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Shallow-Buried Transuranic Waste: A Comparison of Remediation Alternatives at Los Alamos National Laboratory

ABSTRACT

As part of its overall cleanup activities, the U.S. Department of Energy (DOE) has identified two alternative remediation plans for the 126,000 cubic meters (m³) of radioactive transuranic (TRU) waste generated from defense-program activities that were disposed in shallow burial at DOE sites before 1970: (1) removal for deep geologic disposal, or (2) on-site containment. This article identifies and compares the different legal requirements for the disposal of TRU waste, notes differences in DOE's plans for remediation, and summarizes federal remediation decisions for this waste at DOE generator sites. The article then evaluates these two disposal options at Los Alamos National Laboratory, where DOE has not yet made a decision on remediation for TRU waste containing 20,800 Curies of radioactivity. If DOE's remediation goals are to protect public health and the environment from long-term risks and demonstrate consistency in national TRU waste management practices, then this article recommends that DOE exhume these materials at Los Alamos and dispose of them at the Waste Isolation Pilot Plant (WIPP) in southern New Mexico. Otherwise, DOE should publish a 10,000-year performance assessment of the two disposal alternatives.

I. INTRODUCTION

By enacting the Atomic Energy acts of 1946 and 1954, Congress gave the Atomic Energy Commission (AEC), the predecessor agency of the Department of Energy (DOE), the sole responsibility and ownership of fissionable materials used in defense programs, as well as the obligation to protect the health and safety of the public from these materials.¹

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1. Atomic Energy Act of 1946, Pub. L. No. 585-724, § 5(a)(2), 60 Stat. 755, 760 (codified as amended at 42 U.S.C. § 2011 (2000)); Atomic Energy Act of 1954, Pub. L. No. 703, §§ 2, 52, 68 Stat. 919, 921, 929-930 (1954) (codified as amended at 42 U.S.C. § 2011 (2000)).

Exercising these authorities, DOE disposed of transuranic (TRU) waste² generated by U.S. defense programs at six generator sites at shallow and intermediate depths.³ This article focuses on shallow-buried TRU waste⁴ at the sites and does not address the contamination of soil or groundwater, nor does it address TRU waste buried at much greater depths. This waste was placed in cardboard boxes, plastic bags, or steel drums and was disposed in shallow trenches or pits⁵ at the following six sites: Hanford Site, in Washington State; Idaho National Laboratory (INL)⁶; Los Alamos National Laboratory (LANL), in New Mexico; Nevada Test Site, near Las Vegas, Nevada; Oak Ridge National Laboratory (ORNL), in Tennessee; and Savannah River National Laboratory, in South Carolina.⁷

In 1970, the DOE recognized that the long-term hazards of TRU waste warranted greater isolation than that provided by shallow land burial and directed its field offices to stop disposing of TRU waste at the facilities in this manner. Facilities were directed to take immediate action to begin segregating, packaging, and burying TRU waste in a manner that could be easily retrieved within a 20-year period or beyond.⁸ A few

2. The U.S. Environmental Protection Agency defines TRU waste as “waste containing more than 100 nanocuries of alpha-emitting transuranic isotopes, with half-lives greater than 20 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.” 40 C.F.R. § 191.02(i) (2006).

3. OFFICE OF ENVTL. MGMT., U.S. DEP’T OF ENERGY, PUB. NO. DOE/EM-00-0384, BURIED TRANSURANIC-CONTAMINATED WASTE INFORMATION FOR U.S. DEPARTMENT OF ENERGY FACILITIES 21 tbl.1 (2000) [hereinafter BURIED TRU WASTE]; see also John M. Peterson et al., *Volume and Activity of Buried Transuranic-Contaminated Wastes at U.S. Department of Energy Facilities*, 82 HEALTH PHYSICS 1, 7 tbl.1 (2002). DOE defines shallow-buried TRU as waste buried within 30 meters (98 feet) of the surface, but does not specify a minimum depth. See BURIED TRU WASTE, *supra* at 3; Peterson et al., *supra* at 3.

4. BURIED TRU WASTE, *supra* note 3, at 1 (“Radioactive wastes meeting the current definition of transuranic (TRU) waste were disposed of by shallow land burial and other techniques at a number of sites owned and operated by the federal government in support of the nuclear weapons program from the 1940s through 1970s.”).

5. LAWRENCE E. ALLEN, N.M. ENVTL. EVALUATION GROUP, PUB. NO. EEG-87, IDENTIFICATION OF ISSUES CONCERNING BURIED TRANSURANIC WASTE 1, 11 (2003).

6. Formerly known as Idaho National Environmental and Engineering Laboratory (INEEL).

7. BURIED TRU WASTE, *supra* note 3, at 22 tbl.2. In 2004, Savannah River’s laboratory was designated a national laboratory. However, the site that includes more than the laboratory is still called the Savannah River Site.

8. U.S. Atomic Energy Comm’n, Immediate Action Directive, AEC Manual, IAD No. 0511-21, at 2 (Mar. 20, 1970) [hereinafter AEC Immediate Action Directive]. See also BURIED TRU WASTE, *supra* note 3, at 7; Peterson et al., *supra* note 3, at 4 (reporting that in 1973 AEC

sites, such as LANL, the Savannah River National Laboratory, and ORNL “continued to bury some TRU waste well into the 1970s” with “the intent of” retrieving the waste.⁹ Only later did all DOE sites begin storing newly produced TRU waste in a retrievable manner for eventual deep geologic disposal. The DOE refers to this retrievably buried TRU waste as stored or legacy TRU waste.¹⁰ The directive does not mention or provide guidance on the previously disposed shallow-buried TRU waste.¹¹

In 1992, Congress changed the dual authorities of the DOE to dispose of TRU waste and to determine the safety of the practice by assigning the responsibility to set standards for the safe disposal to an independent regulator, the U.S. Environmental Protection Agency (EPA).¹² The EPA had issued standards¹³ in 1985 for safe geologic dispo-

defined TRU waste as that which contains “more than 10 nCi/g of TRU alpha-emitting radionuclides”). DOE in 1982 raised the threshold concentration for TRU waste to be 100 nCi/g. *Id.* In 1988, DOE revised the definition of TRU waste as exceeding 100 nCi/g at the time of assay. U.S. Dep’t of Energy, Radioactive Waste Mgmt., DOE Order 5820.2A, at 4 (Sept. 26, 1988). See U.S. Dep’t of Energy, Radioactive Waste Mgmt., DOE Order 435.1, at 3 (July 9, 1999) [hereinafter DOE Order 435.1]. Order 435.1 refers to DOE Manual 435.1-1. See U.S. Dep’t of Energy, Radioactive Waste Mgmt. Manual, DOE Manual 435.1-1 (July 9, 1999) [hereinafter DOE Manual 435.1-1]. Transuranic waste is defined in Chapter III of DOE Manual 435.1-1, “Transuranic Waste is radioactive waste containing more than 100 nanocuries (3700 becquerels) of alpha-emitting transuranic isotopes per gram of waste, with half-lives greater than 20 years, except for: (1) High-level radioactive waste; (2) Waste that the Secretary of Energy has determined, with the concurrence of the Administrator of the Environmental Protection Agency, does not need the degree of isolation required by the 40 CFR Part 191 disposal regulations; or (3) Waste that the Nuclear Regulatory Commission has approved for disposal on a case-by-case basis in accordance with 10 CFR Part 61.” This definition is identical to EPA’s definition, see 40 C.F.R. § 191.02(i) (2006). Note that this DOE Manual also states, “Transuranic waste disposed of prior to implementation of the 1970 Atomic Energy Commission Immediate Action Directive regarding retrievable storage of transuranic waste is not subject to the requirements of DOE O 435.1, *Radioactive Waste Management*, and this Manual.” DOE Manual 435.1-1, *supra* at III-1.

9. BURIED TRU WASTE, *supra* note 3, at 7; Peterson et al., *supra* note 3, at 5.

10. BURIED TRU WASTE, *supra* note 3, at 49–50 (describing stored TRU waste). “Most of [buried TRU] waste was identified as being contact-handled waste (with a dose rate less than 200 mrem/hr). Only a few percent (by volume) of the buried TRU waste was considered to be remote-handled waste (with a dose rate above 200 mrem/hr).” *Id.* at 16; see generally A. B. Wolbarst et al., *An Overview of EPA Regulation of the Safe Disposal of Transuranic Waste at the Waste Isolation Pilot Plant*, 80 HEALTH PHYSICS 2 (2001) (describing legacy TRU waste).

11. See AEC Immediate Action Directive, *supra* note 8.

12. Waste Isolation Pilot Plant Land Withdrawal Act, Pub. L. No. 102-579, §§ 8, 16(f), 106 Stat. 4777, 4786–87, 4793–94 (1992) (amended by Waste Isolation Pilot Plant Land Withdrawal Amendment Act, Pub. L. No. 104-201, § 3181–3191, 110 Stat. 2422, 2851–54 (1996)).

13. 40 C.F.R. § 191 (2006).

sal¹⁴ of defense-stored TRU waste and yet-to-be generated waste in the future. These standards require the DOE to demonstrate that it can limit releases of these long-lived radionuclides over a period of 10,000 years. In 1993, the EPA re-promulgated its 1985 standards for the safe disposal of TRU waste. These EPA standards are not retroactive, so they do not apply to the previously disposed 126,000 cubic meters (m³) of TRU waste in shallow burial.¹⁵

While EPA's 1985 standards apply to the future safe disposal of TRU waste, the DOE continues to be responsible for the TRU waste disposed under shallow ground cover under its Atomic Energy Act authorities.¹⁶ The DOE identified two alternative remediation plans for all of its 126,000 m³ of shallow-buried TRU waste: (1) stabilize in place, or (2) remove for deep geologic disposal.¹⁷ In 2000, the DOE reported plans to exhume one-third of the shallow-buried TRU waste at the six generator sites, while leaving the rest to be stabilized in place¹⁸—with the qualification that the DOE would work with “federal, state and local regulatory agencies and other stakeholders” to obtain consensus.¹⁹

The objectives of this article are to identify plans or decisions to remediate shallow-buried TRU waste at each of the DOE's six generator sites and to compare within the context of those decisions the DOE's two remediation options for shallow-buried TRU waste at LANL. Part II provides background information about the shallow-buried TRU waste at each of the six generator sites and ends with an evaluation of TRU waste issues at LANL; Part III gives additional information on LANL; Part IV describes the approach taken to compare remediation options for LANL; Part V compares the remediation options for LANL; Part VI presents a discussion of LANL findings and other federal decisions on the remediation of TRU waste; and Part VII summarizes the article's findings and recommendations to exhume some of the shallow-buried TRU waste at LANL, based on the following arguments:

- In 1970, the DOE stopped the shallow disposal of TRU waste because of its hazard and began storing the waste for

14. DOE began disposing TRU waste at the Waste Isolation Pilot Plant (WIPP) in March 1999. U.S. Dep't of Energy Waste Isolation Pilot Plant, <http://www.wipp.energy.gov/index.htm> (last visited Apr. 26, 2009); WIPP News Results, http://www.wipp.energy.gov/pr/1999nr.htm#Worlds_First_Begins_Operations (last visited Apr. 26, 2009).

15. See 40 C.F.R. § 191.11(b)(2).

16. Atomic Energy Act of 1946, Pub. L. No. 585-724, § 5(a)(2), 60 Stat. 755, 760 (codified as amended at 42 U.S.C. § 2011 (2000)); Atomic Energy Act of 1954, Pub. L. No. 703, §§ 2, 52, 68 Stat. 919, 921, 929–930 (1954) (codified as amended at 42 U.S.C. § 2011 (2000)).

17. BURIED TRU WASTE, *supra* note 3, at 11–12.

18. *Id.* at 18.

19. *Id.* at 3.

deep geologic disposal. While not legally required to do so, the DOE should consistently apply this rationale and exhume LANL's shallow-buried TRU waste for reasons of long-term risk reduction, as well as for consistency and parity.

- The DOE argued as justification for its Waste Isolation Pilot Plant (WIPP) that leaving TRU waste in storage is too risky due to the probability of human intrusion. Therefore, the DOE should include human intrusion in its analysis of the long-term radiological risks of shallow-buried TRU waste.
- It is inconsistent for the DOE to leave 20,800 Curies of plutonium-239 in shallow land burial at LANL, while shipping stored TRU waste—containing 11,000 Curies of plutonium-239—to WIPP for deep geologic disposal. The DOE should not expose future generations in northern New Mexico to greater, long-term radiological risk from shallow-buried TRU waste when future generations in southern New Mexico are assured of lower, long-term radiological risk due to deep geologic burial of TRU waste at WIPP.
- Idaho and the DOE have agreed to exhume the most hazardous shallow-buried TRU waste in Idaho for shipment to WIPP in New Mexico. New Mexico should have similar protection for its citizens.
- Finally, because the United States has been the beneficiary of a strong nuclear deterrent, it has the responsibility as a nation to deal with its waste products and should not pass the burden on to future generations.

II. REMEDIATION OF SHALLOW-BURIED TRU WASTE

The DOE has identified two options for the six generator sites that contain an estimated 126,000 m³ of radioactive TRU waste disposed before 1970. These options include: (1) leave the waste in place for *in situ* stabilization, or (2) exhume it for disposal at DOE's WIPP facility in southern New Mexico.²⁰ Rather than make the same decision for this shallow-buried TRU waste at every site, DOE policy²¹ has been to work with appropriate federal, state, and local regulators and other stakeholders “on a site-specific basis under CERCLA [Comprehensive Environmental Response, Compensation, and Liability Act], RCRA [Resource Conservation and Recovery Act], or applicable state statute[s].”²²

20. BURIED TRU WASTE, *supra* note 3, at 11–12, 18.

21. *Id.* at 3.

22. *Id.* at 20.

Four of the six sites²³ are subject to the CERCLA of 1980,²⁴ while others are subject to the RCRA of 1976.²⁵ For perspective, RCRA covers the cradle-to-grave management of new hazardous wastes to avoid future contamination problems, while CERCLA deals with the cleanup of hazardous substances from past activities.²⁶ States can require federal facilities regulated by RCRA to cleanup or take “corrective action” for hazardous wastes²⁷ but not for wastes containing special nuclear or byproduct material, which is regulated under the Atomic Energy Act and gives the DOE sole responsibility and ownership for these materials.²⁸ According to Katherine Probst and Michael McGovern, “[t]his regulation by DOE of its own activities is referred to as ‘self regulation.’ DOE must comply with a host of internal directives and regulations that implement the provisions of the AEA [Atomic Energy Act] and govern the management and storage of nuclear materials.”²⁹ CERCLA, however, provides the “EPA authority to address radioactive substances”³⁰ but not “high level radioactive substances.”³¹ CERCLA, also known as Superfund, was amended in 1986 to include federal facilities.³² For federal facilities designated as CERCLA sites, “[t]ypically DOE cleanup ac-

23. See U.S. GOV'T ACCOUNTABILITY OFFICE, PUB. NO. GAO-07-761, NUCLEAR WASTE PLANS FOR ADDRESSING MOST BURIED TRANSURANIC WASTES ARE NOT FINAL, AND PRELIMINARY COST ESTIMATES WILL LIKELY INCREASE 3-4 (June 2007) (showing that the Hanford Site, Idaho National Laboratory, Oak Ridge National Laboratory, and Savannah River National Laboratory are subject to CERCLA) [hereinafter GAO NUCLEAR WASTE PLANS]. This report focuses on five of the six generator sites identified in BURIED TRU WASTE, *supra* note 3, and excludes the Nevada Test Site. The Nevada Test Site follows RCRA. Nev. Div. of Env'tl. Prot., Permit for a Hazardous Waste Management Facility, http://ndep.nv.gov/BOFF/hw9_intr.pdf (last visited Apr. 18, 2009); Nev. Div. of Env'tl. Prot., Summary of Program Functions 4-5, http://ndep.nv.gov/boff/bff_program0107.pdf.

24. Comprehensive Environmental Response, Compensation and Liability Act of 1980, Pub. L. No. 96-510, 94 Stat. 2767 (codified as amended at 42 U.S.C. § 9601 (2000)).

25. Resource Conservation and Recovery Act of 1976, Pub. L. No. 94-580, 90 Stat. 2795 (codified as amended at 42 U.S.C. § 6901 (2000)); KATHERINE N. PROBST & MICHAEL H. MCGOVERN, RESOURCES FOR THE FUTURE, LONG-TERM STEWARDSHIP AND THE NUCLEAR WEAPONS COMPLEX 7-8 (1998) [hereinafter PROBST & MCGOVERN]. RCRA excludes all radioactive materials while CERCLA only excludes high-level radioactive substances. See STEVEN FERREY, ENVIRONMENTAL LAW: EXAMPLES AND EXPLANATIONS 293, 335, 342 (3d ed. 2004).

26. See FERREY, *supra* note 25, at 334-35.

27. Raymond Takashi Swenson, *Federal Agency Liability under the Superfund Act: It Goes Beyond Federal Facilities*, FED. FACILITIES ENVTL. J. 23, 32 (Winter 2004).

28. Atomic Energy Act of 1946, Pub. L. No. 585-724, § 5(a)(2), 60 Stat. 755, 760 (codified as amended at 42 U.S.C. § 2011 (2000)); Atomic Energy Act of 1954, Pub. L. No. 703, §§ 2, 52, 68 Stat. 919, 921, 929-930 (1954) (codified as amended at 42 U.S.C. § 2011 (2000)).

29. PROBST & MCGOVERN, *supra* note 25, at 7-8.

30. *Id.* at 8.

31. FERREY, *supra* note 25, at 335, 342.

32. PROBST & MCGOVERN, *supra* note 25, at 7-8.

tivities are governed by legally binding agreements signed by DOE, EPA, and the relevant state environmental agency” and in some cases with tribal governments.³³ Hence, RCRA and CERCLA differ with respect to applicability to radioactive materials, so states with a RCRA site may be at a disadvantage regarding cleanup decisions on radioactive waste.

DOE’s evaluation at each site is based on “the technical situation, current and future risks, land-use plans for the facility and nearby area, availability of cost-effective technologies and other local concerns.”³⁴ Hence, the remediation solution selected is not the same for all sites where each site has unique characteristics. This DOE policy of evaluating TRU waste disposed in shallow burial differs from the requirements promulgated by EPA in 1985 for future disposal of all TRU waste, whether stored or yet-to-be generated.

In the next section, we provide a brief description of the generator sites, describe the role of each within the nuclear weapons complex, examine whether the site follows a CERCLA or RCRA process, and briefly describe what is known of the site’s shallow-buried TRU waste. We also report whether DOE has made a remediation decision at each site. The article then focuses on Los Alamos National Laboratory and examines whether DOE TRU waste management practices for TRU waste disposed at Los Alamos National Laboratory in shallow burial are consistent with EPA requirements for future TRU waste disposal.

A. Description of the Generator Sites

In late 1942,³⁵ Los Alamos, a remote location in northern New Mexico, was selected as the site for the Manhattan Project “to design and build an atomic bomb.”³⁶ Originally named Los Alamos Scientific Laboratory, Los Alamos National Laboratory (LANL) opened in 1943, and in 1945 its scientists and engineers detonated the first atomic bomb near Alamogordo in southern New Mexico. After World War II, LANL’s mission evolved to support the defense programs of the U.S. government. LANL’s primary mission today is to ensure “the safety, security, and reliability of the nation’s nuclear deterrent.”³⁷

33. *Id.* at 8.

34. BURIED TRU WASTE, *supra* note 3, at 3.

35. Los Alamos National Laboratory, History: Site Selection, <http://www.lanl.gov/history/road/siteselection.shtml> (last visited Apr. 18, 2009).

36. Los Alamos National Laboratory, Los Alamos History, <http://www.lanl.gov/history/overview.shtml> (last visited Apr. 18, 2009).

37. Los Alamos National Laboratory, About Los Alamos, <http://www.lanl.gov/about.shtml> (last visited Apr. 18, 2009).

In addition to LANL, DOE manages five other sites where TRU waste generated by the nation's defense programs has also been disposed under shallow ground cover: Oak Ridge National Laboratory, which worked on gaseous diffusion technology for uranium isotope separation;³⁸ Hanford Site; Idaho National Laboratory; Savannah River National Laboratory, where DOE operated nuclear reactors on site;³⁹ and the Nevada Test Site, where DOE performed 100 atmospheric⁴⁰ and 828 underground nuclear tests.⁴¹

B. Quantities of Shallow-Buried Waste and Remediation Decisions

The total radioactivity of TRU waste at the six DOE sites was 397,000 Curies (Ci) in 2006.⁴² TRU waste is highly heterogeneous and its composition varies at these six sites due to the presence of different radionuclides with varying longevities and toxicities. Some alpha-emitting TRU waste radionuclides have fairly short half-lives, such as plutonium-238, which has a half-life of 87.7 years.⁴³ It also generates heat by rapid radioactive decay.⁴⁴ Other constituents of TRU waste that have a much shorter half-life may also be present, such as plutonium-241, which is a beta emitter and has a half-life of only 14.4 years—meaning it will have only 0.7 percent of its original radioactivity in 100 years. Some TRU waste alpha-emitting radionuclides have much longer half-lives, such as americium-241, which has a half-life of 432 years,⁴⁵ and consequently retain their radioactivity for longer periods of time. Because the shallow-buried TRU waste at LANL is mostly plutonium-239 with a half-life of

38. NAT'L RESEARCH COUNCIL, RESEARCH NEEDS IN SUBSURFACE SCIENCE: U.S. DEPARTMENT OF ENERGY'S ENVIRONMENTAL MANAGEMENT SCIENCE PROGRAM 18 (2000) [hereinafter SUBSURFACE SCIENCE].

39. See *id.* at 18.

40. NAT'L NUCLEAR SEC. ADMIN., U.S. DEP'T OF ENERGY, PUB. NO. DOE/NV-716-REV1, NEVADA TEST SITE HISTORY, ATMOSPHERIC TESTS AT THE NEVADA TEST SITE (2005), http://www.nv.doe.gov/library/factsheets/DOENV_716_Rev1.pdf.

41. SCOTT M. BOWEN ET AL., LOS ALAMOS NAT'L LAB., PUB. NO. LA-13859-MS, NEVADA TEST SITE RADIONUCLIDE INVENTORY: 1951-1992, at 1 (2001).

42. BURIED TRU WASTE, *supra* note 3, at 21 tbl.1; see also *id.* at 52 tbl.G-1 (showing the half-life of the major radionuclides and demonstrating that the total Ci keeps changing due to the different half-lives). The Appendix, based on BURIED TRU WASTE, *supra* note 3, at 21 tbl.1, shows that the total radioactivity decreased from 745,000 Ci to 397,000 Ci in 2006 due to radioactive decay. We report the 397,000 Ci in 2006 to provide some limited comparisons among sites.

43. ROGER W. BREWER, LOS ALAMOS NAT'L LAB., PUB. NO. NEA/NSC/DOC(95)03/VII, PLUTONIUM-238 AND PLUTONIUM-239 REPLACEMENT MEASUREMENTS PERFORMED USING JEZEBEL 2 (1997).

44. *Id.*

45. BURIED TRU WASTE, *supra* note 3, at 52.

24,100 years,⁴⁶ LANL's TRU waste will retain 75 percent of its original radioactivity after 10,000 years. The following subsections provide estimates of the quantity of shallow-buried TRU waste and the status of remediation decisions at each DOE site.

1. Savannah River National Laboratory

The Savannah River National Laboratory occupies an area of approximately 300-square miles and is located near Aiken, South Carolina.⁴⁷ Construction began in the early 1950s⁴⁸ to build production reactors capable of producing radionuclides, such as plutonium, for nuclear weapons.⁴⁹

The Savannah River National Laboratory is subject to CERCLA regulation and is on the Superfund National Priorities list.⁵⁰ Pursuant to CERCLA, Savannah River National Laboratory follows interagency agreements on the cleanup of chemical and radioactive materials.⁵¹ DOE estimated by 2006 that the TRU waste radioactivity at Savannah River National Laboratory was 18,500 Ci⁵² (in a volume of 4,530 m³),⁵³ which is about 4.7 percent of the total radioactivity at all six sites. Further, the TRU activity decreased from 21,900 Ci to 18,500 Ci due to radioactive decay.⁵⁴

DOE decided to leave the Savannah River National Laboratory's TRU waste in place and built a barrier to prevent the migration of radionuclides.⁵⁵ The barrier contains layers of "vegetation, soil, clay, and synthetic liners."⁵⁶ A fence prevents animal and human access to the area.⁵⁷ The decision to leave the shallow-buried TRU waste in place was reached by consensus through extensive involvement "with regulators and other stakeholders."⁵⁸

46. *Id.* at 12, 52.

47. SUBSURFACE SCIENCE, *supra* note 38, at 18.

48. Savannah River Site, History Highlights, <http://www.srs.gov/general/about/history1.htm> (last visited Apr. 18, 2009).

49. SUBSURFACE SCIENCE, *supra* note 38, at 18.

50. GAO NUCLEAR WASTE PLANS, *supra* note 23, at 3.

51. Savannah River Site, http://www.em.doe.gov/PDFs/PubPDFs/annrpt_3-14srs.pdf (last visited Apr. 18, 2009).

52. BURIED TRU WASTE, *supra* note 3, at 12.

53. *Id.* at 21 tbl.1.

54. *Id.* at 22.

55. GAO NUCLEAR WASTE PLANS, *supra* note 23, at 4.

56. *Id.*

57. *Id.*

58. BURIED TRU WASTE, *supra* note 3, at 20.

2. Oak Ridge National Laboratory (ORNL)

The Oak Ridge Reservation occupies an area of approximately 60 square miles and is located near Knoxville, Tennessee,⁵⁹ and includes the Oak Ridge National Laboratory, which was built “as a research and development facility to support plutonium production technology.”⁶⁰ Two other sites are part of the Oak Ridge Reservation: The Y-12 Plant and the K-25 Plant, “formerly known as the Oak Ridge Gaseous Diffusion Plant . . . [also] was created to produce highly enriched uranium for nuclear weapons.”⁶¹ We focus on the Oak Ridge National Laboratory because it contains shallow-buried TRU waste.

Similar to the Savannah River National Laboratory, Oak Ridge National Laboratory is a CERCLA site⁶² and reports a TRU activity of six Ci,⁶³ in a volume of 570 m³.⁶⁴ This amounts to 0.0015 percent of the total shallow-buried TRU waste at all six DOE sites. The volume of the TRU waste and its associated radioactivity at Oak Ridge are “generally unknown.”⁶⁵ Although DOE indicated in 2000 that it may excavate certain shallow-buried TRU waste at ORNL,⁶⁶ DOE decided to cap the waste and leave it in place after reaching consensus with the various stakeholders.⁶⁷ DOE based this decision on concern for the health and safety of workers potentially exposed to radiation during the exhumation because “DOE lacked adequate information on the specific location, condition, or concentration of the wastes in the burial sites”⁶⁸ and the amounts involved are so low.

3. Nevada Test Site (NTS)

The Nevada Test Site occupies an area of approximately 1,350-square miles in southern Nevada.⁶⁹ DOE performed 100 atmospheric and 828 underground nuclear tests there and operates a low-level and mixed low-level radioactive waste management facility at the site.

Unlike the previous two DOE sites, the Nevada Test Site is subject to RCRA.⁷⁰ During the mid-1980s, classified TRU waste from the Rocky

59. SUBSURFACE SCIENCE, *supra* note 38, at 18.

60. *Id.*

61. *Id.*

62. GAO NUCLEAR WASTE PLANS, *supra* note 23, at 3.

63. BURIED TRU WASTE, *supra* note 3, at 22.

64. *Id.* at 21 tbl.1.

65. *Id.* at 12.

66. *Id.*

67. GAO NUCLEAR WASTE PLANS, *supra* note 23, at 12.

68. *Id.*

69. SUBSURFACE SCIENCE, *supra* note 38, at 18.

70. GAO NUCLEAR WASTE PLANS, *supra* note 23, at 4.

Flats Plant, a former nuclear weapons production facility near Denver, Colorado, was mislabeled as low-level waste.⁷¹ The waste was disposed in a trench within Nevada Test Site's Area-5, a low-level and mixed, low-level waste disposal site.⁷² As of 2006, the corrected shallow-buried TRU waste activity for the site was 152 Ci (in a volume of 21 m³),⁷³ which is 0.038 percent of the total 397,000 Ci of shallow-buried TRU for all six sites.⁷⁴ The total activity of waste in Area-5 is estimated to be 1.9 million Ci.⁷⁵ For additional perspective, the total radioactivity decay corrected to 1992 from underground weapons testing at NTS,⁷⁶ including fission products, induced activity, and actinides, has been estimated to be 132 million Ci.⁷⁷ Hence, the activity levels of the shallow-buried TRU waste are small compared to the site's total radioactivity. In addition, DOE reports that "the exact location of disposal is uncertain," making "costs and hazards of retrieval . . . high."⁷⁸ The authors of a special investigative report recommend leaving the buried TRU waste in place because they report that it met the requirements of DOE Manual 435.1-1 and 40 CFR § 191 over 10,000 years.⁷⁹ While DOE Manual 435.1-1 does not apply to the pre-1970, shallow-buried TRU waste, it may apply to waste mistakenly disposed in the 1980s. The investigative report does include human intrusion in its analyses, but only under present conditions of institutional control,⁸⁰ which appears to differ from the EPA requirement that

71. Greg Shott et al., U.S. Dep't of Energy, Rev 1.0, DOE/NV/25946—470 Special Analysis of Transuranic Waste in Trench T04C at the Area 5 Radioactive Waste Management Site, Nevada Test Site, Nye County, Nevada 2 (2008), available at <http://www.osti.gov/bridge/servlets/purl/928845-JsyPhq/928845.pdf> (last visited Apr. 27, 2009) [hereinafter SPECIAL ANALYSIS NTS]. The Rocky Flats Environmental Technology Site occupies an area of approximately 350 acres near Denver, Colorado, where production ended in 1989. They produced nuclear weapons components and activities included, among other things, plutonium recovery and purification. See SUBSURFACE SCIENCE, *supra* note 38, at 18.

72. SPECIAL ANALYSIS NTS, *supra* note 71, at 2.

73. BURIED TRU WASTE, *supra* note 3, at 21 tbl.1.

74. *Id.* at 12.

75. U.S. DEP'T OF ENERGY, DOE/NV/11718—449-REV2, National Nuclear Security Administration Nevada Site Office, Integrated Closure and Monitoring Plan for the Area 3 and Area 5 Radioactive Waste Management Sites at the Nevada Test Site 55 (2005), available at <http://www.osti.gov/bridge/servlets/purl/935164-G4edbb/>.

76. BOWEN, *supra* note 41, at 1.

77. *Id.* at 21.

78. SPECIAL ANALYSIS NTS, *supra* note 71, at 3.

79. *Id.* at 97–98. The TRU waste under shallow ground cover at the Nevada Test Site was included in the BURIED TRU WASTE, *supra* note 3, and PETERSON, *supra* note 3, but they refer to DOE Manual 435.1-1, *supra* note 8, which does not include TRU waste disposed before 1970.

80. SPECIAL ANALYSIS NTS, *supra* note 71, at 52 (describing assumptions of analyses).

models should not assume any credit for institutional control⁸¹ for more than 100 years.⁸²

4. Hanford Site

The Hanford Site is an area of approximately 560 square miles and is located in southeastern Washington State.⁸³ The site produced materials for making nuclear weapons and had “several production reactors”⁸⁴ that, like Savannah River National Laboratory, produced plutonium.⁸⁵

The Hanford Site is subject to regulation by CERCLA and is on the National Priorities List.⁸⁶ The shallow-buried TRU waste activity at the site is 60,000 Ci⁸⁷ (in a volume of 75,800 m³),⁸⁸ which is 15 percent of the total radioactivity buried at the six DOE sites. Hanford Site’s TRU waste was disposed in trenches near the Columbia River,⁸⁹ and extensive studies are underway to evaluate alternative remediation solutions. A tripartite plan for dealing with the stored TRU waste was developed by DOE, Washington State, and EPA. In December 2007, EPA and Washington State’s Department of Ecology prepared a white paper proposing that TRU waste disposed in shallow land burial before 1970 and TRU waste stored since then should be processed the same way if the wastes pose similar risks.⁹⁰ In another paper, the Government Accountability Office (GAO) noted that engineered barriers “may not provide adequate long-term protection for human health and the environment.”⁹¹ Washington, EPA, and DOE continue to discuss whether to stabilize the disposed TRU waste in place or to exhume some or all of it for disposal at DOE’s TRU waste disposal facility—WIPP, in southern New Mexico.

81. Institutional control means that the site is under control of DOE or some other federal agency where access is restricted.

82. 40 C.F.R. § 191.14(a) (2006) (“Active institutional controls over disposal sites should be maintained for as long a period of time as is practicable after disposal; however, performance assessments that assess isolation of the wastes from the accessible environment shall not consider any contributions from active institutional controls for more than 100 years after disposal.”).

83. *SUBSURFACE SCIENCE*, *supra* note 38, at 18.

84. *Id.*

85. *See id.*

86. *GAO NUCLEAR WASTE PLANS*, *supra* note 23, at 3.

87. *BURIED TRU WASTE*, *supra* note 3, at 22.

88. *Id.* at 21 tbl.1.

89. *GAO NUCLEAR WASTE PLANS*, *supra* note 23, at 16.

90. EPA & Wash. Dep’t of Ecology, *Considerations for Cleanup of the Hanford 200 Area National Priorities List Site 8* (2007), *available at* <http://yosemite.epa.gov/r10/cleanup.nsf/sites/hanford>.

91. *GAO NUCLEAR WASTE PLANS*, *supra* note 23, at 16.

5. Idaho National Laboratory (INL)

The Idaho National Laboratory (formerly known as Idaho Engineering and Environmental Laboratory, Idaho Engineering Laboratory, and National Reactor Testing Station) is an area of approximately 890 square miles and is located near the upper Snake River plain in Idaho.⁹² Since 1949, researchers at Idaho National Laboratory have built and tested nuclear reactors on site and are known today for their research and development in nuclear energy.⁹³

The Idaho National Laboratory is a CERCLA site⁹⁴ and contains 75 percent of the radioactivity of all the shallow-buried TRU waste at the six DOE sites. DOE estimates a 53 percent decrease in INL's TRU waste radioactivity from 634,000 Ci in 1995 to 297,000 Ci in 2006.⁹⁵ This decrease in radioactivity came about because 63 percent of INL's TRU waste is plutonium-241, a beta emitter with a short 14.4-year half-life.⁹⁶

As part of a lawsuit settlement⁹⁷ over the temporary storage of spent nuclear fuel, a high-level waste, Idaho negotiated an agreement⁹⁸ with DOE to remove TRU waste from INL for deep geologic disposal at WIPP. The agreement states that "DOE shall ship all transuranic waste now located at INL, currently estimated at 65,000 cubic meters in volume, to the Waste Isolation Pilot Plant (WIPP). . . ." ⁹⁹ DOE took the position, however, that the agreement did not apply to previously disposed shallow-buried TRU waste. Idaho sued to force DOE to abide by the state's interpretation of the agreement, and after a series of court actions, the U.S. District Court for the District of Idaho ruled on May 25, 2006, that all buried TRU waste at INL shall be removed "once it is determined if and how it can safely be moved."¹⁰⁰ Two years later DOE appealed that decision to the Ninth Circuit Court of Appeals where it argued that pre-

92. SUBSURFACE SCIENCE, *supra* note 38, at 18.

93. See U.S. Dep't of Energy, Idaho National Laboratory, National Security Nuclear Nonproliferation, <http://www.inl.gov/nationalsecurity/capabilities/nonproliferation/index.shtml> (last visited Apr. 27, 2009).

94. GAO NUCLEAR WASTE PLANS, *supra* note 23, at 3.

95. BURIED TRU WASTE, *supra* note 3, at 22.

96. *Id.* at 11.

97. Swenson, *supra* note 27, at 33-34 ("[I]n 1991 the state of Idaho brought a lawsuit under NEPA to block decisions by DOE to bring 'spent nuclear fuel' ('burned out' from being used in a reactor) temporarily to the INL, pending completion of a permanent repository at Yucca Mountain, Nevada.").

98. Idaho Dep't of Env'tl. Quality, Contamination at INL: Text of the 1995 Settlement Agreement (1995), available at http://www.deq.state.id.us/inl_oversight/contamination/settlement_agreement_entire.cfm.

99. *Id.* at B.1.

100. Public Serv. Co. v. Kempthorne, 2006 U.S. Dist. LEXIS 34584, at *61 (D. Idaho May 25, 2006).

viously disposed shallow-buried TRU waste is not included in the meaning of “all transuranic waste,” because to impose that broad meaning would create a “conflict between the Agreement and an earlier Federal Facilities Agreement and Consent Order,” between Idaho and DOE.¹⁰¹ Nonetheless, the Court ruled in Idaho’s favor on each item.¹⁰² Despite the favorable ruling, DOE and Idaho announced an agreement¹⁰³ on July 1, 2008, to implement a cleanup plan to excavate at least 7,485 m³, or 20 percent, of the 36,800 m³ of shallow-buried TRU waste at INL.¹⁰⁴ A 2007 GAO report noted that the cost of exhuming and transporting all of the 36,800 m³ TRU waste to WIPP would be \$8.2 billion.¹⁰⁵ The agreement to remove the waste designated as targeted waste, based on reviews of records of radioactivity and density, is intended to remove the most hazardous TRU waste and has won the support of EPA as well as former Idaho governors Phil Batt and Cecil Andrus.¹⁰⁶ The remaining waste is slated to be covered by an earthen cap to limit migration to the aquifer below the site. DOE plans to continue to monitor the waste and the aquifer. According to a DOE press release, the latest agreement (in July 2008) fully resolves all issues involved in the litigation between Idaho and DOE.¹⁰⁷ It is important to note that this agreement does not mention the March 2008 court decision. This remediation outcome is unique among DOE sites because it resulted from a negotiated cleanup stemming from the settlement of a lawsuit over high-level nuclear waste.

6. *Los Alamos National Laboratory (LANL)*

Unlike four of these DOE sites, LANL is a RCRA site.¹⁰⁸ It reports a total TRU activity of 21,000 Ci,¹⁰⁹ which is mostly plutonium-239¹¹⁰ with a half-life of 24,100 years¹¹¹ in a volume of 8,620 m³.¹¹² LANL’s TRU waste accounts for about 5.3 percent of the estimated total radioactivity of TRU waste at DOE’s six sites. In accordance with the provisions of the Atomic Energy Act to manage special nuclear material and protect the

101. *United States v. Otter*, 270 Fed.Appx. 568, 569–570 (9th Cir. 2008).

102. *Id.* at 570.

103. See Press Release, U.S. Dep’t of Energy, State, Federal Government Agree on INL Buried Waste Cleanup Plan (July 1, 2008) [hereinafter Press Release], available at <http://www.id.doe.gov/NEWS/PressReleases/PR080701.htm>.

104. See *id.*

105. GAO NUCLEAR WASTE PLANS, *supra* note 23, at 21.

106. Press Release, *supra* note 103.

107. *Id.*

108. GAO NUCLEAR WASTE PLANS, *supra* note 23, at 9.

109. BURIED TRU WASTE, *supra* note 3, at 12.

110. *Id.* at 25.

111. *Id.* at 21.

112. *Id.* at 52.

health of the public,¹¹³ transuranic waste was disposed on site at various DOE facilities, including LANL,¹¹⁴ until DOE ordered the practice discontinued in 1970.¹¹⁵ LANL, however, “continued to bury some TRU waste well into the 1970s.”¹¹⁶ DOE reports that “[w]hile the intent of these burials may have been retrievable storage at that time, most of these wastes are currently believed to be irretrievably buried.”¹¹⁷ DOE has offered no specific justification for its conclusion that these wastes are irretrievably buried and, in a 2005 report on LANL, does not mention the pre-1970, shallow-buried TRU waste.¹¹⁸ So while no final remediation decision has been made with respect to the shallow-buried TRU waste at LANL, the current plan is to leave this TRU waste in place.

C. Summary

Although states have no regulatory authority over these defense wastes, DOE has chosen to manage shallow-buried TRU waste on a site-specific basis, working with federal, state, and local regulatory agencies, as well as other stakeholders, to achieve consensus on remediation plans. Note that DOE had the authority to self-regulate the safe disposal of these radioactive wastes until Congress assigned that responsibility to EPA in 1992, but DOE had recognized the hazard of shallow burial of

113. Atomic Energy Act of 1946, Pub. L. No. 585-724, § 5(a)(2), 60 Stat. 755, 760 (codified as amended at 42 U.S.C. § 2011 (2000)); Atomic Energy Act of 1954, Pub. L. No. 703, §§ 2, 52, 68 Stat. 919, 921, 929–930 (1954) (codified as amended at 42 U.S.C. § 2011 (2000)).

114. BURIED TRU WASTE, *supra* note 3, at 7.

115. AEC Immediate Action Directive, *supra* note 8, at 2.

116. BURIED TRU WASTE, *supra* note 3, at 7.

117. *Id.*

118. U.S. DEP’T OF ENERGY, LOS ALAMOS NATIONAL LABORATORY, END STATE VISION FOR LOS ALAMOS NATIONAL LABORATORY, LA-UR-05-8429, ER2005-0205 (2005) [hereinafter END STATE VISION LANL]. This document never mentions plans for the shallow-buried TRU waste. DOE refers to Technical Area-54’s (TA-54) Material Disposal Area G (MDA G) as “interim storage” for the TRU waste to be sent to WIPP. *Id.* at 4-40. DOE also mentions the legacy TRU waste at TA-54 MDA G that will be cleaned up and sent to WIPP but does not mention the shallow-buried TRU waste in the same area. *Id.* at 4-54. DOE states,

MDA G has undergone intense scrutiny as both a permitted RCRA storage facility and an authorized DOE low-level waste disposal facility. In addition MDA G has undergone intensive investigation as a legacy waste cleanup site. Site characterization to determine the nature and extent of contaminants beneath MDA G was completed in 2005 and an investigation report was submitted to [New Mexico Environment Department] NMED in September 2005.

Id. However, this report dealt only with hazardous contaminants. DOE states, “The term ‘contaminant’ does not include radionuclides or the radioactive portion of mixed wastes.” *Id.* at E-5.

TRU waste and chose to store the wastes beginning in 1970 for deep geologic disposal.

The Savannah River National Laboratory, Oak Ridge National Laboratory, the Hanford Site, and Idaho National Laboratory are subject to CERCLA, while LANL and the Nevada Test Site are subject to RCRA. DOE sites regulated by CERCLA may be subject to agreements that require cleanup of radioactive materials. DOE sites regulated by RCRA, however, are not subject to such agreements because RCRA regulates only hazardous materials. The parties involved at Oak Ridge National Laboratory and the Savannah River National Laboratory have agreed to have DOE manage the TRU waste there in place. All TRU waste at INL, including shallow-buried TRU waste disposed before 1970, were required by a March 2008 court order to be exhumed and removed to deep geologic disposal at WIPP—DOE's TRU waste facility in southern New Mexico. Because of the high cost, DOE and Idaho subsequently agreed to exhume 20 percent of the TRU waste and manage the remaining 29,000 m³ in place. A decision to leave the TRU waste at the Nevada Test Site is anticipated. The Hanford Site is undergoing extensive site investigations and evaluations under a tripartite committee composed of EPA, Washington State's Department of Ecology, and DOE, so no remediation decision has been made. The remaining site, LANL, is examined in more detail in the following section.

III. LOS ALAMOS NATIONAL LABORATORY

The majority of LANL's shallow-buried TRU waste radioactivity is within Technical Area-54 (TA-54), which is located southeast of Los Alamos and adjacent to San Ildefonso Pueblo. This article addresses only the shallow-buried TRU waste in the waste pits located in TA-54's Material Disposal Area G (MDA G) because that site contains 99 percent of the total radioactivity (20,800 Ci) and 55 percent of the total volume (4,790 m³) of TRU waste at LANL.¹¹⁹ DOE reports that the 20,800 Ci inventory at MDA G is mostly plutonium-239 with a half-life of 24,100 years.¹²⁰ As evidence that the majority of this waste is plutonium-239, DOE did not reduce the amount of plutonium-239 estimated to be present in 2006 by radioactive decay,¹²¹ so for the purposes of this paper we assume that all of it is plutonium-239. The long half-life of plutonium-

119. BURIED TRU WASTE, *supra* note 3, at 22 tbl.2 (the report does not provide a map or details on locations of the buried TRU waste and low level waste disposal sites in MDA G).

120. For a description of the waste inventory at LANL, see BURIED TRU WASTE, *supra* note 3, at 12. For a description of the half-life of plutonium-239, see *id.* at 52.

121. See *id.* at 12. One might also expect some plutonium-240 to be present. Because its half-life is 6,540 years, there would only be a reduction of 0.039 percent in radioactivity in

239 is important because it means that 97 percent of LANL's TRU waste will still be present in 1,000 years and 75 percent will still be present in 10,000 years.

DOE reports that there are 20,800 Ci of plutonium-239 in MDA G, while the contact-handled¹²² (CH-TRU) waste stored at LANL and destined for removal to WIPP contains only 11,000 Ci of plutonium-239.¹²³ This means that there is about twice as much plutonium-239 disposed in shallow land burial at MDA G pits now than the total amount slated to be shipped from LANL to WIPP for deep geologic disposal.¹²⁴ Further, DOE reports that the concentration of plutonium-239 at LANL to be disposed at WIPP is 3.9 Ci/m³.¹²⁵ The concentration of plutonium-239 in the MDA G pits at LANL is 4.3 Ci/m³.¹²⁶ However it is important to note that there are other transuranic nuclides present in the waste, which brings the average to more than 25 Ci/m³.¹²⁷

Also, several issues should be considered with respect to any comparisons made between shallow-buried TRU waste and the post-1970 TRU waste regulated by EPA. While the 1985 EPA disposal standards are not retroactively applicable to waste disposed prior to 1970, some of the requirements can be compared. First, it is possible to compare the shallow-buried plutonium-239 to be left at LANL with that going to WIPP because EPA's release limits for containment over a period of 10,000 years are for specific radionuclides.¹²⁸ Releases from LANL's shallow-buried TRU waste could not exceed 2.08 Ci of plutonium-239 over a 10,000-year period if EPA's release limits for plutonium-239 were applied to LANL's shallow-buried TRU waste. Second, DOE did not include human intrusion in its risk analyses for leaving TRU waste under shallow burial, which is an EPA requirement for the stored TRU waste

37 years. Since DOE states that most of the radioactivity is plutonium-239, we have elected to treat all the waste as plutonium-239 for the purpose of analysis.

122. See *id.* at 16 (where contact handled TRU waste has a surface dose rate less than 200 mrem/hour).

123. U.S. DEP'T OF ENERGY, 40 C.F.R. PT. 191, SUBPARTS B AND C COMPLIANCE RECERTIFICATION APPLICATION, ATTACHMENT F: TRANSURANIC WASTE INVENTORY UPDATE REPORT (2004) [hereinafter TRU WASTE INVENTORY]; *Id.* at 59 tbl.DATA-F-35.

124. Calculation by authors where 20,800 Ci / 11,000 Ci = 1.9.

125. TRU WASTE INVENTORY, *supra* note 123, at 69.

126. Calculation by authors where 20,800 Ci / 4,790 m³ = 4.3 Ci/m³.

127. Calculation by authors where (5,800,000 total TRU Ci - 1,000,000 RH-TRU Ci) / (175,600 m³ total volume - 7080 m³ RH TRU volume) = 28 Ci/m³. See BURIED TRU WASTE, *supra* note 3, at 18.

128. Environmental Protection Act, 40 C.F.R. § 191.13 app. A for subpart B at tbl.1 (2006) (where 100 Ci plutonium-239 can be released per million curies of transuranics emplaced).

destined for WIPP.¹²⁹ Earlier analyses by DOE show that human intrusion is the primary risk for leaving the waste in place.¹³⁰ Finally, if the shallow-buried TRU waste in MDA G were to be exhumed and shipped to WIPP, LANL's shallow-buried TRU waste, totaling 20,800 Ci of plutonium-239, would increase the anticipated WIPP plutonium-239 inventory of 560,000 Ci¹³¹ by a mere 3.7 percent.

DOE "believes that the current approach for managing buried TRU-contaminated waste sites on a site-specific basis is appropriate, and DOE will continue to work with regulators and local citizens in reaching consensus plans for each of these sites."¹³² New Mexico, however, does not have legal authority to regulate defense-program TRU waste, nor does any state.

After New Mexico issued an order to investigate and clean up LANL's shallow-buried TRU waste, it was sued by the University of California, which was then manager of LANL.¹³³ The lawsuit was dropped,¹³⁴ and the New Mexico Environment Department, DOE, and the Regents of the University of California reached an agreement on March 1, 2005,¹³⁵ to clean up the *non-radioactive*, toxic waste at LANL through a consent order. The order requires LANL to evaluate the extent of non-radioactive environmental contamination and to take appropriate remedial action to clean up toxic chemical constituents by the end of 2015.¹³⁶ The consent order resulted from negotiations to settle the lawsuit. While the requirements of the consent order apply to the hazardous waste component of mixed waste at LANL, it does not apply to radionuclides or the radioactive portion of the mixed waste,¹³⁷ which arguably pose a greater risk than the hazardous waste. Further, DOE does

129. BURIED TRU WASTE, *supra* note 3, at 16.

130. See U.S. DEP'T OF ENERGY, DOC. NO. DOE/EIS-0026-S-2, 1 WASTE ISOLATION PILOT PLANT DISPOSAL PHASE FINAL SUPPLEMENTAL ENVIRONMENTAL IMPACT STATEMENT 5-169 (1980) [hereinafter WIPP SEIS II], for a description of intrusion at facilities with shallow-buried TRU waste. "For waste in unconsolidated waste forms, evaluated under No Action Alternative 2, long-term and repeated intrusion activities could result in thousands of radiation-related LCFs [latent cancer fatalities] over a 10,000-year evaluation period." *Id.*

131. See TRU WASTE INVENTORY, *supra* note 123, at 59 tbl.Data F-35.

132. BURIED TRU WASTE, *supra* note 3, at 4.

133. Plaintiff's Complaint for Declaratory Relief, Univ. of Cal. Regents v. D'Antonio, No. 6:02-CV-00637-MV-DJS (D.N.M June 3, 2002) (on September 30, 2002, Defendant Maggiore was replaced by D'Antonio).

134. See Notice of Dismissal of Case by Plaintiff without Prejudice, Univ. of Cal. Regents v. D'Antonio, No. 6:02-CV-00637-MV-DJS (D.N.M June 3, 2002).

135. STATE OF NEW MEXICO ENVTL. DEP'T. ET AL., COMPLIANCE ORDER ON CONSENT 1 (2005).

136. *Id.* at 231-33 tbl.XII-1.

137. *Id.* at 10 ("This Consent Order contains no requirements for radionuclides or the radioactive portion of mixed waste. Therefore, any radionuclides found in any media at the

not mention LANL's shallow-buried TRU waste in its End State Vision for LANL.¹³⁸ Finally, there is some public pressure to close Area G's low-level waste disposal operations,¹³⁹ which could limit DOE's ability to make future management decisions about the shallow-buried TRU waste there if additional caps or barriers are installed. The much greater relative hazard from the radiological components of LANL's TRU waste is discussed as follows.

The relative risks of the radiological hazards in LANL's TRU waste are considerably greater than the toxic, non-radiological hazards regulated under RCRA. Three examples, presented below, demonstrate this disparate risk and serve to emphasize the importance of controlling the radiological constituents in mixed waste.

The New Mexico Environmental Evaluation Group (EEG), created in 1978 to conduct an independent evaluation of the public health and environmental impact of the proposed WIPP project, published a report in 1999 concluding that the risks from the radionuclide component of mixed wastes are significantly greater than the risks from its non-radiological, hazardous waste components.¹⁴⁰ Specifically, the report found that "[r]adionuclide annual risks to a resident farmer from average releases to the surface following human intrusion 1,000 years after WIPP closure are one order of magnitude greater than total risks from VOCs [Volatile Organic Compounds]."¹⁴¹ The report also concluded that hazardous metals are a negligible hazard for routine operations, operational accidents, and long-term releases.¹⁴²

A 1997 report by J.W. Buck et al., evaluating the long-term impacts of TRU waste found that if the stored TRU waste were left at LANL rather than being shipped to WIPP, the number of latent cancer fatalities (LCF) at LANL from the radiation after the loss of institutional control would be more than 300 times greater than from the chemical hazards.¹⁴³ The report also found that the probability of a cancer from radiation

Facility [LANL] shall not be subject to this Consent Order or any enforcement action relating to this Consent Order.").

138. See END STATE VISION LANL, *supra* note 118.

139. Northern New Mexico Citizens' Advisory Board Top Three Issues, https://plus44.safe-order.net/nmcb//TOP_ISSUES_08.jpg (last visited May 1, 2009).

140. J. K. CHANNELL & R. H. NEILL, ENVTL. EVALUATION GROUP, EEG-72, A COMPARISON OF THE RISKS FROM HAZARDOUS WASTES AND RADIOACTIVE WASTE PORTIONS OF THE WIPP INVENTORY 33 (July 1999).

141. *Id.* at 28.

142. *Id.* at 33.

143. J.W. BUCK ET AL., ANALYSIS OF THE LONG-TERM IMPACTS OF TRU WASTE REMAINING AT GENERATOR/STORAGE SITES FOR NO ACTION ALTERNATIVE 2, PNNL-11251 UC-600, at 3.36 tbl.3.6, 3.39 tbl.3.8 (1997) [hereinafter BUCK]. Calculation by authors where $300 = 0.08/2.4 \text{ E-}04$.

would be 350 times greater than from the hazardous chemicals.¹⁴⁴ Similarly, J.W. Buck et al. estimated that if all the stored TRU waste were to be left at the generating sites indefinitely,¹⁴⁵ the aggregate radiological impact from seven DOE sites totaled over the 10,000-year evaluation period would be 807 LCFs.¹⁴⁶ The authors estimated that the comparable hazardous chemical carcinogenic impact was 0.002 cancers, which means the radiation source represented a risk 400,000 times greater than the hazardous chemical source.¹⁴⁷ Hence, the consent order addressing non-radiological, toxic materials is inadequate to address the radiological hazards, which arguably pose the greatest risk to human health and the environment. Therefore, this article further examines the 4,790 m³ of shallow-buried TRU waste at MDA G, which contains 99 percent of the radioactivity at LANL.

IV. APPROACH

The comparison of remediation options for shallow-buried TRU waste at LANL is complicated by the fact that there were no published standards for TRU waste at the time they were buried. The EPA disposal standards issued in 1985¹⁴⁸ for the future disposal of TRU waste, however, include containment requirements, individual protection requirements, groundwater protection requirements for groundwater and nearby individuals, as well as assurance requirements for long-term containment.¹⁴⁹ While these requirements do not apply to the shallow-buried TRU waste at LANL disposed before 1970, they help serve as a useful guide for determining a remediation option for the shallow-buried TRU waste. EPA does not approve waste disposal by DOE, they only certify that DOE's application is in compliance with EPA's standards.¹⁵⁰ Several

144. *Id.* at 3.36 tbl.3.6, 3.39 tbl.3.8 (for lifetime probability of LCF from radiation of 4.5 E-05 and for lifetime probability of cancer from hazardous chemicals of 1.3 E-07). Calculation by authors where $350 = 4.5 \text{ E-}05 / 1.3 \text{ E-}07$.

145. *Id.* at v, vi.

146. *Id.* at v. The report identified 7, as opposed to 6, DOE sites in its analyses: Hanford Site, Idaho National Laboratory, Lawrence Livermore National Laboratory, Los Alamos National Laboratory, Oak Ridge National Laboratory, Rocky Flats Environmental Technology Site, and Savannah River Site. *Id.* at iii.

147. BUCK, *supra* note 143, at iii-vi. Calculation by authors where $807 \text{ LCF} / 0.002 \text{ LCF} = 403,500$.

148. Environmental Protection Act, 40 C.F.R. § 191.01 (2006).

149. Wolbarst, *supra* note 10, at 113; 40 C.F.R. § 191.14(a)-(f) (for a description of assurance requirements "[t]o provide the confidence needed for long-term compliance with the requirements of § 191.13").

150. 40 C.F.R. § 191.01 (2006).

of the factors in EPA's protection requirements are discussed more fully below.

A. Containment Requirements¹⁵¹

For the geologic disposal of TRU waste, EPA requires a probabilistic risk assessment to show that there is less than a 1-in-10 probability that no more than 100 Ci of plutonium-239 per million curies of long-lived alpha emitters will be cumulatively released to the environment over a period of 10,000 years.¹⁵² As noted earlier, if this requirement is applied to the shallow-buried TRU waste at LANL, it would limit releases to the environment over 10,000 years to 2 Ci of plutonium-239 out of the 20,800 Ci in shallow land burial. DOE has not published requirements limiting plutonium releases by an amount, or over a given time period for shallow-buried TRU waste.¹⁵³ A New Mexico Environment Department official reports, however, that there have been discussions with DOE to use a 1,000-year control period for the non-radiological chemical waste.¹⁵⁴

B. Individual Protection Requirements

EPA's regulations also specify limits for annual radiation doses to individuals. Calculations are required to show that for a period of 10,000 years the annual committed effective dose for an individual does not exceed 15 millirems from all potential pathways.¹⁵⁵ Similarly, the objective of DOE Order 435.1 is to manage radioactive waste in a "manner that is protective of worker and public health and safety, and the environment"¹⁵⁶ and directs employees and contractors to follow DOE Manual

151. 40 C.F.R. § 191.13 (1993).

152. Environmental Protection Act, 40 C.F.R. § 191 app. A for subpart B at tbl.1 (2006).

153. DOE has not published requirements for shallow-buried TRU waste in the following materials: U.S. DEP'T OF ENERGY, USE OF RISK-BASED END STATES, POLICY DOE P 455.1, (2003); U.S. DEP'T OF ENERGY, GUIDANCE FOR DEVELOPING RISK-BASED SITE-SPECIFIC END STATE VISION (2003); END STATE VISION LANL, *supra* note 118; U.S. DEP'T OF ENERGY, ER 2005-0205, DOE ORDER 450.1, ENVIRONMENTAL PROTECTION PROGRAM (2003).

154. Telephone Interview with David Cobrain, New Mexico Environment Department (July 17, 2007) [hereinafter Cobrain].

155. 40 C.F.R. § 191.15. "Individual protection requirements. (a) Disposal systems for waste and any associated radioactive material shall be designed to provide a reasonable expectation that, for 10,000 years after disposal, undisturbed performance of the disposal system shall not cause the annual committed effective dose, received through all potential pathways from the disposal system, to any member of the public in the accessible environment, to exceed 15 millirems (150 microsieverts)." *Id.*

156. DOE Order 435.1, *supra* note 8, at 1.

435.1-1.¹⁵⁷ DOE Manual 435.1-1 requires that the future disposal of TRU waste follow the requirements of 40 C.F.R. Part 191, the EPA standard, unless it has been exempted.¹⁵⁸ DOE, however, also states that TRU waste that has been disposed before 1970 is not subject to the requirements of DOE Manual 435.1-1 and DOE Order 435.1.¹⁵⁹ DOE has not provided orders for this previously disposed waste.

C. Assurance Requirements¹⁶⁰

Assurance requirements are actions to help ensure the isolation of the waste. Due to the inherent uncertainty in modeling the long-term behavior of TRU waste, EPA requires various actions to increase confidence such waste will remain isolated. Actions intended to provide greater assurance include monitoring, placing markers to identify the waste's location, filing records in libraries, and disallowing credit for institutional control for more than 100 years.¹⁶¹

These EPA requirements for future disposal of either stored or yet-to-be generated TRU waste are different than the factors that DOE, as a self-regulator under the Atomic Energy Act (1954),¹⁶² has identified for remediation of TRU waste that has been disposed in shallow burial. DOE states that its decision to exhume or leave TRU waste in place is based on factors of "technical situation, current and future risks, land-use plans for the facility and nearby area, availability of cost effective methodologies, and other local concerns."¹⁶³ While these factors appear to be reasonable, we are unaware of any published analyses of the consequences should TRU waste fail to meet one of these factors at LANL or any of the other sites, nor are we aware of definitions for any of DOE's factors. Perhaps the most important requirements missing from the DOE list of factors are limits on radioactive releases and specific time periods over which releases must be limited. The lack of standard definitions may lead to different interpretations of each of these factors by DOE and the public. For example, the DOE factor called "future risk" may seem reasonable for a

157. *Id.* at 3, 4, attachment 1.

158. DOE Manual 435.1-1, *supra* note 8, at III-1, III-7, (P) Disposal.

159. *Id.* at III-1 ("Transuranic waste disposed of prior to implementation of the 1970 Atomic Energy Commission Immediate Action Directive regarding retrievable storage of transuranic waste is not subject to the requirements of DOE Order 435.1, *Radioactive Waste Management*, and this Manual.").

160. Environmental Protection Act, 40 C.F.R. § 191.14 (2006).

161. 40 CFR § 191.14(a); See *supra* note 81 for a quote describing institutional control.

162. Atomic Energy Act of 1946, Pub. L. No. 585-724, § 5(a)(2), 60 Stat. 755, 760 (codified as amended at 42 U.S.C. § 2011 (2000)); Atomic Energy Act of 1954, Pub. L. No. 703, §§ 2, 52, 68 Stat. 919, 921, 929-930 (1954) (codified as amended at 42 U.S.C. § 2011 (2000)).

163. BURIED TRU WASTE, *supra* note 3, at 3.

50-year period, but may not be intended to apply for an evaluation period over thousands of years.

The list of factors used by DOE for remediation decisions on shallow-buried waste does not specify health effects, limits on radioactive releases, or the length of time to evaluate the radiological consequences of each option, while the EPA requirements do. Based on our review of the factors and requirements, we identified seven criteria to make comparisons. Some factors, such as technical situation, were addressed as “technical feasibility,” which we define as whether remediation can be accomplished under current technology. Definitions of current and future risks are missing from DOE factors, so we focused on separating “worker safety,” “health effects” to the general public, and “long-term period of concern.” While DOE factors do not mention uncertainties directly, most environmental decisions require consideration of uncertainties, so we included “uncertainties” as a factor. Finally, we revised the DOE factor of “land-use plans” for the facility and nearby area with “long-term, land-use plans.” Rather than attempt to operationalize “local concerns,” we include local issues in “uncertainties” and “health effects.” So while our list is not exhaustive, we chose the following seven criteria to assess the merits of the two remedial actions of exhumation and leave-in place: (1) technical feasibility; (2) worker safety; (3) long-term period of concern; (4) uncertainties; (5) health effects; (6) costs; and (7) long-term land-use plans.

V. COMPARISON OF REMEDIATION OPTIONS

A. Technical Feasibility

We define technical feasibility as whether remediation can be accomplished with current technology. With respect to leaving the waste in place, there is no unique engineering problem with initially stabilizing the waste in place, nor are there technical feasibility problems with periodically restoring and repairing engineered barriers, including ground covers or caps, or with replacing markers after 100 years. J.W. Buck et al., however, assume a catastrophic failure of caps after 500 years.¹⁶⁴ The challenge for the leave-in place option, therefore, will be in recognizing the need to restore and repair engineered caps to insure containment of the plutonium if institutional control is lost.

Similarly, the retrieval of 4,790 m³ of shallow-buried TRU waste is also logistically feasible. There are numerous examples of DOE’s successful removal of shallow-buried TRU waste. DOE began retrieving “a

164. BUCK, *supra* note 143, at 3.25.

small amount” of TRU waste at INL.¹⁶⁵ Also, drums of stored TRU waste at LANL have been retrieved.¹⁶⁶ And DOE plans to remove “a small amount of buried transuranic waste that threatens the Columbia River” at Hanford.¹⁶⁷ Nonetheless, DOE reports that the shallow-buried TRU waste at LANL is “essentially irretrievably buried.”¹⁶⁸ DOE’s assertion that waste buried under less than two meters of ground cover¹⁶⁹ is irretrievable is presented without any justification with regard to worker safety or costs.

Both of DOE’s remediation options appear to be technologically feasible in the short term. The leave-in-place option of monitoring and restoration of engineered barriers, however, does not appear to be feasible in the long term after institutional control is lost or after a catastrophic failure of caps.¹⁷⁰ Therefore, exhumation is preferable for this category.

B. Worker Safety

Worker safety is an important objective identified in DOE Order 435.1.¹⁷¹ Although leaving LANL’s TRU waste in place will not initially entail any exposure to workers, observed increases in the concentrations of radionuclides in the air¹⁷² at MDA G in TA-54 within the first few decades after TRU waste disposal deserve attention. D.H. Kraig and R.C. Conrad report that when workers dug a trench at a depth of one meter to install a water line at LANL they brought contaminated material, includ-

165. GAO NUCLEAR WASTE PLANS, *supra* note 23, at 4.

166. GILBERT MONTROYA, TRANSURANIC WASTE INSPECTABLE PROJECT (TWISP) FINAL REPORT: WASTE RETRIEVAL FROM PADS 1, 2, AND 4 AT TA-54, AREA G, LOS ALAMOS NATIONAL LABORATORY, LA-13980-MS, LA-13980-MS 2 (2002).

167. GAO NUCLEAR WASTE PLANS, *supra* note 23, at 4.

168. BURIED TRU WASTE, *supra* note 3, at 7.

169. For information on depths of shallow-buried waste for LANL, see G. J. GONZALES ET AL., LOS ALAMOS NAT’L LAB., U.S. DEP’T OF ENERGY, PUB. NO. LA-13719-MS, THE RELATIONSHIP BETWEEN POCKET GOPHERS (*Thomomys bottae*) AND THE DISTRIBUTION OF BURIED RADIOACTIVE WASTE AT THE LOS ALAMOS NATIONAL LABORATORY 10–11 (2000) [hereinafter GONZALES ET AL.] (“The below-grade TRU waste trenches are between 61 and 91 m (200 and 300 ft) long, 4 m (13 ft) wide, and 1.8 m (6 ft) deep. All trenches are closed and covered with crushed tuff . . . [T]he depth of the topsoil and tuff originally placed on top of the disposal pits and waste trenches varies but rarely exceeded 1 m deep.”).

170. See BUCK, *supra* note 143, at 3.25.

171. DOE Order 435.1, *supra* note 8, at 1 (“The objective of this Order is to ensure that all Department of Energy (DOE) radioactive waste is managed in a manner that is protective of worker and public health and safety, and the environment.”).

172. D.H. Kraig & R.C. Conrad, *Air Monitoring Data Reveal Previously Unknown Contamination of Radioactive Waste Disposal Area*, 243(2) J. OF RADIOANALYTICAL & NUCLEAR CHEMISTRY 353, 356 (2000) [hereinafter Kraig].

ing plutonium-239, to the surface. They also report that subsequent road construction over the contaminated area resulted in the re-suspension of this material.¹⁷³ Hence, occupational radiation inhalation exposure to workers will probably continue to occur in the future if the waste is left in place. Because these examples of human intrusion and worker exposure occurred during the period of institutional control, the question arises whether a hazard would be recognized after institutional control is lost.

Conversely, exhuming and processing the wastes now could entail potential radiation inhalation exposure to the workers. Therefore, determining a preference between the two remediation options is a matter of balancing the benefits and risks to workers today versus potential risks to populations and workers engaged in repairing caps and covers in the future. Such comparisons are of limited value because occupational exposures are confined to adults who are paid to accept a voluntary risk whereas future generations of all ages will be involuntarily exposed to the risks. Therefore, while exhumation presents a potential occupational radiation risk to workers now, leaving the TRU waste in place presents a latent risk to future workers who may accidentally intrude upon the waste and fail to recognize the hazard. This difficult-to-quantify latent, future risk makes this category difficult to evaluate, so we make no recommendation.

C. Long-term Period of Concern

EPA concluded after a long public process¹⁷⁴ that a 10,000-year time span was an appropriate period of concern over which to predict cumulative releases of long-lived, alpha-emitting radionuclides for permanent geologic disposal of TRU waste.¹⁷⁵ With respect to the shallow-buried plutonium-239 TRU waste at LANL, 97.2 percent, or 20,218 Ci, will still be present in 1,000 years if it is left in place and 15,600 Ci will remain after 10,000 years. Although DOE does not specify a period of time over which releases of TRU radionuclides should be limited from shallow-buried TRU waste, DOE should adopt EPA's 10,000-year period of concern for its evaluation of LANL's shallow-buried TRU waste for consistency.

For additional justification for the longer period of concern, consider the following three examples. First, in 1980 DOE calculated the radiological consequences at Malaga Bend on the Pecos River in New

173. *Id.*

174. Environmental Protection Act, 40 C.F.R. § 191.13 (1993).

175. *Id.*

Mexico of a breach at the WIPP repository containing TRU waste; the maximum doses occurred at 1.2 to 1.4 million years in the future.¹⁷⁶ Although the doses were negligible, DOE elected to analyze this scenario over an extremely long time frame, indicating a recognition that these radioactive wastes will persist in the environment for a long time horizon. Second, the U.S. Nuclear Regulatory Commission (NRC) licensing requirements for land disposal of low-level waste greater than Class C state that concentrations of alpha-emitting radionuclides greater than 100 nano-Curies per gram (nCi/g) are not acceptable for near-surface disposal.¹⁷⁷ The NRC also noted that shallow-buried, low-level wastes with less than 100 nCi/g should have a minimum of five meters of ground cover or have an intruder barrier to protect against human intrusion for at least 500 years.¹⁷⁸ This example is significant because EPA requires greater isolation for TRU waste because it is more hazardous over longer periods of time than Class C low-level waste. Third, a 1995 National Academy of Sciences report determined that limiting releases for 10,000 years may not be adequate for high-level waste and recommended that a longer time period should be evaluated, as much as a million years.¹⁷⁹

These three examples indicate that shallow burial of TRU waste at LANL cannot be relied upon to isolate plutonium-239 from the accessible environment. Even when buried at a depth of 655 meters, EPA requires an analytical period of 10,000 years for TRU waste. Therefore, exhumation is the preferred option under this category.

176. WIPP SEIS II, *supra* note 130, at 5-139.

177. U. S. Nuclear Regulatory Comm'n, 10 C.F.R. § 61.55(a)(3), Licensing Requirements for Land Disposal of Radioactive Waste (Nov. 21, 2001). "(iii) Class C waste is waste that not only must meet more rigorous requirements on waste form to ensure stability but also requires additional measures at the disposal facility to protect against inadvertent intrusion. The physical form and characteristics of Class C waste must meet both the minimum and stability requirements set forth in § 61.56. (iv) Waste that is not generally acceptable for near-surface disposal is waste for which form and disposal methods must be different, and in general more stringent, than those specified for Class C waste. In the absence of specific requirements in this part, such waste must be disposed of in a geologic repository as defined in part 60 or 63 of this chapter unless proposals for disposal of such waste in a disposal site licensed pursuant to this part are approved by the Commission." *Id.*

178. 10 C.F.R. § 61.52(2) (2008) ("Wastes designated as Class C pursuant to § 61.55, must be disposed of so that the top of the waste is a minimum of five meters below the top surface of the cover or must be disposed of with intruder barriers that are designed to protect against an inadvertent intrusion for at least 500 years.").

179. NAT'L RESEARCH COUNCIL, TECHNICAL BASES FOR YUCCA MOUNTAIN STANDARDS 67 (1995).

D. Uncertainties

There are a significant number of ways human intrusion could occur with the leave-in-place option because there are numerous human activities that could disturb waste under shallow ground cover. Well drilling, farming, mineral exploration, recreational activities, and construction are all potential incursions that could release TRU waste material to the environment, potentially contaminating the aquifer. As noted earlier, human intrusion did occur at LANL's MDA G when a water line was installed and as a result of road construction.¹⁸⁰ Note that DOE has excluded human intrusion from its risk analysis of shallow-buried TRU waste.¹⁸¹ Additionally, pocket gophers have dug tunnels in MDA G at the horizon of the buried waste, possibly resulting in the detection of radioactivity in animal tissues and local biota, though there is some disagreement as to whether or not gophers are responsible for the "upward transport of radionuclides."¹⁸²

The future size of the population at risk is also relevant for the leave-in-place option. While we have no way of knowing the future population size, a population increase of about a one-half percent per year would increase the total population by a factor of 5 in 300 years, thereby increasing the number of people potentially exposed to radiation.

For deep geologic disposal of TRU waste at WIPP, EPA does not permit DOE to take credit in their performance assessments for the assumption that institutional control will prevent radioactive releases beyond 100 years.¹⁸³ Hence, analyses of long-term releases from shallow-buried TRU waste at LANL should also not permit credit for institutional controls preventing releases beyond 100 years of institutional control.

In its justification for WIPP, DOE stated that TRU waste in surface storage facilities or shallow burial would be "easily accessible" in the event of loss of institutional control.¹⁸⁴ Beyond 100 years, when government control to limit access cannot be assumed, EPA requires passive institutional control, including markers and public documents warning

180. Kraig, *supra* note 172, at 353, 356.

181. BURIED TRU WASTE, *supra* note 3, at 16.

182. GONZALES ET AL., *supra* note 169, at 1; *but see* R.L. Budd et al., *The Uptake and Distribution of Buried Radionuclides by Pocket Gophers*, A39(3) J. OF ENVTL. SCI. & HEALTH 611, 611 (2004) ("Concentrations of ²⁴¹Am, ²³⁸Pu, ²³⁹Pu, and ³H in some gophers, soil, and vegetation were higher than at reference sites; however, only ³H in gopher carcasses at only one of five sites within MDA G was higher than a conservative ecological screening level.").

183. 40 C.F.R. § 191.14(a).

184. WIPP SEIS II, *supra* note 130, at 5-169.

of hazards.¹⁸⁵ We are unaware of any publicly available published reports by DOE explaining a system for passive control of TRU waste at LANL. We understand, however, that the issue will be addressed in a future report.¹⁸⁶

It is also difficult to determine what future societies will deem to be an acceptable risk from involuntary radiation exposure. For example, in 1957 the annual allowable exposure from atmospheric weapons testing at the Nevada Test Site to people living off-site was 3.9 Roentgen (R) per test series.¹⁸⁷ In 2008, EPA issued a final rule for the high-level waste repository at Yucca Mountain, Nevada, for an allowable committed effective dose equivalent of 15 millirem per year (0.015 rem/year) for a period up to 10,000 years and 100 millirem per year (0.1 rem/year) from 10,000 years through the period of geologic stability.¹⁸⁸ Units of rem and Roentgen are not equal,¹⁸⁹ but are reasonably comparable to show the dramatic reduction in allowable exposure over a 50-year period. Conversely, the exhumation option with burial at WIPP has relatively few inherent uncertainties, the principal one being the risk of future drilling into the TRU waste at a depth of 655 meters.

We recognize there are uncertainties in the estimates of quantities of shallow-buried TRU waste, but it is also difficult to estimate the amount of existing stored TRU waste and the amount expected to be generated by future operations. For example, in 1996 DOE estimated that LANL had 76,900 Ci of plutonium-239 *existing* in the stored TRU waste¹⁹⁰ for disposal at WIPP. The 2004 estimate in the Compliance Recertification Application for the total amount to be shipped from LANL is only 11,000 Ci,¹⁹¹ which is a seven-fold reduction in DOE's estimation. In another case, the 1996 estimated total of plutonium-239 for WIPP decreased 29 percent to 560,000 Ci in the 2004 Compliance Recertification Applica-

185. 40 C.F.R. § 191.14(c).

186. Cobrain, *supra* note 154.

187. U.S. ATOMIC ENERGY COMM'N, ATOMIC TESTS IN NEVADA 28 (1957).

188. Public Health and Environmental Radiation Protection Standards for Yucca Mountain, NV, 73 Fed. Reg. 61,256, 61,287–61,288 (Oct. 15, 2008) (to be codified at 40 C.F.R. pt. 197).

189. THE HEALTH PHYSICS AND RADIOLOGICAL HEALTH HANDBOOK 688 (Bernard Shleien ed., rev. ed. 1992) [hereinafter RAD HANDBOOK]; P. AARNE VESILIND ET AL., ENVIRONMENTAL POLLUTION CONTROL 208 (3d ed. 1990). A Roentgen is a measure of radiation exposure from the absorption of 87.7 ergs of ionizing radiation in a gram of air. A "Rem" stands for Roentgen equivalent man. *Id.*

190. U.S. DEP'T OF ENERGY, DOE/CAO-95-1121, TRANSURANIC WASTE BASELINE INVENTORY REPORT (REVISION 3) C-9 (1996).

191. TRU WASTE INVENTORY, *supra* note 123, at 59 tbl.Data F-35 (Row ²³⁹Pu, column LA).

tion to EPA.¹⁹² It is unknown¹⁹³ whether any alpha-emitting, low-level wastes are commingled with the material in the TA-54 MDA G pits containing plutonium-239.¹⁹⁴ If the wastes are commingled, exhumation would pose a major challenge given current technologies.

While exhumation now presents a potential occupational radiation risk to workers, leaving the TRU waste in place presents a latent inhalation risk to future workers who may fail to recognize the hazard and accidentally intrude upon the waste. This difficult-to-quantify latent future risk makes this category difficult to evaluate. Similarly, uncertainties in predicting the behavior of TRU waste under shallow ground cover are considerably greater than for TRU waste buried at a depth of 655 meters. Therefore, to limit uncertainties, exhumation and burial at WIPP is the preferred remediation option for this category.

E. Health Effects

Perhaps the most compelling reason to relocate this waste to a safer, deeper location was provided by DOE in its 1981 justification to place stored TRU waste in deep geologic formations at WIPP. DOE said it was “unacceptable”¹⁹⁵ to leave the stored TRU waste in shallow burial trenches and surface storage facilities because intruders “could receive substantial radiation doses” and that this situation “would persist in the surrounding environments at the treatment sites exposing on-site and off-site populations to chronic health impacts.”¹⁹⁶

DOE’s 1997 justification for WIPP analyzed the consequences of leaving all the TRU waste at the generating sites indefinitely and not building WIPP.¹⁹⁷ In that analysis, DOE assumed four feet of ground cover, similar to the depth of shallow-buried TRU waste at LANL; that institutional control would be lost in 100 years;¹⁹⁸ that the carbon-steel drums containing the TRU waste would degrade in 100 years;¹⁹⁹ and that any concrete pad or barrier would “catastrophically fail” in 500 years.²⁰⁰ DOE reported that subsequent inadvertent human intrusion into this

192. U.S. DEP’T OF ENERGY, DOE/CAO-95-1121, TRANSURANIC WASTE BASELINE INVENTORY REPORT (REV 3) C-9 (June 1996); *see also* TRU WASTE INVENTORY, *supra* note 123, at 59 tbl.Data F-35.

193. Cobrain, *supra* note 154.

194. *Id.*

195. Waste Isolation Pilot Plant (WIPP), Record of Decision, 46 Fed. Reg. 9,162, 9,163 (Jan. 28, 1981).

196. WIPP SEIS II, *supra* note 130, at 5-169.

197. 2 *id.* (describing the No Action Alternatives).

198. 2 *id.* at I-2.

199. *Id.* at I-17.

200. BUCK, *supra* note 143, at 3.25.

waste in surface and near-surface facilities could include basement or building excavation, road building, pipeline or utility emplacement, scavenging, or casual intrusion.²⁰¹ DOE estimated that after institutional control was lost, a farming family of four—two adults and two children, living in the vicinity and consuming food grown during the first year of intrusion would have a probability of 1.0 of a latent cancer fatality (i.e., a certainty of a cancer fatality).²⁰² DOE calculated that consuming contaminated crops, inhaling re-suspended contamination, external radiation, and inadvertent ingestion of contaminated soil would deliver a radiation dose of 2,400 rem, primarily from plutonium-239 and americium-241.²⁰³ DOE further stated that TRU waste stored on the surface in unconsolidated waste form “could result in thousands of radiation-related LCFs [Latent Cancer Fatalities] over a 10,000-year evaluation period,” from long-term and repeated human intrusion activities.²⁰⁴ Although such calculations are of limited value since we do not know dietary habits or the state of medical practice in the far distant future, it nonetheless demonstrates that DOE is aware of the risks of shallow-buried TRU waste and even used those risks as a primary justification for the construction of WIPP.

For waste under two meters of ground cover, the distinction between whether human intrusion or naturally occurring soil erosion returns these materials to the biosphere in the long-term future is irrelevant, as the following examples indicate.

TRU waste disposed at the Subsurface Disposal Area at INL in the 1960s were covered with about a meter of soil.²⁰⁵ “Additional overburden was added over time to repair subsidence and promote surface drainage. The estimated overburden thickness in Pit 4 and Pit 6 ranges from 1.2 m to 2.1 m (4 to 7 feet).”²⁰⁶ A 1991 review noted that several incidents of flooding at the Subsurface Disposal Area burial grounds prompted the installation of drainage canals, culverts, and sump pumps, as well as an effort to raise the soil level above the pits.²⁰⁷ Despite these efforts to engineer solutions, flooding still occurred during institutional control. This

201. WIPP SEIS II, *supra* note 130, at 5-169.

202. 2 *id.* at I-31, I-32.

203. BUCK, *supra* note 143, at 2.6 tbl.2.2.

204. WIPP SEIS II, *supra* note 130, at 5-169.

205. U.S. DEP'T OF ENERGY, DOE/NE-ID-11223, ENGINEERING EVALUATION/COST ANALYSIS FOR THE ACCELERATED RETRIEVAL PROJECT II 6 (Mar. 2005) [hereinafter COST ANALYSIS].

206. *Id.*

207. D.A. ARRENHOLZ & J.L. KNIGHT, IDAHO NAT'L ENG'G LAB., WTD-91-027, HISTORICAL REPORT OF TRANSURANIC WASTE PITS AND TRENCHES AT THE SUBSURFACE DISPOSAL AREA OF THE RADIOACTIVE WASTE MANAGEMENT COMPLEX AT THE INEL 4 (1991) [hereinafter ARRENHOLZ & KNIGHT].

example illustrates the impracticality of leaving shallow-buried TRU waste at LANL and being dependent on some form of institutional control over thousands of years.

DOE evaluation of the radiological consequences of naturally occurring disruptive events was based on a 1997 analysis by J.W. Buck et al. that estimated that if the waste was left on the surface at INL the total erosion of ground cover would be 0.485 m (1.59 feet) over a period of 10,000 years.²⁰⁸ That estimate understates the actual observed removal of ground cover over a period of just a few decades and undermines DOE's estimate that less than two feet of ground cover would erode from naturally occurring disruptive events at INL over 10,000 years.

DOE stated in 2000 that the 1997 estimates of 13 cancer fatalities from the long-term, 10,000-year consequences of leaving TRU waste in shallow pits at INL and LANL were too high, assuming that intrusion into the burial grounds did not occur.²⁰⁹ But EPA's standards for deep geologic burial require DOE to address the likelihood of these unwanted radioactive residuals returning to the biosphere through either naturally occurring disruptive events or by inadvertent human intrusion. Therefore, it is vital for DOE to include human intrusion in analyzing the consequences of TRU waste returning to the biosphere from shallow burial trenches.

As noted earlier, for waste under less than two meters of ground cover, there is no substantive difference between these materials returning to the biosphere by either naturally occurring processes or man-made intrusions over a 10,000-year span. However, for WIPP, DOE's analyses show that human intrusion scenarios result in the greatest exposure²¹⁰ because the probability is extremely low that a naturally occurring disruptive event would return to the biosphere any waste buried 655 meters underground.²¹¹

Given this analysis, we believe future generations in northern New Mexico should not be exposed to a radiation risk that is not accepted for TRU waste disposed in southern New Mexico. Accepting a greater health risk over a 10,000-year period for waste buried under shallow ground cover than for waste buried 655 meters underground—on the sole basis that EPA's regulations are not retroactively applicable to waste buried 15 years earlier—ignores potential consequences to public health. Hence, the argument that DOE should exhume these materials

208. BUCK, *supra* note 143, at 3.33.

209. BURIED TRU WASTE, *supra* note 3, at 16.

210. 2 WIPP SEIS II, *supra* note 130, at H-56 through H-59.

211. WIPP SEIS II, *supra* note 130, at 5-169.

for deep geologic disposal due to their long-term radiological risk is an argument for consistency and parity, not a legal one.

EPA certified the DOE Compliance Certification Application for WIPP on the basis that there are no predicted health effects from the disposal of TRU waste at a depth of 655 meters. Hence, we do not expect a 3.7 percent increase in WIPP's plutonium-239 inventory from the exhumed shallow-buried TRU waste at LANL to have any influence on predicted health effects from WIPP. Given all of these reasons, exhumation is the preferred remediation option for the health effects category.

F. Costs

The GAO has reported that DOE estimated that adding a "surface cap" at LANL for "arid conditions and institutional controls" would cost \$113.9 million.²¹² However, the task of estimating long-term costs of *in situ* management if the TRU waste is left in place becomes much more difficult. For *in situ* management to work, future generations living near Los Alamos would have to recognize that a TRU-waste hazard exists. This would require a program of continuous monitoring and remediation of the ground cover and cap over thousands of years. While it is possible to estimate the costs of placing a concrete cap over the contaminated area, J.W. Buck et al. assume that this type of cap will "fail catastrophically" after 500 years.²¹³ How often it will be replaced after the loss of institutional control over the 10,000-year period of concern is not known. Also, the calculated certainty of a fatal cancer in the course of a year of exposure to a farming family of four in the area over 10,000 years needs to be publicly aired and valued. Because of all these uncertainties over a 10,000-year period, it is not possible to undertake a meaningful cost analysis for *in situ* management because the range of values for the majority of long-term variables is unknown.

We can, however, provide a simple cost estimate for exhuming the TRU waste from LANL by looking at a comparable project at INL that exhumed buried TRU waste from under two meters of ground cover.²¹⁴ DOE identified the shallow-buried TRU waste in INL's Pit 4 and Pit 6 for exhumation at the Subsurface Disposal Area and estimated that there are about 21,000 drum equivalents.²¹⁵ At 0.208 m³/drum, the volume of TRU waste would be approximately 4,400 m³ of shallow-buried TRU waste. In 2005, DOE estimated the total cost of exhuming the shallow-buried TRU waste at INL for disposal at WIPP would be \$181.5 mil-

212. GAO NUCLEAR WASTE PLANS, *supra* note 23, at 20.

213. BUCK, *supra* note 143, at 3.25.

214. See COST ANALYSIS, *supra* note 205.

215. *Id.* at 7.

lion.²¹⁶ Since the volume of LANL's shallow-buried TRU waste is 4,790 m³, the estimate for LANL should be about the same dollar amount. Though the cost is substantial, the total cost for cleaning up radioactive environmental contamination at all of DOE's generating sites has been estimated to be approximately \$147.3 billion.²¹⁷

While we present a simple cost estimate for the exhumation option, we are not able to provide a meaningful long-term cost comparison with the leave-in-place option due to the uncertainties to estimate long-term costs. This comparison, however, raises a much more difficult question: What will make future generations better off in the long term? Selecting the option of in-place management for LANL's TRU waste today may mean lower government expenditures and debt for near-term generations, but may adversely impact future generations in the long term.

G. Long-term Land-Use Plans

We are unaware of any DOE publication stating requirements for long-term stewardship of shallow-buried TRU waste to prevent radioactive releases to the environment (such as caps, restoration of ground cover, or monitoring), or any publication evaluating the consequences of such releases after the loss of institutional control. DOE does not mention TRU waste in its End State Vision report for LANL, but should, considering the length of time that plutonium-239 will persist in the environment and potentially affect land use in the future.

For TRU waste buried beneath 655 meters, the probability of human intrusion returning these materials to the biosphere is extremely unlikely. Simply stated, long-term land use by future generations is much less of a concern if the wastes are located in a deep geologic formation. Even so, EPA requires DOE to warn of the long-term dangers at WIPP by including markers and records in libraries.²¹⁸ Given the low probability of human intrusion at WIPP, exhumation of LANL's shallow-buried TRU waste appears to be the preferred remediation option for this category.

H. Summary

With limited information, most of the comparisons we have evaluated provide support for exhuming the shallow-buried TRU waste at

216. *Id.* at 18.

217. U.S. DEP'T OF ENERGY, OFFICE OF ENVTL. MGMT., DOE/EM-0362, ACCELERATING CLEANUP PATHS TO CLOSURE ES-5 (June 1998).

218. 40 C.F.R. § 191.14(c).

LANL and disposal at WIPP. Table 1, below, provides a summary of our comparisons and recommendations for each option.

Table 1. *In Situ* vs. Exhumation: A Comparison of Remediation Options

Category	<i>In situ</i> (or in-place) Option	Exhumation Option	Recommendation
Technical feasibility.	Long-term challenge.	INL is doing this already.	Exhumation
Worker safety.	Lower risks for present workers.	WIPP has an excellent safety record.	Not clear. <i>In situ</i> preferable in the short term, but this is less clear for the long term given that there is a more permanent solution available at WIPP.
Long-term period of concern.	At 1,000, years 97.2 percent of plutonium-239 will still be present.	10,000 years	Exhumation
Uncertainties	Many	Fewer	Exhumation
Health Effects.	Public and environmental risks.	Deep geological disposal has lower risk.	Exhumation
Costs	Not available for either short term or long term.	\$182 million estimate.	Not clear. Short term <i>in situ</i> stabilization appears to be preferable, but in the long term exhumation could ultimately be more cost-effective.
Long-term, land-use plans.	Limits options for land use.	More options for land use.	Exhumation

VI. DISCUSSION

An analysis of the remediation options for shallow-buried TRU waste at LANL shows that the majority of evidence supports exhumation and deep geologic disposal. This finding differs from decisions made or expected to be made at Savannah River National Laboratory, Oak Ridge National Laboratory, and the Nevada Test Site, where DOE

has negotiated with regulators and stakeholders, reaching a consensus to stabilize the shallow-buried TRU waste in place. The purpose of this section is to discuss our analysis of LANL in relation to other federal decisions on the management of TRU waste, given that DOE has the authority and responsibility to continue to manage TRU waste disposed before 1970, whereas EPA regulations, issued in 1985, apply to the future safe disposal of TRU waste.

LANL has more TRU waste radioactivity than Oak Ridge National Laboratory, Nevada Test Site, or the Savannah River National Laboratory. Savannah River National Laboratory contains plutonium-241, a beta emitter with a 14.4 year half-life that decays to 0.7 percent of its original activity in 100 years. Participants in the decision-making process at the Savannah River National Laboratory agreed that the risks to workers from the exhumation of the waste were greater than the risks of leaving it in place. Waste at the Savannah River National Laboratory has shorter half-lives (see Appendix), as indicated by the decrease in the TRU activity from 21,900 Ci to 18,500 Ci within just a few years. The Oak Ridge National Laboratory and the Nevada Test Site have trivial TRU activity levels in comparison to LANL. Therefore, all three sites present radically different situations than the one at LANL, which has 20,800 Ci of radioactivity, most of which has a half-life of 24,100 years.

While both LANL²¹⁹ and INL²²⁰ have TRU waste buried under approximately two meters of ground cover, DOE will exhume about 20 percent of the 36,800 m³ at INL for deep geologic burial at WIPP and stabilize the remainder in place but thus far plans to leave a similar amount of shallow-buried TRU waste in place at LANL. Although the courts held that all the shallow-buried TRU waste at INL should be exhumed, Idaho, DOE, and EPA agreed to this arrangement due to the estimated costs of over \$8 billion to remove all the shallow-buried TRU waste. DOE also plans *in situ* management for the buried-TRU waste at LANL, but those plans have not yet been finalized.²²¹ New Mexico was in a different position than Idaho; it was sued by the management of LANL when it tried to issue an order for cleanup. Neither case provides evidence of successful stakeholder involvement within the decision-making process, given that both went to court to work out a solution. Both cases are examples of non-cooperative, rather than cooperative solutions.

As an alternative to DOE's identified options of leaving the TRU waste in place or exhuming it for deep geological burial, a 2005 National

219. GONZALES ET AL., *supra* note 169, at 10, 11 (noting that TRU waste at LANL is buried under less than two meters of ground cover at MDA G).

220. ARRENHOLZ & KNIGHT, *supra* note 207, at 6, 36.

221. BURIED TRU WASTE, *supra* note 3, at 12.

Academy of Sciences report, discussing shallow-buried TRU waste emplaced in a manner that does not facilitate retrieval, suggested investigating risk-based analyses that would compare the benefits and risks of different actions by means of a formal, well-structured, decision-making process conducted by an independent entity.²²² However, the shallow-buried TRU waste at LANL does not appear to be a good candidate for such alternative consideration to exhumation because it was emplaced in a manner that facilitates removal and there would be a substantial reduction in long-term risk by removing approximately 335 kilograms²²³ (or 738 pounds) of plutonium-239 from surface disposal.

Interestingly, the 1985 EPA standards for TRU waste disposal contain a mechanism for DOE to request alternative disposal methods²²⁴ to deep geologic disposal. According to EPA,²²⁵ DOE has not pursued that option at LANL. Another National Academy of Sciences committee investigated the management option of leaving radioactive wastes in place as an alternative to deep geologic disposal.²²⁶ It suggested cocooning radioactive sources by covering them with a large structure with a 75-year design life.²²⁷ However, this approach appears to be inadequate for the situation at LANL, if credit for the prevention of intrusion by institutional control cannot be assumed beyond 100 years, let alone thousands of years. The use of markers to delineate the burial grounds to deter human intrusion is prudent and reasonable, but there are a number of observed failures of such markers. The locations of the shallow-buried radioactive wastes at INL are not accurately known because pit and trench boundary markers have been moved.²²⁸ Modeling has been suggested as a way to ascertain the risks and to provide information to future site managers to help ensure that known features and anticipated

222. NAT'L RESEARCH COUNCIL, RISK AND DECISIONS ABOUT DISPOSITION OF TRANSURANIC AND HIGH-LEVEL RADIOACTIVE WASTE, COMMITTEE ON RISK-BASED APPROACHES FOR DISPOSITION OF TRANSURANIC AND HIGH-LEVEL RADIOACTIVE WASTE 3-7 (2005).

223. RAD HANDBOOK, *supra* note 189, at 265 (noting that the value for specific activity of plutonium-239 (Pu-239) is 2.3×10^{10} TBq/g or 0.062 Ci/g). The authors calculate kilograms of Pu-239 by dividing its total activity in MDA G (20,800 Ci) by its specific activity (0.062 Ci/g). This equals 334,572 g, or 335 kg. To convert kilograms to pounds, multiply 335 kg by 2.205, yielding 738 pounds.

224. 40 C.F.R. § 191.16.

225. Telephone Interview with Ray Clark, U.S. Env'tl. Protection Agency (Mar. 11, 2008).

226. NAT'L RESEARCH COUNCIL, IMPROVING THE CHARACTERIZATION AND TREATMENT OF RADIOACTIVE WASTES FOR THE DEPARTMENT OF ENERGY'S ACCELERATED SITE CLEANUP PROGRAM 44 (2005) [hereinafter IMPROVING CHARACTERIZATION].

227. *Id.*

228. ARRENHOLZ & KNIGHT, *supra* note 207, at 8.

processes at a site are not lost.²²⁹ Synthetic caps and liners were identified as containment mechanisms, but questions remain regarding their ability to contain radioactive wastes for hundreds of years.²³⁰ Again, these alternatives appear to be of little value over a period of thousands of years, especially if a site is decommissioned and institutional control is lost.

VII. SUMMARY AND RECOMMENDATIONS

We recommend that DOE exhume 4,790 m³ of TRU waste, containing approximately 20,800 Ci of plutonium-239, that are covered with less than two meters of ground cover at LANL's MDA G in TA-54 and dispose of this waste 655 meters underground at the WIPP repository in southern New Mexico. We base this recommendation on the following points:

- In 1970, AEC (now DOE) recognized that the long-term hazards of shallow-buried TRU waste were much greater than previously believed, ordered the practice to be discontinued immediately, and began storing TRU waste for eventual deep geologic disposal at WIPP. DOE was convinced that shallow burial posed unacceptable long-term risks to people.
- Although DOE's shallow disposal of TRU waste before 1970 was legal, EPA's subsequent standards, enacted in 1985 and re-promulgated in 1993, require DOE to demonstrate that future disposal of defense-program TRU waste in a deep geologic repository can limit releases of radioactivity to the environment over 10,000 years because of their extreme hazard. Hence, exhuming LANL's shallow-buried TRU waste for deep geologic disposal is an argument for consistency and parity, not a legal one.
- It is inconsistent for DOE to leave 20,800 Ci of plutonium-239, in shallow land burial at LANL while shipping stored TRU waste, containing 11,000 Ci of plutonium-239, to WIPP for deep geologic disposal. The long-term radiological risk from TRU waste should not be greater for future generations in northern New Mexico than in southern New Mexico. The long-term radiological risks of leaving TRU waste in place at LANL are considerably more hazardous than the non-radiological Volatile Organic Chemical (VOC) hazards of the waste, which is regulated under RCRA. Hence, *in situ* stabilization plans based on RCRA hazards are inadequate

229. IMPROVING CHARACTERIZATION, *supra* note 226, at 54.

230. *Id.* at 52–53.

to protect the public from the most significant risks posed by the TRU waste's long-term radiological hazards.

- DOE and the Idaho National Laboratory have agreed to exhume the most hazardous TRU waste at INL for shipment to WIPP in New Mexico. Therefore, New Mexico should receive similar protection for its citizens. While not legally enforceable, this argument is based on consistency and parity.
- Finally, because the United States has been the beneficiary of a strong nuclear deterrent program, it has the responsibility as a nation to deal with its nuclear waste products and should not pass this burden on to future generations.

Given that DOE said that it would work with “regulators and local citizens” to obtain consensus on shallow-buried TRU waste issues, we recommend that elected and appointed officials from New Mexico request that these wastes, buried near the surface at LANL, be exhumed and sent to WIPP.

If DOE elects to leave the waste in shallow land burial, it should justify its decision by publishing: (1) an analysis of the risks and costs of in-place stabilization versus exhumation, repackaging, waste characterization, transportation, and disposal at WIPP; (2) an analysis of the long-term radiological consequences of leaving the waste in place over a 10,000-year period, including human intrusion; and (3) plans for long-term stewardship of LANL's shallow-buried TRU waste, including monitoring and restoration of ground cover, and the placement of markers due to the uncertainties associated with long-term institutional control.

APPENDIX

SHALLOW-BURIED TRU WASTE AT DOE SITES²³¹

Facility	Volume (m ³)	TRU Activity (Ci)	Decay-Corrected TRU Activity (Ci) to 2006	Decision
Savannah River National Laboratory	4,530	21,900	18,500	<i>In situ</i> stabilization with an earthen cap. ²³²
Oak Ridge National Laboratory (ORNL)	570	6	6	<i>In situ</i> stabilization with an earthen cap. ²³³
Nevada Test Site (NTS)	21	229	152	<i>In situ</i> stabilization has been recommended; ²³⁴ a decision is forthcoming.
Hanford Site	75,800	67,800	60,000	No decision yet. DOE is investigating a preferred solution. ²³⁵
Idaho National Laboratory (INL)	36,800	634,000	297,000	Both DOE and Idaho have agreed to exhume 7,485 m ³ of TRU waste for shipment to WIPP. DOE will cap the remainder of shallow-buried waste in place. ²³⁶
Los Alamos National Laboratory (LANL)	8,620	21,000	21,000	No decision yet. DOE plans to leave the waste in place. ²³⁷
TOTAL	126,000	745,000	397,000	

231. BURIED TRU WASTE, *supra* note 3, at 21 tbl.1 (summarizing buried TRU waste within the DOE complex).

232. *Id.*

233. GAO NUCLEAR WASTE PLANS, *supra* note 23, at 4.

234. SPECIAL ANALYSIS NTS, *supra* note 71, at 98 (“[T]here is a reasonable expectation that the TRU waste disposed in T04C with implementation of the planned institutional controls meets the requirements of DOE Manual 435.1-1.”).

235. GAO NUCLEAR WASTE PLANS, *supra* note 23, at 3.

236. Press Release, *supra* note 103.

237. GAO NUCLEAR WASTE PLANS, *supra* note 23, at 3–5.

