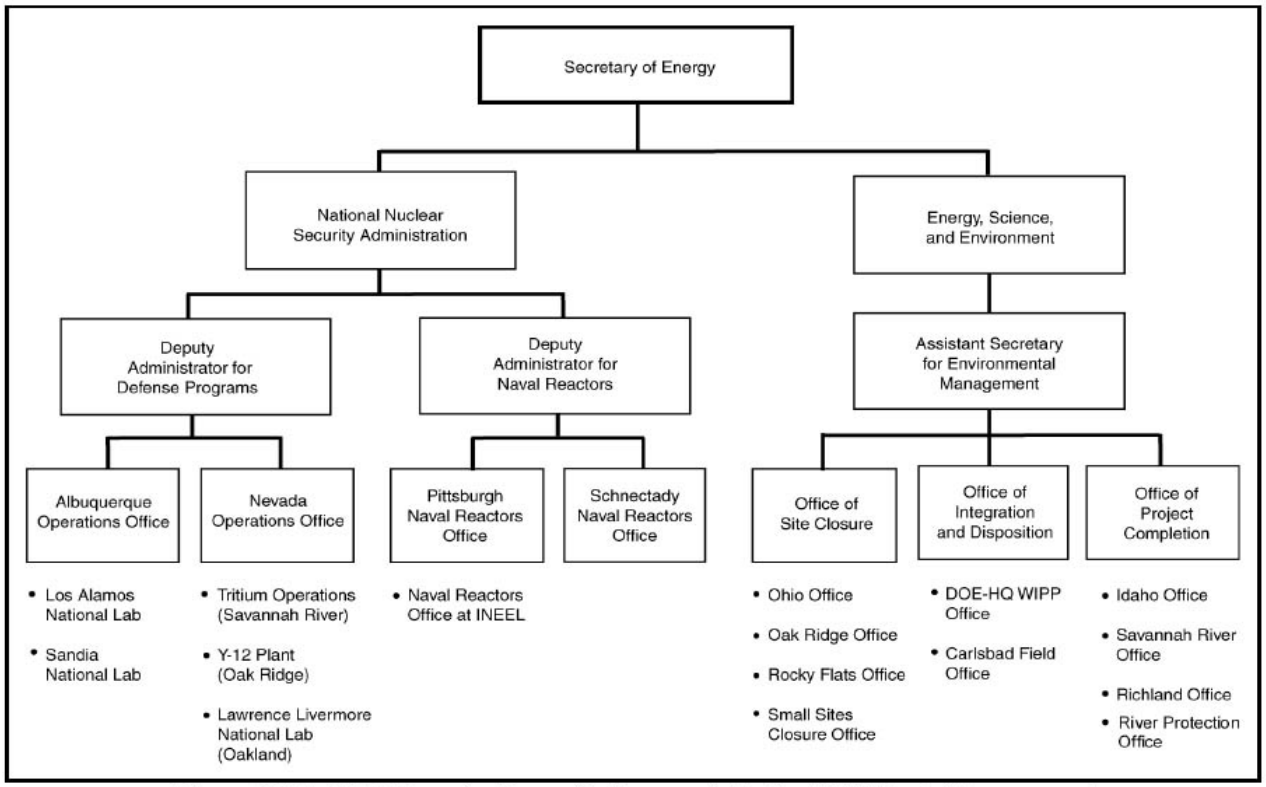

Fig. 3. DOE organizations with responsibility for TRUW management.

This paper describes the present status and projected path forward for the safe management and disposal of the nation's TRUW legacy. These descriptions focus on the CBFO and are preceded by background information on:

- The organizational structure, mission, and goals of primary DOE organizations involved in resolving the nation's TRUW legacy;
- The origination, definition, and amounts of the TRUW that may be disposed at the WIPP site; and
- The current infrastructure and status at the WIPP site, including (a) the basic premise of the WIPP disposal system and (b) the results of the total systems performance analyses (TSPAs) conducted to demonstrate the safe, long-term/post-closure performance of the WIPP repository.

A concise summary of the initiatives and target milestones involved in the CBFO's path forward for continuing to reduce the national risk and mortgages for the nuclear weapons TRUW legacy follows the background information. A summary of the primary benefits provided by the WIPP TRUW repository concludes the text. References shown by numbers in parenthesis in the text (1-21) are listed after the summary. Important terms and clarifications to quotes are highlighted in *italics* throughout the text.

BACKGROUND

Organizational Structure, Mission, and Goals of Primary DOE Organizations Involved in Resolving the Nation's TRUW Legacy

TRUW generation began with the manufacture of nuclear weapons in the 1940s. Research and development (R&D) efforts at laboratories around the U.S., as well as weapons production, account for the majority of TRUW in today's inventory. Additional TRUW will be generated as many DOE sites make the transition from nuclear weapons production to environmental restoration and decommissioning. Fig. 3 shows a composite of sections of various DOE organizations responsible for managing the nation's TRUW. Both the National Nuclear Security Administration and the Office of Energy, Science, and Environment have these responsibilities. As noted in DOE M 435.1-1, Radioactive Waste Management Manual, the document for implementing DOE Order 435.1, the Deputy Assistant Secretary for Integration and Disposition (EM-20) is responsible for developing, implementing, and maintaining an integrated complex-wide program plan for TRUW. A summary of roles and responsibilities for implementing an integrated national TRUW-program strategy is described below. Key to the successful implementation of this strategy is EM-20, the DOE Headquarters (DOE-HQ) WIPP Office (EM-23), the CBFO, Operations Offices, and TRUW sites. (8)

EM-1 provides program policy development and guidance for the assessment and cleanup of inactive waste sites and facilities, and waste management operations. It also develops and implements an aggressive applied waste R&D program to provide innovative environmental technologies to yield permanent disposal solutions at reduced costs; and oversees the transition of contaminated facilities from various DOE programs to environmental restoration once they are determined to be surplus to their original mission. EM-1 provides centralized management for the DOE for waste management operations, environmental restoration and related applied R&D programs and activities, including the EM program policy guidance to all DOE Operations Offices in these areas. It is also responsible for the institutional health and long-term planning, landlord activities, and for overall site integration and operations and provides direction, policy, and management oversight to the DOE Operations Offices at Idaho (ID), Ohio (OH), Rocky Flats (RF), Richland (RL), Savannah River (SR), and the Office of River Protection (ORP) at Richland as the Lead Program Secretarial Officer (LPSO). This includes overall line accountability for site-wide environment, safety and health, safeguards and security, and for implementation of policy promulgated by DOE-HQ staff and support functions. (8)

In July 1996, the then EM-1 issued a challenge to "get more cleanup done sooner than currently planned" and accelerate the process of cleaning up the nuclear weapons complex. In response to this challenge, a vision was established to complete environmental cleanup at most of the nation's current TRUW generator and storage sites within a decade. (6) This vision in turn is reflected in current TRUW management decisions for budget, sequencing of projects, and implementation of actions to meet program objectives. To meet this vision, the involved EM organizations are committed to:

- Maintaining compliance with applicable environmental and other legal requirements to the fullest extent practicable;
- Ensuring the health and safety of its workforce;
- Reducing risks to the public and the environment;
- Supporting the involvement of Tribal Nations, the states, and other stakeholders, i.e., affected and interested parties; and
- Deploying innovative technologies to assure that reduction of risk and mortgage, i.e., the cost of environmental cleanup is accelerated.

In consideration of this overall vision, the recommended configuration was developed through application of an iterative systems analysis. This process integrates individual site waste management plans with those of other sites and collectively with TRUW transportation and WIPP operations. The following TRUW systems goals were established by which the effectiveness of possible configurations could be judged:

1. Maintain compliance with Federal Facility Compliance Act (FCCA) consent orders, unilateral orders, and regulatory agreements.
2. Accelerate reduction of risk and mortgage by coordinating TRUW management programs and projects among sites.
3. Integrate TRUW management systems to maximize disposal of TRUW by the end of fiscal year 2006 (FY06), i.e., September 30, 2006.
4. Maximize the waste handling and disposal efficacy of the WIPP.

On November 19, 2001, EM-1 issued a Memorandum to the Director, Office of Management and Budget and Evaluation, Chief Financial Officer, that responded to the September 21, 2001, request by the Deputy Secretary to outline specific EM Priorities. The Memorandum outlined the following priorities:

1. Improve safety performance.
2. Reduce cost and time required to complete the EM cleanup mission.
3. Close RF, Fernald, and Mound by 2006.
4. Consolidate nuclear material out of EM sites by 2004.
5. Eliminate the need to process high-level liquid wastes.
6. Make EM a better customer.
7. Shrink the EM footprint.
8. Get wastes to disposal facilities quickly.
9. Reshape EM systems and infrastructure to drive accelerated cleanup and closure.

TRUW system integration involves a sequential and iterative process that relies in part on computer-based model simulations. These simulations provide the ability to consider various configuration possibilities. The model and associated integration is built in large part on input from, and discussions with, the TRUW sites, and reflect stakeholder interests to the extent such interests were incorporated into site plans. Outputs of the computer simulations are evaluated to determine the extent to which a configuration achieved the waste management system goals. In addition, output is assessed to identify specific waste

processing elements preventing the configuration from achieving goals in an efficient manner. Based on these analyses, adjustments are made to those waste-processing elements identified as impediments to improved performance.

EM-20 provides guidance to facilitate the coordinated, timely, safe, and cost-effective disposition of nuclear materials and waste. It is responsible for promoting, enabling, and expediting site closure and project completion by conducting and providing multi-site services that facilitate the timely, coordinated, safe, and cost-effective disposition of nuclear materials and waste, and deactivation and decommissioning of excess contaminated facilities. Interdependencies exist between DOE sites and between EM and other DOE programs. Hence, EM-20 conducts technical integration activities to develop integrated policy, planning, technical, and analytical guidance and assistance for the EM program, including disposition strategies for nuclear materials and wastes, as well as providing services that promote, enable, and expedite disposition and closure. EM-20 also identifies disposition pathways for excess nuclear materials, spent nuclear fuels, legacy wastes and remediation wastes, analyses options with stakeholder input, and facilitates decision-making between offices and programs. EM-20 also implements multi-site services such as support for pollution prevention/waste management analyses, deactivation and decommissioning efforts, lessons learned and technology transfer activities, transportation, TRUW disposal at the WIPP site and the foreign research reactor spent nuclear fuel acceptance program. EM-20 is responsible for promoting, enabling, and expediting site closure and project completion. As illustrated in Fig. 3, both EM-23 and the CBFO report to EM-20. Key functions of EM-20 are to:

- Develop DOE HQ policy, program guidance and direction to achieve an effective, efficient, technically sound, safe, and environmentally acceptable waste treatment, storage, and disposal system. This office also approves technical, cost and schedule baselines, and reviews and approves major changes as appropriate;
- Promote integration and coordination of TRUW treatment, storage, transportation, and disposal activities with the TRUW sites;
- Develop strategies, options, analyses, and recommendations in support of policy development, long-range planning and cost effectiveness; and
- Formulate waste management budget requirements and allocations, as well as associated justification, documentation, and testimony for the program. This also includes reviews of site requests and development of independent recommendations for waste management resource requirements and funding levels based on site and national policies and plans.

The mission of EM-23 is to provide leadership, policy, and program budget direction and guidance, strategic analyses, integration, evaluation, and representation and advocacy of EM program activities within the purview of the CBFO. The TRUW program encompasses all activities associated with the treatment, storage, transportation, and disposal of TRUW in compliance with applicable internal and external program and environmental protection and safety and health requirements. Key functions of EM-23 are to:

- Assure that WIPP and TRUW-related issues and problems are promptly brought to the attention of appropriate officials for resolution;
- Promote integration and coordination of TRUW treatment, storage, transportation, and disposal activities with TRUW source sites;
- Develop strategies, options, analyses, and recommendations in support of policy development, long-range planning, and cost-effectiveness for the WIPP program;
- Develop and implement performance measures to ensure a timely and cost-effective program; and
- Conduct program representation and advocacy functions.

The mission of the CBFO is to protect human health and the environment by safely disposing of defense-related TRUW at WIPP and by establishing an effective system of management of TRUW from generation to disposal. The CBFO develops and directs implementation of the NTP, assesses compliance with the program guidance, and ensures the commonality of activities and assumptions among all TRUW sites. The CBFO created the Office of the NTP to serve as the focal point and lead the nation's TRUW management efforts. The CBFO Office of the NTP is responsible for development and management of a comprehensive waste management strategy. The CBFO Office of the NTP:

- Works with operations offices to coordinate and integrate the various program elements (TRUW inventory, transportation, waste characterization, TRUW characterization process certification, WIPP disposal and system integration) carried out across the DOE TRUW system;
- Assesses efficiency and effectiveness of TRUW systems operations;
- Develops guidance for long-term storage and disposal options for all TRUW (defense and non-defense) and for the development of TRUW-treatment technologies to ensure compatibility and compliance with applicable requirements;
- Evaluates the impact of policies and criteria on the TRUW sites' operations and institutional programs and develops and implements plans, policies, and guidance documents so that programmatic efforts comply in a timely and cost-effective manner;
- Provides technical guidance to develop and implement TRUW characterization programs and information systems to support requirements that govern the collection of TRUW characterization data; and
- Manages TRUW transportation system and shipping corridors; provides training programs for interested state, tribal, and local emergency responders.

Origination, Definition, and Amounts of the TRUW that May be Disposed at the WIPP Site

During the Cold War era, the USA built a significant strategic nuclear arsenal. One distinct by-product of this nuclear-weapons production was clothing, tools, rags, residues, debris, and other items contaminated with small amounts of man-made radioactive elements; mostly plutonium. Today, this waste is grouped in the following three categories, based essentially on origin/source and radioactivity at the surface of the package/container/canister (from lowest to highest): (1) LLW; (2) TRUW; and (3) HLW. The statutory cornerstone for all U.S. radioactive waste-management and disposal activities is the Atomic Energy Act of 1954 (AEA). (9) In the case of the WIPP site, the WIPP Land Withdrawal Act of 1992 (LWA), (1) as amended in 1996 (LWAA), (2) contains the current statutory framework. The following LWA definitions and limitations pertain to the safe management and disposal of TRUW at the WIPP site (clarifying comments are shown in *italics):*

> "The term transuranic waste means waste containing more than 100 nanocuries *(3,700 becquerels [Bq])* of alpha-emitting transuranic isotopes per gram of waste with half-lives greater than 20 years, except for (A) high-level radioactive waste; (B) waste that the Secretary (*of Energy*) has determined with the concurrence of the Administrator (*the U.S. Environmental Protection Agency [EPA])* does not need the degree of isolation required by the disposal regulations; or (C) waste that the Nuclear Regulatory Commission has approved for disposal on a case-by-case basis in accordance with part 61 of title 10, Code of Federal Regulations *(10 CFR 61)."*

The LWA also contains the following definitions and limitations on the TRUW that may be disposed at the WIPP site (clarifying comments are shown in *italics):*

> "(a) Transuranic Waste Limitations.
> (1) Rem *(Sievert [Sv])* limits for remote-handled transuranic waste.
> (A) 1,000 rems per hour *(10 Sv per hour [Sv/h])*. No transuranic waste received at WIPP may have a surface dose rate in excess of 1,000 rems per hour *(10 Sv/h).*
> (B) 100 rems per hour *(1 Sv/h).* No more than 5 percent by volume of the remote-handled transuranic waste received at WIPP may have a surface dose rate in excess of 100 rems per hour *(1 Sv/h).*
> (2) Curie limits for remote-handled transuranic waste.
> (A) Curies *(becquerels[Bq])* per liter. Remote-handled transuranic waste received at WIPP shall not exceed 23 curies *($8.51x10^{11}$ Bq)* per liter maximum activity level (average over the volume of the canister).
> (B) Total Curies *(Bq).* The total curies *(Bq)* of remote-handled transuranic waste received at WIPP shall not exceed 5,100,000 curies *($18.87x10^{16}$ Bq)."*

As indicated above, and as defined elsewhere in the LWA, the following two TRUW categories exist in order of increased radioactivity, *measured at the surface of the container:*

1. Contact-handled TRUW (CH-TRUW), which means TRUW "with a surface dose not greater than 200 millirem per hour" *(2 milliSv/h).*
2. Remote-handled TRUW (RH-TRUW), which means TRUW "with a surface dose rate of 200 millirem per hour *(2 milliSv/h)* or greater." However, the surface dose rate may not exceed 1,000 rems/h *(10 Sv/h*). Furthermore, the DOE has agreed with the State of New Mexico to limit the amount of RH-TRUW in the WIPP repository to 7,080 m^3. (10)

Also, approximately 50 % of the TRUW to be disposed at WIPP may be mixed with regulated hazardous constituents. This category of TRUW is referred to as *mixed-TRUW* and is regulated under both the LWA, as amended, and the Resource Conservation and Recovery Act of 1976 (RCRA). (11)

In summation, three different TRUW categories, i.e., CH-TRUW, RH-TRUW, and mixed-TRUW, may be disposed at the WIPP site as follows:

- The receipt, management, and disposal of non-mixed TRUW require a functional certification decision from the EPA, followed by periodic recertifications by the EPA at least every five years after the commencement of TRUW disposal; and
- The receipt, management, and disposal of mixed-TRUW require a favorable RCRA Part B Permit from the New Mexico Environment Department (NMED).

The DOE obtained the EPA's certification decision on May 13, 1998, (12) and the NMED's RCRA Part B Permit on October 27, 1999. (13) It should be noted that both the EPA certification decision and the RCRA Part B Permit (a) were conditional and (b) excluded the disposal of RH-TRUW pending additional documentation. Furthermore, based on applicable laws and regulations, but augmented with then-ongoing practices, the CBFO developed WIPP Waste Acceptance Criteria (WAC) (14). Hence, the WIPP WAC defines the CH-TRUW that presently may be received and disposed at the WIPP site. Suffice it to mention that distinguishing between mixed and non-mixed TRUW is a complicated process that involves some of the most complex processes and difficult to apply provisions of environmental law.

TRUW is a LLRM category that, typically, contains the same long-lived radioisotopes as those found in long-lived radioactive waste categorized as ILW and HLW in other countries. Hence, described below are

the TRUW radioisotopes most critical to the safe, long-term performance of the WIPP repository. This information is intended to facilitate other nations to relate their LLRMs to the U.S. TRUW. Table 1 lists 30 of the most common radionuclides in the existing TRUW. (15)

Table I. Dominating Radionuclides in Currently Stored TRUW.

Actinium (Ac) 225, 227	Cobalt (Co) 60	Promethium (Pm) 147
Americium (Am) 241, 243	Curium (Cm) 243, 244, 245	Protactinium (Pa) 233, 234
Antimony (Sb) 125	Europium (Eu) 152, 154, 155	Radium (Ra) 224, 225, 226
Barium (Ba) 137	Francium (Fr) 221	Radon (Rn) 220, 222
Bismuth (Bi) 210, 212, 213, 214	Krypton (Kr) 85	Ruthenium (Ru) 106
Cadmium (Cd) 109	Lead (Pb) 209, 210, 212, 214	Strontium (Sr) 90
Californium (Cf) 252	Neptunium (Np) 237, 239	Technetium (Tc) 99
Carbon (C) 14	Nickel (Ni) 63	Thorium (Th) 228, 229, 231, 234
Cerium (Ce) 144	Plutonium (Pu) 238, 239, 240, 241, 242	Uranium (U) 232, 233, 234, 235, 237, 238
Cesium (Cs) 134, 137	Praseodymium (Pr) 144	Yttrium (Y) 90

Pursuant to applicable LLRM disposal regulations in the USA, (16,17) the WIPP post-closure safety/performance assessments (SAs/PAs) are based on normalized radionuclide releases relative to the initial radionuclide inventory and incorporate radioactive decay and ingrowths over time. Hence, the present activity of a radionuclide may not be significant to post-closure SAs/PAs. Specifically, at the time WIPP closes, *in alphabetical order,* the nine component radionuclides with the greatest activities are: (1) Americium 241 (Am^{241}); (2) Cesium 137 (Cs^{137}); (3-6) Plutonium 238, 239, 240, 242 ($Pu^{238,239,240,242}$); (7) Strontium 90 (Sr^{90}); and (8-9) Uranium 233, 234 ($U^{233,234}$). In addition, the U^{238} component is being measured (assayed) because its large mass-fraction and low activity dilutes the overall activity of transported uranium species. These ten radionuclides overwhelmingly exceed the activities of all other radionuclides combined and are the only radionuclides that need to be limited at the WIPP site. (15) However, although Am, Pu, Cs, and Sr comprise more than 99 % of potential post-closure radionuclide releases at present and projected inventory levels, Cs and Sr are important for about 200 years and Am is important for about 3,000 years. Hence, only $Pu^{239,240}$ are important beyond 3,000 years. Actually, the total activity at emplacement and during the entire 10,000-year regulatory period is dominated by the activities of the following four radionuclides: Am^{241} and $Pu^{238,239,240}$. (15) Also, after approximately 300 years, the radionuclide inventory in CH- and RH-TRUW is almost identical, which was considered in the SAs/PAs presented in the 1996 WIPP Compliance Certification Application (CCA). (15)

The Current Infrastructure and Status at the WIPP Site

The WIPP site (Fig. 1) is located in a sparsely populated desert area in New Mexico. As described in another paper at this conference (18), the WIPP site has been subjected to a broad range of site characterization and repository development activities since 1975. (5) As illustrated in Fig. 4, at the end of the year 2001, the WIPP site hosts an underground research laboratory (URL), the North Experimental Area, and the surface and subsurface facilities, equipment, and trained personnel required by laws, regulations, DOE Orders, the EPA certification decision, and the RCRA Part B Permits for safely receiving, handling, and disposing up to 175,584 m^3 of TRUW. Both the WIPP URL and repository are situated approximately 650 m below the ground surface in the lower half of a carefully characterized and selected, 250 million year old, 600 m thick, virtually undisturbed and impermeable bedded-salt horizon in the Salado Formation (Fig. 4).

CH-TRUW disposed at WIPP mainly consists of containerized (208-liter steel drums or standard waste boxes [SWBs]) clothing, tools, rags, solidified sludges, residues, debris and other items contaminated with small amounts of radioactive, man-made elements (Table 1). Since these synthetic byproducts of nuclear weapons production remain radioactive for tens of thousands of years, they pose an exposure risk to workers, the public, and the environment. Sound environmental practice requires that TRUW be safely contained and isolated for the duration of its toxicity period, protecting the public health and the environment of current and future generations.

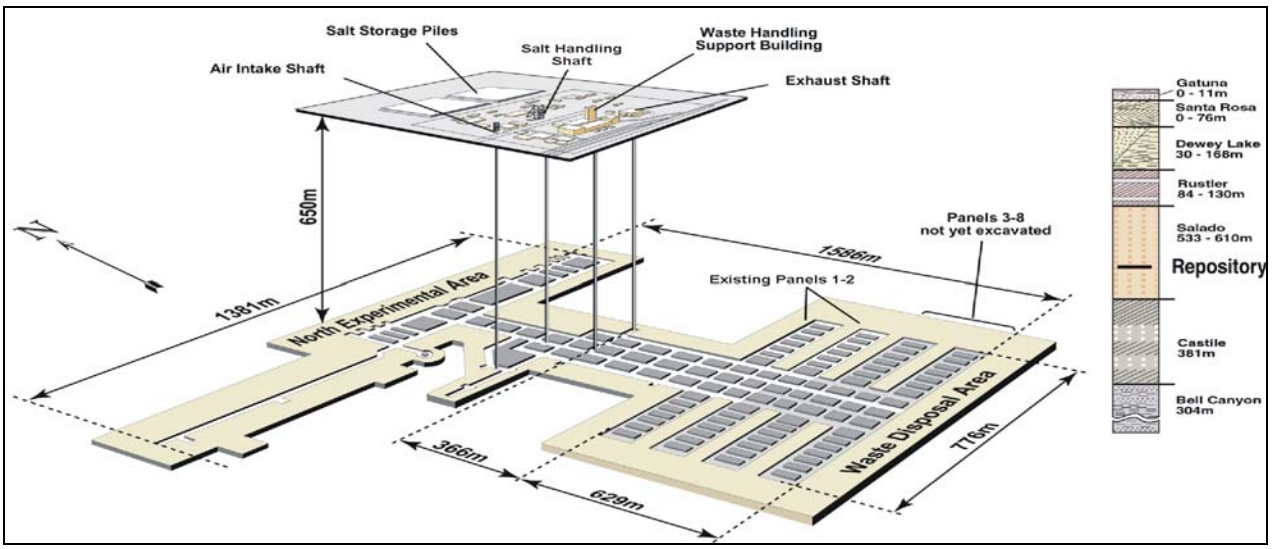

Fig. 4. Schematic illustration of surface and subsurface/underground facilities at the WIPP site (left) and the stratigraphic column of the WIPP Disposal System (right).

As shown in Fig. 4, the baseline repository layout/design comprises eight separate panels and each panel hosts seven disposal rooms. Each disposal room is 4-m high, 10-m wide, and 91-m long. The current disposal scheme involves stacking the CH-TRUW containers and/or SWBs in the disposal rooms and placing up to 8,000 RH-TRUW containers in horizontal holes in the walls between the disposal rooms. The centerline for the RH-TRUW holes will be located approximately 1.2 m above the floor/invert and spaced approximately 2.4-m apart. Bags containing granulated magnesium oxide (MgO) are attached to CH-TRUW containers and SWBs to maintain stable chemical conditions to minimize actinide solubility in the disposal room during the 10,000-year regulatory period. According to conducted analyses (15), actinide solubility is the key to the safe long-term performance of the WIPP repository, because all CH-TRUW (more than 95 % of the total TRUW volume) is contained in short-lived containers. The MgO will also absorb brine and thereby reduce the amount of liquid available for radionuclide transport.

Geologic containment and isolation is the fundamental premise for safe disposal of LLRMs at the WIPP site. The inherent rheological (creep) characteristics of the repository host rock (salt) are projected to close the 4-m-high, unsupported, disposal room openings at an average rate of between 10 and 20 centimeters per year and fully encapsulate the emplaced LLRMs into a virtually impermeable salt/waste monolith within 300 years. However, as illustrated in Fig. 4, due to this creep phenomenon, only two of eight currently planned disposal panels have been constructed to date to avoid costly maintenance and, more importantly, costly ground support systems that would extend the time required for the encapsulation of the emplaced LLRMs. The remaining six panels will be constructed as disposal needs arise in the future.

Pursuant to the LWA, (1) the DOE must recertify the WIPP TRUW repository at least every five years after the March 26, 1999, commencement of disposal operations. Hence, the first recertification is due by March 26, 2004. In support of the pending "first" re-certification application, the CBFO has commissioned studies designed to address both operational and post-closure safety issues at WIPP. Three of these post-closure-safety issues are:

- The very conservative assumptions;
- The conceptual and numerical models; and
- The parameter ranges and values used in the 1996 WIPP CCA. (15)

Due to the scientific, engineering, institutional, socio-economic, and political complexities embodied in the siting, constructing, certifying, permitting, and operating the WIPP site/repository, all DOE offices involved in the resolution of the nation's TRUW legacy are committed to early, continuous, mutually constructive interactions with local, State, tribal, and other Federal institutions, stakeholders (affected and interested parties), and oversight and review groups. For example, the DOE has worked closely with local WIPP communities since 1973, and in 1981 agreed with the State of New Mexico to cooperate and collaborate with state officials on important public health and safety issues. (10) In addition, the National Academy of Sciences (NAS) and the New Mexico Environmental Evaluation Group (EEG) have monitored and commented on the WIPP program since 1978, At the end of the year 2001, the NAS had issued ten major reports and several additional letter and interim reports, and the EEG had issued more than 80 reports. Two NAS reports issued in the year 2001 entitled "Improving Operations and Long-Term Safety of the Waste Isolation Pilot Plant" and "Characterization of Remote-Handled Transuranic Waste for the Waste Isolation Pilot Plant", respectively, (19,20) are of particular importance to the CBFO's present and continued safe management of the WIPP and the NTP. For example, the following statements and recommendations were made by the NAS in the first of these reports (19):

> "The overarching finding and recommendation … is that the activity that would best enhance confidence in the safe long-term performance of the repository is to monitor critical performance parameters during the long pre-closure phase of repository operations (35 to possibly 100 years)."

The other report contains eight RH-TRUW-related findings and the following concluding statement: (20)

> "Overall, the committee acknowledges and supports DOE's endeavors to improve worker safety, reduce costs, and eliminate unnecessary self-imposed requirements."

The CBFO will evaluate the findings and recommendations presented in the aforementioned two NAS reports and address these findings and recommendations as appropriate. Likewise, the CBFO evaluates and responds to any observation and recommendation presented by the EEG.

At the end of the year 2001, the CBFO, supported by local contractors, has safely received and disposed nearly 500 shipments of CH-TRUW from five of the 23 TRUW generator and storage sites at the WIPP site (Fig. 1). However, the current CH-TRUW receipt and disposal capacity at the WIPP site is considerably greater than both the capacity at the nation's TRUW generator and storage sites to characterize and prepare CH-TRUW for shipment, and the existing infrastructure for shipping CH-TRUW to the WIPP site. Hence, as described below, a primary focus area in the CBFO's path forward is the improvement of the capacity of the TRUW characterization and shipping components, also referred to as "filling the pipeline to WIPP". By improving the capacity of these components to an average rate of 17 CH-TRUW shipments per week, the period for the national risk and the costly DOE stewardship involved in ensuring that the stored TRUW remains under strict safeguards, also referred to as the "national mortgage", will be reduced in accordance with the above EM milestones.

The CBFO mission also includes making the underground research facilities (URFs) and infrastructure at the WIPP site available to scientists who wish to conduct experiments, to the extent such experiments (a) can be conducted without interfering with WIPP's primary TRUW disposal mission and (b) reflect current budget priorities. The WIPP URFs provide a particularly suitable environment for experiments in many scientific disciplines related to repository science, mining technology, fissile materials accountability and transparency, and deep geophysics. For example, the salt formation hosting the WIPP repository and URL is naturally very low in primordial radioactive isotopes. Hence, it is very well suited for experiments involving low radiation dose physics. Thence, the CBFO prepared an Environmental Assessment for conducting astrophysics and other basic science experiments at the WIPP site and reached a Finding of No Significant Impact in early 2001. Currently, two experiments in astrophysics conducted for several years by LANL are located in the WIPP URL. The astrophysics experiment gallery is well lighted with power and data communications available for use by the science experiments. Prototype detectors for monitoring neutrinos from supernovae and measuring neutrino-less double beta decay are in the advanced planning stage. Six other teams of scientists have proposed astrophysics experiments to the DOE and are seeking funding from the scientific community for those experiments.

As described in another paper at this conference (18) and other documents prepared by the CBFO (e.g., 21), between 1983 and 1995, the WIPP URL hosted a suite of *in-situ* tests designed to establish the ability of rock salt to safely contain and isolate both TRUW and HLW. As shown in Fig. 4, the WIPP URL is located approximately 900 m north of the repository and includes approximately two km of drifts approximately 10 m wide and 6 m high, and several test rooms/areas of varying dimensions. Furthermore, in April 1992, the WIPP URL hosted a successful CH-TRUW retrievability feasibility test. In addition, in 1999, the WIPP repository served as the test bed for an International Atomic Energy Agency (IAEA)-sponsored nuclear waste repository transparency demonstration. In October 2001, the WIPP URL was designated as one of three URFs in the IAEA's "Network of Centers of Excellence on **T**raining in and **D**emonstration of **W**aste Disposal Technologies in Underground Research Facilities", also referred to as the TDW Network. The IAEA's primary objectives for the TDW Network are to:

- Supplement national efforts and promote public confidence in deep geological disposal of LLRMs;
- Contribute to the resolution of key scientific and technical issues; and
- Encourage the transfer and preservation of knowledge and technologies.

Of particular significance to the successful certification and past and current broad-based public and political acceptance and support of the WIPP LLRM repository is its very high post-closure safety. For example, one of the WIPP Safety Cases, presented in the 1996 WIPP CCA, projected the amount of radionuclide releases over the 10,000 year regulatory post-closure period to be less than 10 percent (%) of the related regulatory limits even if the repository integrity was breached by multiple human intrusions. (15) The 1996 WIPP CCA also projected that, if the repository was not breached by any human intrusion, the maximum cumulative effective annual dose (MCEAD) to an individual residing at the boundary of the 41.6 km^2 WIPP site was approximately 3 % of the related regulatory limit. It should be mentioned that the related regulations (16,17) are very prescriptive and stringent. For example, the regulatory permitted MCEAD is only 4 % of the natural average background radiation in the USA, which means that the potential radiation from the WIPP repository is only 0.13 % of the average natural background radiation in the USA. Hence, the following two conclusions may be drawn from the WIPP Safety Cases:

1. The host rock for the WIPP repository (salt) provides excellent containment and isolation of LLRMs.
2. The WIPP repository could accommodate more LLRMs within the applicable regulatory framework than currently allowed by applicable laws.

CBFO's PATH FORWARD

As described above, the WIPP repository has been in operation for almost 3 years. In addition, both the national and local systems for safe TRUW management and disposal continue to be subjected to a dynamic process of evolution and improvement that will last throughout the 35-year operational and 10-year closure phases of the WIPP repository. At the end of the year 2001, the primary EM directions to the CBFO are to:

- Implement, maintain, and continuously improve quality assurance (QA) programs in accordance with the CBFO QA Program Document (QAPD);
- Evaluate overall methods for system reengineering and outsourcing to provide for significant program savings over the next 10 years;
- Evaluate their base programs to achieve productivity and efficiencies; and
- Be the recognized leader and broker of radioactive and hazardous waste management technologies to national and international government and private organizations.

The DOE is committed to honoring the obligation to clean up the legacy of contamination resulting from nuclear weapons research, production, and testing. The WIPP repository is a critical, integral element in solving the nation's TRUW legacy. Being a global first-and-only-kind-of-facility, the WIPP repository also is serving as an international beacon setting the standards for safe, environmentally sound, and cost-effective geological disposal of LLRMs.

In summation, the CBFO's path forward is governed by the following goals:

- The safe and cost-effective characterization and removal of all WIPP-WAC-compliant CH-TRUW, RH-TRUW, and mixed-TRUW from 17 of the nation's 23 TRUW generator and storage sites by the year 2006;
- The safe and cost-effective characterization and removal of all WIPP WAC-compliant CH-TRUW, RH-TRUW, and mixed-TRUW from the remaining six sites by the year 2034;
- The continued safe, cost-effective operation and closure of the nation's TRUW management system in compliance with all applicable laws, regulations, agreements, and DOE Orders;
- The commencement of RH-TRUW disposal in the year 2003; and
- The timely preparation and submittal to the EPA of the first recertification application for the WIPP repository.

Contingent upon the availability of adequate financial resources and authority, EM-23 and the CBFO are confident that these goals can be met. Indeed, based on the current CH-TRUW and mixed-TRUW disposal capacity at the WIPP site, the aforementioned TRUW-removal schedule could even be accelerated, which would further reduce the national risk and mortgage related to the TRUW legacy.

SUMMARY OF BENEFITS PROVIDED BY THE WIPP

The WIPP repository is the first-and-only-of-its-kind facility in the world for safe disposal of LLRMs. (5) The continued safe operation of the WIPP repository is the beacon and successful solution to the DOE's environmental cleanup and removal of all TRUW from the surface and near-surface of the nation's 23 nuclear weapons complex sites by the year 2034 to a depth of more than 650 m below the ground surface in a very stable, virtually impermeable, 250 million year old, 600 m thick salt bed at the WIPP site. A unique aspect of the WIPP disposal concept is that it relies upon the geologic setting and the shaft seals for providing the regulatory-required, post-waste emplacement/disposal protection of workers' and the public's health and safety. Indeed, excepting the shaft seals, the purpose of any other engineered barrier system (EBS) is to provide the regulatory-required pre-waste-emplacement/disposal protection of

workers' and the public's health and safety. Actually, the radionuclide containment and isolation characteristics of the geologic setting at the WIPP site provide much higher protection to humans and the environment than that required by applicable regulations. Indeed, the projected potential post-closure radiation from WIPP is less than 10 % of applicable regulatory limits and less than 0.15 % of the average natural background radiation in the USA. In other words, *the WIPP TRUW repository is very safe.*

At the end of the year 2000, more than 50 million people resided within 80 km of the nation's 23 TRUW generator and storage sites, whereas less than 30 people resided within 16 km of the WIPP site (Fig. 1). Hence, in addition to being the long-sought environmental solution to a specific national need, *the WIPP repository also provides a significant national risk reduction* both to current and many future generations that may serve as a role model for similar LLRM-disposal solutions elsewhere.

In 1998, the EM accelerated the schedule for cleanup and removal of TRUW from the nation's nuclear weapons complex. *The accelerated EM schedule reduced the national mortgage for the TRUW legacy* in that it reduced both the period for the national risk imposed by the stored TRUW and the costly stewardship involved in ensuring that both the environmentally contaminated sites and the TRUW remained under strict safeguards.

At the end of the year 2001, the infrastructure required at the WIPP site for meeting the accelerated EM schedule is in place. However, the TRUW receipt and disposal capacity at the WIPP site is considerably greater than both the related national capacity to (1) characterize and prepare TRUW for shipment and (2) shipping TRUW to the WIPP site. Hence, *the CBFO's current focus is on filling the pipeline to WIPP*. Indeed, an additional benefit of the WIPP repository is embodied in the fact that existing TRUW receipt and disposal capacities at the WIPP site facilitate an acceleration of the current EM schedule for removal of CH-TRUW and mixed-TRUW from the nation's 23 nuclear weapons complex sites. In other words, additional reductions in the national risks and mortgage stemming from the nuclear weapons complex TRUW legacy are potentially available.

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