

3. WASTE AREA GROUP 7 DESCRIPTION AND BACKGROUND

The RWMC, located in the southwestern quadrant of the INEEL, encompasses a total of 72 ha (177 acres) and is divided into three separate areas by function: the SDA, the TSA, and the administration and operations area. The original landfill, established in 1952, was called the NRTS Burial Ground. Now part of the SDA, the original landfill covered 5.2 ha (13 acres) and was used for shallow land disposal of solid radioactive waste. In 1958, the disposal area was expanded to 35.6 ha (88 acres). Relocating the security fence in 1988 to outside the dike surrounding the disposal area established the SDA's current size as 39 ha (97 acres). The TSA was added to the RWMC in 1970. Located adjacent to the east side of the SDA, the TSA encompasses 23 ha (58 acres) and is used to store, prepare, and ship retrievable TRU waste to the Waste Isolation Pilot Plant (WIPP) southeast of Carlsbad, New Mexico. The 9-ha (22-acre) administration and operations area at the RWMC includes administrative offices, maintenance buildings, equipment storage, and miscellaneous support facilities. A detailed map of the physical layout of all RWMC disposal locations and facilities is provided in Figure 3-1. Facilities storing radioactive and hazardous waste also are identified in the figure (see Section 3.1.1).

Section 3 provides description and background of the RWMC specific to the OU 7-13/14 comprehensive RI/FS:

- Section 3.1—The operational background of the RWMC is presented, beginning with an analysis of collocated facilities and followed by descriptions of disposal practices at the RWMC since 1952, past retrieval efforts, surface cover maintenance, and subsidence history.
- Section 3.2—The CERCLA framework specific to the RWMC is defined and a summary of the WAG 7 OUs is provided.
- Section 3.3—The process followed to develop the source term inventory from existing disposal records is outlined.
- Section 3.4—The contaminant screening process used for the baseline risk assessment is summarized.

In Sections 3.5 through 3.9, results of several recently completed or ongoing investigations are discussed that are relevant to the OU 7-13/14 comprehensive RI/FS decision making, and future remedial design/remedial action (RD/RA) for the SDA. Some of these investigations are not yet documented in citable sources. Others are discussed in detail in published reports, but have not been summarized elsewhere in this ABRA. Therefore, these additional activities are summarized here for completeness.

- Section 3.5—Past geophysical investigations completed at the SDA since 1989 are summarized.
- Section 3.6—A summary of historical soil studies between 1959 and 1970 is provided.
- Section 3.7—The SDA probing project and ongoing data collection process is described.
- Section 3.8—Results are presented of several actinide retardation studies based on RWMC-specific soil.

Legend

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| WMF-601 | Radiation Control Field Office |
| WMF-602 | RWMC Highbay |
| WMF-603 | RWMC Pumphouse |
| WMF-604 | Change House and Lunchroom |
| WMF-609 | Heavy Equipment Storage Shed |
| WMF-610 | Stored Waste Examination Pilot Plan (SWEPP) |
| WMF-611 | Operations Office |
| WMF-613 | Office Bldg and Operational Support Facility |
| WMF-614 | Propane Vaporizer Housing |
| WMF-615 | SWEPP Drum Venting System Bldg |
| WMF-617 | SWEPP Maintenance Facility |
| WMF-618 | TRUPACT-II Loading Facility |
| WMF619 | Communications Bldg, Dial Rm |
| WMF-620 | Work Control Center Facility (Operations) |
| WMF-621 | Work Control Center Support Facility (Operations) |
| WMF-622 | Office Annex |
| WMF-624 | Fire Riser Enclosure |
| WMF-627 | Propane Pump Enclosure |
| WMF-628 | Type II Storage Module No. 1 |
| WMF-629 | Type II Storage Module No. 2 |
| WMF-630 | Type II Storage Module No. 3 |
| WMF-631 | Type II Storage Module No. 4 |
| WMF-632 | Type II Storage Module No. 5 |
| WMF-633 | Type II Storage Module No. 6 |
| WMF-634 | Type II Storage Module No. 7 |
| WMF-635 | Type I Storage Module |
| WMF-636 | Transuranic Storage Area Retrieval Enclosure |
| WMF-637 | Operations Control Bldg and Security Office |
| WMF-639 | Firewater Pumphouse No. 2 |
| WMF-641 | Vapor Vacuum Extraction Monitoring Well No. D02 |
| WMF-642 | Vapor Vacuum Extraction Monitoring Well No. 880/1D |
| WMF-643 | Vapor Vacuum Extraction Monitoring Well No. 880/2D |
| WMF-645 | Construction Manager Support Trailer |
| WMF-646 | Field Support Trailer |
| WMF-648 | Intermediate-Level Transuranic Storage Facility Trailer |
| WMF-649 | Vapor Vacuum Extraction Monitoring Well No. 9301 |
| WMF-649 | Vapor Vacuum Extraction Monitoring Well No. 9302 |
| WMF-651 | Radiation Control Trailer |
| WMF-652 | Security Trailer |
| WMF-653 | Office Annex No. 2 |
| WMF-655 | Material Handling Facility |
| WMF-656 | Maintenance Facility |
| WMF-657 | Construction Field Support Trailer |
| WMF-658 | Radioactive Waste Management Complex Office |
| WMF-660 | Automatic Transfer Switch Building |
| WMF-661 | Hazardous Materials Storage |
| WMF-664 | Maintenance |
| WMF-665 | Truck Off Loading Facility |
| WMF-666 | Retrieval Building |
| WMF-667 | Processing Building |
| WMF-668 | Utility Building |
| WMF-703 | Propane Tank |
| WMF-709 | Water Storage Tanks |
| WMF-714 | Intermediate-Level Transuranic Storage Facility (ILTSF) Pad No. 1 |
| WMF-720 | ILTSF Pad No. 2 |
| WMF-727 | Firewater Storage Tank |
| WMF-732 | Propane Tank |
| WMF-734 | Fuel Tank |
| WMF-737 | Fuel Tank |
| | Cold Test Pit North |
| | Cold Test Pit South |
| AMWTF | Advanced Mixed Waste Treatment Facility |

- Section 3.9—Results of ongoing C-14 and beryllium block investigations are reviewed and discussed.
- Section 3.10—Findings of the Criticality Safety Study of the SDA for the OU 7-13/14 RI/FS are summarized.
- Section 3.11—References for Section 3 are listed.

3.1 Operational Background

According to the FFA/CO (DOE-ID 1991), WAG 7 is defined as the RWMC facility, the subsurface beneath the RWMC into which contaminants may have migrated laterally or vertically, and any contamination in the SRPA originating from the RWMC. The primary focus of this ABRA is on buried waste in the SDA. The collocated facilities analysis for WAG 7 is summarized below, followed by past and current operations and practices relative to the OU 7-13/14 comprehensive RI/FS.

3.1.1 Collocated Facilities Analysis for Waste Area Group 7

As discussed in Section 1.1, the RI/BRA focused on risk to human health and environment from waste buried in the SDA. However, a collocated facilities analysis (Whitaker 2002) was performed to determine whether any current or inactive facilities, structures, or operations within or proximal to the RWMC could have an impact on cumulative risk assessment or on effectiveness of future remedial action. For the RI/BRA, collocated facilities are defined as buildings, structures, or processes that (a) are proximal or share the same area as WAG 7 and (b) may contribute to cumulative environmental impacts.

Each of the more than 50 individual buildings and structures at the RWMC (see Figure 3-1) was evaluated for a potential contribution to cumulative risk of WAG 7.

A four-step screening process was used (see Figure 3-1). The first step eliminated from further consideration any building or structure that had never processed, used, or stored any hazardous materials. The second step eliminated buildings or structures that housed hazardous or radioactive materials below threshold quantities, as specified in Superfund Amendment and Reauthorization Act Title III (Public Law 99-499). The third step eliminated buildings and structures that historically had used, processed, or stored hazardous materials but that were operated with appropriate controls (i.e., measures to prevent or mitigate releases to the environment). The fourth step eliminated buildings or structures that currently process, use, or store radiological materials or RCRA-regulated hazardous waste, but that are operated with appropriate controls and mitigation plans following current guidance and requirements. Any facility, structure, or operation that could not satisfy at least one of these four criteria would be evaluated for potential contribution to cumulative risk.

In the collocated facilities analysis, Whitaker (2002) concluded that all facilities, structures, and operations within or proximal to the RWMC could be eliminated as contributing to WAG 7 cumulative risk by satisfying requirements of one of the screening criteria. None of the collocated facilities was found to pose a potential impact to cumulative risk at WAG 7 or to pose an imminent threat of hazardous release. Figure 3-1 provides a graphical summary of the screening results. Most of the facilities are administrative buildings that pose no risk to the environment. Though substantial waste inventories are stored at TSA, facilities containing waste are managed under RCRA permits and other controls, and will be closed in accordance with RCRA requirements. Therefore, these facilities will not affect cumulative risk for WAG 7.

3.1.2 Historical Operations from 1952 to 1985

In *A History of the Radioactive Waste Management Complex at the Idaho National Engineering Laboratory* (EG&G 1985), past operations were discussed in terms of the following four time intervals:

- Early disposal operations from 1952 to 1959
- Interim operations from 1960 to 1963
- Mid- to late 1960s operations from 1964 to 1969
- Late operations from 1970 to 1985.

The interval definitions were based on disposal practices of the day and waste that was received during the period. Information that follows was obtained from the History of the RWMC at the INEEL document (EG&G 1985).

3.1.2.1 Disposals from 1952 to 1959. The original NRTS landfill, now known as the SDA, was established in 1952. The facility was managed and operated by the U.S. Atomic Energy Commission (AEC). The first trench was opened for disposal of solid waste in July 1952. The RWMC Acid Pit, located outside of the original disposal area, began receiving waste in 1954. Between 1952 and 1957, Trenches 1 through 10 were excavated to basalt and averaged 1.8 m (6 ft) wide, 274.3 m (900 ft) long, and 3.7 m (13 ft) deep. In 1957, Pit 1 was excavated for the disposal of large bulky items. With excavation of Pit 1, space in the original landfill was nearly consumed; therefore, the facility was expanded in 1958 to 36 ha (88 acres). The Acid Pit, no longer outside of the disposal area, was incorporated into the SDA.

Disposal practices during this time depended on classification of waste as either routine or nonroutine. Routine solid waste was identified based on exposure relative to daily occupational limits. Routine solid waste, typically consisting of paper, laboratory glassware, filters, metal pipe fittings, and other items contaminated by mixed fission products during NRTS operations, was packaged in cardboard boxes. Boxes were taped shut and collected in dumpsters that eventually were emptied into trenches. Nonroutine solid waste, defined as waste that could cause excess personnel exposure, was placed either in wooden boxes or in garbage cans. Special transport containers and vehicles were used to haul the waste to the disposal site. Before 1957, the radiation level was not limited for any disposal, and items registering up to 12,000 R/hour were buried. Both nonroutine and routine solid waste was covered with soil, but according to different schedules. Nonroutine solid waste was covered immediately, whereas routine solid waste boxes may have been left exposed until the end of an operating week. Because completion of a disposal documentation form was not a requirement until 1959, early disposal records are sketchy. Procedures were standardized in 1959 with the establishment of formal definitions of routine and nonroutine solid waste. Standardized procedures also required completion of a disposal form.

During the early waste disposal period, the NRTS also accepted waste shipments for permanent disposal from the Rocky Flats Plant (RFP)^a under the authorization of the AEC. From 1954 to 1957, the RFP TRU-contaminated waste, packaged in drums or wooden crates, was stacked horizontally in pits and trenches along with the NRTS mixed fission product waste. Therefore, most of the pits and trenches in the original landfill, Trenches 1 through 10 and Pit 1, contain NRTS waste interspersed with

a. The Rocky Flats Plant, located 16 mi (26 km) northwest of Denver, was renamed the Rocky Flats Plant Environmental Technology Site in the mid-1990s. In the late 1990s, it was again renamed, to its present name, the Rocky Flats Plant Closure Project.

TRU-contaminated waste from the RFP (see Figure 3-1). Records for RFP disposals did not accompany those shipments. Instead, an annual summary of disposals provided total radionuclide content and waste volume.

Originally, trench locations were identified and recorded by metal tags placed at regular intervals along the barbed-wire enclosure that surrounded the landfill. This procedure was discontinued in the late 1950s, and concrete survey monuments were placed at the ends of the centerline of each trench and at the corners of each pit. A brass plate was affixed to each monument and stamped with the trench or pit number, dates indicating when the trench or pit was opened and closed, and a direction arrow. Older disposal sites were retrofitted with monuments, but accuracy of the locations is uncertain.

3.1.2.2 Disposals from 1960 to 1963. In late 1959, the AEC determined that land disposal was preferable to offshore ocean disposal of solid radioactive waste. However, a commercially operated land disposal site was not available to private industries licensed by the AEC. Therefore, the AEC created an interim program for disposal of solid radioactive waste generated by AEC licensees, while commercial sites were selected and established. Two facilities were selected for interim disposal—the NRTS and Oak Ridge National Laboratory. From 1960 until commercial burial sites became available in 1963, the NRTS accepted approved shipments from off-Site generators. Because of security concerns, waste shipments from RFP to the NRTS continued after commercial sites opened.

During the early 1960s, several changes occurred in NRTS waste disposal operations. First, the AEC delegated authority to manage and operate the landfill to the NRTS operating contractor, Phillips Petroleum Co. Tasks managed under this authority included radiological surveillance and arrangements for nonstandard disposals. The contractor refined and formalized standard practices for disposal operations and implemented a system of careful record keeping. Another change in disposal practices affected physical burial of TRU waste from RFP. Beginning in November 1963 (and continuing until 1969), drums from RFP were dumped into pits rather than stacked to reduce labor costs and personnel exposures. Environmental monitoring systems were improved by placing film badges around the perimeter of the facility.

From 1960 to 1963, when the interim program was active, Trenches 16 through 25 and Pits 2 through 5 were open for disposal of waste (see Figure 3-1). These excavations received some mixture of stacked or dumped RFP TRU-contaminated waste, NRTS waste, and off-Site waste.

3.1.2.3 Disposals from 1964 to 1969. By the mid-1960s, concern about the environmental impacts of waste disposal significantly influenced waste management practices. Disposal practices, monitoring systems, and the adequacy of facilities were subjected to critical scrutiny, which resulted in passage of environmental legislation designed to protect the environment. The particular concern has always been to maintain water quality in the SRPA. Numerous studies conducted by various agencies concluded that previous burial of radioactive waste did not generate off-Site health or safety problems. However, several improvements were recommended to monitor and mitigate potential impacts from continued waste burial.

Modifications to procedures for permanent interment included increasing the minimum trench depth of 0.9 m (3 ft) to 1.5 m (5 ft), lining the bottoms of excavations with at least 0.6 m (2 ft) of soil underburden, compacting waste by dropping a heavy steel plate on the waste dumped in trenches, and increasing the soil cover over each disposal area from a minimum soil cover of 0.6 m (2 ft) to 0.9 m (3 ft). These modifications were implemented between 1964 and 1970 when Trenches 33 through 49 were active (see Figure 3-3). Information on the specific trenches that were compacted with the steel plate is not available. In addition, burial of waste classified as TRU was discontinued in 1970. Instead, TRU waste was transferred to the TSA for retrievable storage.

According to EG&G (1985), the environmental monitoring program was revised during this period. The 35 film badges around the perimeter of the landfill were replaced with 18 thermoluminescent dosimeters. Water samples also were collected and analyzed from subsurface monitoring holes and field investigations were conducted to assess leaching. The report concludes that specific threats to the aquifer had not been identified.

3.1.2.4 Disposals from 1970 to 1985. The greatest departure from previous disposal practices during this period was implementation of the 1970 AEC “Policy Statement Regarding Solid Waste Burial” (EG&G 1985; AEC 1970). The policy required segregated and retrievable storage of all solid TRU waste. Originally, TRU waste was defined as all waste contaminated with TRU radionuclides in concentrations greater than 10 nCi/g (AEC 1973). In 1982, TRU waste was redefined in DOE Order 5820.1, “Management of Transuranic Contaminated Material,” as waste materials containing any alpha-emitting radionuclide with an atomic number greater than 92, a half-life longer than 20 years, and a concentration greater than 100 nCi/g at the end of the period of institutional control as defined in DOE M 435.1-1, “Radioactive Waste Management Manual.”

The AEC also committed to removing TRU waste from the NRTS. Correspondence between state and federal officials is contained in the *Environmental and Other Evaluations of Alternatives for Long-Term Management of Stored INEL Transuranic Waste* (DOE-ID 1979, Appendix A). The new policy initiated several changes in waste disposal practices within the SDA and led to the creation of the TSA. These changes are discussed below.

3.1.2.4.1 Transuranic Storage Area Retrievable Waste Disposal from 1970 to 1985—Following the adoption of the 1970 policy, interim practices allowing storage and “. . . retrieval of contamination-free waste containers after periods of up to 20 years. . .” (EG&G 1985) were developed, implemented, tested, and revised. Most of these practices are still in use today. Abovegrade storage was selected for TRU interim storage, which resulted in establishing the TSA (see Figure 3-1) in late 1970. Several large asphalt storage pads, the Intermediate Level Transuranic Storage Facility, the Stored Waste Examination Pilot Plant (SWEPP) (see Figure 3-1), and other structures were constructed within the TSA during this period to implement the new policy.

Contact-handled waste stored at the TSA is being removed and shipped to WIPP. Therefore, waste temporarily stored within the TSA was not considered in the WAG 7 Interim Risk Assessment (IRA) (Becker et al. 1998), and practices within the TSA are not addressed in detail in this document.

Generally, contact-handled TRU waste was primarily received from off-Site generators and placed in interim storage from 1970 to 1982 on TSA Pads 1, 2, and R (see Figure 3-1). This waste was packaged in containers, stacked in subdivided areas called cells, and covered with dirt. In some cases, layers of waste were separated by fire-retardant plywood. At TSA Pad 1, cells were segregated by earthen firebreaks. A final cover of wood, plastic sheeting, and soil seeded with grass was placed over each cell as it was filled to capacity. Operations at TSA Pads 1 and R were conducted in the open and exposed to weather. A movable air support weather shield (ASWS) was constructed over the southern portion of TSA Pad 2 in 1975, enabling all-weather operations. The ASWS was shifted along with storage operations from south to north as cells were filled. Earth-covered portions of TSA Pads 1, R, and 2 were all closed by 1982.

Transuranic Storage Area Pad 3, constructed in 1983, provided the foundation for a second, much larger ASWS (see Figure 3-1), which also was called the SWEPP Certification and Segregation Building WMF -612). In general, SWEPP is used to examine containerized waste to verify compliance with WIPP waste acceptance criteria. Waste containers are subjected to a series of tests to evaluate container integrity and to verify and assay container contents. The Certification and Segregation Building (WMF-612 or

ASWS-3) was built in 1985 over the southern two-thirds of Pad 3. Contact-handled TRU waste containers were stored on ASWS-3 pending examination and shipment or disposition. The Certification and Segregation Building was deactivated, decontaminated, and decommissioned in 2000 to provide space for construction of the AMWTF (EG&G 1990; Schwaller 1991; Lugar 1994).

The Intermediate Level Transuranic Storage Facility (ILTSF) (see Figure 3-1) was constructed to store TRU waste emitting beta or gamma radiation at levels requiring special handling and shielding. Exposure rates between 200 mR/hour and 4,500 R/hour at the container surface were specified originally. The upper exposure-rate limit was revised to 100 R/hour in 1982 to comply with revised WIPP waste acceptance criteria. The facility consists of two pads, one built in 1975 and one in 1985. The facility provides belowground interim storage in shielded vaults formed of steel pipes of varying diameters. Vaults are embedded in a compacted earthen embankment and covered by two asphalt pads. Asphalt allows use of heavy machinery during waste unloading and retrieval operations.

3.1.2.4.2 Subsurface Disposal Area Operations from 1970 to 1985—Since 1970, solid TRU waste received at the RWMC has been segregated from non-TRU solid waste and placed in interim storage at the TSA. Low-level waste (LLW) at the RWMC contaminated with TRU isotopes less than or equal to 100 nCi/g but greater than 10 nCi/g also was excluded from disposal in the SDA and placed in interim storage at TSA. Low-level waste contaminated with TRU isotope less than or equal to 10 nCi/g was disposed of in the SDA.

A pad was constructed within the SDA in an area unsuitable for subsurface disposal because of shallow surficial sediments. Originally called the Engineered Waste Storage Area, it was later called the Transuranic Disposal Area and is now called Pad A (see Figure 3-1). Pad A waste contains TRU alpha-emitting radioisotopes with concentrations less than 10 nCi/g and exposure rates less than 200 mR/hour at the container surface. Pad A waste was not officially categorized as TRU, but interim disposal techniques were implemented to expedite potential retrieval. Boxes were stacked around the periphery of Pad A, and drums were stacked horizontally in staggered layers and covered with soil. Disposal operations were conducted on Pad A from 1972 to 1978. The Pad A waste were covered with a final soil layer with a minimum thickness of 0.9 m (3 ft), contoured to a maximum slope of 3:1, and seeded with grass.

Other modifications including compaction, packaging criteria, and enlarging pit volumes were made to SDA disposal practices during 1970 to 1985 because of concern about space availability. The NRF began compacting its disposals in 1971. The design criteria developed by NRF were used to design a system subsequently installed at the RWMC by 1974. Generators of waste at the INEEL, except NRF, began sorting their own waste and shipping non-TRU compactable waste to the RWMC in plastic bags to expedite compaction operations. Packaging criteria were modified in 1978 to facilitate close-packed array stacking within the pits. Pits were expanded by using heavy equipment to remove fractured basalt from the base of the excavations. Beginning with Pit 17 in 1980, explosive fracturing was used to deepen pit excavations. A soil underburden at least 0.6 m (2 ft) thick was added to cover basalt before waste was interred, and a final layer of compacted soil at least 0.9 m (3 ft) thick was used to cover buried waste. In 1985, the practice of incorporating a geotextile liner into the underburden was implemented. In combination, the above practices greatly expanded usable space within the SDA and significantly extended the operational lifetime of the facility.

Disposal practices also were modified to minimize personnel exposures to radiation emanating from waste. Beginning in 1977, areas not suited for pits were reserved for SVRs, typically used for disposing of remote-handled waste. Drilled in rows, soil vaults consisted of unlined, cylindrical, vertical holes with diameters ranging from 0.4 to 2 m (1.3 to 6.5 ft) and averaging about 3.6 m (12 ft) deep. Vaults in any given row are at least 0.6 m (2 ft) apart. A layer of soil at least 0.6 m (2 ft) thick was placed in bottoms of holes when basalt was penetrated during drilling. Soil vaults were designed for disposing of

high-radiation waste that was defined as material producing a beta-gamma exposure rate greater than 500 mR/hour at a distance of 0.9 m (3 ft). Soil vault disposals were conducted concurrently with trench disposals from 1977 to 1981. Trenches also received high-radiation waste until trench disposal was discontinued in 1981.

General disposal practices were the same for pits and trenches. Compacted waste was bailed, larger bulky items were wrapped in plastic, and smaller noncompactable waste was contained in wooden boxes covered with fire-retardant paint. Waste was placed into the excavations by free-air transfer or in shielded casks, depending on the exposure rate measured on the outside of the waste container. Both types of waste were buried in separate areas within a given excavation. As each excavation became full, the disposal area was crowned with a final compacted soil cover at least 0.9 m (3 ft) thick.

3.1.3 Radioactive Waste Management Complex Operations from 1985 to the Present

Current disposal practices have not changed significantly since 1985. However, details about handling various types of waste are more readily available. Information about RWMC operations from 1986 to the present was taken from the RWMC Safety Analysis Report (INEEL 2000a), the DOE Land Use Plan (DOE-ID 1996), and the WAG 7 Collocated Facilities Analysis (Whitaker 2002). Some of the information in these documents is briefly summarized in the discussion that follows, which is subdivided into disposal within the SDA, operations within the TSA, and activities within the administrative area.

Waste is received at the RWMC for storage, examination, or disposal. Documentation accompanying each waste shipment is reviewed on arrival and the shipment is examined visually for discrepancies and damage. Radiological surveys are conducted to ensure that radiation and contamination readings meet requirements. Requirements are specified in the RWMC waste acceptance criteria (DOE-ID 2001). If any abnormalities are discovered either in waste or associated documentation, they are resolved with the generator of the waste before the waste is formally accepted. Once accepted, waste is transferred to the SDA or the TSA, as appropriate.

3.1.3.1 Subsurface Disposal Area Operations from 1985 to the Present. Current operations within the SDA consist of subsurface burial of LLW in pits and concrete vaults (see Figure 3-1) from INEEL operations. No off-Site generated waste has been received for disposal since the early 1990s. Use of trenches was discontinued in 1982, and all SVRs were closed by August 1995 (Seitz, Keck, and McCarthy 2001). Waste emplaced in the SDA is classified as remote- or contact-handled LLW depending on whether radiation levels at 1 m (3.3 ft) from the package surface are greater than or less than 500 mR/hour, respectively. In general, remote-handled LLW is entombed in concrete vaults in the southwest corner of Pit 20, and contact-handled LLW is stacked in a pit. Though seldom required, large bulky LLW with exposure rates in excess of 500 mR/hour is buried in a pit.

Waste disposed of in the SDA must meet the requirements of waste acceptance criteria (DOE-ID 2001). However, exceptions can be obtained from DOE by completing an analysis that shows that overall limits on LLW inventories will not be exceeded. Exceptions have been made roughly once every three years. These exceptions have been related to a given disposal exceeding concentration limits or for unanticipated waste containing short-lived radionuclides such as H-3 or Cs-137. Waste disposal operations in the SDA are currently anticipated to extend until 2020 (McCarthy et al. 2000).

3.1.3.1.1 Pit Disposals—Pits 17 through 20 comprise a single, large excavated area currently used for disposal of LLW. Though Pits 15 and 16 are closed, boundaries between these two pits and Pits 17 and 18 are only administrative (Yokuda 1992). Boxes on the west side of Pits 15 and 16 have been covered with soil for shielding purposes while disposal operations are conducted. The pits were blasted into basalt to a total depth of approximately 10 m (33 ft) and the exposed basalt was covered with 0.6 m

(2 ft) of soil and a thin layer of gravel (McCarthy et al. 2000). A contoured earthen berm surrounds Pits 17 through 20.

Waste is stacked within pits using forklifts and cranes. Stack height is limited by the self-supporting strength of the containers and by administrative controls. Maximum stack height is about 7.3 m (24 ft). As areas of the pits become full, waste is covered with approximately 1.2 m (4 ft) of fine-grained soil from on-Site sources. The soil cover is spread and compacted with dozers, sloped for drainage, and seeded with grass. Seitz, Keck, and McCarthy (2001) provide additional information relating to the interim closure of the LLW disposal operations ongoing in Pits 17 through 20.

3.1.3.1.2 Concrete Vaults—Concrete vaults, used for remote-handled LLW, are located in the southwest corner of Pit 20. The concrete vaults were designed to conserve space within the SDA. Constructed of precast reinforced concrete sections resting on an integral base plate, vaults are configured in honeycomb arrays. Each array is surrounded by soil for additional shielding and seismic stability. Void spaces between vaults in each array are filled with sand. Once full, each vault is covered with a 1.2-m (4-ft) thick reinforced concrete plug. Seams between adjacent plug caps are sealed with acrylic caulk at the surface of the array to inhibit moisture infiltration (McCarthy et al. 2000). Approximately 50 concrete vaults have been constructed in Pit 20 and about half of them are full. Current plans include constructing additional concrete vaults in FY 2003 (McCarthy et al. 2000).

3.1.3.1.3 Soil Vault Rows—Disposal in soil vaults was discontinued in 1993 (Seitz, Keck, and McCarthy 2001). Soil vaults are unlined holes bored 5.2 to 7.6 m (17 to 25 ft) deep that received remote-handled, containerized waste transferred from a bottom-discharge shipping cask. Full vaults were covered with least 0.9 m (3 ft) of soil. Additional soil was added when necessary to reduce exposure rate above the covered vault to less than 1 mR/hour at the soil surface. Periodic inspection and maintenance is conducted to ensure that soil vaults have at least 1.8 m (6 ft) of cover.

3.1.3.2 Transuranic Storage Area – 1985 to the Present. The primary purpose of current TSA operations is to provide environmentally safe and compliant management of contact-handled and remote-handled TRU waste stored at the RWMC. Receipt of off-Site generated contact-handled TRU waste ceased in 1989 when the last RFP waste was sent to INEEL. One additional TRU shipment was received from Argonne National Laboratory in Chicago in 1995 for waste generated in support of INEEL activities with state approval. Operations at the TSA are focused toward preparing and shipping 3,100 m³ of stored TRU waste from the RWMC to WIPP by December 31, 2002, in accordance with the 1995 Settlement Agreement (DOE 1995). Preparation includes waste examination, segregation, certification, and interim storage and retrieval activities. The TSA consists of storage buildings, the Intermediate Level Transuranic Storage Facility, the SWEPP, Transuranic Storage Area - Retrieval Enclosure, the AMWTF, and support facilities as described in the RWMC Safety Analysis Report (INEEL 2000a) (Figure 3-1). More than 100,000 containers of TRU waste are stored at TSA. Approximately 90% of the containers are 55-gal steel drums. The remaining 10% include 1.2 × 1.5 × 1.8-m (4 × 5 × 6-ft) steel bins, 83- and 30-gal steel drums, plywood boxes, fiber-reinforced boxes, modular steel boxes, and some oversized containers (LMITCO 1995b).

3.1.3.2.1 Transuranic Storage Area Storage Pads 1, 2, and R—The TSA Pads 1, 2, and R were developed to provide retrievable interim storage for contact-handled TRU waste. This method of soil-covered waste storage was discontinued and TSA Pads 1, R, and most of 2 were closed in 1982. One end of Pad R was used to receive and stage waste for transfer into an ASWS or RCRA-compliant storage module. Installed in 1973 over Cell 3 at the northern end of Pad 2, ASWS-2 (WMF-711) collapsed from high winds in 1986. The ASWS was reinforced with a steel frame and remained in service until 1999 when it was dismantled. This building supported storage operations until 1997 when all

accessible waste was moved into RCRA-compliant storage buildings. Activities at the closed pads are limited to monitoring and maintenance until the soil-covered waste is removed.

3.1.3.2.2 Transuranic Storage Area Retrieval Enclosure—The TSA-Retrieval Enclosure, Building 636, constructed from 1994 to 1996, is a metal building that extends over the TSA Pad 1 and R areas. An adjacent annex extends over Cells 1, 1A, and 2 of TSA Pad 2. The enclosure provides a work area that allows year-round retrieval of contact-handled TRU waste presently stored on these three Pad Areas. In 2001, the building was transferred to the Advanced Mixed Waste Treatment Project, and preparations are under way to retrieve the soil-covered stored waste.

3.1.3.2.3 Waste Storage and Examination Facilities—The EPA issued a Notice of Noncompliance to DOE in 1990 for deficiencies in the configuration of stored waste at the TSA (EPA 1990). Subsequently, seven RCRA-approved Type 2 storage modules, designated WMF-628 to -634, were constructed between 1994 and 1995 for interim storage.

Drum venting and testing are conducted in WMF-635, a RCRA-approved Type 1 modular building. The building encloses the existing Drum Venting Facility, WMF-615 (see Figure 3-1). Building WMF-635 supports drum venting operations, gas generation testing, and preparation and loading of certified TRU waste for shipment to WIPP. One portion of the WMF-635 building is heated and insulated to thaw waste prior to examination at SWEPP. Another area in WMF-635 is maintained above freezing to provide a sheltered area for drum aspiration after venting. The WMF-635 building also has office space and a lunchroom.

Erected on Pad 3 in 1984, the SWEPP facility (WMF-610) began operations in 1985 to nondestructively examine TRU waste to ensure compliance with the WIPP waste acceptance criteria requirements. The facility contains the real-time radiography and radioassay capabilities to support TRU waste certification. Certification authority for SWEPP was received in August 1985. To date, more than 10,000 drums have been certified and more than 5,000 drums have been shipped to the WIPP. The SWEPP is characterizing waste for shipment to the WIPP.

Various other facilities include maintenance, storage for propane gas, and a sanitary-waste system. The TRUPAC Loading Station, Building WMF-618, is used for nuclear waste shipping.

3.1.3.2.4 Intermediate Level Transuranic Storage Facility—The Intermediate Level Transuranic Storage Facility currently provides storage for remote-handled TRU waste greater than 200 mR/hour at the container surface. The facility contains a total of 256 (16-, 24-, 30-, and 48-in.) diameter vaults, which are embedded in a compacted earth berm. These vaults were designed to store TRU waste having exposure rates between 0.2 R/hour and 4,500 R/hour at the surface of the container. In addition, the facility also contained 16 vaults permitted under RCRA to store mixed TRU waste from Test Reactor Area (TRA). Receipt of off-Site generated remote-handled TRU waste was discontinued at the facility in 1995.

In November 1997, the mixed remote-handled TRU waste was retrieved from vaults into shielded overpacks and placed in permitted storage in WMF-628 as contact-handled TRU waste to reduce inspection costs. In October 2000, the State of Idaho requested that the permitted vaults be closed based on no future need having been identified for mixed remote-handled TRU waste storage (Jason Associates 2001). Vault closure was completed in 2001 and accepted by the State of Idaho in November 2001 (Bullock 2001).

3.1.3.2.5 Advanced Mixed Waste Treatment Facility—In December 1996, DOE awarded BNFL Inc. and its partners a privatized, fixed-price contract to design, construct, and operate the

AMWTF. The AMWTF was required by the Settlement Agreement (DOE 1995) between the DOE, the U.S. Navy, and the State of Idaho. The Settlement Agreement requires that 65,000 m³ of TRU waste be shipped out of Idaho for final disposition at WIPP by December 31, 2018. Phase I of the AMWTF consisted of successfully completing all required preliminary permits and approvals by July 2000. Phase II of the AMWTF, which began in August 2000, specified that the design, development, and construction should be completed by December 2002. One storage module and the TSA Retrieval Enclosure were transferred in 2001 to the AMWTF project. Phase III is planned to start in 2003 and consists of waste retrieval, characterization, and facility operation (INEEL 2001a, 2001b).

3.1.3.3 Administration and Operations Area Activities from 1985 to the Present. The administration and operations area includes administrative offices, security and gatehouse operations, radiological control support, maintenance buildings, equipment storage, and miscellaneous support facilities. A complete description of each facility is given in the RWMC Safety Analysis Report (INEEL 2000a) and the WAG 7 Collocated Facilities Analysis (Whitaker 2002).

3.1.4 Subsurface Disposal Area Buried Waste Retrievals

Five buried waste retrievals were conducted in the SDA during 1969 and the 1970s to assess condition of waste and waste containers, retrieve drums of TRU waste for aboveground storage, attempt to retrieve experimental laboratory equipment, check contents of selected containers, and assess difficulty in retrieving waste and waste containers in various stages of deterioration. Five INEEL programs have retrieved waste from 11 locations in the SDA, as shown in Figure 3-2:

- Pit 1—Conducted in 1969, the Pit 1 project was unsuccessful at retrieving some experimental laboratory equipment inadvertently buried in Pit 1 (Hiaring, Horton, and Schlafman 1992).
- Pits 2, 5, 10, and 11—The Solid Radioactive Waste Retrieval Test, also known today as the Allied Chemical Corporation ACI-120 project, comprised retrieval of 16 drums from Pits 2, 5, 10, and 11 for examination in the Auxiliary Reactor Area (ARA)-I Hot Cell. Retrieval of one of three special drums for the Atomic Energy Commission was successful (Thompson 1972).
- Pits 11 and 12—In the Initial Drum Retrieval, Project, all the drums from Pits 11 and 12 were retrieved and transferred either to the TSA or to Pad A (known at the time as the Transuranic Disposal Area) (Card and Wang 1976; McKinley and McKinney 1978a). A total of 20,262 drums were retrieved with a waste volume of 4,397 m³.
- Pits 1 and 2, Trenches 1, 3, 5, 7, 8, 9, and 10—The Early Waste Retrieval Project was initiated to investigate problems associated with large-scale removal of buried waste contaminated with TRU elements from the SDA landfill (Card 1997; McKinley and McKinney 1978b; Bishoff and Hudson 1979). A total of 457 drums were retrieved. The total volume of waste for the project was 170.4 m³.
- Pad A—In the Penetration and Inspection Project, conducted in 1978 and 1979, the condition of waste placed on Pad A, previously called the Transuranic Disposal Area, was examined (Bishoff 1979a, 1979b). No waste was retrieved.

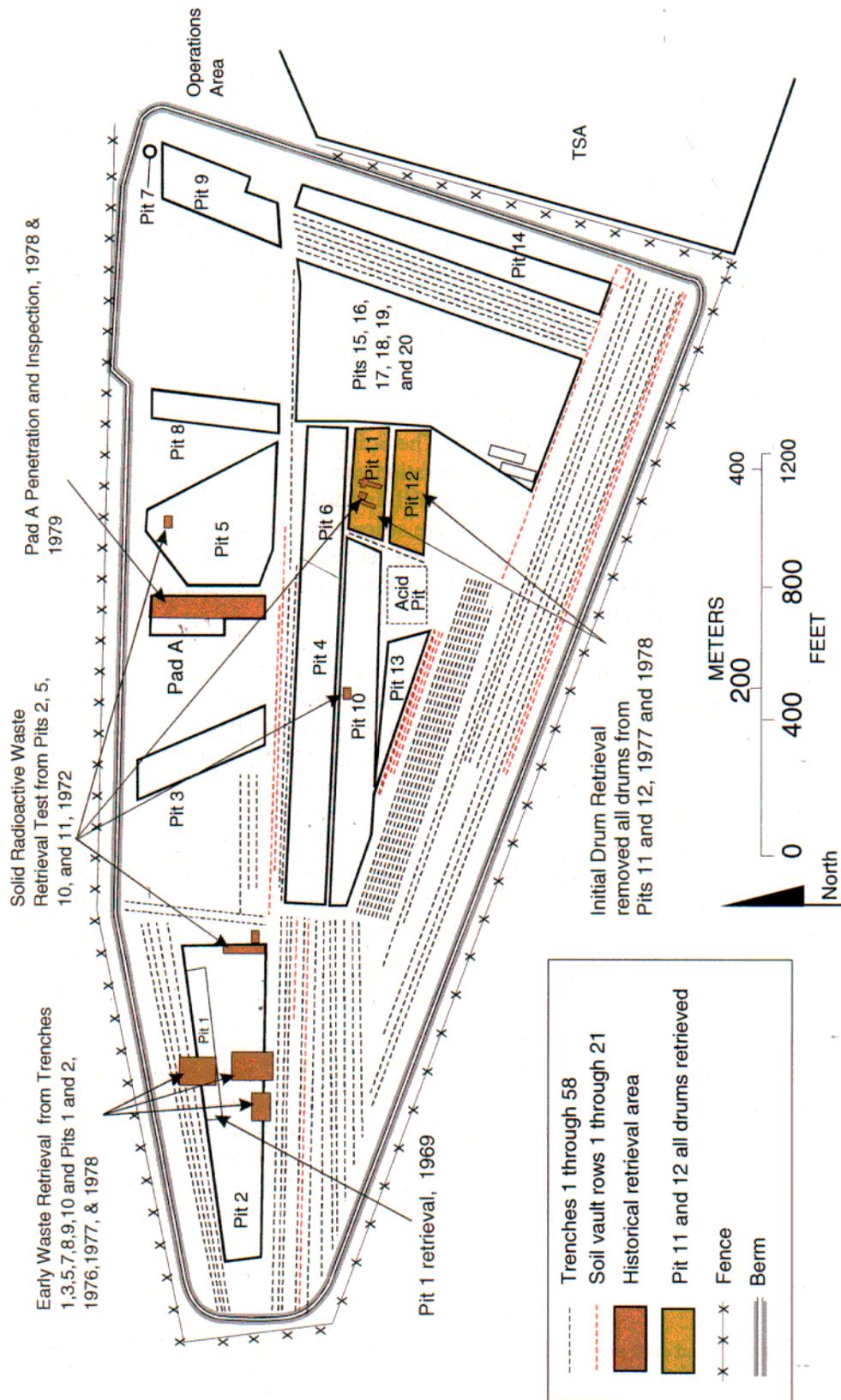


Figure 3-2. Past waste retrievals by five programs in 11 locations from the Subsurface Disposal Area.

3.1.4.1 Pit 1 Retrieval. Information about the Pit 1 retrieval in 1969 is sparse. The retrieval was conducted in the fall of 1969 in an effort to retrieve some experimental equipment that may have been inadvertently buried in the landfill. The retrieval received one paragraph of explanation in an unpublished draft report.^b Photographs of the work appeared in *A Photographic Report of Disposal and Storage Activities at the Radioactive Waste Management Complex* (Hiaring, Horton, and Schlafman 1992). The retrieval was conducted in the fall of 1969 and apparently was not successful in locating the experimental equipment. Undamaged drums were found to be well preserved, but boxes and other similar packaging material had deteriorated. Pit 1 was open from 1957 to 1959; so, the waste had been buried for approximately 10 to 12 years. The exact number of drums retrieved is not known, but photographs indicate at least 25. The pictures show a small crew with an excavator removing drums in several locations from what is believed to be Pit 1. The pictures do not show any environmental controls and the men are performing the work in street clothes, coveralls, hats, and gloves. No respiratory protection is evident. Though Pit 1 received TRU and LLW, based on the level of protection indicated in the photographs, digging probably took place in an area containing LLW.

3.1.4.2 Solid Waste Retrieval Test Retrieval. In 1971, the Atomic Energy Commission requested a series of solid waste retrieval tests on RFP waste buried in the SDA to gain insight into problems that may arise from a large-scale retrieval operation. The Solid Waste Retrieval Test, also called the ACI-120 project, was conducted by Allied Chemical Corporation and consisted of excavating and studying contents of drums and boxes from sites within the landfill. In addition, the Atomic Energy Commission requested retrieval of three specific drums that were suspected of containing excessive amounts of plutonium. One of the three specific drums was located. The retrievals focused on removing drums from Pits 2, 5, 10, and 11. Retrievals from each pit and subsequent hot cell examinations of the retrieved waste are summarized below (Thompson 1972).

3.1.4.2.1 Pit 2—Six of the drums stacked in Pit 2 were exhumed and transported to the ARA-I Hot Cell for sorting and sampling. Excavations at Pit 2 were complicated by drums being found along the edge of the pit outside pit boundary markers. Previous flooding may have caused these drums to move from their original location. Containers removed from Pit 2 had been buried for approximately 12 years and were in the poorest condition of any encountered during the retrieval test. Some of the drums were corroded through and sludge was leaking from them. On two occasions, clear liquid leaked from sludge drums. Some drums were open and plastic bags typically used as inner liners at that time were not in evidence. The general condition of the drums and potential for contamination slowed retrieval operations markedly. Soil cover over the drums at that time was about 30 to 46 cm (12 to 18 in.). The plutonium concentrations in the interstitial and underburden soil varied from about 1E-03 to 1E-01 nCi/g soil. Contamination at this level made working conditions difficult because respirators and frequent changes of protective clothing were required.

3.1.4.2.2 Pit 5—Five of the waste drums dumped in Pit 5 were exhumed and sent to the ARA-I Hot Cell for examination. Waste containers had been buried for approximately 7 years before retrieval. Initial efforts to open the pit with a bulldozer and scraper were not successful because the waste was not located at the pit's edge, but was found approximately 6 m (20 ft) inside the pit boundary. The drums were randomly oriented with large quantities of dirt interspersed among them. About one-half of the volume of the area excavated was filled with dirt. One-fourth of the drums exhumed were damaged or lidless. Several drums were either rebagged before removal because they were punctured during digging,

b. Appendix I to a November 1971 unpublished draft report titled "1969 Pit 1 Retrieval, Burial Ground Chronological Historical Development and Highlights."

or were rebagged in place and left in the excavated area. Ten of the sixteen drums exhumed could not be identified specifically. One sludge drum damaged during the excavation discharged a clear liquid.

Several RFP plastic-wrapped filters were found. Remnants of cardboard cartons that had contained filters also were observed. A soil sample taken near the filter boxes showed plutonium contamination of 1.14 nCi/g. Direct radiation readings of 20 mR/hour were noted at 0.9 m (3 ft) from the filter boxes. No attempt was made to exhume the filters because handling equipment at the excavation site was inadequate to contain potential contamination spread and prevent unnecessary exposure to personnel.

A box was located for retrieval by investigating a surface depression. The top of the box was missing and the wood was severely deteriorated. Health physics smears indicated about 1,000 dpm. Because of the apparent overall high contamination levels and poor box condition, box and contents were left in place. The report concluded, "Future excavations in dumped pits where wooden boxes are involved probably will require special attention and the contents of the wooden boxes removed piece-by-piece" (Thompson 1972). Plutonium concentrations in three soil samples collected from the top of the box were 5.58E-04, 2.55E-03, and 4.51E-02 nCi/g.

Soil analysis results for Pit 5 samples collected during the excavation indicate that the general plutonium concentrations were quite low, about 1E-02 to 1E-03 nCi/g.

3.1.4.2.3 Pit 10—Pit 10 was entered with the intent of retrieving Drum No. 771-3431, one of the specific drums requested for inspection by the Atomic Energy Commission. Though disposal records indicated that Pit 10 received this drum, neither Drum No. 771-3431 nor any other drum from the same load was found in Pit 10. About one-half of the drums were without identification, and about one-fourth were lidless or crushed.

Random placement of the drums, which resulted from dumping, greatly complicated and slowed digging operations. Many seriously damaged drums were found, some of which were open with the inner liner ruptured. Loose material—protective mask canisters, tags, plastic material, and drum lids—was observed. The main cause of loose material and damaged drums appears to have been the practice of dumping drums. This practice also resulted in large portions of the pit volume, approximately 50%, being filled with dirt instead of waste. Because it was necessary to hand-dig and lift the drums, only 24 drums were exhumed over a 3-day period. The Pit 10 excavation was the first project where dust respirators routinely were required to protect personnel. Whole-body counts of the two laborers who did most of the manual work showed no detectable plutonium. All the drums suffered physical damage caused by heavy equipment used to level and cover during and after burial. Corrosion, though present, did not appear to be a significant factor in overall drum condition.

A soil sample taken before the excavation showed plutonium concentrations of 6.22E-04 nCi/g contamination (Thompson 1972, Figure 18). However, a special sample taken from excavated soil showed a plutonium concentration of 2.28E-01 nCi/g.

3.1.4.2.4 Pit 11—Disposal records indicated that Pit 11 contained two of the drums specifically requested by the Atomic Energy Commission to be retrieved. Five additional drums also were scheduled to be removed from Pit 11 for examination in the ARA-I Hot Cell. Drum No. 771-7285 was found close to the area designated by SDA records. Retrieval of this container was relatively straightforward. Topsoil was removed with a backhoe and the drums in the pit, which had been buried for approximately 18 months, were lifted out using a chain-hook-lifting device and crane. Drum No. 771-16500, the next drum to be retrieved, was part of a large backlog of 5,000 drums stored aboveground because of inclement weather during the winter of 1970. As conditions and weather permitted, this backlog of drums was moved and stacked in Pit 11. As a result, the shipment that contained Drum No. 771-16500 became

scattered. Thirty of the 152 drums in this shipment were located but the rest could not be found, including Drum No. 771-16500. Five drums of waste material selected at random were removed from Pit 11 and transported to the ARA-I Hot Cell for sorting and sampling. The five drums included one sludge drum and four drums of miscellaneous waste and scrap that had been buried for approximately 1 year. Nine soil samples were taken between and under the drums, and plutonium concentrations were $2\text{E}-03$ nCi/g or less. Movement of plutonium contamination in the soil caused by leaching and infiltration was not addressed by the Solid Waste Retrieval Test Project (Thompson 1972). Samples were collected from excavated soil and from soil between and under the drums. The condition of the drums in Pits 2, 5, and 10 was reported as leaking, crushed, corroded, damaged and missing lids. Soil contamination is likely the result of direct contact with waste.

3.1.4.2.5 Results of Hot Cell Sorting—Sixteen drums exhumed from the SDA were opened and qualitatively examined for general drum and waste condition. Drum condition varied from excellent (nominal corrosion) to poor (corroded through) as a result of both age and method of handling during burial. Drums that were dumped, bulldozed, and crushed generally were in bad condition. Plastic bags lining the drums exhibited a wide range of conditions from no liner, to sealed liners with contamination well contained. Moisture content in the waste varied from dry to saturated with free liquid in the bottom of the drum.

Following is a summary of observations made during the sorting and sampling phase of the test. No previous assay data for plutonium were available for seven drums because the Rocky Flats identification numbers were not legible. Sixteen drums averaged 80% full, two drums were 40% full, and seven drums were 100% full. Material in the drums was composed of combustible and noncombustible waste. Approximately 37% was noncombustible waste (e.g., metal, wire, and equipment) and 63% was combustible waste (e.g., paper, rags, rubber gloves, plastic, and wipes). Drums that had been buried 18 months were in good condition with light surface rusting. Ring closures were removed by unscrewing the fastening bolts. However, those drums that had been buried for 7 to 12 years were heavily rusted, with one drum completely rusted through. Bolts holding the ring closures of these drums had to be cut off with a hacksaw. Nine of the 16 drums were not sealed, as evidenced by rubber sealant being out of position, obvious infiltration of water, or a bent lid. Plastic bag drum liners were in various condition. Three drums had no liner, five liners were folded over and not taped shut, three were taped shut but were punctured or rotted, and five were taped shut and intact. Two sets of health physics smears were taken for each drum opened. The first set was taken from outside the drum lid before its removal, and the second was taken on the underside of the lid and on top of the waste just after the drum lid was removed. Smears taken outside the drum did not exceed 100 cpm. The highest smear count from inside a lid was 55,000 cpm. Four drums had liquid standing in the bottom, and five were dry. The remaining seven drums were damp, either from wet wipes and rags found inside or from water that leaked into the drum. The contents of the drums that could be identified by RFP numbers were consistent with the contents listed in the RFP records.

3.1.4.3 Initial Drum Retrieval. The Initial Drum Retrieval was designed and implemented to demonstrate safe retrieval, packaging, and transfer to interim storage of drums containing TRU waste buried from 1968 to 1970 at the SDA. All drums from Pits 11 and 12 (the most recently buried RFP waste drums) were retrieved, repackaged, and transferred to TSA Pad R or were placed on Pad A in the SDA. Drums containing TRU waste were transported to TSA Pad R, and non-TRU waste drums, containing Series-745 sludge and depleted uranium were transported to Pad A. The project started using 83-gal overpack drums and then changed to overpack cargo containers that held 72 drums. This change substantially reduced costs and improved productivity.

The viability of drum retrieval was demonstrated. A total of 20,262 drums was retrieved with a waste volume of $4,397\text{ m}^3$. Soil contamination was not a significant problem. Soil samples were taken for field screening, but no analytical results from contaminated soil samples were reported. Drums that were

retrieved were mostly in good condition and soil in Pits 11 and 12 did not present a contamination problem. The final report (McKinley and McKinney 1978a) states that about 6.1% of the drums (1,236 drums) had external alpha contamination to 120,000 cpm and these drums all came from Pit 11. Drums from Pit 12 had no external contamination except for some fixed contamination. Approximately 2.4% of the drums (486 drums) were breached and about one third of these drums (162 drums) leaked free liquids. The leaking free liquid was usually uncontaminated though contamination levels up to 40,000 cpm were found in some of the liquids. No further analysis was reported in the document.

The Initial Drum Retrieval is a good example of retrieval under practically ideal conditions. Drums were stacked, and very little damage to them occurred during disposal. The drums had not been spread or compacted with heavy equipment and were in excellent condition. They were buried during the period from 1968 to 1970 and were retrieved from 1974 through 1978. The Initial Drum Retrieval project is the most successful retrieval conducted in the SDA.

3.1.4.4 Early Waste Retrieval. The Early Waste Retrieval Project was designed and implemented to investigate problems associated with removing TRU waste from belowground burial. Retrievals from Pits 1 and 2 and Trenches 1, 5, 7, 8, 9, and 10 were implemented over the 3-year period of 1976, 1977, and 1978, and are described below. The goals or objectives of the program were as follows:

- Develop methods and equipment for safe retrieval of buried TRU waste
- Develop methods for handling and repackaging retrieved TRU waste
- Determine risks and hazards involved with TRU waste retrieval
- Develop methods to minimize risks and hazards of waste retrieval
- Provide data and information for the design of future retrieval equipment and facilities
- Provide data and information for selecting a long-term waste management alternative
- Determine the extent of TRU isotope migration into the soil in pits and trenches.

The work was performed within an ASWS and a moveable confinement building. The ASWS was a fabric structure that provided weather protection. The confinement building was a portable metal structure with a three-cell change booth system attached to the personnel entrance door to control contamination during entry and egress from the contaminated area. For protection, workers wore bubble suits, which were totally enclosed personal protective equipment suits with supplied air, analogous to Level A protective clothing currently used. Workers also wore anti-contamination clothing under the bubble suit. Excavation was performed using manual labor and a tractor equipped with a front-end loader and a backhoe. Exhumed waste was repackaged as required, and some drums were placed in plastic bags or overpack containers. Loose waste was bagged and placed in drums or cardboard containers. Operations during the summer experienced some problems with heat stress for workers in bubble suits. This was mitigated with vortex cooling air from the supplied air line and by managing duration of work periods.

The total waste volume for the Early Waste Retrieval Project was 170.4 m³. The Early Waste Retrieval Project was a successful retrieval operation and demonstrated that waste in Pits 1 and 2 and Trenches 1, 5, 7, 8, 9, and 10 could be retrieved safely. The project also determined that maintaining environmental control could be extremely challenging and that techniques applied during the Early Waste Retrieval were slow and methodical.

3.1.4.4.1 1976 Early Waste Retrieval—In 1976, Early Waste Retrieval activities included deployment of a plastic-coated fabric ASWS and a smaller, portable confinement building to enclose the excavation area inside the ASWS.

The ASWS and the confinement building were erected and retrieval began approximately 140 m (460 ft) west of the southeast corner of Pit 2 (Thompson 1972, Figures 3 and 4). Retrieval of waste began in May 1976 and a total of 42 m³ of waste was retrieved by the end of September 1976. The retrieval included 80 drums and 25 m³ of loose waste and soil. Five drums were damaged or were missing covers but contained no free liquid. Ten drums leaked liquids when removed from the landfill and four leaking drums contained contaminated liquids, but only one resulted in soil contamination. Contamination was totally contained within the confinement building.

The confinement building was moved during July from the west end to the east end of the ASWS, remaining over Pit 2. When retrieval was resumed, 12 drums of waste were retrieved in the routine manner without encountering high contamination. Two drums leaked a clear liquid contaminated with Pu-238 to 2E+06 cpm. The drums were bagged and placed in overpack containers. Contamination in the soil was very mobile and was spread by air currents. However, cleanup operations personnel discovered that water spray would help control contamination if water was sprayed in the air and allowed to settle on the contaminated area, while direct application tended to mobilize the contaminants. Contamination was contained in the confinement building, but cleanup took several days. The area from which the drums were removed was covered with plastic and soil and the retrieval operation continued in another area within the confinement building. This incident proved that contamination, difficult to contain and requiring special procedures to handle safely, could be encountered during retrieval operations.

3.1.4.4.2 1977 Early Waste Retrieval—Waste retrieved from Pit 2 and Trenches 8 and 10 during the Early Waste Retrieval in 1977 consisted of drums, loose waste, and contaminated soil. The total waste for the effort comprised 240 drums representing a total of 50 m³ of waste, 21.2 m³ of loose waste, 6.4 m³ of contaminated soil, and 12.9 m³ of waste generated from retrieval operations. The generated waste included bubble suits, decontamination materials, and anti-contamination clothing. The total waste volume was 90.5 m³. Seventy percent of drums retrieved from Pit 2 and Trench 10 and all drums retrieved from Trench 8 were severely breached. Free liquid leaked from about 9% of drums, and 5% were externally contaminated. Though alpha-contamination levels greater than 2E+06 cpm were frequently encountered, available equipment and established safety and operating procedures were effective in protecting personnel and the environment.

The 1977 Early Waste Retrieval Project also included peripheral studies related to buried-waste retrieval. A TRU isotope migration study (Humphrey and Tingey 1978) indicated that contaminant migration (Pu-238, -239, -240 and Am-241) from waste was limited to a distance of approximately 0.6 m (2 ft), but trace contamination as far as 1.8 m (6 ft) was found. Part of this migration may have been caused by historical flooding. A container development study (McKinley and McKinney 1978b) resulted in purchasing a compactor to compact loose waste into 208-L (55-gal) drums. Soil binder studies (McKinley and McKinney 1978b) resulted in the use of fabric for dust and contamination control.

A near surface exploration of Pit 1 and Trenches 1, 5, 7, and 9 was conducted before moving the ASWS over these areas. Near surface exploration was conducted by digging a trench 0.9 to 1 m (3 to 4 ft) wide and perpendicular to the trenches, down to the top of buried waste. Drums in Pit 1 were stacked and in fair to good condition. No drums were externally contaminated, and direct radiation was less than 5 mR/hour. Numerous filters and frames were found mixed with the drums. The filters were contaminated from 2,000 cpm to greater than 2E+06 cpm and had deteriorated wooden frames. Trench 1, which was opened on July 8, 1952, and closed on October 1, 1954, was positively identified by two drum tags, one dated August 20, 1953, and the other dated October 1, 1954. Waste containers in Trench 1 appeared to be

almost completely disintegrated. Retrieved waste consisted of glass vials, metal filings, tubing, and gloves. Beta-gamma contamination levels were very low, with 6,000 cpm alpha being the highest level encountered. Trench 5, which was opened on November 4, 1955, and closed on March 29, 1956, also was identified by drum tags dated February 2, 1955. Drums had been randomly dumped and exhibited poor integrity. Low-level beta-gamma and alpha contamination was discovered on some contents of the drums with direct readings noted up to 50 mR/hour. Contents appeared to be filters and graphite molds. Only a few drums were found in Trench 7. The majority of the waste was not contained and consisted of sample bottles, tubing, plastic, and several lengths of pipe. Waste had low-level beta-gamma contaminants, but no alpha contamination was detected. Trench 9, which was opened on January 17, 1957, and closed on September 6, 1957, was identified by drum tags dated May 13, 1957. Drums were randomly dumped, but appeared to be in good condition. No external contamination was encountered on the drums. Miscellaneous loose waste, such as tubing, bottles, gloves, and a small cart, was mixed with the drums. Low-level beta-gamma contamination was found on these items, but no alpha contamination was detected.

The confinement building and other support equipment were removed from the ASWS in August 1977. The ASWS was deflated and dismantled for movement over Pit 1 and Trenches 5, 7, and 9.

3.1.4.4.3 1978 Early Waste Retrieval—As part of Early Waste Retrieval activities in 1978, the ASWS anchor blocks were relocated and the ASWS was moved and inflated over Pit 1 and Trenches 5, 7, and 9. The confinement building and other support equipment were placed in the ASWS, a new breathing air supply system was installed and activated, and new operating procedures and associated training were introduced. Retrieval operations resumed in February and continued through September 1978. The project retrieved 137 55-gal drums and approximately 65% of drums were breached. These drums had many rust holes, and several fell apart as they were being retrieved. About 3% of retrieved drums leaked free liquid with alpha-contamination levels ranging from 2,000 to 80,000 cpm. Many drums had fixed alpha contamination on their external surfaces that ranged from 2,000 to greater than $2E+06$ cpm. One drum had radiation levels to 300 mR/hour at contact. Retrieved loose waste was partially contained in deteriorated wooden boxes. Alpha-contamination levels on the loose waste ranged from 4,500 to $2E+06$ cpm. Loose waste, including metal cylinders and glass vials, exhibited beta-gamma contamination. An analysis of contamination in Trench 7, including the liquid in vials, indicated Sr-90 and Cs-137 to levels of 200 mR/hour. Approximately 4.9 m^3 , or 17% of the retrieved volume excluding self-generated waste, comprised alpha- and beta-contaminated soil. The volume of self-generated waste from retrieval operations was 4.3 m^3 or 15% of the retrieved waste volume.

During the 1978 retrieval, 457 drums were retrieved with a volume of 94.5 m^3 . Retrieved loose waste and contaminated soil amounted to 34.4 and 24.3 m^3 , respectively. The self-generated waste from retrieval operations was 17.2 m^3 .

3.1.4.5 Pad A Penetration and Inspection. Penetration and inspection activities conducted in 1978 and 1979 were performed to check the condition of waste placed on the Transuranic Disposal Area, known today as Pad A. Pad A penetration was undertaken to retrieve drums for inspection and sample the soil immediately surrounding them for leakage and contaminant migration. Boxes in Pad A were stacked outside the pad, and drums were stacked inside the perimeter formed by boxes. Penetration into the side of Pad A revealed that boxes were in an advanced state of deterioration. The deteriorated condition of the wooden boxes and concern over safe handling precluded retrieval of any drums. Within the scope of this project, removing drums could not be performed in a safe manner while maintaining control of the spread of contamination.

3.1.5 Summary of Disposals in the Subsurface Disposal Area

The life spans of the disposal units in the SDA are provided in Figure 3-3. Locations of disposals of TRU and LLW in the SDA are shown in Figure 3-4. Transuranic waste from RFP is buried primarily in Pits 1, 2, 3, 4, 5, 6, 9, 10, 11, and 12 and Trenches 1 through 10. Trenches 11 through 15 also may contain TRU waste from RFP. The remainder of the SDA is generally considered LLW. The areas, volumes, and dates of operation for SDA trenches, pits, and SVRs are provided in Tables 3-1 to 3-3. The annual and total disposal inventories for WAG 7 COPCs are listed in Section 4.

3.1.6 Soil Cover and Surface Drainage Maintenance

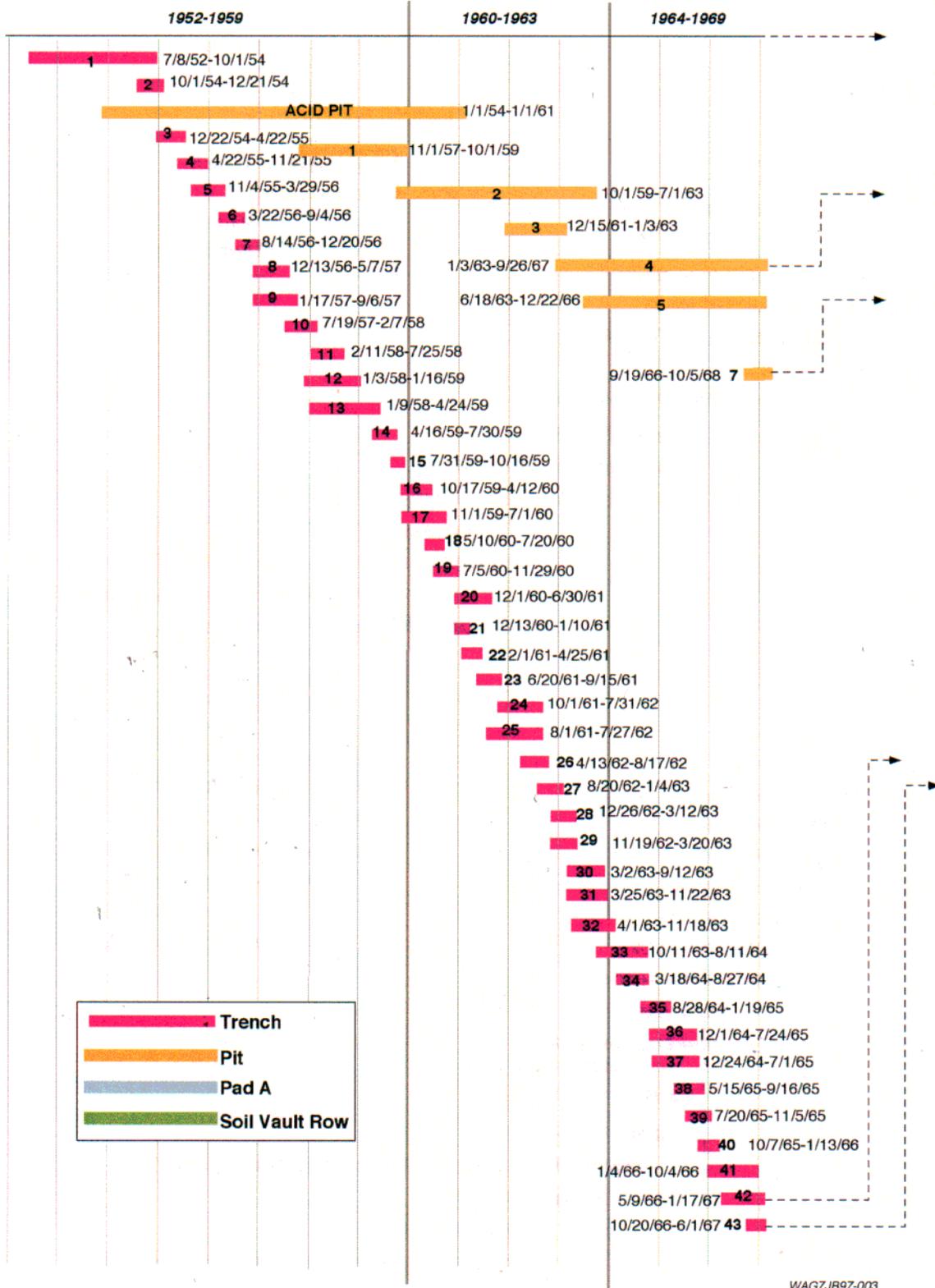
The first trenches were opened for waste disposal at the SDA in 1952. Soil periodically was added over filled trenches. Routine contact-handled waste was dumped into trenches and was not covered until the operating week ended. Nonroutine remote-handled waste deposited into trenches was covered immediately, but records of the earliest burials give no indication of depth of earth cover or limits on radiation emitted after soil was added. In 1962, the standard practice was modified to limit the exposure rate to 1 mR/hour at 0.9 m (3 ft) above the surface and to require at least 0.9 m (3 ft) of soil cover.

Neupauer (1995) discussed SDA soil-cover thickness and cited several references dealing with modifications to soil cover in the SDA. In the most recent report on SDA soil cover, Barnes (1989), summarized the soil cover modifications. Table 3-4 is a reproduction of a table copied from the Barnes (1989) report and shows that soil was added from 1975 to 1979 and again from 1985 to 1987. Total thickness of cover over the pits is a minimum of 1 m (3 ft), while minimum cover over the trenches ranges from 0.5 to 0.9 m (1.5 to 3 ft).

3.1.6.1 Subsidence in the Subsurface Disposal Area. In addition to maintaining surface drainage, subsidence repair is implemented, when needed, to fill holes that appear in the soil cover. Most subsidence occurs in the spring. Subsidence is expected to continue unless measures to eliminate void spaces in the waste zone are implemented.

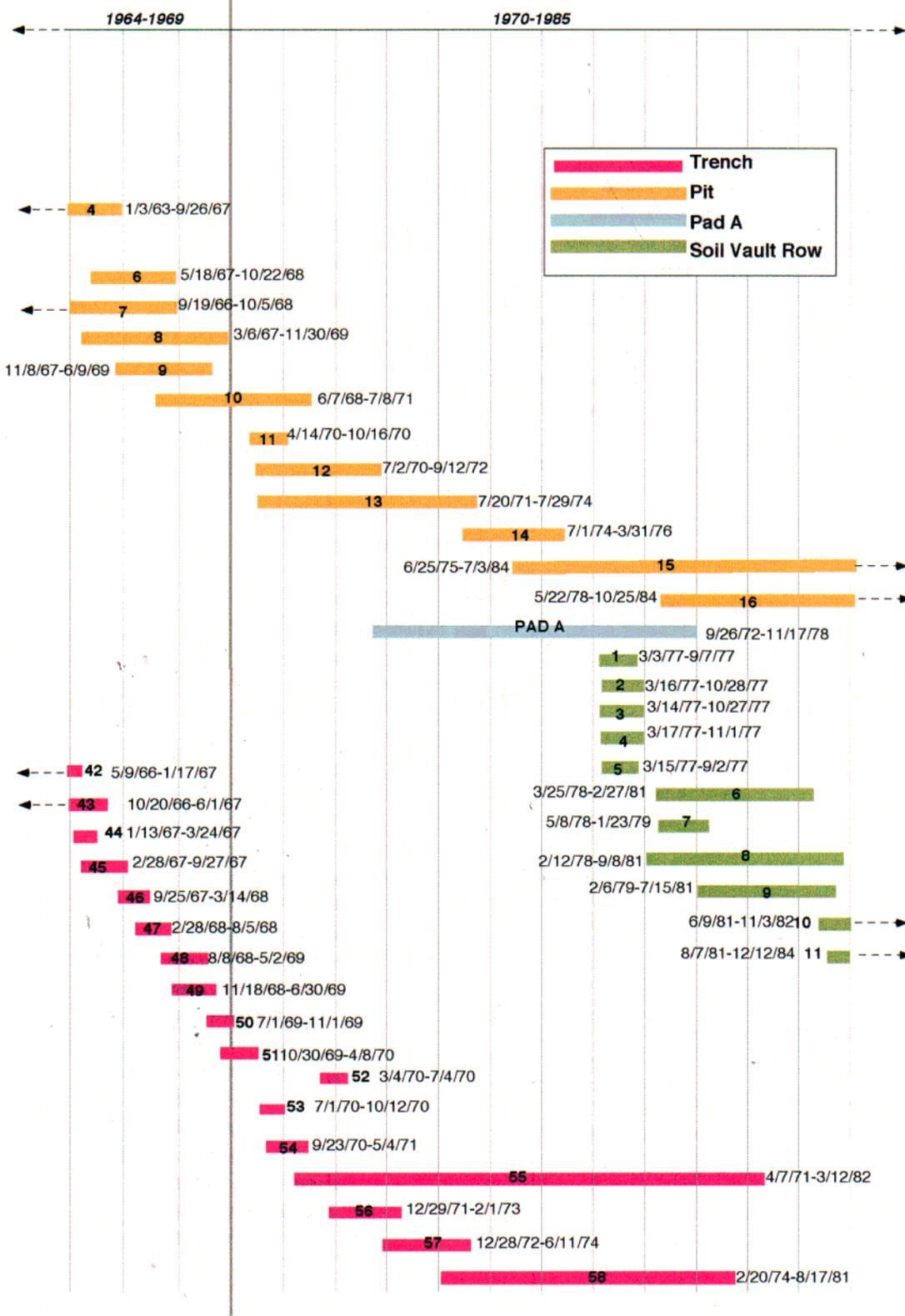
Data collected for subsidence occurrences from 1996 to 2001 are presented in Table 3-5. The number of occurrences ranges from five in 2001 to 17 in 1998. Some areas of subsidence have been long and narrow (101 × 1 m [330 × 4 ft]) and some are almost square (12 × 11 m [39 × 35 ft]). Depths ranged from 8 cm (3 in.) to 4 m (12 ft). Pad A is the only location in the SDA where subsidence is persistent.

Subsidence areas typically are repaired by filling holes with soil obtained from the spreading areas. Soil is hauled to the area, dumped close to the subsidence, and pushed into the hole with a front-end loader. The soil is compacted by hand or by driving a front-end loader over the filled area. During spring thaw, vehicles are prohibited from driving over waste disposal areas in the SDA. Radiation levels were measured below 100 cpm for each occurrence, except in April 2001, when 1,000 cpm was measured at Pit 4.



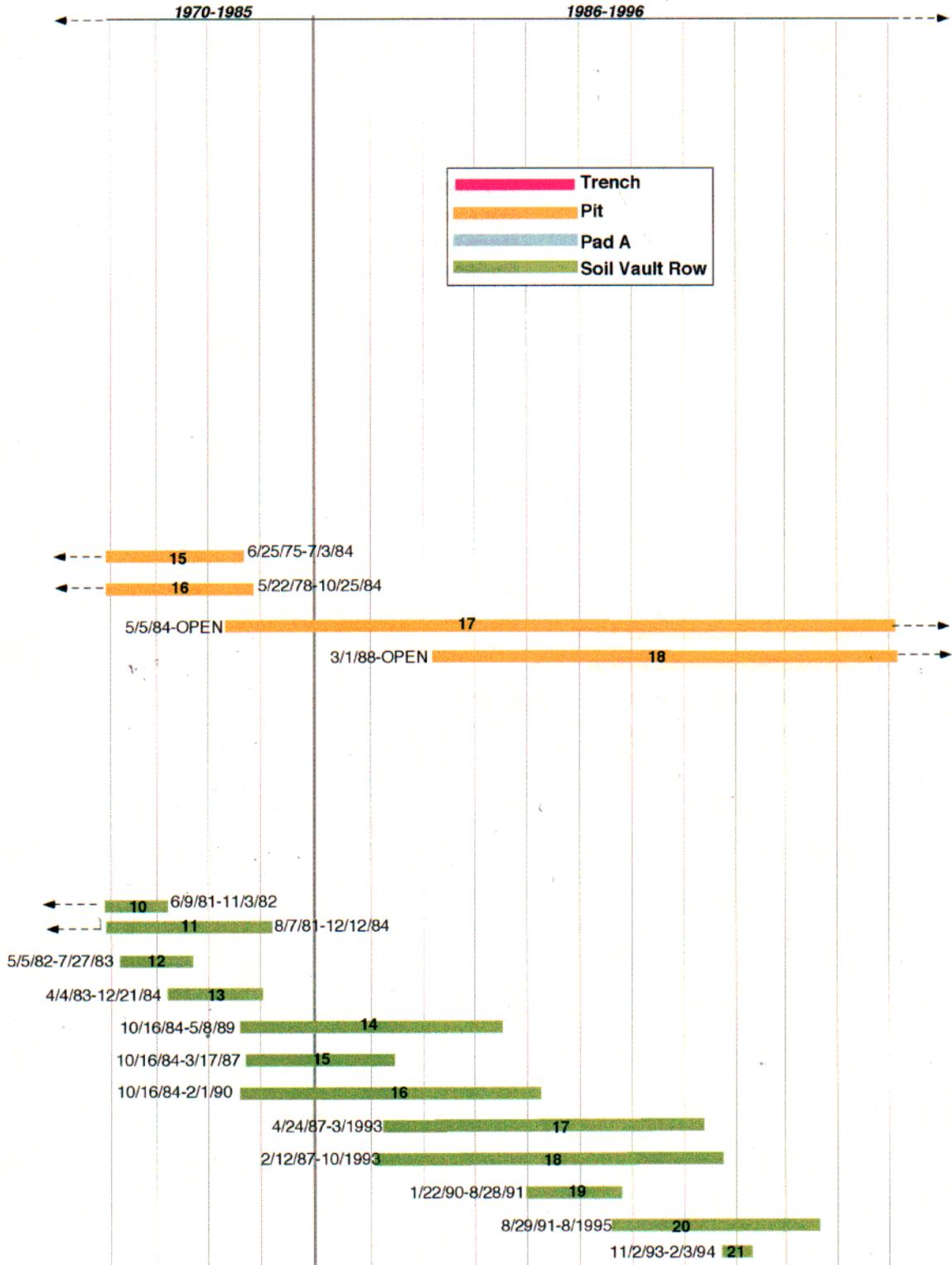
WAG7JB97-003

Figure 3-3. Subsurface Disposal Area life spans of trenches, pits, Pad A, and soil vault rows.



WAG7JB97-003

Figure 3-3. (continued).



WAG7JB97-003

Figure 3-3. (continued).

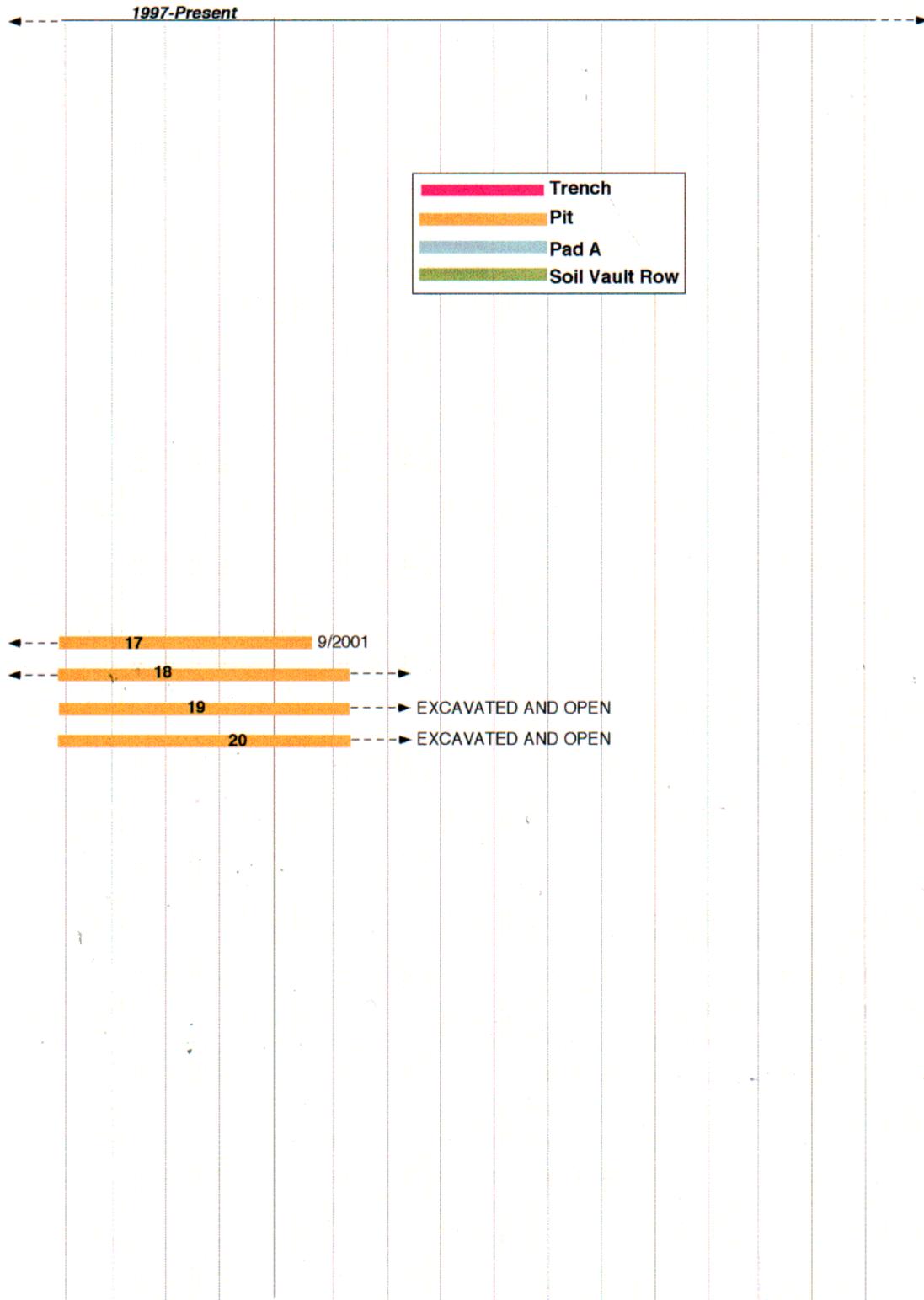


Figure 3-3. (continued).

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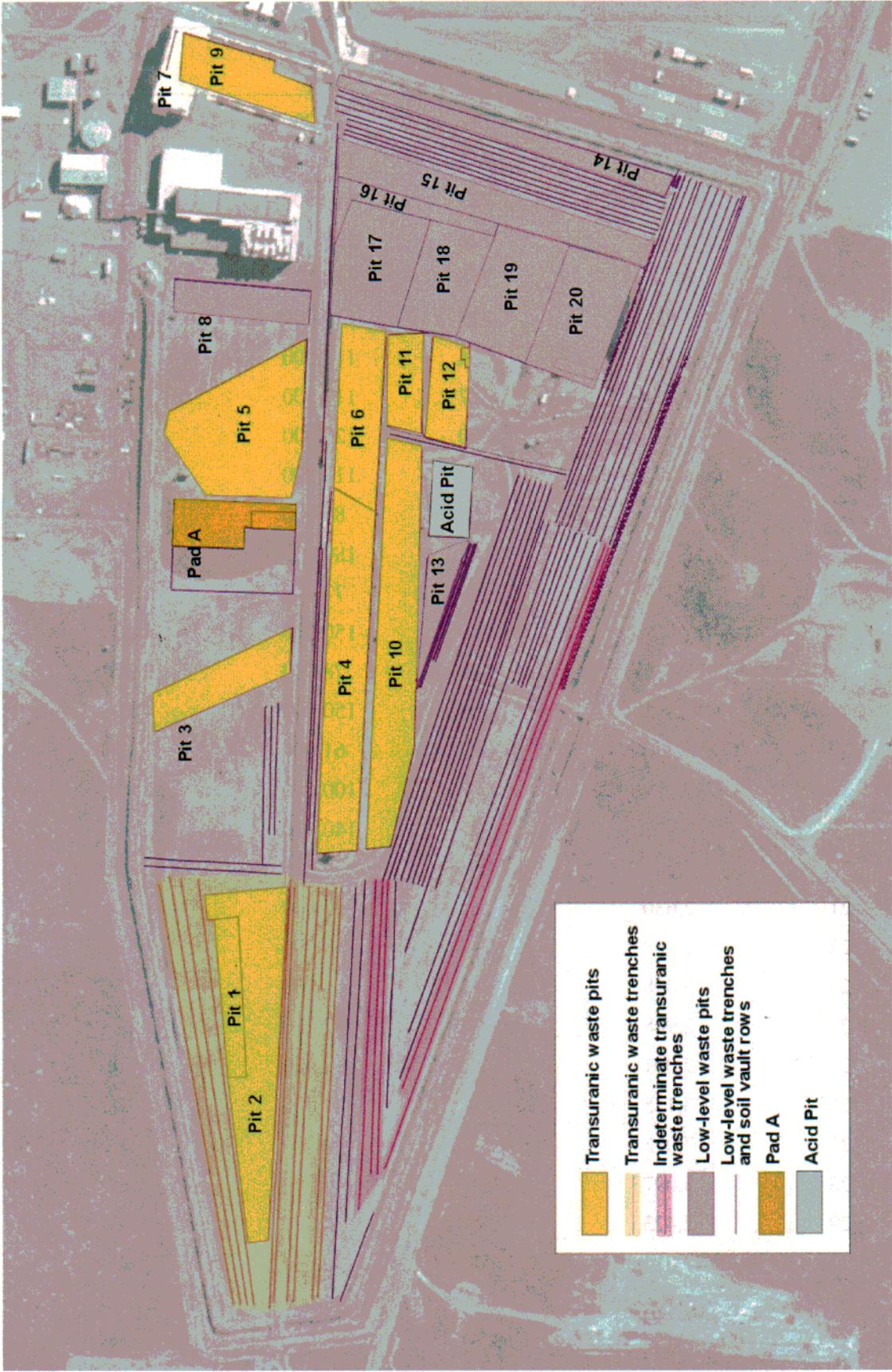


Figure 3-4. Transuranic and low-level waste disposal locations in the Subsurface Disposal Area.

Table 3-1. Areas and volumes of Subsurface Disposal Area trenches including overburden.

| Trench | Area (ft ²) | Area (m ²) | Volume (ft ³) | Volume (m ³) |
|--------|----------------------------|---------------------------|------------------------------|-----------------------------|
| 1 | 8,043 | 747 | 110,000 | 3,100 |
| 2 | 8,015 | 745 | 110,000 | 3,100 |
| 3 | 7,777 | 723 | 110,000 | 3,100 |
| 4 | 7,812 | 726 | 120,000 | 3,400 |
| 5 | 8,155 | 758 | 110,000 | 3,100 |
| 6 | 7,826 | 727 | 110,000 | 3,100 |
| 7 | 8,120 | 754 | 110,000 | 3,100 |
| 8 | 7,826 | 727 | 110,000 | 3,100 |
| 9 | 8,610 | 800 | 120,000 | 3,400 |
| 10 | 8,092 | 752 | 110,000 | 3,100 |
| 11 | 6,279 | 583 | 89,000 | 2,500 |
| 12 | 12,502 | 1,162 | 180,000 | 5,000 |
| 13 | 5,439 | 505 | 77,000 | 2,100 |
| 14 | 10,969 | 1,019 | 150,000 | 4,200 |
| 15 | 5,495 | 511 | 78,000 | 2,200 |
| 16 | 10,801 | 1,003 | 150,000 | 4,200 |
| 17 | 4,270 | 397 | 61,000 | 1,700 |
| 18 | 7,180 | 667 | 100,000 | 2,800 |
| 19 | 9,905 | 920 | 140,000 | 3,900 |
| 20 | 7,000 | 650 | 99,000 | 2,800 |
| 21 | 2,630 | 244 | 37,000 | 1,000 |
| 22 | 2,658 | 247 | 38,000 | 1,100 |
| 23 | 3,098 | 288 | 44,000 | 1,200 |
| 24 | 2,948 | 274 | 42,000 | 1,200 |
| 25 | 7,001 | 650 | 99,000 | 2,800 |
| 26 | 3,115 | 289 | 44,000 | 1,200 |
| 27 | 7,013 | 652 | 99,000 | 2,800 |
| 28 | 3,097 | 288 | 44,000 | 1,200 |
| 29 | 2,423 | 225 | 34,000 | 950 |
| 30 | 7,014 | 652 | 100,000 | 2,800 |
| 31 | 3,104 | 288 | 44,000 | 1,200 |
| 32 | 2,457 | 228 | 35,000 | 980 |

Table 3-1. (continued)

| Trench | Area (ft ²) | Area (m ²) | Volume (ft ³) | Volume (m ³) |
|--------|----------------------------|---------------------------|------------------------------|-----------------------------|
| 33 | 7,013 | 652 | 99,000 | 2,800 |
| 34 | 7,280 | 676 | 100,000 | 2,800 |
| 35 | 7,012 | 94 | 99,000 | 2,800 |
| 36 | 8,610 | 800 | 120,000 | 3,400 |
| 37 | 7,003 | 651 | 99,000 | 2,800 |
| 38 | 6,421 | 597 | 91,000 | 2,500 |
| 39 | 6,993 | 650 | 99,000 | 2,800 |
| 40 | 7,292 | 677 | 100,000 | 2,800 |
| 41 | 7,001 | 650 | 99,000 | 2,800 |
| 42 | 7,952 | 739 | 110,000 | 3,100 |
| 43 | 6,667 | 619 | 95,000 | 2,700 |
| 44 | 3,504 | 326 | 50,000 | 1,400 |
| 45 | 7,959 | 739 | 110,000 | 3,100 |
| 46 | 6,703 | 623 | 95,000 | 2,700 |
| 47 | 7,966 | 740 | 110,000 | 3,100 |
| 48 | 6,685 | 621 | 95,000 | 2,700 |
| 49 | 7,728 | 718 | 110,000 | 3,100 |
| 50 | 6,601 | 613 | 94,000 | 2,600 |
| 51 | 7,987 | 742 | 110,000 | 3,100 |
| 52 | 6,349 | 590 | 90,000 | 2,500 |
| 53 | 8,057 | 749 | 110,000 | 3,100 |
| 54 | 6,373 | 592 | 90,000 | 2,500 |
| 55 | 8,134 | 756 | 110,000 | 3,100 |
| 56 | 8,134 | 756 | 110,000 | 3,100 |
| 57 | 6,346 | 590 | 90,000 | 2,500 |
| 58 | 6,447 | 599 | 91,000 | 2,500 |

a. Initial estimates shown in U.S. Customary System units were obtained from Becker et al. (1996). Width of a typical trench is about 7 ft. Areas are consistent with current GIS data. Depth of trenches is an approximation. Average depth of all the trenches is 15.5 ft including overburden. Volumes were rounded to the closest 1,000 ft³.

Table 3-2. Areas and volumes of Subsurface Disposal Area pits including overburden.

| Pit | Area (ft ²) | Area (m ²) | Volume (ft ³) | Volume (m ³) |
|----------|----------------------------|---------------------------|------------------------------|-----------------------------|
| 1 | 24,913 | 2,315 | 350,000 | 9,800 |
| 2 | 78,425 | 7,286 | 1,100,000 | 31,000 |
| 3 | 41,830 | 3,886 | 590,000 | 16,000 |
| 4 | 107,082 | 9,948 | 1,600,000 | 45,000 |
| 5 | 108,754 | 10,104 | 1,500,000 | 42,000 |
| 6 | 54,984 | 5,108 | 780,000 | 22,000 |
| 7 | 100 | 9 | 400 | 11 |
| 8 | 31,294 | 2,907 | 440,000 | 12,000 |
| 9 | 45,541 | 4,231 | 650,000 | 18,000 |
| 10 | 110,942 | 10,307 | 1,600,000 | 45,000 |
| 11 | 24,859 | 2,310 | 350,000 | 9,800 |
| 12 | 29,910 | 2,779 | 420,000 | 12,000 |
| 13 | 19,290 | 1,792 | 270,000 | 7,600 |
| 14 | 40,704 | 3,782 | 580,000 | 16,000 |
| 15 | 74,805 | 6,950 | 1,100,000 | 31,000 |
| 16 | 22,246 | 2,067 | 310,000 | 8,700 |
| 17 | NA | NA | NA | NA |
| 18 | NA | NA | NA | NA |
| 19 | NA | NA | NA | NA |
| 20 | NA | NA | NA | NA |
| Acid Pit | 21,291 | 1,978 | 300,000 | 8,400 |

NA = not applicable. Low-level waste disposal operations are currently ongoing in Pits 17 through 20.

Initial estimates shown in U.S., Customary System units were obtained from Becker et al. (1996). Areas are consistent with current GIS data. Depth of the pits is an approximation. Average depth of all the pits is 14 ft including overburden. Volumes were rounded to the closest 1,000 ft³.

Table 3-3. Volumes of Subsurface Disposal Area soil vault rows including overburden.

| <u>Soil Vault Row</u> | <u>Volume (m³)^a</u> |
|-----------------------|---|
| 1 | 3.3 |
| 2 | 0.57 |
| 3 | 0.85 |
| 4 | 0.65 |
| 5 | 0.42 |
| 6 | 7.1 |
| 7 | 70 |
| 8 | 14 |
| 9 | 170 |
| 10 | 35 |
| 11 | 9.3 |
| 12 | 25 |
| 13 | 110 |
| 14 | 28 |
| 15 | 180 |
| 16 | 180 |
| 17 | 14 |
| 18 | 23 |
| 19 | 250 |
| 20 | 270 |
| 21 | 0.3 |

a. Gross volumes were taken from LMITCO (1995a).

Table 3-4. Estimated soil cover thickness.

| Disposal Site | Initial Thickness ^a (ft) | Additions 1975 to 1979 ^b (ft) | Additions 1985 to 1987 ^c (ft) | Total Thickness ^d (ft) | Proposed Addition ^e (ft) |
|--|--|--|--|--------------------------------------|---|
| Pit 1 | 1.5 to 2.0 | 1.5 to 2.0 | — | 3.0 to 4.0 | 0 to 1.0 |
| Pit 2 | 2.0 to 3.0 | 1.5 to 2.0 | — | 3.5 to 5.0 | 0 to 1.0 |
| Pit 3 | 2.0 to 3.0 | 2.0 to 3.0 | — | 4.0 to 6.0 | 2.0 to 3.0 |
| Pit 4 | 3.0 | 3.0 to 5.0 | 0 to 1.0 | 6.0 to 9.0 | 0 to 1.0 |
| Pit 5 | 3.0 | 1.0 to 3.0 | 0 to 1.0 | 4.0 to 7.0 | 0 to 1.0 |
| Pit 6 | 3.0 | 3.0 to 5.0 | 0 to 2.0 | 6.0 to 9.0 | 0 to 1.0 |
| Pit 7 | 3.0 | — | 0 to 1.0 | 3.0 to 4.0 | 0 to 1.0 |
| Pit 8 | 3.0 | — | 1.0 to 3.0 | 4.0 to 6.0 | 0 to 1.0 |
| Pit 9 | 3.0 | 2.0 to 3.0 | 0 to 1.0 | 5.0 to 7.0 | 0 to 1.0 |
| Pit 10 | 3.0 | 3.0 to 5.0 | — | 6.0 to 8.0 | 0 to 1.0 |
| Pit 11 | 3.0 | — | 2.0 to 4.0 | 5.0 to 7.0 | 0 to 1.0 |
| Pit 12 | 3.0 | — | 3.0 to 5.0 | 6.0 to 8.0 | 0 to 1.0 |
| Pit 13 | 3.0 | — | 1.0 to 3.0 | 4.0 to 6.0 | 0 to 1.0 |
| Pit 14 to 16 | 3.0 | — | — | 3.0 | 0 to 1.0 |
| Trenches | | | | | |
| 1, 5, 7, 9 | 1.5 to 2.0 | 1.0 to 3.0 | — | 2.5 to 5.0 | 0 to 2.0 |
| 2, 3, 4, 6, 8, 10, 11, 13, 15 | 1.5 to 2.0 | — | 0.5 to 4.0 | 2.0 to 6.0 | 0 to 1.0 |
| 12, 14 | 1.5 to 2.0 | — | 0 to 1.0 | 1.5 to 3.0 | 0 to 1.0 |
| 16, 19, 23, 26, 28, 31, 34, 36 | 2.0 to 3.0 | — | 0.5 to 3.0 | 2.5 to 6.0 | 0 to 1.0 |
| 17, 58 | 2.0 to 3.0 | — | 1.0 to 4.0 | 3.0 to 7.0 | 0 to 1.0 |
| 18, 38 | 2.0 to 3.0 | — | 0 to 1.0 | 2.0 to 4.0 | 0 to 1.0 |
| 20, 25, 27, 30, 33, 35, 37, 39 | 2.0 to 3.0 | — | 1.0 to 2.0 | 3.0 to 5.0 | 0 to 1.0 |
| 21, 22, 24, 29, 32 | 2.0 to 3.0 | — | — | 2.0 to 3.0 | 2.0 to 3.0 |
| 40, 42, 45, 47, 49, 51, 53, 55 | 3.0 | — | 0 to 2.0 | 3.0 to 5.0 | 0 to 1.0 |
| 41, 43, 46, 48, 50, 52, 54, 56, 57 | 3.0 | — | 0 to 1.0 | 3.0 to 4.0 | 0 to 1.0 |
| Acid Pit | 2.0 to 3.0 | — | 2.0 to 4.0 | 4.0 to 7.0 | 0 to 1.0 |
| Pad A | 3.0 | — ^f | — ^f | — ^f | — ^f |
| Soil vault rows | 3.0 | — | 0 to 1.0 | 3.0 to 4.0 | 0 to 1.0 |
| Areas between waste | — | — | 0 to 5.0 | 0 to 5.0 | 0 to 2.0 |

Note: Dash indicates no soil added.

Basis:

a. Initial thickness Barnes (1989) References 8, 11, 22, 42. b. 1975 to 1978 addition (Barnes 1989) Reference 20, Drawings 156168, 158246-7, 196261.

c. 1985 to 1987 addition (Barnes 1989) Reference 45 and comparison of 1980 and 1987 aerial survey contour maps.

d. Proposed addition (Barnes 1989) mark up of Drawing 356697.

e. Does not include soil added in 1970 to 1973, 1980 to 1981, or subsidence maintenance, or soil removed by erosion and animal burrowing (Barnes 1989).

f. Pad A is above grade. Surface repairs are conducted as post-remediation maintenance pursuant to the Record of Decision for Operable Unit 7-12 (DOE-ID 1994e). Subsidence repairs are common on Pad A (see Table 3-5).

Table 3-5. Subsidence data collected from 1996 to 2001 for the Subsurface Disposal Area.

| Location | Length | Width | Average Depth | Maximum Depth | Exposed Waste |
|-------------------------------------|------------|----------------|---------------|---------------|---------------|
| April 2001 | | | | | |
| Mixed Waste (MW) Trench 1 | 40 in. | 12 in. | 24 in. | 8 ft 6 in. | No |
| Low-Level Waste (LLW) Trench 58 | 8 ft | 4 ft | 4 in. | 12 in. | No |
| Pad A (northeast) | 23 ft | 3 ft 6 in. | 4 in. | 36 in. | No |
| Pit 4 | 7 ft 6 in. | 5 ft | 3 in. | 24 in. | No |
| MW Trench 5 | 18 in. | 8 in. | 18 in. | 24 in. | No |
| October 2000 | | | | | |
| LLW Pit 15 fence line | 115 ft | 1/4 to 1/8 in. | 1 in. | 40 in. | No |
| LLW Pit 15 fence line | 15 in. | 12 in. | 10 in. | 40 in. | No |
| MW Trench 47 | 26 in. | 24 in. | 18 in. | 9 ft | No |
| March 2000 | | | | | |
| LLW Pad A (cracks) | 12 ft | 1/2 to 2 in. | 1 to 2 in. | 3 in. | No |
| LLW Pad A (cracks) | 16 ft | 1/2 to 2 in. | 1 to 2 in. | 3 in. | No |
| August 1999 | | | | | |
| MW Pit 4 | 16 ft | 8 ft | 12 in. | 2 ft 6 in. | No |
| June 1999 | | | | | |
| MW Trench 49 | 8 ft | 40 in. | 15 in. | 5 ft. | No |
| April 1999 | | | | | |
| MW Trench 51 | 179 ft | 17 ft | 17 in. | 3 ft | No |
| LLW Pit 15 | 25 ft | 7 ft | 3 ft | 12 ft | Yes |
| LLW Pit 16 fence line | 300 ft | 4 ft | 6 in. | 2 ft | No |
| MW Trench 41 | 18 ft | 20 ft | 12 in. | 18 in. | No |
| MW Pit 12 | 18 ft | 7 ft | 12 in. | 20 in. | No |
| MW Trench 47 | 58 ft | 8 ft | 20 in. | 4 ft | No |
| MW Trench 36 | 8 ft | 10 ft | 6 in. | 8 ft | No |
| MW Trench 36 | 39 ft | 35 ft | 6 in. | 2 ft | No |
| MW Trench 16 | 36 ft | 10 ft | 6 in. | 30 in. | No |
| MW Pit 10 | 35 ft | 30 ft | 6 in. | 10 in. | No |
| MW Pit 10 | 30 ft | 37 ft | 6 in. | 10 in. | No |
| MW Trench 38 | 12 ft | 6 ft | 12 in. | 2 ft | No |
| MW Trench 7 | 26 ft | 9 ft | 6 in. | 8 in. | No |
| MW Trench 7 | 4 ft | 5 ft | 4 in. | 12 in. | No |
| Soil Vault Row (SVR) 18 (by Pit 13) | 18 in. | 16 in. | 14 in. | 16 in. | No |

Table 3-5. (continued).

| Location | Length | Width | Average Depth | Maximum Depth | Exposed Waste |
|---------------------|-------------|-------------|---------------|---------------|---------------|
| June 1998 | | | | | |
| MW Trench 7 | 26 in. | 12 in. | 11 in. | 14 in. | No |
| LLW Trench 58 | 24 in. | 9 in. | 8 in. | 60 in. | No |
| MW Trench 6 | 36 in. | 36 in. | 9 in. | 9 in. | No |
| MW Trench 6 | 112 in. | 7 ft | 20 in. | 24 in. | No |
| MW Trench 6 | 12 ft | 6 ft | 25 in. | 30 in. | No |
| MW Trench 6 | 3 ft | 12 in. | 18 in. | 20 in. | No |
| MW Trench 47 or 49 | 32 in. | 32 in. | 10 in. | 19 in. | No |
| LLW Pit 16 | 18 ft | 36 in. | 18 in. | 18 in. | No |
| MW Trench 58 | 8 ft | 4 ft | 12 in. | 4 ft 6 in. | No |
| MW Trench 14 | 7 ft | 6 ft 6 in. | 12 in. | 5 ft 6 in. | No |
| MW SVR 14 | 15 in. | 15 in. | 16 in. | 16 in. | No |
| MW SVR 14 | 3 ft | 2 ft 6 in. | 12 in. | 16 in. | No |
| MW SVR 14 | 4 ft 6 in. | 40 in. | 32 in. | 32 in. | No |
| MW Trench 45 | 40 ft | 6 ft | 8 in. | 24 in. | No |
| LLW Pad A | 8 in. | 14 ft. | Filled | Filled | No |
| LLW Pad A | 24 in. | 24 in. | 9 in. | 24 in. | No |
| LLW Trench 57 | 21 in. | 21 in. | 5 in. | 8 in. | No |
| MW SVR 17 | 5 ft | 6 ft 4 in. | 8 in. | 14 in. | No |
| MW SVR 17 | 5 ft | 5 ft | 6 in. | 6 in. | No |
| MW SVR 17 | 5 ft 2 in. | 5 ft 5 in. | 5 in. | 5 in. | No |
| MW SVR 17 | 5 ft 4 in. | 5 ft 5 in. | 4 in. | 4 in. | No |
| MW SVR 17 | 5 ft. 5 in. | 5 ft 10 in. | 8 in. | 17 in. | No |
| MW SVR 17 | 5 ft 3 in. | 5 ft 10 in. | 8 in. | 8 in. | No |
| MW SVR 17 | 5 ft | 5 ft | 9 in. | 9 in. | No |
| MW SVR 17 | 4 ft 4 in. | 5 ft | 6 in. | 6 in. | No |
| MW SVR 17 | 5 ft | 7 ft | 12 in. | 12 in. | No |
| MW SVR 17 | 5 ft 3 in. | 5 ft 10 in. | 24 in. | 24 in. | No |
| MW SVR 17 | 6 ft | 7 ft | 5 in. | 15 in. | No |
| MW Trench 45 | 4 ft 7 in. | 9 ft 9 in. | 8 in. | 8 in. | No |
| Gate 26 | 7 ft | 9 ft | 12 in. | 12 in. | No |
| LLW Pad A | 42 ft | 19 to 29 ft | 10 ft | 10 ft | Yes |
| October 1996 | | | | | |
| SVR 17 | 36 in. | 33 in. | 10 in. | 1 ft | No |
| Pad A | 1 ft 17 in. | 17 in. | 2 ft 6 in. | 3 ft | No |
| Pad A | 1 ft 6 in. | 1 ft | 2 ft 6 in. | 3 ft | No |

Table 3-5. (continued).

| Location | Length | Width | Average Depth | Maximum Depth | Exposed Waste |
|----------------------|--------|--------|---------------|---------------|---------------|
| February 1996 | | | | | |
| SVR 17 | 6 ft | 5 ft | 2 ft | 30 in | No |
| Pit 10 | 4 ft | 3 ft | 2 ft | 2 ft | No |
| Pit 10 | 26 in. | 18 in. | 6 in. | 6 in. | No |
| Pit 10 | 23 ft | 15 ft | 18 in. | 3 ft | No |
| Pit 10 | 27 ft | 15 ft | 1 ft | 29 in. | No |
| Pit 10 | 28 ft | 20 ft | 17 in. | 17 in. | No |

3.2 Summary of Waste Area Group 7 Operable Units

As previously mentioned, WAG 7 was subdivided for assessment using criteria that differed from those applied to other WAGs at the INEEL. For example, some OUs in WAG 7 are defined in terms of exposure pathways rather than the physical delineation of units. Site codes also were assigned differently than for other WAGs. The other WAGs were divided into OUs that were further subdivided into sites. Each site was assigned a unique site code. The sites within a given OU, which have similar physical characteristics or operational histories, were grouped into OUs to expedite investigation. Operable Unit 7-11 was the only OU out of the 14 OUs assigned to WAG 7 that was subdivided into sites. The three sites in OU 7-11 are identified as RWMC-01, -02, and -03. The six OUs composing the SDA—OUs 7-01, 7-02, 7-03, 7-10, 7-12, and 7-13—all were given the same site code, RWMC-04. Despite the shared site code, different OUs are addressed with varying levels of investigative rigor (i.e., Track 1 and Track 2 investigations, interim actions, and RI/FS). The only other WAG site code, RWMC-05, was assigned to the Track 1 investigation of historical releases in the TSA, also known as OU 7-09. Operable Unit 7-14, the comprehensive RI/FS, has been combined with the RI/FS for pits and trenches, OU 7-13 and is now OU 7-13/14 (see Section 1.3). Three other site codes address specific exposure pathways, and two OUs address the vadose zone beneath the RWMC.

Three of the 14 WAG 7 OUs were designated for Track 1 investigation, six were designated for Track 2 investigation, one was designated for interim action, and four were designated for an RI/FS. Most OUs were evaluated to some extent before the start of work on the OU 7-13/14 comprehensive RI/FS. Many of the investigations were initiated under the Consent Order and Compliance Agreement (DOE-ID 1987). Therefore, the Track 1 and 2 investigations were in progress when the FFA/CO (DOE-ID 1991) was signed, and most were completed before the DOE guidance documents (DOE-ID 1992, 1994b) for such evaluations were complete. All but OU 7-11, septic tanks and drain fields, were rolled into the OU 7-13/14 comprehensive RI/FS. The OU sites, classifications, and brief descriptions are given in Table 3-6. The descriptions include brief summaries of the completed CERCLA investigations. Additional information about each WAG 7 OUs is presented in subsequent subsections.

Table 3-6. Operable units and sites in Waste Area Group 7.

| Operable Unit | Description and Summary | Classification | Site Code |
|---------------|--|----------------|---------------|
| 7-01 | Subsurface Disposal Area (SDA) soil vaults. The Track 2 investigation (Burns, Becker, and Jones 1994) evaluated only soil vault rows SVRs 1 through 13. Assessment of SVRs 14 through 20 was deferred to the comprehensive remedial investigation and feasibility study (RI/FS) (Operable Unit [OU] 7-14). The investigation, based on existing data, identified potential unacceptable risks. Because existing data were not sufficient to make remedial decisions, the OU was slated for combination with the OU 7-13 or OU 7-14 RI/FS. | Track 2 | RWMC-04 |
| 7-02 | SDA Acid Pit. A result of the Track 2 investigation (Jorgensen et al. 1994) was identifying potential unacceptable risks from mercury in the groundwater ingestion pathway. The decision to roll the OU into the transuranic (TRU) waste pits and trenches RI/FS (OU 7-13) was based on large uncertainties in several sensitive parameters used in the Track 2 risk assessment. In 1997 the Acid Pit was grouted as part of a treatability study (Loomis, Zdinak, and Jessmore 1998). The Acid Pit was evaluated further in the Interim Risk Assessment (IRA) (Becker et al. 1998) based on additional studies to reduce the uncertainties, and the site was subsequently eliminated from further evaluation (DOE-ID 1998b). | Track 2 | RWMC-04 |
| 7-03 | Non-TRU-contaminated waste pits and trenches. The Track 1 investigation (EG&G 1993a) evaluated existing data for three of 18 pits, 26 of 58 trenches, and none of the SVRs. Potential unacceptable risks were identified for multiple radioactive and nonradioactive constituents. Therefore, the OU was rolled into the TRU pits and trenches RI/FS (OU 7-13). | Track 1 | RWMC-04 |
| 7-04 | Air pathway. The Track 2 preliminary scoping screening (LMITCO 1994a) evaluated air pathway exposures for the entire SDA (pits, trenches, and soil vaults). Potential unacceptable risks were identified for Am-241 and carbon tetrachloride. The OU was retained for further evaluation using more refined techniques in the pits and trenches RI/FS (OU 7-13) and the comprehensive RI/FS (OU 7-14). | Track 2 | None assigned |

Table 3-6. (continued).

| Operable Unit | Description and Summary | Classification | Site Code |
|---------------|--|----------------|---------------|
| 7-05 | <p>Surface water pathways and surficial sediments. Potential unacceptable risks by Cs-137 external exposure were identified for both occupational and residential scenarios (Burns, Loehr, and Waters 1993). The action determination (DOE-ID 1994c) preserved the OU for the pits and trenches RI/FS (OU 7-13) and the comprehensive RI/FS (OU 7-14) to ensure further evaluation for surface water pathways and surficial sediments associated with the SDA.</p> | Track 2 | None assigned |
| 7-06 | <p>Groundwater pathway. Previously acquired information and data collected under the Track 2 investigation (Burgess, Higgs, and Wood 1994) were used to evaluate the groundwater contamination associated with Radioactive Waste Management Complex (RWMC) operations. The action determination (DOE-ID 1994a) for OU 7-06 calls for continued monitoring of groundwater and further evaluation of risk in the pits and trenches RI/FS (OU 7-13) and the comprehensive RI/FS (OU 7-14).</p> | Track 2 | None assigned |
| 7-07 | <p>Vadose zone radionuclides and metals. The only exposure pathway associated with this OU is groundwater ingestion. Unacceptable risks for total nitrogen and several radionuclides were identified in the Track 2 investigation (LMITCO 1994b), which included a summary of the results of the Preliminary Scoping Risk Assessment (PSRA) (Loehr et al. 1994) and the Revised Preliminary Scoping Risk Assessment (Burns et al. 1994). Therefore, the OU was retained for more refined assessment in the pits and trenches RI/FS (OU 7-13) and the comprehensive RI/FS (OU 7-14).</p> | Track 2 | None assigned |
| 7-08 | <p>Vadose zone organics. The organic contamination in the vadose zone (OCVZ) RI/FS (Duncan, Troutman, and Sondrup 1993) identified unacceptable carcinogenic and noncarcinogenic risks. A remedial action to remove vapors using vapor vacuum extraction was implemented and is currently in progress. Data obtained from the OCVZ project were incorporated into the comprehensive RI/FS (OU 7-14).</p> | RI/FS | None assigned |

Table 3-6. (continued).

| Operable Unit | Description and Summary | Classification | Site Code |
|---------------|---|----------------|-------------------------------|
| 7-09 | Transuranic Storage Area (TSA) releases. This Track 1 investigation (EG&G 1993b) evaluated the risk potential from radionuclide, organic, and inorganic contamination resulting from historical TSA operations. Insufficient data were available to support a decision; therefore, the OU was deferred to the OU 7-14 comprehensive RI/FS for additional evaluation. Subsequently, however, further assessment of OU 7-09 was delayed until after the TSA facility is closed (DOE-ID 1998b). | Track 1 | RWMC-05 |
| 7-10 | Pit 9 process demonstration. A preliminary risk assessment (McClellan, del C. Figueroa, and King 1991) supported the classification of Pit 9 as an interim action. The remedy selected and documented in the Pit 9 Record of Decision (ROD) (DOE-ID 1993) includes physical separation, treatment, and stabilization of Pit 9 waste. The Pit 9 ROD was modified in 1998 (DOE-ID 1998a) to a revised, three-staged approach for implementing the remedy. Stage I focused on subsurface characterization and has largely been completed. Stage II, involving limited retrieval, is ongoing. Stage III is full-scale retrieval of TRU waste in Pit 9. | Interim action | RWMC-04 |
| 7-11 | Septic tanks and drain fields. This OU comprises three septic systems within the RWMC, two in the administrative area and one in the TSA. The Track 1 investigation found no unacceptable risks. A no further action determination (EG&G 1993c) was signed, and the OU was eliminated from further study in the comprehensive RI/FS (OU 7-14). | Track 1 | RWMC-01 RWMC-02 RWMC-03 |
| 7-12 | Pad A. The Pad A RI/FS (Halford et al. 1993) identified potentially unacceptable future scenario risks caused by ingestion of nitrate-contaminated groundwater. The ROD (DOE-ID 1994e) documented the remedial action selected for the OU, which consisted of augmenting and maintaining the existing soil cover, monitoring environmental media, and continuing institutional control indefinitely. The decision to include this OU in the comprehensive RI/FS (OU 7-14) was based on the revised Pad A inventory documented in the Historical Data Task (LMITCO 1995a) and the requirement to assess cumulative risk in the comprehensive RI/FS. | RI/FS | RWMC-04 |

Table 3-6. (continued).

| Operable Unit | Description and Summary | Classification | Site Code |
|---------------|---|----------------|-----------|
| 7-13 | Transuranic pits and trenches. The Preliminary Scoping Risk Assessment (Loehr et al. 1994) and the Revised PSRA (Burns et al. 1994), in conjunction with the information from the assessments of the other OUs in WAG 7, revealed the implausibility of evaluating risks for the SDA solely based on the exposure pathway or segregated source terms. Therefore, this OU was combined with OU 7-14 (Huntley and Burns 1995), for the OU 7-13/14 comprehensive RI/FS. | RI/FS | RWMC-04 |
| 7-13/14 | Waste Area Group 7 Comprehensive RI/FS. The OU 7-13 RI/FS was combined with OU 7-14 (Huntley and Burns 1995). To become the OU 7-13/14. The comprehensive RI/FS addresses cumulative risks associated with the RWMC. With the exception of OUs 7-02 and 7-11, all of the OUs listed above are considered in the evaluation. | RI/FS | NA |

3.2.1 Operable Unit 7-01, Subsurface Disposal Area Soil Vaults, Track 2 Investigation

In the OU 7-13/14 RI/FS Work Plan (Becker et al. 1996), 21 SVRs were identified within the SDA. However, the OU 7-01 Track 2 investigation (Burns, Becker, and Jones 1994) addressed only those disposals occurring from 1952 to 1983 and buried in SVRs 1 through 13. Waste generated after 1983 and buried in SVRs 14 through 21 meets current RWMC waste acceptance criteria and is not included in the definition of OU 7-01. The total inventory from all SVRs is evaluated in this ABRA. Except as noted otherwise, the information below was taken from the Track 2 Summary Report (Burns, Becker, and Jones 1994), which indicated that all soil vaults would be reanalyzed in the OU 7-13/14 comprehensive RI/FS.

As discussed in Section 3.1.2.4, soil vault disposal began in 1977 to conserve the disposal space available within the RWMC and to minimize personnel exposures to ionizing radiation (EG&G 1985). The soil vaults were designed for the disposal of high-radiation waste, defined as materials producing a beta-gamma exposure rate of greater than 500 mR/hour at a distance of 0.9 m (3 ft). The soil vaults are unlined, vertical, cylindrical borings ranging from 0.4 to 2 m (1.3 to 6.5 ft) in diameter and averaging about 3.6 m (12 ft) deep. When basalt was penetrated during drilling of the soil vault, at least 0.6 m (2 ft) of soil was placed in the hole to cover the bedrock underlying the vault. Soil vaults are drilled in precise rows with individual vaults separated from their neighboring vaults in the same or adjacent rows by a minimum of 0.6 m (2 ft). The SVRs are scattered throughout the southern two-thirds of the SDA.

After waste containers are placed in a soil vault, the vault is covered with several feet of soil. Two general requirements govern the thickness of soil cover that must be applied: (a) the soil must be at least 0.9 m (3 ft) thick and (b) the exposure rate above the covered vault must be less than 1 mR/hour at the soil surface. According to RWMC personnel, much more than 0.9 m (3 ft) of space is usually left for the soil cover. Though records of exact soil cover thicknesses are not maintained, most soil vaults have at least 1.8 m (6 ft) of cover.

The Track 2 evaluation of SVRs 1 through 13 (Burns, Becker, and Jones 1994) was based on existing inventory data and new samples were not collected from the SVRs. A semiquantitative risk evaluation in the Track 2 investigation addressed a current occupational scenario and residential exposure

scenarios for 30, 100, and 1,000 years in the future. External exposure to ionizing radiation was the only exposure pathway of potential concern identified for the current occupational scenario. External exposure to ionizing radiation and ingestion of groundwater were considered for the three residential evaluations. All other exposure scenarios and exposure routes were eliminated from evaluation based on the Track 2 Summary Report results. Radionuclides were the only COPCs identified for OU 7-01. Curie totals were compiled from the Radioactive Waste Management Information System (RWMIS) database and decayed from the time of disposal to the time of evaluation. All COPCs were evaluated for the external exposure scenarios using the computer code MICROSIELD to estimate the exposure rates to occupational and residential receptors. The input parameters and model output are presented in Burns, Becker, and Jones (1994). The modeling incorporated the assumption that the vaults are covered by a minimum of 1.8 m (6 ft) of soil. The Track 2 upper-bound risk estimate for current occupational external exposure is $7\text{E}-03$ (Burns, Becker, and Jones 1994). Estimated upper-bound risks for the 30-, 100-, and 1,000-year residential external exposure scenarios are $9\text{E}-04$, $7\text{E}-07$, and $6\text{E}-13$, respectively.

The COPCs were screened further for the evaluation of groundwater ingestion risks based on a calculated 50-year travel time from the soil surface to the water table. Modeling by GWSCREEN (Rood 1994) was performed for isotopes with estimated inventories greater than $1\text{E}-10$ Ci after 50 years of decay. The groundwater transport parameters, slope factors, and model output are given in Burns, Becker, and Jones (1994). The estimated upper-bound risk within the 30- to 1,000-year residential evaluation period is $5\text{E}-06$ for groundwater ingestion.

As a result of the Track 2 scoping activities (Burns, Becker, and Jones 1994), DOE-ID, EPA, and IDEQ determined that OU 7-01 should be included in an RI/FS (DOE-ID 1995). The decision was based on the potentially unacceptable risk from direct exposure to ionizing radiation and the need for further evaluation of biotic intrusion, erosion, and deposition risk potentials. Because existing data were not sufficient to make final remedial decisions, the OU was retained for further evaluation in the OU 7-14 comprehensive RI/FS.

3.2.2 Operable Unit 7-02, Acid Pit, Track 2 Investigation

The RWMC Acid Pit is a $1,900\text{-m}^2$ ($20,490\text{-ft}^2$) area near the center of the SDA between Pits 12 and 13, and is roughly rectangular with dimensions of 60×32 m (197×104 ft). The Acid Pit was established in 1954 outside the original 13-acre landfill. The pit was excavated down to basalt, which ranged in depth from 4.6 to 6.4 m (15 to 21 ft) below surface. The basalt was then covered with soil to a thickness of 0.3 to 0.6 m (1 to 2 ft) before disposal operations began. According to the RWMIS database, liquid waste was disposed of in the Acid Pit regularly from 1954 until 1961, and the pit may have received additional waste sporadically until the early 1970s (Jorgensen et al. 1994). Final closure operations in 1961 included filling the pit with a soil cover of a minimum of 0.9 m (3 ft) thick to match the local gradient and planting an overlying vegetation layer of crested wheatgrass. Additional soil up to 0.5 m (1.5 ft) thick has been placed in recent years for routine contouring and subsidence control.

The RWMC Acid Pit received liquid organic and inorganic waste. Some of the waste was contaminated with low-level radioactivity. Though records for historical disposals are incomplete, most of the waste buried in the Acid Pit was probably generated at the INEEL. Personnel interviews and record searches indicate that the waste liquids include carbon tetrachloride, organic solvents, radiologically contaminated acids, and cleaning solutions. Radiologically contaminated waste probably contains low levels of uranium, Sr-90, Cs-137, Co-60, and TRU isotopes. Typically, liquid waste was poured directly into the pit. Lime was sometimes added to neutralize acids. Waste disposal records were researched as part of the Acid Pit characterization effort. All records were tabulated from shipping manifests and evaluated under the Track 2 investigation. The complete disposal list appears in the Track 2 Summary Report (Jorgensen et al. 1994).

The Track 2 evaluation (Jorgensen et al. 1994) was conducted before the Track 2 guidance document (DOE-ID 1994f) was available. Uncertainties associated with several parameters required for fate and transport modeling led to numerous conservative assumptions, producing a hazard quotient (HQ) of 1,210 associated with the ingestion of mercury-contaminated groundwater. The surrogate mercury compound used in modeling and the distribution coefficient or K_d value used in risk calculations represented a mercury species that is soluble with virtually no partitioning to subsurface soil (Jorgensen et al. 1994). Based on the Track 2 evaluation, DOE-ID, EPA, and IDEQ concluded that the Acid Pit should be investigated further in an RI/FS. The Action Determination (DOE-ID 1994b) was based on the uncertainties associated with the HQ of 1,210 for the ingestion of mercury-contaminated groundwater. At that time, OU 7-02 was included for additional study and refined risk assessment in the OU 7-13/14 comprehensive RI/FS.

The K_d s and contaminant concentrations used in the Track 2 investigation were reviewed.^c The sample and concentration data indicated that mercury is not mobile in the Acid Pit environment, according to the review conclusion.

While the assumptions used in the Track 2 evaluation bounded the risk, the results were overly conservative to the degree they may drive a remedial action for the Acid Pit that is not warranted (DOE-ID 1994b). Substantial evidence supports the conclusion that Acid Pit risks should be assessed in the OU 7-13/14 comprehensive evaluation using a more realistic contaminant concentration and a more appropriate K_d (Jorgensen et al. 1994).

Additional studies included assessing the chemical form of mercury in the Acid Pit through secondary ion mass spectrometry,^d reviewing the disposal mass, and identifying a more appropriate K_d . The conclusion of these studies was that the unidentified chemical forms of mercury in the Acid Pit have limited mobility. The results were used to support the development of the IRA (Becker et al. 1998). As a consequence, mercury was eliminated as a COPC for WAG 7 and the Acid Pit was eliminated from further evaluation in the OU 7-13/14 comprehensive RI/FS. The various studies associated with the Acid Pit are summarized in the IRA (Becker et al. 1998).

In 1997, a CERCLA treatability study (Loomis, Zdinak, and Jessmore 1998) was conducted at the Acid Pit. The areas of highest mercury concentration were targeted and immobilized by grouting. A 4.3 × 4.3-m (14 × 14-ft) section near the center of the pit was treated. The average bottom depth in the area was about 4.9 m (16 ft). Approximately the lower 2.1 m (7 ft) were grouted. The total volume of grout applied, through 68 penetrations of the subsurface, was 12,473 L (3,295 gal). Following a curing period, 10 core holes were drilled to evaluate the success of the grouting. The cored material was tested by a toxicity characteristic leaching procedure for mercury and was evaluated for extent of mixing. The area was covered with soil and contoured to prevent ponding. The area was then planted with grass. In 2002, all that remains of most of the contamination at OU 7-02 is a grout monolith. Complete details about the Acid Pit grouting are available in the treatability study report (Loomis, Zdinak, and Jessmore 1998).

c. Dicke, C. A., Interdepartmental Communication to K. J. Holdren, May 6, 1997, "Review of the Track 2 Summary Report for the Radioactive Waste Management Acid Pit and Interpretation of the Acid Pit Secondary Ion Mass Spectrometry Analysis," CAD-01-97, Idaho National Engineering and Environmental Laboratory, Lockheed Martin Idaho Technologies Company, Idaho Falls, Idaho.

d. Groenewold, G. S., 1997, Interdepartmental Communication to D. K. Jorgensen, March 21, 1997, "Scoping Studies to Identify Forms of Mercury in Acid Pit Soil Samples," GSG-10-97, Idaho National Engineering and Environmental Laboratory, Lockheed Martin Idaho Technologies Company, Idaho Falls, Idaho.

3.2.3 Operable Unit 7-03, Nontransuranic-Contaminated Waste Pits and Trenches, Track 1 Investigation

Historical waste disposal records were examined to classify pits and trenches according to the category of waste in them. Disposal areas with TRU concentrations greater than 10 nCi/g were assigned to OU 7-13 and combined with the comprehensive RI/FS as OU 7-13/14. Those with TRU concentrations no greater than 10 nCi/g were assigned to OU 7-03 and evaluated according to Track 1 guidance (DOE-ID 1992). The OU 7-03 Track 1 investigation (EG&G 1993a) focused on evaluating existing data for two of the 18 pits and 26 of the 58 trenches, which comprised Pits 7 and 8 and Trenches 18, 21 through 25, 27 through 31, 33, 35 through 38, 40 through 44, 46, 50, 53, 54, 57, and 58. The SVRs were not addressed.

Most of the waste in the non-TRU pits and trenches was generated at the INEEL. The historical disposal practices discussed in Section 3.2 are descriptive of the OU 7-03 disposals. Typically, soil was excavated to basalt, soil underburden was placed before the disposal process began, and a final soil cover was added when each disposal site was closed. The opening and closing dates are listed in Figure 3-3, and the areas and volumes for each excavation are listed in Tables 3-1 through 3-3.

Radioactive constituents were evaluated in the Track 1 investigation (EG&G 1993a). Existing data were not sufficient to quantify risk from nonradioactive hazardous substances, but the Track 1 risk summary report (EG&G 1993a) indicated that soil-gas data and other information suggested that contaminants might be migrating from OU 7-03. Radioactive constituent quantities were taken from the RWMIS database and adjusted for decay. The estimated concentration for each COPC was compared to the soil concentration that would generate a 1E-06 risk in each standard Track 1 pathway and scenario specified in the Track 1 guidance (DOE-ID 1992). If an estimated concentration was greater than the calculated risk-based soil concentration, a potential unacceptable risk was identified.

Potential unacceptable risks were identified for multiple radioactive constituents in a variety of pathways and scenarios. Therefore, the Action Determination, signed by representatives of DOE-ID, EPA, and IDEQ and attached to the Track 1 risk summary (EG&G 1993a), assigned the OU to further evaluation in the OU 7-13 TRU pits and trenches RI/FS.

3.2.4 Operable Unit 7-04, Air Pathway, Track 2 Investigation

Operable Unit 7-04, described as the air pathway, represents an exposure pathway rather than a discrete site. A summary report was not prepared for OU 7-04. Instead, the Track 2 evaluation was limited to the preparation of an abbreviated scoping package (LMITCO 1994a). All of the pits, trenches, and soil vaults in the entire SDA, were considered in the evaluation except Pad A, which was assessed under OU 7-12. Two release mechanisms were addressed: (a) volatilization of volatile organic compounds (VOCs) to the atmosphere and (b) biotic transport of contaminants from the waste to the surface followed by suspension of radionuclide-contaminated surface soil.

The Track 2 investigation (LMITCO 1994a) included only a summary of existing data and previously conducted risk assessments, except for the risk from radon gas. The maximum risk from radon gas was determined to be 3E-06. The VOC source term and risk assessment were taken from the Organic Contamination in the Vadose Zone (OCVZ) RI/FS report (Duncan, Troutman, and Sondrup 1993). The remaining source term, consisting of non-VOC hazardous contaminants and inventories of radioactive isotopes, came from a draft version of the Historical Data Task (HDT). The HDT addressed disposals only through 1983 and did not include Pad A. The risk analysis for the HDT source term came from the Preliminary Scoping Risk Assessment (PSRA) (Loehr et al. 1994), which was superseded by the Revised PSRA (Burns et al. 1994) for the SDA. The Revised PSRA was based on modified HDT inventory.

Surface soil concentrations available for windborne transport of fugitive dust were provided by the sampling conducted in support of a study of the OU 7-05 surface water and surficial sediment pathway (Burns, Loehr, and Waters 1993).

Potential risks from VOCs were estimated in the OCVZ RI/FS (Duncan, Troutman, and Sondrup 1993). The OCVZ RI/FS addressed occupational and residential exposure scenarios using standard parameters to estimate carcinogenic and noncarcinogenic risks from VOCs. Potential unacceptable risks were identified for both occupational and residential receptors for inhalation pathways. Though carbon tetrachloride was the only contaminant identified in the Track 2 evaluation with a carcinogenic risk in excess of $1E-06$ or an HQ greater than 1, the OCVZ RI/FS also identified trichloroethylene (TCE) as a COPC. For the occupational scenario, the maximum inhalation risk and HQ for carbon tetrachloride were $6E-05$ and 2, respectively. The maximum occupational inhalation risk for TCE was $4E-06$. A TCE HQ could not be estimated because reference doses were not available. The maximum inhalation risks for the residential scenario were $3E-05$ and $8E-06$ for carbon tetrachloride and TCE, respectively. The residential HQ for carbon tetrachloride was 5.

The PSRA modeled biotic transport of nongaseous radionuclides from a waste disposal location to the ground surface followed by suspension and transport of airborne fugitive dust. Residential risks were estimated for 30-year intervals every 100 years for the period of 100 to 1,000 years in the future. Occupational risks were estimated for the 100-year institutional control period (DOE M 435.1-1). Standard Track 2 exposure parameters were applied. The Track 2 Summary Report (LMITCO 1994a), citing the results from Loehr et al. (1994) and Burns et al. (1994), indicated maximum potential risks of $1E-06$ for Pu-239 and $3E-06$ for Am-241. Estimated inhalation pathway risks for all other radionuclides were less than $1E-06$. Details on the risk assessment are available in the PSRA reports (Loehr et al. 1994; Burns et al. 1994).

Because of the potential unacceptable risks discussed above, the air pathway OU was retained for further evaluation. As stated in the Action Determination attached to the Track 2 evaluation, the air pathway is to be assessed in the BRA of the OU 7-13/14 RI/FS (LMITCO 1995c).

3.2.5 Operable Unit 7-05, Surface Water Pathways and Surficial Sediments, Track 2 Investigation

Operable Unit 7-05 comprises the surficial sediments to a depth of 0.3 m (1 ft) and deeper sediment sequences deposited by surface water run-off within the local drainage basin of the RWMC. Elements of the Track 2 investigation (Burns, Loehr, and Water 1993) included examining historical data, designing a sample plan based on the historical studies, sampling surficial sediments within WAG 7, and assessing risk based on the Track 2 samples.

Radionuclide and nonradioactive data were available from previous investigations. Analyses of soil samples for hazardous nonradioactive constituents did not yield evidence of contamination. However, alpha- and gamma-emitting radionuclides were detected at sufficiently high levels to warrant further evaluation (Burns, Loehr, and Waters 1993). Therefore, the Track 2 sampling focused on the collection of sediment samples from drainage and ponding areas not addressed in previous sampling programs.

Soil samples were collected from 42 locations within WAG 7 and analyzed for alpha- and gamma-emitting isotopes by spectroscopy. Because beta-emitters were not identified as COPCs for OU 7-05, beta analysis was not performed. Alpha-emitting isotopes Pu-239 and Pu-238/Am-241, Pu-238/Am-241 (Pu-238 and Am-241 were reported together in the Track 2 investigation) at three of 42 sample locations were detected at concentrations above Track 1 guidance background values (DOE-ID 1992). Compared to the Track 1 Pu-239 background value of 0.13 pCi/g, concentrations

ranging from 0.18 to 0.93 were detected. The isotopes Pu-238/Am-241 were detected in a range from 0.126 to 0.49 pCi/g compared to the Track 1 background values of 0.0024 pCi/g for Pu-238 and 0.008 pCi/g for Am-241. Concentrations of Th-230 and Th-232 also were detected in concentrations slightly above background values. Concentrations of all other alpha-emitting isotopes were consistent with background values. One location yielded a Cs-137 concentration of 2.23 pCi/g. The Track 1 background value for Cs-137 is 1.3 pCi/g. All other gamma-emitting isotopes were below background concentrations.

Cesium-137, Pu-239, Pu-238, and Am-241 were considered in the Track 2 risk evaluation for OU 7-05. Evaluation of Th-230 and Th-232 was deferred to WAG 10. Estimated risks from external exposure to Cs-137 for the occupational and residential scenarios were 3E-05 and 2E-05, respectively. Estimated risks for all other contaminants, regardless of the exposure scenario or pathway, were less than 1E-06 (Burns, Loehr, and Waters 1993).

Because a potential for unacceptable risks was identified, DOE-ID, EPA, and IDEQ retained OU 7-05 for further evaluation. The action determination for OU 7-05 (DOE-ID 1994c) specified that the surface water pathway (see Section 4 for updated monitoring data) would be assessed in the OU 7-13 pits and trenches RI/FS and OU 7-14 comprehensive RI/FS.

3.2.6 Operable Unit 7-06, Groundwater Pathway, Track 2 Investigation

The characteristics of an exposure pathway rather than potential risks from a discrete source were examined in the OU 7-06 Track 2 investigation. However, the focus of the OU 7-06 Track 2 investigation was unique. Rather than estimating potential risks, the evaluation was designed to identify groundwater pathway data gaps, determine optimal data collection schemes to address the data gaps, and initiate data collection programs. Risks from groundwater were evaluated both in the PSRAs (Loehr et al. 1994; Burns et al. 1994) and in the *WAG 7 Groundwater Pathway Track 2 Summary Report* (Burgess, Higgs, and Wood 1994). The overall objectives of the OU 7-06 preliminary scoping discussed in the summary report were to establish a groundwater-monitoring network to characterize any contamination migrating from the SDA to the SRPA and to determine whether the monitoring network fulfilled regulatory requirements. The previously existing data, an analysis of data gaps, Track 2 fieldwork designed to fill data gaps, results, and recommendations for future work are discussed in the Track 2 Summary Report (Burgess, Higgs, and Wood 1994). Though the Track 2 Summary Report (DOE-ID 1994a) offers some interpretations of the previously existing and newly acquired data, the risk assessment for the groundwater ingestion pathway was deferred to the OU 7-14 comprehensive RI/FS.

Track 2 groundwater pathway characterization efforts addressed three areas of interest: groundwater, the vadose zone, and local geology. Groundwater data gaps included variability in the direction of groundwater movement (i.e., flow reversals), vertical gradients, effects of fractured basalt preferential flow paths, the extent of contamination, and characterization of upgradient contaminant concentrations. Vadose zone data gaps included the extent and distribution of radiochemical, organic, and inorganic contaminants. Geologic data gaps addressed the physical properties of vadose zone media, stratigraphic variability, and the thickness of the aquifer.

Six additional aquifer-monitoring wells and six vadose zone boreholes were constructed within WAG 7 to address groundwater and vadose zone data gaps. Commonly designated the M-series wells, the new aquifer monitoring wells were located next to the six OU 7-08 OCVZ boreholes to satisfy the needs of both the groundwater Track 2 investigation and the OCVZ RI/FS. In addition, an existing well, USGS-118, was improved to allow monitoring of soil vapor and groundwater. The Track 2 scope included constructing the wells, collecting the first round of sample data, and establishing an ongoing monitoring program (see Section 4 for current monitoring results).

To address the geologic data gaps, the drilling of a continuous corehole to a depth of 366 m (1,200 ft) in an upgradient location to the northeast of the RWMC was prescribed in the OU 7-06 Track 2 Summary Report (Burgess, Higgs, and Wood 1994). An initial hole, called C1, was discontinued at a depth of 171 m (560 ft). An alternate core, C1A, was completed to a depth of 550 m (1,805 ft) at a distance of 10.3 m (34 ft) from C1. Plans included caliper, video, natural-gamma, density, neutron, dielectric constant, formation-temperature, magnetic-susceptibility, and resistivity logging by the USGS. Though most of the logs were generated, the analyses were not completed and documented. However, visual descriptions of the core were used to assess the variability of WAG 7 stratigraphy. Fifty-three individual basalt flows and eight sedimentary interbeds were identified in Coreholes C1 and C1A. Fourteen of the basalt flows and two of the sedimentary interbeds did not appear in both locations.

The only exposure pathway associated with OU 7-06 was groundwater ingestion. Risks for total nitrogen and several radionuclides were identified in the Track 2 investigation, which summarized the results of the PSRAs (Loehr et al. 1994; Burns et al. 1994). Therefore, the OU was retained for further evaluation in the OU 3-13 pits and trenches RI/FS and the OU 3-14 comprehensive RI/FS (DOE-ID 1994a).

3.2.7 Operable Unit 7-07, Vadose Zone Radionuclides and Metals, Track 2 Investigation

Potential migration of contaminants through the vadose zone and into the aquifer was addressed in OU 7-07. Like several OUs in WAG 7, OU 7-07 represented an exposure pathway rather than a contaminant source. Groundwater ingestion was the only pathway addressed. Contaminants of potential concern were limited to radionuclides, metals, and specified inorganic compounds. Though the OU did not include the waste buried at the SDA, contaminants included constituents migrating from the buried waste. The Track 2 evaluation was limited to the preparation of a scoping package (LMITCO 1994b) that summarized the results of the previous groundwater risk assessment presented in the PSRA reports (Loehr et al. 1994; Burns et al. 1994). Based on the HDT, the PSRAs were limited to disposals through 1983. According to the OU 7-07 Track 2 Preliminary Scoping Report (LMITCO 1994b), Pad A inventories and disposals subsequent to 1983 would be evaluated in the OU 3-14 comprehensive RI/FS.

The PSRAs were based on contaminant release and transport modeling rather than detected contaminant concentrations from vadose zone samples. The modeling did not implement the Track 2 risk assessment methodology, which incorporates the assumption that all contaminants are available for immediate release to the environment. Instead, the PSRAs applied differential release modeling that accounted for containment and the physical and chemical forms of waste. The Disposal Unit Source Term (DUST) computer code (Sullivan 1992) was used to model various release mechanisms (i.e., surface-to-water partitioning, metal corrosion, and equilibrium solubility of liquids and solids). The buried waste, though not included in the definition of OU 7-07, constituted the source volume and area used for contaminant release modeling. Transport through the vadose zone into the aquifer was modeled with GWSCREEN (Rood 1994) using the source mass flux from the DUST model. Simulations estimated the peak groundwater concentrations regardless of time.

Residential risk from ingestion of contaminated groundwater was evaluated for two periods following 100 years of institutional control, as defined in DOE M 435.1-1: 100 to 1,000 years in the future and after 1,000 years. Standard EPA default parameters were used to calculate intake and exposure. Groundwater risks for 19 radioisotopes, beryllium, cadmium, mercury, and total nitrogen (the sum of contributions from various nitrogen compounds including nitrate, nitric acid, and ammonia) were evaluated. Risks were below 1E-06 and HQs were less than 1 for beryllium, cadmium, and mercury. An HQ of 2 was estimated for total nitrogen, but the maximum concentration in groundwater was predicted to occur at least 50 years before the end of the 100-year institutional control period assumed for the

assessment. The simulated HQ was $4E-07$ at the end of 100 years. Therefore, metals and nitrogen compounds were not identified as groundwater risk drivers. However, risk estimates were greater than $1E-06$ for several radioisotopes. Risk estimates for C-14, I-129, and Tc-99 were $4E-03$, $1E-02$, and $1E-04$, respectively, for the period of 100 to 1,000 years. Risk estimates between $1E-04$ and $1E-06$ were observed for Am-241, Ni-59, Np-237, U-234, U-235, and U-238 for the post-1,000-year period.

Empirical evidence supported the conclusion from the modeling results that contaminants could be migrating. Observations and analytical data from the 1974 Initial Drum Retrieval Project indicated minimal radiological contamination (see Section 3.1.4.3). The 1976 Early Waste Retrieval Project indicated that many buried drums had lost integrity. Soil samples yielded positive detections of Pu-239/240, Am-241, and Cs-137 in the soil beneath the waste and above the first basalt interface (see Section 3.1.4.4). Boreholes also were drilled and sampled intermittently between 1971 and 1987. A total of 273 samples at various depths within the vadose zone down to the C-D interbed (approximately 73 m [240 ft]) were statistically analyzed (Dames & Moore 1994). Vadose zone background values were developed by analyzing samples from six wells located outside the SDA. Analytical results from vadose zone sediment samples from 32 wells within the SDA were evaluated to determine whether radionuclides were migrating downward from the buried waste. Data supported the conclusion that anthropic Am-241, Pu-238, Pu-239/240, and U-235 existed in the vadose zone, though the detection frequencies were low (see Section 4) for updated monitoring results. Operable Unit 7-07 was retained for further evaluation in the OU 7-14 comprehensive investigation, based on the Track 2 evaluation (LMITCO 1994b).

3.2.8 Operable Unit 7-08, Organic Contamination in the Vadose Zone Remedial Investigation/Feasibility Study

Organic contamination in the vadose zone was identified for an RI/FS in OU 7-08 (DOE-ID 1994d) in the FFA/CO. The OU 7-08 RI/FS addressed the OCVZ that had been released from the SDA disposal pits and trenches, from land surface to the top of the SRPA, which is at a depth of approximately 177 m (580 ft). The OU 7-08 RI/FS addressed OCVZ generated by the disposal of containerized 743-series sludge^e from the RFP (Duncan, Troutman, and Sondrup 1993). The amount of VOCs in 743-series organic waste was originally estimated by Kudera (1987) to be 334,627 L (88,400 gal) comprising approximately 171,328 L (45,260 gal) of Texaco Regal Oil, 92,413 L (24,413 gal) of carbon tetrachloride, and 70,886 L (18,726 gal) of miscellaneous organic compounds. Analysis of data obtained since the OU 7-08 RI/FS has resulted in a much larger source estimate for carbon tetrachloride, 530,000 L (140,000 gal) (Miller and Varvel 2001). Effects of the larger inventory were used for this ABRA (see Sections 3.3.2.3 and 4.8).

In the OU 7-08 RI/FS (Duncan, Troutman, and Sondrup 1993), both existing and newly acquired data were considered that showed VOCs had been detected in soil vapor, surficial soil, perched water, and the SRPA. Interpretation of the sample data supported the conclusion that VOCs were migrating from the disposal pits into the vadose zone and continuing to move both laterally and vertically in the subsurface. Concentrations of carbon tetrachloride have been detected above the maximum contaminant level (MCLs) in the aquifer near the SDA. The baseline risk assessment portion of the OU 7-08 RI/FS addressed occupational and residential exposure scenarios for three time intervals: the current industrial period (1992 to 2021), the institutional control period (1992 to 2091), and the post-institutional control period (2092 to 2121). Carcinogenic risks greater than $1E-06$ but less than $1E-04$ were estimated for all three time periods for both occupational and residential exposures. The HQs for noncarcinogenic effects,

e. The waste is called 743-series sludge because it was processed into sludge in the Rocky Flats Plant (RFP) Building 774 and was later coded at the Idaho National Engineering and Environmental Laboratory (INEEL) as Content Code 3 organic waste to distinguish it from other types of waste from RFP Building 774 that were shipped to the INEEL.

particularly from the inhalation and ingestion of contaminated groundwater, were much more significant. The estimated HQs were as high as 6 for resident children during the modeled 100-year institutional control, 5 for post-institutional resident children, and 2 for current workers. Additional information is contained in the OU 7-08 RI/FS (Duncan, Troutman, and Sondrup 1993).

Considered in conjunction with the concentrations of VOCs detected in perched water and aquifer samples, the results of the OU 7-08 RI/FS supported a decision to remediate organic compounds in the vadose zone. A vapor vacuum extraction (VVE) treatability study was conducted in 1993 to evaluate VVE technology for application at the SDA (Lodman et al. 1994). The study included several tests to optimize VVE performance and to evaluate hydraulic characteristics of the vadose zone. The study successfully demonstrated that VOCs were effectively captured from extracted vapor using carbon adsorption beds. The 1993 demonstration recovered approximately 1,340 kg (2,900 lb) of VOCs (Lodman et al. 1994). The VVE method was compared to other remedial options and identified as the preferred remedial alternative for OCVZ.

Completion of the OU 7-08 RI/FS eventually led to the OU 7-08 Record of Decision (ROD) (DOE-ID 1994d), specifying remediation of the OCVZ using extraction and destruction of these organic contaminant vapors accompanied with vadose zone and aquifer monitoring.

The major components of the selected remedy include the following:

- Installation and operation of five vapor extraction wells (including an existing vapor extraction well) at the RWMC as a part of Phase I operations. The selected remedy includes options to expand the number of vapor extraction wells during Phase II and III operations.
- The installation and operation of off-gas treatment systems to destroy the organic contaminants present in the vapor removed by the extraction wells.
- The addition of soil vapor wells to monitor the performance of the vapor extraction wells and verify the attainment of OU 7-08 remedial action objectives (RAOs). Soil vapor monitoring also will provide information to evaluate the need for potential modifications to the selected remedy as treatment proceeds.

The objectives of the selected remedy are to reduce the human health and environmental risks associated with the organic contaminants present in the vadose zone and to prevent federal and state drinking water standards from being exceeded. The selected remedy does not address the buried waste in the SDA. The remaining buried waste could extend the timeframe required to achieve RAOs using the selected remedy, because the remaining organic mass in the source term could act as a continued source of vadose zone organic contamination (DOE-ID 1994d). Because carbon tetrachloride had been detected above the MCL prior to the start of the selected remedy, additional wells are planned to characterize the extent of VOCs in the vadose zone and aquifer beneath and surrounding the SDA.

The primary OU 7-08 RAO, as identified in the ROD (DOE-ID 1994d), is to ensure that risks to future groundwater users are within acceptable guidelines and that future contaminant concentrations in the aquifer remain below federal and state MCLs. The RAOs also include preliminary remediation goals (PRGs), which are based on the results of fate and transport modeling using the PORFLOW model. The PRGs were the estimated soil vapor concentrations that could remain after remediation and not result in future groundwater concentrations above MCLs. Detailed information is contained in the OU 7-08 sampling report (Bauer and Ovink 2000).

A vapor vacuum extraction with treatment system, comprising three treatment unit and extracting from up to five wells, was constructed and began operating January 1996. Since the beginning of Phase I operations in January of 1996, approximately 121,899 lbs of total VOCs have been removed and treated through September 5, 2002. The total VOCs removed include approximately 76,930 lbs of carbon tetrachloride, 18,285 lbs of TCE, 6,095 lbs of PCE, 5,961 lbs of 1,1,1-trichloroethane (TCA), and 14,628 lbs of chloroform. Initially, extraction was to be conducted in three 2-year phases. Though progress toward achieving cleanup goals has been realized, the original schedule appears to have been overly optimistic, necessitating extensions for Phase II and III operations. Reasons for the extensions are that the subsurface may contain a large reservoir of VOC mass and that active release from the buried waste is still occurring.

The OU 7-08 remedial action, as described in the OU 7-08 ROD (DOE-ID 1994d), is designed to add additional phases, as needed, to ensure the selected remedy achieves RAOs. The intent was to operate the system for 2 years, evaluate the performance of the system, and make modifications and improvements, as necessary. The ROD stated that the actual duration of each phase would depend on elements such as equipment procurement and installation that may be involved with each potential phase transition. In addition, organic waste remaining in the pits could extend the timeframe required to achieve RAOs using the selected remedy because the remaining organic waste could act as a long-term source of organic contamination in the vadose zone. Operations and monitoring for Phase II are expected to continue until active extraction is no longer required to ensure that RAOs will be met. Project lifecycle planning incorporates the assumption that the source of the organic contamination will be eliminated or reduced such that active extraction from the vadose zone beneath the SDA will not be required beyond 2014. This estimate is based on the following assumptions:

- The OU 7-13/14 ROD will be finalized in 2008
- The selected remedy for OU 7-13/14 will be implemented in 2010
- The selected remedy for OU 7-13/14 will reduce or eliminate the source of the organic contamination by 2012
- Once the source of the organic contamination is reduced or eliminated (i.e., the buried waste is treated or removed), no more than 2 years (i.e., 2012 to 2014) will be required to extract and treat organic vapors remaining in the vadose zone. Monitored vapor concentrations must satisfy the conditions required for shutdown of active extraction (INEEL 2002e).

Once the decision has been reached to shut down active extraction, the remedial action will transition into Phase III. During Phase III, a compliance verification period of one year will be implemented to determine if continued operation is warranted. If verification confirms that the system can be shut down, the remedial action will terminate and the long term monitoring phase will begin. A minimum of one year for compliance verification (i.e., 2015) is anticipated; therefore, Phase III could be completed in a minimum timeframe of one year, the duration of the verification, but is anticipated to continue for at least 4 years (i.e., 2018). During the long-term monitoring phase, the extraction with treatment systems will remain shut down and vapor monitoring will be conducted less frequently than during operations or compliance verification periods.

Soil vapor studies have been conducted to assist in characterizing the nature and extent of VOC sources at the SDA. In lieu of a direct inspection of subsurface waste, shallow soil-gas surveys have been conducted to observe source release traits and trends. Shallow soil-gas surveys were conducted in 1987, 1992, 1999, 2000, and 2001 to provide comparative shallow soil-gas data and will be used in identifying source locations and characteristics (Housley and Sondrup 2001).

3.2.9 Operable Unit 7-09, Transuranic Storage Area Releases, Track 1 Investigation

Operable Unit 7-09 was identified in the FFA/CO Action Plan (DOE-ID 1991) as historical contaminant releases to the environment from the TSA. Therefore, the source term for this OU is not the waste stored at the TSA. All waste accumulated at the TSA eventually will be retrieved and moved to the WIPP or another approved permanent federal repository. The Track 1 investigation (EG&G 1993a) considered the risk potential from radionuclide, organic, and inorganic contamination from possible secondary sources such as asphalt and soil that may have been contaminated by past releases.

The TSA consists of TRU waste in boxes and drums that are stacked on asphalt pads and, on TSA Pad R, the waste also is covered with earth. The only evidence of contaminant release from the TSA was discovered in April 1988 during a routine transfer of a waste box from TSA Pad R to the now-decommissioned Certification and Segregation Building (WMF-612) at the RWMC. A breached box was discovered and subsequent radiological surveys revealed alpha contamination on the surfaces of some other waste boxes, the asphalt floor on part of Pad R, and part of the floor of this building. The breached box was resealed, contaminated box surfaces were decontaminated, and contamination was fixed in place on the asphalt using surface sealers. During the radiological surveys and inspections that followed, two other breached boxes were discovered and similar cleanup actions were taken.

A soil-gas survey conducted over the TSA earthen berms detected elevated concentrations of volatile organics in noncontiguous areas on the edges of the survey area. These data suggested some volatilization of organics to the atmosphere from waste stored at the TSA. As part of the OCVZ remedial action, a monitoring well was drilled between the SDA and the TSA to determine whether historical TSA releases may have contributed to the volatile organic plume detected during soil-gas surveys. Data were not conclusive.

The Track 1 investigation (EG&G 1993a) concluded that no apparent unacceptable risks were generated by historical releases of contaminants; however, sufficient uncertainty existed about the cleanup of Pad R and potential VOCs in TSA soil to retain OU 7-09 for further evaluation in the OU 7-14 comprehensive RI/FS.

Subsequently, DOE-ID, IDEQ, and EPA determined that the evaluation of OU 7-09 should be deferred until the TSA operations have been terminated and the facility has been closed under RCRA (DOE-ID 1998b). The strategy is to identify target analytes for soil samples collected under the RCRA closure action in cooperation with DOE-ID, IDEQ, and EPA under the CERCLA program and to determine an appropriate CERCLA response based on the results.

3.2.10 Operable Unit 7-10, Pit 9 Process Demonstration Interim Action

Operable Unit 7-10 encompasses Pit 9, an active disposal pit from November 1967 through June 1969. The pit, located in the northeastern corner of the SDA (see Figure 3-1), comprises approximately 0.4 ha (1 acre) and is roughly trapezoidal in shape with areal dimensions of 115 by 40 m (379 by 127 ft) (McClellan, del C. Figueroa, and King 1991). The average depth to basalt within the pit is 5.3 m (17.5 ft). The original excavation was completed to basalt, and then backfilled with approximately 1.1 m (3.5 ft) of soil before disposal operations commenced. The pit contains approximately 7,080 m³ (250,000 ft³) of overburden, 4,250 m³ (150,000 ft³) of packaged waste, and 9,910 m³ (350,000 ft³) of underburden and interstitial soil (DOE-ID 1993).

Between February 1968 and September 1968, waste shipments containing VOCs, TRU radionuclides, and metals were transported from the RFP in Colorado for burial in Pit 9. Pit 9 also received waste shipments from various INEEL facilities while the pit was open (INEEL 2000b).

The RFP waste includes drums of sludge contaminated with a mixture of TRU elements and organic solvents, boxes of assorted solid waste, and cardboard boxes containing empty contaminated drums (DOE-ID 1993). The RFP waste in Pit 9 contains approximately 29 kg of plutonium and 0.94 kg of americium (Einerson and Thomas 1999). Backfill soil was placed over the waste after each disposal and a final soil layer up to about 1.8 m (6 ft) thick covers the entire pit.

In a preliminary risk evaluation of Pit 9 (McClellan, del C. Figueroa, and King 1991), the upper-bound risks for only the occupational scenario were estimated. Because this preliminary risk modeling did not reflect physical conditions at Pit 9, subsequent evaluations relied on soil and water sample data to describe the nature and extent of the contamination (DOE-ID 1992).

Trace amounts of plutonium and americium were detected in the subsurface at the SDA (DOE-ID 1993). Aquifer samples yielded detectable concentrations of CCl₄, chloroform, TCA and TCE. With the exception of CCl₄, all detected groundwater concentrations were less than the MCLs. An August 11, 1987, analysis detected 6 mg/L of CCl₄ in Well USGS-090, which was slightly above the 5-mg/L MCL (Mann and Knobel 1987).

A combination of physical separation, chemical extraction, and stabilization to recover contaminants and reduce the source of contamination is specified in the Pit 9 ROD (DOE-ID 1993), which documented the preferred remedial alternative. Implementation of the preferred alternative, according to the Pit 9 ROD, is contingent upon successful demonstration that the cleanup criteria and other performance objectives can be met.

The initial effort to implement the Pit 9 ROD was through a fixed price, privatized subcontract with Lockheed Martin Advanced Environmental Systems. Based on difficulties during the design and construction phase, original OU 7-10 milestones were missed and project delays resulted. The delays led to an informal dispute resolution process under the INEEL FFA/CO for OU 7-10 that was conducted in 1997. A revised path forward for the project, consisting of contingency planning, was reached through the dispute process. The contingency plan was prepared to accomplish the agreed-to scope of work and was documented in a revised Remedial Design/Remedial Action Scope of Work (LMITCO 1997) and a subsequent Explanation of Significant Differences (DOE-ID 1998a). The revised RD/RA Statement of Work, Explanation of Significant Differences outline a three-staged approach for Pit 9:

- Stage I: A subsurface sampling phase, which in part was to be used for determining the location of the Stage II effort within the Pit 9 area and subsurface exploration to obtain materials for bench-scale studies and allow for characterization.
- Stage II: Excavation and retrieval of TRU waste from a 6.1 × 6.1-m (20 × 20-ft) area within Pit 9. A remedial action report describing how the cleanup objectives established by the Pit 9 Record of Decision were met would be completed at the conclusion of Stage II. The limited retrieval and excavation would be conducted to obtain materials for pilot-scale treatability studies, in situ and ex situ treatment tests, and characterization of waste and soil.
- Stage III: Full-scale excavation and retrieval of TRU waste in the entirety of Pit 9.

Significant progress has been made in accomplishing the Stage I objectives outlined in the 1997 RD/RA Statement of Work and 1998 Explanation of Significant Differences. Stage I implementation led to the definition of two phases. Phase I consists of installing probes and downhole geophysical logging. Phase II consists of coring, sample retrieval and analysis, and bench-scale treatability studies.

Stage II implementation was also initiated in 1997 leading to the submittal of a draft 90% design^f in accordance with the enforceable deadline in June of 2000. Schedule and cost considerations associated with the approach described in that document led to a modified approach for Stage II, referred to as the OU 7-10 Glovebox Excavator Method Project, that is currently being implemented (INEEL 2001c). The longer-than-anticipated schedule associated with the Stage II RD/RA Work Plan submittal has led to an ongoing formal dispute resolution under the FFA/CO.

On February 15, 2002, DOE submitted notification of Critical Decision 1 (DOE O 413.3), approval to proceed from conceptual design to preliminary design, to the Idaho Department of Environmental Quality (IDEQ) and EPA based on the design outlined in the *Waste Area Group 7 Analysis of OU 7-10 Stage II Modifications* (INEEL 2001c), which set forth an expedited plan for completion of Stage II, and approval, and the *OU 7-10 Glovebox Excavator Method Project Conceptual Design Report for Critical Decision 1* (INEEL 2002a).

However, on April 16, 2002, an Agreement to Resolve Disputes was reached between DOE, the State of Idaho, and EPA (DOE 2002), which requires the completing the following activities and schedule, superseding previous FFA/CO milestones for OU 7-10:

Stage II

- Submit Notification of Critical Decision 2/3, approval to proceed to procurement and construction by no later than August 30, 2002
- Submit Stage II remedial design (completed project design) by no later than October 31, 2002
- Commence construction of Stage II by no later than November 30, 2002, and submit notification to IDEQ and EPA of commencement of construction, "substantial continuous onsite physical construction."
- Submit notification of Critical Decision 4 (operations phase) by February 28, 2004
- Commence Stage II excavation, substantial continuous onsite physical waste retrieval and packaging operations" by March 31, 2004, and notification to IDEQ and EPA
- Complete Stage II excavation by October 31, 2004, and a draft remedial action report

Stage III

- Submit Stage III 10% design by September 2005
- Complete remedial design for Stage II and commence construction by March 31, 2007
- Commence Stage II operations within 6 months of construction.

The status of work completed on Stages I, II, and III is delineated in the next section.

f. The 90% design was presented in a draft remedial design document that was never finalized, "Draft Operable Unit 7-10 (OU 7-10) Staged Interim Action Project, Stage II, RD/RA Work Plan Primary Deliverable Submittal," Binder I-A, "Remedial Design/Remedial Action Work Plan for Stage II of the Operable Unit 7-10 (OU 7-10) Staged Interim Action Project," DOE/ID-10767.

3.2.10.1 Stage I, Phase I Progress. A 12 × 12-m (40 × 40-ft) study area was selected to meet the objectives of Stage I based on a review of inventory records and the results of geophysical surveys of the pit. A historical record search was conducted, including earlier studies of the surface geophysical characteristics, to identify the most likely areas of the pit that contain the target Rocky Flats Plant waste. The results of this search led to the selection of the 12 × 12-m (40 × 40-ft) study area in the southwest portion of Pit 9 as the site for Stage I probing and coring activities.

The following Stage I activities have been completed:

- Project objectives and data quality objectives were developed to define the Stage I activities.
- Noninvasive geomagnetic techniques were used to identify significant concentrations of ferrous materials (e.g., drums or drum residue) within Pit 9. Based on the analysis of this information, an area of high metallic concentration was selected as the study area for the project.
- In December of 1999, a commercially available sonic drill rig was used to drive tipped steel casings into the designated area of Pit 9. In the initial campaign, twenty of these casings, referred to as Type A probes (see Section 3.6.4), were driven through the soil and waste until refusal occurred. These probeholes provided access to place logging instrumentation inside the casing at various depths.

Subsurface geophysical and radiation detection logging in the cased probeholes was completed. The instruments used to accomplish this were passive gamma and passive neutron detectors for identifying Pu-239 and other TRU; a shielded, directional, passive gamma detector to identify the azimuthal location of gamma-emitting sources; a neutron-gamma (n, gamma) tool to detect the prompt gamma-rays from chlorine (a potential indicator for halogenated hydrocarbons), and a neutron-neutron soil moisture gauge to measure soil moisture content.

Two additional probing campaigns were completed in 2000. The first campaign was located on the east side of the pit in an area determined from the shipping records to include graphite debris. The second was in the northern half of the pit in an area determined from shipping records to include ventilation filters.

The following observations and conclusions have been developed based on analysis of the information gained during this probing campaign:

- The vertical waste zone boundaries can be estimated within approximately 1 ft.
- Measurements of plutonium and americium correlate reasonably with disposal records.
- High concentrations of radionuclides are easily measured.
- Probing resolves some of the ambiguities existing in the current geophysical data. Specifically, the geophysical data indicate the probable location of metal drums, but no indication of the contents. Probing data unambiguously identify overburden and waste regions in the vicinity of each probehole. In addition, logging provides indications of the depths of the waste.
- Under certain conditions, specifically the absence of interfering signals from multiple waste forms within the detection range of the sensors, specific waste forms can be identified.
- Chlorine can be located at concentrations exceeding 300 ppm and 20 wt%.

- Soil moisture measurements above and below the waste zone can be accurately determined.

3.2.10.2 Stage I, Phase II Progress. The second phase of Stage I was to obtain core samples from six locations selected from the results of Phase I. Activities completed included development of Technical and Functional Requirements (INEEL 2002b), a Preliminary Safety Assessment (INEEL 2000d), design disclosure documents, and mockup testing of specific parts. In April 2000, work on the coring system was discontinued in favor of an alternate probehole method identified by OU 7-13/14 to acquire similar data (see Section 3.6.4). Instrumented probes were used to obtain information from within the waste in the SDA.

3.2.10.3 Stage II Progress. Based on the results of analysis conducted to expedite Stage II (INEEL 2001c), the glovebox excavator method will be the approach used for the Stage II retrieval demonstration. The objectives of the glovebox excavator method retrieval demonstration are the following:

- Demonstrate waste retrieval
- Provide information on any contaminants of concern present in the underburden
- Characterize waste for safe and compliant storage
- Package waste in containers acceptable for transfer to the AMWTF.

The Glovebox Excavator Method Project's retrieval system consists of a fabric weather enclosure structure, steel confinement structure, a standard excavator, ventilation system, and other supporting equipment. The excavator boom and bucket are housed inside the steel confinement structure, while the operator and other excavator components are located outside the confinement structure but inside the fabric weather enclosure. Locating the excavator operator and material packaging and handling personnel outside the confinement structure reduces worker radiological and chemical exposure and risk.

The glovebox excavator method will include removal of the overburden to a specified depth by the excavator. The excavator arm, contained within the confinement structure, then will be used to excavate a semicircular swath of waste zone material. The retrieved waste zone material will be placed in a transfer cart by the excavator bucket. The cart will be used to transport waste zone materials inside gloveboxes where the material will be inspected, categorized, and sampled. Each of three gloveboxes is equipped with three drum bagout stations for packaging the material into 55- and 85-gal drums. It is estimated that approximately 350 55-gal drums and 150 85-gal drums will be generated and transferred to the AMWTF for processing.

3.2.10.4 Stage III Progress. Stage III activities are outlined in the 1997 RD/RA Work Plan (LMITCO 1997) and 1998 Explanation of Significant Differences (DOE-ID 1998a) for OU 7-10. Implementation of work scope directly related to Stage III has not occurred at this time because Stage III milestones depend on the progress of Stages I and II.

3.2.11 Operable Unit 7-11, Septic Tanks and Drain Fields, Track 1 Investigation

Operable Unit 7-11 comprises three septic systems within the RWMC, two in the administrative area, and one within the TSA. All three systems received sanitary waste discharges from various buildings in administrative control areas of the RWMC. All the septic systems were analyzed for radiological constituents (e.g., barium, methyl ethyl ketone, and cresols) as part of the Track 1 investigation. No radiological contamination was detected and all detected constituents were below

regulatory limits. Therefore, the Track 1 investigation concluded that the septic systems do not pose any significant risk. A no further action determination (EG&G 1993c) was signed, and the OU was eliminated from further study in the OU 7-14/ comprehensive RI/FS.

3.2.12 Operable Unit 7-12, Pad A, Remedial Investigation/Feasibility Study

Pad A is an aboveground asphalt pad ($73 \times 102 \text{ m} \times 5 \text{ to } 7.6 \text{ cm}$ [$240 \times 335 \text{ ft} \times 2 \text{ to } 3 \text{ in.}$] thick). It was constructed for disposal of packaged solid mixed waste (hazardous waste contaminated with radioactive material) primarily from RFP. Originally called the Engineered Waste Storage Area, this pad was later called the Transuranic Disposal Area and is now known as Pad A. The pad was constructed in 1972 within the SDA in an area unsuitable for subsurface disposal because of shallow surficial sediments.

More than 20,000 waste containers including 18,232 55-gal drums and 2,020 $1.2 \times 1.2 \times 2\text{-m}$ ($4 \times 4 \times 7\text{-ft}$) plywood boxes, were placed on the pad between September 1972 and August 1978. Most containers were double-lined with polyethylene but some containers were only single-lined. Approximately 40% of the pad was covered with waste when Pad A was closed in 1978 (DOE-ID 1994e).

Primarily nitrate salts, depleted uranium, and sewage sludge are disposed of on Pad A. The specific components of the approximately $13,341 \text{ yd}^3$ of waste are listed below:

- About $9,483 \text{ yd}^3$ of evaporator salts, primarily sodium nitrate and potassium nitrate from RFP that are contaminated with less than 10-nCi/g levels of TRU isotopes
- Approximately $2,943 \text{ yd}^3$ of waste from RFP consisting primarily of uranium oxides, uranium castings waste, beryllium foundry waste, and machining waste, which is a mixture of depleted uranium and beryllium foundry waste
- Dry sewage from RFP that is contaminated with less than 10 nCi/g levels of TRU isotopes
- Miscellaneous INEEL-generated radioactive waste such as laboratory waste, radiological instrument counting sources, and uranium standards.

Miscellaneous waste at Pad A includes salts, soil, concrete, and other materials. The evaporator salts (i.e., nitrates) have been reviewed against 40 Code of Federal Regulations (CFR) 261.21(a)(4) and 49 CFR 172.151 and appear to exhibit the properties of an oxidizer and, therefore, can have the characteristic of ignitability. The radionuclides include plutonium, americium, thorium, uranium, and K-40. All but two waste shipments disposed of on Pad A contained TRU alpha-emitting radioisotopes with concentrations less than 10 nCi/g and exposure rates less than 200 mR/hour at the container surface. The other two shipments, consisting of a total of 10 drums, contained waste with concentrations greater than 100 nCi/g (DOE-ID 1994e).

According to information from the RWMIS, about 10,143,000 lb of inorganic salts from RFP are contained in 1,275 plywood boxes and 15,400 drums at Pad A. The total inorganic salt waste consists of approximately 60% sodium nitrate, 30% potassium nitrate, and 10% chloride, sulfate and hydroxide salts. The salts comprise 71% of the total waste volume at Pad A (MK-FIC 1994).

The Pad A RI/FS (Halford et al. 1993) consisted mainly of compiling, documenting, and evaluating existing data because substantial monitoring, sampling, and drum retrieval information was available. The risk assessment identified potentially unacceptable future scenario risks from ingestion of nitrate-contaminated groundwater by sensitive receptors (e.g., infants and children).

Documented in the Pad A ROD (DOE-ID 1994e), the remedial action selected for Pad A included limited action consisting of augmenting and shaping the existing soil cover, slope correction, maintaining institutional controls indefinitely, and maintaining and monitoring the soil cover indefinitely. The goal of the limited action was to continue to prevent contact with the Pad A waste under the soil cover. Remediation activities were classified into two components: (a) recontouring the Pad A soil cover and (b) installing environmental monitoring equipment (Parsons 1995).

The waste pile was covered with a soil layer 0.9 to 1.8 m (3 to 6 ft) thick and was completed at the end of the 1994 field season. In November 1994, the area was seeded with crested wheat grass to minimize soil erosion and covered with rock armor in February 1995. Monitoring equipment installed during the Pad A limited action included one horizontal and five vertical boreholes for lysimeters and one horizontal and several vertical neutron access tubes. The horizontal neutron access tube did not provide any useful data and the horizontal lysimeter did not work correctly. Use of the vertical NATs was discontinued in 1996. Vertical lysimeters, however, are monitored routinely. The monitoring data are used on an ongoing basis to assess the potential migration of moisture and contamination through Pad A to the subsurface. The post-remedial action 2-year review of Pad A was completed in 1997 by IDEQ and EPA (Koch 1997), and the 5-year review is scheduled for completion in 2002.

3.2.13 Operable Unit 7-13, Transuranic Pits and Trenches Remedial Investigation/Feasibility Study

The PSRAs, in conjunction with the information from the assessments of the other OUs in WAG 7, revealed the implausibility of evaluating risk for the SDA solely on the basis of the exposure pathway or segregated source terms. Based on the information, the regulators determined that the TRU pits and trenches should not be assessed independently, but should be combined with the OU 7-14 comprehensive RI/FS into one all-encompassing risk assessment. Therefore, the TRU pits and trenches OU was combined with OU 7-14, becoming the OU 7-13/14 comprehensive RI/FS for WAG 7 (Huntley and Burns 1995).

3.2.14 Operable Unit 7-13/14 Comprehensive Remedial Investigation/Feasibility Study

The TRU pits and trenches, OU 7-13, and the WAG 7 comprehensive RI/FS, OU 7-14, were combined into the OU 7-13/14 comprehensive RI/FS. The OU 7-13/14 comprehensive ABRA, which constitutes the remedial investigation part of the RI/FS, is contained in this report.

3.2.15 Active Low-Level Waste Disposal Operations

The OU 7-13/14 comprehensive RI/FS includes analysis of the ongoing disposals in the active low-level waste disposal pit comprising Pits 17 through 20 in the SDA. Current plans indicating that disposal operations will continue until 2020 (McCarthy et al. 2000) are being reviewed and LLW disposal may be terminated in 2009. Waste placed in the pit through 1999 is explicitly considered in this ABRA. Projected disposal inventories equivalent to the maximum inventories allowed under the current Performance Assessment for the SDA (Case et al. 2000) are addressed in the uncertainty analysis in Section 6.

3.3 Source Term Assessment

Because of the heterogeneous nature of the waste buried at the SDA, sampling is not sufficient to characterize the SDA source term. Therefore, existing disposal records were used to develop the source term inventory as described below.

3.3.1 Historical Data Task

The function of the HDT (LMITCO 1995a) project was compiling a comprehensive inventory of waste that was buried in the SDA from 1952 through 1983. The inventory information is organized according to waste generator and divided into waste streams for each generator. Waste information available in facility operating records, technical and programmatic reports, shipping records, and databases were included in the inventory. Additional information was obtained by reviewing the plant operations that originally generated the waste, interviewing personnel employed as operators, and performing nuclear physics and engineering calculations. The SDA disposal units covered in the project include TRU-contaminated pits and trenches, non-TRU contaminated pits and trenches, the Acid Pit, and SVRs that were open from 1952 through 1983. Total best-estimate, upper-bound, and lower-bound quantities were generated for each contaminant, covering all waste streams from all generators for the time from 1952 to 1983. The development of the HDT is further summarized in the IRA (Becker et al. 1998) and is described in detail in the HDT report (LMITCO 1995a).

3.3.2 Recent and Projected Data Task

The Recent and Projected Data Task (RPDT) (LMITCO 1995b), though similar to the HDT inventory, addressed the waste inventory buried from 1984 to 1993 and disposal estimates projected through 2003. The development of the RPDT is further summarized in the IRA (Becker et al. 1998, Section 3) and is described in detail in the RPDT report (LMITCO 1995b).

3.3.2.1 *Inventory Revisions and Updates.* The HDT and RPDT disposal inventories have been modified to correct errors, incorporate new information about historical disposals, and replace projected disposal data with actual disposal information. The updated inventories were used to support the risk assessment in Section 6. Specific modifications are summarized below.

3.3.2.2 *Supplement to the Recent and Projected Data Task.* To assess completeness, actual disposal data at the SDA for 1994 through 1999 were evaluated, and the findings were published in the Supplement to the RPDT (Little et al. 2001). In most cases, scaling factors were applied to develop inventories for radionuclides that are not typically reported on waste disposal forms but are expected in the waste streams generated by specific processes. The modified actual disposal data replaced the projected disposal data for 1994 through 1999 in this ABRA. Details of the development of the inventories included in these disposals are presented in the Supplement to the RPDT.

3.3.2.3 *Supplement to the Historical Data Task.* Revisions to inventory data in the HDT focus on volatile organic compounds received from RFP and radioactive waste received from TRA, NRF, and ANL-W. A supplement to the HDT report that incorporates recent information is still under development and will be finalized before the OU 7-13/14 record of decision is drafted. Currently available modifications to inventories have been included in this ABRA and are reflected in inventories reported in Section 4.

Revisions to the volatile organic compound inventories associated with RFP 743-series sludge were identified. Carbon tetrachloride inventories are approximately eight times higher than originally reported (Miller and Varvel 2001), while inventory estimates for PCE and methylene chloride were reduced (Varvel 2001). Radionuclide inventory corrections for the RFP 743-series sludge were not identified.

Probable errors were identified in the IRA for the reported TRA inventories during the HDT timeframe. These inventories were corrected and will be included in the supplement to the HDT. Corrected inventories have been incorporated into this ABRA.

Corrections for NRF and ANL-W inventories currently are being assessed and also will be included in the supplement to the HDT. If significant inventory revisions are identified, appropriate recommendations will be developed before remedial decisions for WAG 7 are finalized.

3.3.2.4 Contaminant Inventory Database for Risk Assessment. Taken together, the HDT and RPDT and the revisions to them describe the SDA source term for the OU 7-13/14 comprehensive RI/FS. All waste in the SDA, including all pits, trenches, and soil vaults, the Acid Pit, and Pad A, is captured in the Contaminant Inventory Database for Risk Assessment (CIDRA). Disposal dates for the waste range from 1952 through 1999. Some examples of information presented in CIDRA include types of buried contaminants, amounts of individual contaminants contained in each waste stream, dates of waste-stream disposal, the originator of each waste stream, contaminant physical and chemical forms, and types of containers used during waste-stream disposal. A major limitation of the HDT and RPDT reports, and consequently CIDRA, is a lack of complete disposal information, especially for disposals that occurred during the first two decades of RWMC operations. Historical shipping records rarely defined which pits or trenches received waste, and volumes either were missing from shipping manifests or were estimated based on the shipment weight rather than the waste-stream volume.

3.3.3 WasteOScope

WasteOScope is a customization of the Arc View Geographic Information System (GIS) software package. WasteOScope provides a means to merge existing physical spatial data or historical disposal data at the RWMC and visualize the information on a computer screen or printed graphics (INEEL 2002c, 2001d). The user is able to query, explore, analyze, and then visualize a wide range of waste characterization and inventory data (INEEL 2002d).

Originally, WasteOScope was developed to compare historical disposal data consisting of manifest shipping information from waste generators and trailer load lists received at the RWMC with known burial location data. The waste generator data include type of waste container, number of waste containers, type of waste, radiological data, and origin. Waste generators include INEEL facilities (e.g., TRA, INTEC, TAN, NRF, ANL-W), and off-Site operations (e.g., Rocky Flats). These data sets were then used to create maps detailing where different waste types from different generators were located. Additional information such as waste container and waste volume also has been added.

Geophysical data were added to the system to compare existing pit and trench survey boundaries with subsurface data to verify buried waste locations shown on maps. The results compared very well and, in some cases, were used to relocate pit or trench boundaries. The system has been expanded to include topographic, soil-vapor, surface cover elevations, basalt bedrock contours, aerial photographic data, well locations, Type A and B probe locations, and monitoring data. These other data sets can be viewed while querying historical waste disposal data and can be included on printed graphical representations.

3.4 Contaminant Screening for the Baseline Risk Assessment

Contaminant screening is an iterative process that has been performed to focus the OU 7-13/14 comprehensive RI/FS on contaminants with the greatest potential for causing adverse human health or environmental effects. Key contaminants were identified initially in the PSRAs (Loehr et al. 1994; Burns et al. 1994). The potential for unacceptable risks to groundwater from highly mobile and long-lived radionuclides such as C-14, Tc-99, and I-129 was identified. Potential for unacceptable risks from biotic intrusion into waste and translocation of contaminants to the surface for eventual human exposure also was identified. Additional contaminant screening was included in the OU 7-13/14 RI/FS Work Plan (Becker et al. 1996), the IRA (Becker et al. 1998), and by Hampton and Becker (2000). The analysis of

the nature and extent of contamination that follows in Section 4 and the modeling and risk assessment presented in Sections 5 and 6 are based on the final lists of COPCs. Human health and ecological contaminant screening are summarized below.

3.4.1 Human Health Contaminant Screening for the Baseline Risk Assessment

Human health contaminant screening based on the PSRAs is presented in the OU 7-13/14 RI/FS Work Plan (Becker et al. 1996, Appendix A). The screening was applied to constituents identified in the SDA source term inventory (LMITCO 1995a, 1995b; Little et al. 2001). More than 200 contaminants initially were evaluated to identify those with the greatest potential for causing adverse effects. Three screening criteria were considered:

1. The summary of SDA sampling investigations presented in the HDT report (LMITCO 1995a, Appendix A) was used to identify contaminants that have been detected in SDA surface soil, sedimentary interbed material, perched water, and groundwater. All contaminants that have been detected in one or more of these media failed the first screening criterion.
2. The computer code GWSCREEN (Rood 1994) was used to estimate maximum future groundwater concentration for each contaminant in the SRPA beneath the SDA. All contaminants with predicted groundwater concentrations exceeding MCLs (EPA 1996) failed the second screening criterion.
3. Preliminary risk and HQ values were calculated for each contaminant. These calculations were based on conservative assumptions about future contaminant concentrations and about exposures that might be received by future human receptors. All contaminants that had a predicted risk greater than $1E-07$ or a predicted HQ greater than 0.1 failed the third screening criterion.

Preliminary screening based on the above criteria reduced the COPC list to 86 constituents: 42 radioisotopes and 44 nonradionuclides, with uranium included in both categories, for the IRA. However, five radionuclides, Ac-227, Pa-231, Pb-210, Ra-225, and Th-228, were returned to the list because they have half-lives greater than 1 year. Therefore, a total of 91 COPCs were evaluated in the IRA. Sufficient inventory data and risk assessment parameters were available to quantitatively evaluate 53 COPCs. The remaining COPCs were addressed qualitatively.

Results of the IRA modeling and risk assessment were used to further refine the list of COPCs for analysis in the OU 7-13/14 comprehensive RI/FS (DOE-ID 1998b). Contaminants with carcinogenic risk estimates greater than $1E-06$, a hazard index greater than 0.5, or for which risk curves were $1E-07$ and still increasing at the end of 1,000 years were retained for further evaluation. Twenty-five quantitatively evaluated contaminants were retained for risk analysis: 20 radionuclides and five nonradionuclides. Subsequently, total uranium was eliminated from further analysis because the hazard index was reported erroneously in the IRA as $1E+01$ instead of $1E-01$. However, five uranium isotopes were retained for analysis of carcinogenic risk. Nine qualitatively evaluated contaminants in the IRA also were designated for further analysis if new inventory or toxicity data became available to support assessment in the OU 7-13/14 comprehensive RI/FS: chloroform; dibutylethylcarbutol; nitrocellulose; organic acids; organophosphates; toluene; trichloroethylene; 1,1,1 trichlorethane; and xylene. Because additional information has not been developed, these contaminants will not be reevaluated. The 24 contaminants assessed for human health in this ABRA are listed below.

- | | | | | | |
|-----------|-----------|------------|------------|-----------|--------------------------|
| 1. Ac-227 | 5. Cs-137 | 9. Pa-231 | 13. Ra-226 | 17. U-234 | 21. Carbon tetrachloride |
| 2. Am-241 | 6. I-129 | 10. Pb-210 | 14. Sr-90 | 18. U-235 | 22. Methylene chloride |
| 3. C-14 | 7. Nb-94 | 11. Pu-239 | 15. Tc-99 | 19. U-236 | 23. Nitrates |
| 4. Cl-36 | 8. Np-237 | 12. Pu-240 | 16. U-233 | 20. U-238 | 24. Tetrachloroethylene |

3.4.2 Ecological Contaminant Screening for the Baseline Risk Assessment

Forty-four nonradionuclide and 12 radionuclide ecological COPCs were identified in the preliminary ecological contaminant screening developed by Hampton and Becker (2000). Soil concentrations for contaminants evaluated in that screening were estimated using upper-bound inventories and DOSTOMAN code (Root 1981) simulations. Estimated concentrations were compared to ecologically based screening levels. When the estimated concentration was greater than the ecologically based screening level, the contaminant was identified as an ecological COPC.

Disposal inventories for 32 radionuclide and four nonradionuclide COPCs evaluated in preliminary screening by Hampton and Becker (2000) subsequently were revised (see Section 3.3). Therefore, a final contaminant screening for this ABRA was conducted to assess the result of those inventory modifications.

Soil concentrations calculated from revised, best-estimate inventory quantities were compared to INEEL ecologically based screening levels. Those COPCs for which soil concentration exceeded the ecologically based screening level (EBSL) were evaluated in the ecological risk assessment (see Section 6.6). The results of the final ecological contaminant screening are discussed below for radiological and nonradiological contaminants.

3.4.2.1 Radionuclide Ecological Contaminants of Potential Concern. Soil concentrations using revised source term inventories were estimated using DOSTOMAN for 32 radionuclides originally evaluated in Hampton and Becker (2000). Estimated concentrations were then compared to INEEL ecologically based screening levels, as shown on Table 3-7. Calculated concentrations for the 12 radionuclide COPCs shown in bold text on Table 3-7 exceeded ecologically based screening levels. Three of 11 ecological COPCs, Am-243, Cm-244, and Pu-242, were not identified as COPCs in the preliminary screening (Hampton and Becker 2000). Three COPCs, Np-237, Po-210, and Zn-65, were identified as COPCs in Hampton and Becker (2000), but were eliminated in this screening (see Table 3-7).

Concentrations calculated for Co-60, Eu-154, H-3, Ni-63, Pu-241, Tc-99, Th-228, and U-232 using best-estimate inventory values exceeded the EBSLs (see Table 3-7, footnote e). However, these eight COPCs previously were eliminated by DOSTOMAN modeling results based on the upper-bound inventory estimates (Hampton and Becker 2000, Table 3). The upper-bound inventory quantities used in the DOSTOMAN model (Hampton and Becker 2000) were larger than the best-estimate inventory used in this ABRA (Table 3-8). Modeled surface and subsurface soil concentrations generated from upper-bound inventory quantities were below the EBSL for each COPC (Hampton and Becker 2000, Table 3). Because best-estimate inventory quantities are smaller than upper-bound quantities (Table 3-8), modeled concentrations based on the best-estimate inventory would also be smaller than the EBSLs. Therefore, these eight COPCs were not analyzed further.

Table 3-7. Comparison of estimated soil concentrations based on revised best-estimate inventories to ecologically based screening levels for radionuclide contaminants of potential concern.

| Contaminant of Potential Concern ^a | Best-estimate Inventory ^b (Ci) | Calculated Soil Concentration ^c (pCi/g) | Ecologically Based Screening Level ^d |
|---|---|--|---|
| Ac-227 | 5.12E-07 | 1.11E-06 | 2.04E+05 |
| Am-241 | 1.83E+05 | 3.98E+05 | 1.78E+01 |
| Am-243 | 1.34E+02 | 2.92E+02 | 1.85E+01 |
| C-14 | 5.00E+02 | 1.09E+03 | 3.94E+04 |
| Cl-36 | 1.11E+00 | 2.41E+00 | 7.84E+03 |
| Co-60 ^e | 2.20E+06 | 4.79E+06 | 1.18E+03 |
| Cm-244 | 5.24E+04 | 1.14E+05 | 1.68E+01 |
| Cs-137 | 6.17E+05 | 1.34E+06 | 4.95E+03 |
| Eu-154 ^e | 3.00E+03 | 6.53E+03 | 2.48E+03 |
| H-3 ^e | 1.50E+06 | 3.26E+06 | 3.43E+05 |
| I-129 | 1.58E-01 | 3.44E-01 | 4.76E+04 |
| Nb-94 | 1.00E+03 | 2.19E+03 | 1.87E+03 |
| Ni-63 ^e | 1.32E+06 | 2.87E+06 | 1.14E+05 |
| Np-237 | 2.64E+00 | 5.75E+00 | 1.94E+01 |
| Pa-231 | 8.64E-04 | 1.88E-03 | 2.37E+01 |
| Pb-210 | 5.10E-07 | 1.11E-06 | 2.74E+05 |
| Po-210 | 9.10E-06 | 1.98E-05 | 1.84E+01 |
| Pu-238 | 1.71E+04 | 3.72E+04 | 1.78E+01 |
| Pu-239 | 6.49E+04 | 1.41E+05 | 1.89E+01 |
| Pu-240 | 1.71E+04 | 3.72E+04 | 1.89E+01 |
| Pu-241 ^e | 9.74E+05 | 2.12E+06 | 3.73E+05 |
| Pu-242 | 1.65E+01 | 3.58E+01 | 2.00E+01 |
| Ra-226 ^e | 6.00E+01 | 1.30E+02 | 2.04E+01 |
| Ra-228 | 1.08E-05 | 2.35E-05 | 1.97E+05 |
| Sr-89 | 4.10E+02 | 8.92E+02 | 3.34E+03 |
| Sr-90 | 6.44E+05 | 9.84E+05 | 3.34E+03 |
| Tc-99 ^e | 6.05E+01 | 1.32E+02 | 2.32E+04 |
| Th-228 ^e | 1.02E+01 | 2.22E+01 | 1.81E+01 |
| Th-229 | 6.81E-06 | 1.48E-05 | 3.60E+01 |
| Th-230 | 3.13E-02 | 6.81E-02 | 2.09E+01 |
| Th-232 | 1.34E+00 | 2.93E+00 | 2.43E+01 |
| U-232 ^e | 1.06E+01 | 1.60E+01 | 1.54E+01 |
| U-233 | 1.51E+00 | 3.28E+00 | 2.03E+01 |
| U-234 | 6.74E+01 | 1.47E+02 | 2.05E+01 |

Table 3-7. (continued).

| Contaminant of Potential Concern ^a | Best-estimate Inventory ^b (Ci) | Calculated Soil Concentration ^c (pCi/g) | Ecologically Based Screening Level ^d |
|---|---|--|---|
| U-235 | 5.54E+00 | 1.21E+01 | 2.27E+01 |
| U-236 | 2.86E+00 | 6.23E+00 | 2.17E+01 |
| U-238 | 1.17E+02 | 2.55E+02 | 2.32E+01 |
| Zn-65 | 1.36E+03 | 2.60E+03 | 5.21E+03 |

a. The ecological contaminants of potential concern (COPCs) in bolded text exceeded ecologically based screening levels and, therefore, were evaluated in the ecological risk assessment (see Section 6.6)

b. These values reflect revised disposal inventory quantities unless otherwise noted. Revisions to disposal inventory quantities are discussed in Section 3.3.

c. Soil concentrations were calculated by distributing the inventory amount over a volume of soil $181 \times 669 \times 2.53$ m ($594 \times 2,195 \times 8.3$ ft) deep with a bulk density of 1.5 g/cm^3 (Becker et al. 1996). The volume represents an estimate of the combined volumes for Subsurface Disposal Area pits, trenches, and vaults.

d. The minimum ecologically based screening level across receptor groups was selected for radionuclide contaminants and the smallest level between internal and external exposures was used (DOE-ID 1999).

e. This contaminant was eliminated even though the maximum concentration derived from best-estimate inventories exceeds the ecologically based screening level. The contaminant was eliminated in the preliminary screening because soil concentrations generated by the DOSTOMAN model for upper-bound inventory quantities were below the ecologically based screening level (Hampton and Becker 2000). Best-estimate inventories are smaller than upper-bound inventories and less conservative DOSTOMAN assumptions (e.g., average values instead of maximum values for rooting and burrowing depths) are used in this analysis. Revised modeled soil concentrations would be even smaller than those generated in the preliminary screening. Therefore, this COPC was not analyzed further.

Table 3-8. Comparison of best-estimate inventories and modeled concentrations to upper-bound inventories and modeled concentrations.

| Contaminant of Potential Concern | Best-estimate Inventory (Ci or g) ^a | Upper-bound Inventory ^b (Ci or g) | Best-estimate Concentration ^a (pCi/g or mg/kg) | Upper-bound Concentration ^c (pCi/g or mg/kg) |
|----------------------------------|--|--|---|---|
| Co-60 | 2.20E+06 | 9.39E+06 | 4.79E+06 | 2.04E+07 |
| Eu-154 | 3.00E+03 | 2.07E+04 | 6.53E+03 | 4.50E+04 |
| H-3 | 1.50E+06 | 3.80E+06 | 3.26E+06 | 8.27E+06 |
| Ni-63 | 1.32E+06 | 2.24E+06 | 2.87E+06 | 4.87E+06 |
| Pu-241 | 9.74E+05 | 9.84E+05 | 2.12E+06 | 2.14E+06 |
| Ra-226 | 6.00E+01 | 8.86E+01 | 1.30E+02 | 1.93E+02 |
| Tc-99 | 6.05E+01 | 1.33E+03 | 1.32E+02 | 2.89E+03 |
| Th-228 | 1.02E+01 | 1.56E+01 | 2.22E+01 | 3.39E+01 |
| U-232 | 1.06E+01 | 1.37E+01 | 1.60E+01 | 2.98E+01 |

a. Best-estimate values taken from Table 3-7.

b. Upper-bound inventory quantities are from the Interim Risk Assessment (Becker et al. 1998, Table 4-1). These inventory values were used to produce DOSTOMAN screening concentrations for surface and subsurface soil (Hampton and Becker 2000). All modeled screening concentrations for this group of COPCs were below ecologically based screening levels (see Table 3 of Hampton and Becker 2000).

c. Soil concentrations were calculated by distributing the inventory amount over a total volume of soil formed by an area of 181 × 669 m² and a soil depth of 2.53 m (594 × 2,195 × 8.3 ft) with a bulk density of 1.5 g/cm³ (Becker et al. 1996). The total volume represents an estimate of combined volumes for all disposal units within the Subsurface Disposal Area.

The 12 radionuclide ecological COPCs listed below were retained for evaluation in the ecological risk assessment (see Section 6.6).

- | | | |
|-----------|-----------|-----------|
| 1. Am-241 | 5. Nb-94 | 9. Pu-242 |
| 2. Am-243 | 6. Pu-238 | 10. Sr-90 |
| 3. Cm-244 | 7. Pu-239 | 11. U-234 |
| 4. Cs-137 | 8. Pu-240 | 12. U-238 |

3.4.2.2 Nonradionuclide Ecological Contaminants of Potential Concern. The nonradionuclide COPCs identified in the preliminary screening (Becker et al. 1996) are presented on Table 3-9. With the exception of nitrates (see Section 4.7.1), carbon tetrachloride (see Section 4.8.1), and methylene chloride (see Section 4.8.2), nonradionuclide inventory quantities evaluated in the preliminary screening were not revised for this ABRA (see Section 3.3). In addition, toxicity data and information on disposal quantities are uncertain or not available for 25 nonradionuclide contaminants assessed in the preliminary screening (Hampton and Becker 2000). Consequently, nonradionuclide COPCs identified in the preliminary screening were not reevaluated here. Rather, concentrations based on upper-bound or revised best-estimate inventory quantities for a subset of nonradionuclide COPCs listed on Table 3-9 were incorporated in the ecological risk assessment (see Section 6.6).

Table 3-9. Nonradionuclide ecological contaminants of potential concern identified by comparing estimated soil concentrations based on upper-bound inventories to ecologically based screening levels.

| Ecological Contaminant of Potential Concern ^a | Upper-bound Inventory ^b (g) | Calculated Soil Concentration ^c (mg/kg) | Minimum Ecologically Based Screening Level ^d (mg/kg) |
|--|---|---|--|
| 1,1,2-Trichloro-1,2,2-trifluoroethane | 9.5E+06 | 2.07E+01 | None |
| 3-Methylcholanthrene | Unknown | Unknown | None |
| Alcohols | Unknown | Unknown | None |
| Aluminum nitrate | 2.40E+08 | 5.23E+02 | 4.87E+01, see total nitrates |
| Asbestos ^e | 4.80E+06 | 1.05E+01 | 2.17E+02 |
| Beryllium oxide | Unknown | Unknown | None |
| Cadmium | 2.30E+06 | 5.01E+00 | 2.36E-03 |
| Carbon tetrachloride | 1.30E+08 | 2.83E+02 | 9.71E+00 |
| Chloroform ^e | 3.70E+01 | 8.06E-05 | 1.54E+01 |
| Copper (total) ^{e,f} | 4.52E+04 | 9.93E-02 | 2.11E+00 |
| Dibutylethylcarbutol | Unknown | Unknown | None |
| Versenes (EDTA) | Unknown | Unknown | None |
| Ether | Unknown | Unknown | None |
| Ethyl alcohol ^e | 2.8E+04 | 6.10E-02 | 1.59E+00 |
| Hydrofluoric acid | 9.40E+06 | 2.05E+01 | 5.26E+00 |
| Lead | 7.80E+08 | 1.70E+03 | 9.94E-01 |
| Lithium hydride | Unknown | Unknown | None |
| Lithium oxide | Unknown | Unknown | None |
| Manganese | Unknown | Unknown | 1.05E+01 |
| Magnesium oxide | Unknown | Unknown | None |
| Mercury (total) ^{g,e} | 1.96E+06 | 4.27E+00 | 6.21E-03 ^h , 4.18E+00 ⁱ |
| Methylene chloride | 1.50E+07 | 3.27E+01 | 1.00E+00 |
| Nitrate (total) ^{j,k} | 4.35E+08 | 1.35E+03 | 1.84E+01 |
| Nitrobenzene | Unknown | Unknown | 1.95E+00 |
| Nitrocellulose | Unknown | Unknown | None |
| Nitric acid ^e | 6.10E+07 | 1.33E+02 | 3.28E+01 |
| Organic acids (ascorbic acid) | Unknown | Unknown | None |
| Organophosphates (tributylphosphate) | Unknown | Unknown | 3.99E+01 |
| Potassium chloride | 9.10E+07 | 1.98E+02 | 2.10E+01 |
| Potassium hydroxide | 4.30E+07 | 9.36E+01 | 1.66E+00 |
| Potassium nitrate | 2.40E+09 | 5.23E+03 | 5.52E+01 |

Table 3-9. (continued).

| Ecological Contaminant of Potential Concern ^a | Upper-bound Inventory ^b (g) | Calculated Soil Concentration ^c (mg/kg) | Minimum Ecologically Based Screening Level ^d (mg/kg) |
|--|---|---|--|
| Potassium phosphate | 1.30E+07 | 2.83E+01 | 1.88E+01 |
| Potassium sulfate | 9.10E+07 | 1.98E+02 | 3.25E+01 |
| Sodium chloride | 1.80E+08 | 3.92E+02 | 9.35E+00 |
| Sodium cyanide ^e | 1.90E+03 | 4.14E-03 | 1.43E-01 |
| Sodium nitrate ^e | 4.60E+09 | 3.48E+03 | None, see total nitrate |
| Sodium phosphate | 2.70E+07 | 5.88E+01 | 5.23E+01 |
| Sodium-potassium | 2.30E+06 | 5.01E+00 | None |
| Sulfuric acid | 1.50E+05 | 3.27E-01 | 1.20E-01 |
| Tetrachloroethylene | 2.90E+07 | 6.32E+01 | 3.33E+00 |
| Toluene ^e | 2.50E+05 | 5.44E-01 | 6.04E+01 |
| Trimethylpropane-triester | 1.60E+06 | 3.48E+00 | 1.30E-01 |
| Xylene | 9.80E+05 | 2.13E+00 | 2.78E-01 |

EDTA = ethylenediaminetetraacetic acid

a. The contaminants of potential ecological concern originally were identified in the preliminary screening (Hampton and Becker 2000).

b. Upper-bound inventory quantities were taken from (Becker et al. [1996], Tables 3 and 4 of Appendix B).

c. Upper-bound concentrations were calculated by distributing the inventory amount over a soil volume $181 \times 669 \times 2.53$ m ($594 \times 2,195 \times 8.3$ ft) deep with a bulk density of 1.5 g/cm^3 (Becker et al. 1996). The volume represents an estimate of the combined volumes for Subsurface Disposal Area pits, trenches, and soil vaults.

d. The minimum ecologically based screening level across receptor groups was selected for nonradionuclide contaminants (DOE-ID 1999).

e. The indicated disposal quantity for this contaminant is suspected to be smaller than the actual amount disposed of (Becker et al. 1998).

f. Total includes copper and copper nitrate.

g. Total includes mercury and mercury nitrate monohydrate.

h. The value shown is the ecologically based screening level for organic mercury.

i. The value shown is the ecologically based screening level for inorganic mercury.

j. Total includes aluminum nitrate, ammonia, copper nitrate, mercury nitrate monohydrate, nitric acid, potassium nitrate, sodium nitrate and uranyl nitrate.

k. A best estimate rather than upper-bound disposal quantity was used to calculate concentrations for this contaminant of potential concern.

3.5 Geophysical Investigations

The SDA has been in operation since 1952 receiving various types of waste for subsurface burial (see Section 3.1). As described in Section 3.1.2.1, the boundaries of original waste burial locations initially were marked using metal tags affixed to perimeter fencing. Later, concrete monuments replaced metal tags, but these monuments periodically were disturbed by SDA maintenance operations. Repeated disturbances eventually produced uncertainty about the true position of some pit and trench boundaries. Geophysical investigations using magnetic and electromagnetic methods have been used to delineate pit and trench boundaries, and the seismic refraction method has been used to estimate soil depth.

Magnetic and electromagnetic methods permit accurate mapping of metallic objects in the subsurface. These methods rely on the magnetic properties of iron and steel and on the contrast between the electrical current-conducting properties of metals and nonmetallic soil and waste. Magnetic and electromagnetic methods are highly selective and sensitive for detecting buried waste that contains metal objects.

Seismic methods rely on the contrast between the acoustic properties of soil and bedrock. Seismic refraction methods take advantage of the fact that sound waves propagate much faster through competent bedrock than through soil or waste. At the SDA, basalt bedrock occurs at depths of 3 to 9 m (10 to 30 ft). The shallow bedrock and overlying soil make an ideal environment for seismic refraction studies.

Table 3-10 provides a list of 10 surface geophysical studies conducted at the SDA since 1989. The geophysical surveys range in scale from single pit surveys to surveys of the full SDA. Digital data have been preserved for some of these surveys in electronic databases. In other cases, report tables and graphics provide the only record of field measurements.

Because metallic objects (including 55-gal drums) are prevalent components of many SDA waste shipments, magnetic and electromagnetic mapping has been used successfully for large-scale definition of SDA burial locations. Figures 3-5 and 3-6 are maps indicating strong geophysical anomalies used to identify features in the subsurface that have a different metallic content compared to the general surroundings. Boundaries of metal-bearing waste for most pits and trenches in the northern SDA are readily apparent. In the southern SDA, pits and trenches are not as easily defined, probably because fewer metallic objects are present (Josten and Thomas 2000).

In combination with waste disposal data in WasteOScope (see Section 3.3.3), high-resolution geophysical surveys have been used to target the location of specific waste shipments or groups of shipments. As an example, geophysical data were used at SVR-12 to locate stainless steel reactor components to be investigated as potential sources of C-14 release. Approximate locations of the target reactor components based on inventory records were plotted on high-resolution geophysical maps (see Figures 3-7 and 3-8). The number and spacing of the combined magnetic and electromagnetic geophysical anomalies roughly correspond with the number and spacing of recorded disposals. A geophysical anomaly is a portion of a geophysical survey that is different in appearance from the survey in general (Sheriff 1973). A one-to-one relationship between geophysical anomalies and specific waste shipments was apparent after evaluating inventory descriptions. The geophysical anomalies were then used to establish the actual position of stainless steel reactor components and to locate Type B lysimeter and vapor probes to monitor for C-14 release.

Other recent applications of surface geophysical data at the SDA include defining the following locations:

- Pit 9 boundary delineation

- Operable Unit 7-10 retrieval site
- Pit 9 preliminary probing campaign demonstrating probe installation
- Pit 9 40 × 40-ft probing campaign
- Pit 9 Probing Campaign 1 installing additional probes north of the 12 × 12-m (40 × 40-ft) area
- Pit 9 Probing Campaign 2 investigating high-efficiency particulate air (HEPA) filter and graphite target areas in Pit 9
- Pit 10 southwest boundary
- Depleted uranium focus area in Pit 10
- Americium and neptunium focus area in Pit 10 (see Section 3.7.7)
- Organic sludge focus area in Pit 4 (see Section 3.7.6)
- Activated metal focus area at SVR-12 and -20 (see Section 3.7.9)
- Installing deep soil vapor monitoring and extraction wells
- Installing tracer ports on north boundary of Pit 10
- Installing a well at Pad A
- Individual soil vaults in SVR-9, -10, and -13
- Individual waste shipments in Trenches 1 through 10.

Table 3-10. Summary of Subsurface Disposal Area surface geophysical surveys.

| Performer | Date | Methods | Survey Area | Digital Data |
|--|---------|--|---|--------------|
| UNC Geotech ^a | 1989 | Magnetic, electromagnetic, and seismic | Pit 9 and the Acid Pit | No |
| Buried Waste Robotics ^b | 1991 | Electromagnetic | Pit 9 | No |
| EBASCO Environmental ^c | 1992–93 | Magnetic and electromagnetic | Entire Subsurface Disposal Area (SDA) | Yes |
| EG&G Idaho ^d | 1992 | Magnetic ^e | Pit 9 | Yes |
| S. M. Stoller Corporation ^f | 1995 | Magnetic, electromagnetic, and seismic | Pit 9 | No |
| GeoSense ^g | 1998 | Magnetic ^e and electromagnetic ^e | Pit 9 | Yes |
| U.S. Geological Survey ^h | 1999 | Electromagnetic ^e | Pit 9 | No |
| Harding Lawson Associates ⁱ | 1999 | Magnetic, ^e electromagnetic, ^e and seismic | Pits 4, 6, and 10 | Yes |
| Sage Earth Science ^j | 1999 | Magnetic ^e and electromagnetic ^e | Pits 2, 3, and 5; Soil Vault Rows (SVRs) -1, -2, -3, -4, -5, -6, -7, -8, -9, -10, -11, -12, and -14 | Yes |
| Sage Earth Science ^k | 2001 | Magnetic ^e and electromagnetic ^e | SVR-20 | Yes |

a. Hasbrouck (1989)

b. Griebenow (1992)

c. Ebasco Environmental (1993)

d. Roybal, Carpenter, and Josten (1992)

e. Indicates high-resolution surveys. Stoller Corporation (1995)

g. GeoSense 1999

h. Wright, Smith, and Abraham (1999)

i. Harding Lawson Associates (1999)

j. Sage Earth Science (1999)

k. Carpenter, Glen, Sage Earth Science, Letter Report to Jason L. Casper, Idaho National Engineering and Environmental Laboratory, September 4, 2001, "Subject: SVR-20 Geophysical Survey," Idaho Falls, Idaho.

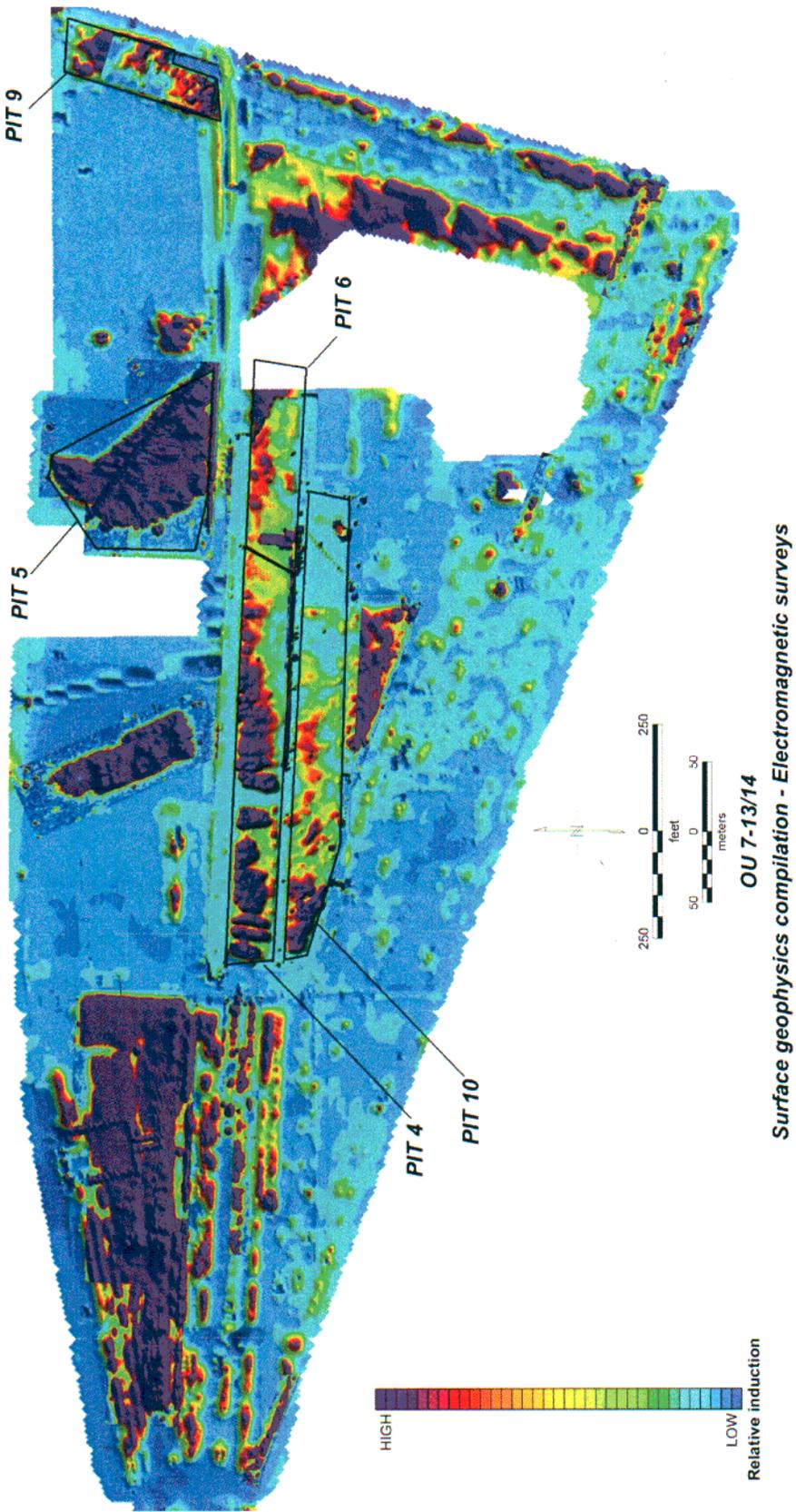


Figure 3-5. Example of a high-resolution geophysical electromagnetic survey at the Subsurface Disposal Area.

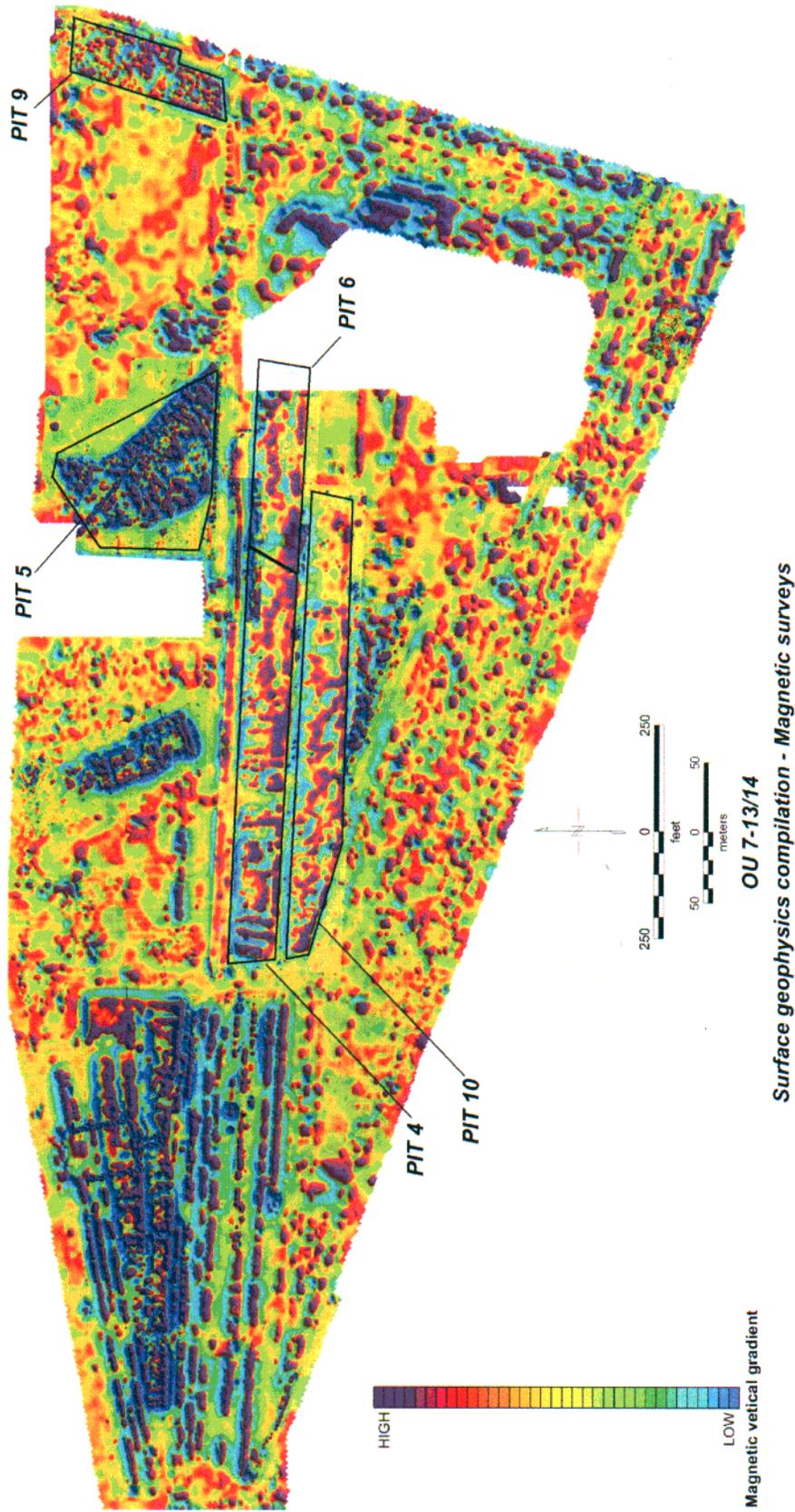


Figure 3-6. Example of a high-resolution geophysical magnetic survey at the Subsurface Disposal Area.

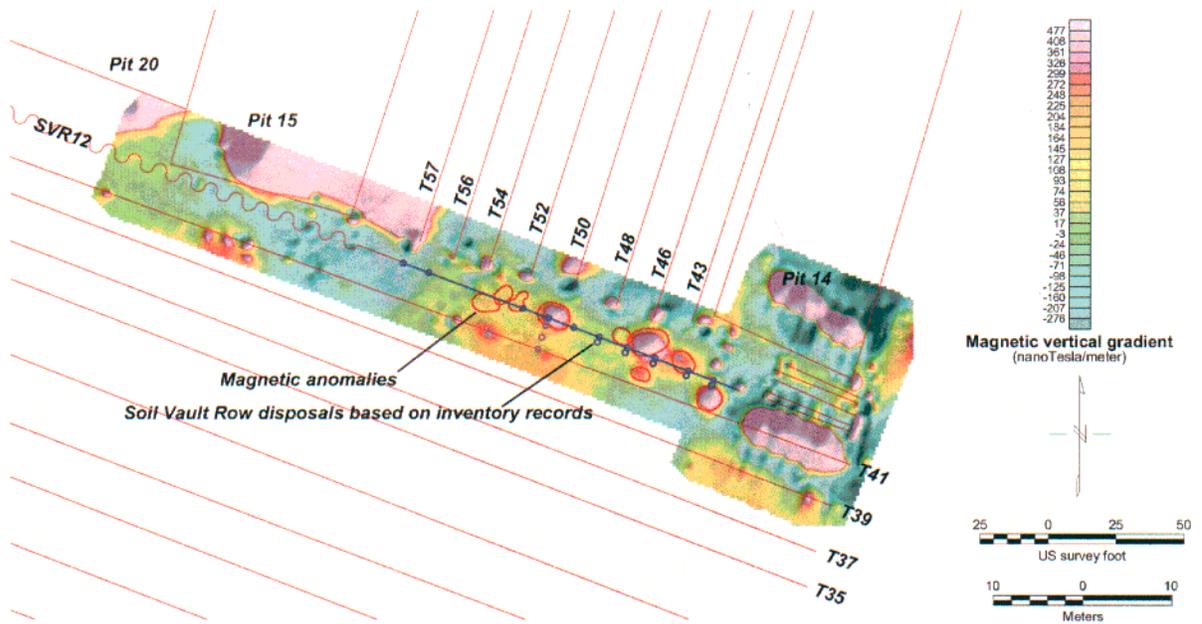


Figure 3-7. Vertical gradient magnetic data for the area surrounding Soil Vault Row 12.

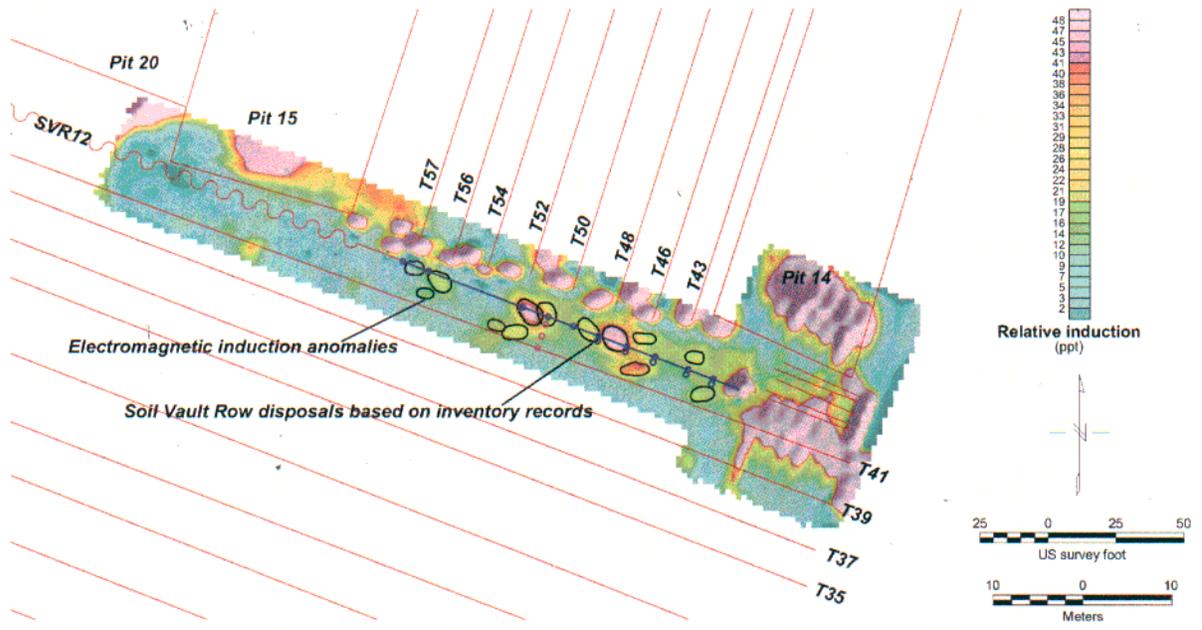


Figure 3-8. Electromagnetic induction data for the area surrounding Soil Vault Row 12.

3.5.1.1 Soil Cover Thickness Estimates Based on Surface Geophysics Data. A

high-resolution geophysical survey of Pits 4, 6, and 10 was completed in 1999. Information available from the survey includes vertical gradient magnetic data and induction electromagnetic data. A summary of soil cover thickness estimates based on the magnetic and electromagnetic data is presented in Table 3-11 (Harding Lawson Associates 1999). Estimates are based on empirical methods and apply only to metallic objects. These geophysical estimates of soil cover thickness correlate very well with historical data (see Section 3.1.6).

Table 3-11. Minimum, maximum, and average soil cover thickness for Pits 4, 6, and 10 based on surface geophysical data.

| Pit | Method | Number | Minimum (ft) ^a | Maximum (ft) ^a | Average (ft) ^a | Estimate ^b (ft) |
|--------|-----------------|--------|---------------------------|---------------------------|---------------------------|----------------------------|
| Pit 4 | Magnetics | 21 | 2.8 | 14.2 | 6.7 | 6 to 9 |
| | Electromagnetic | 22 | 2.8 | 8.9 | 6.9 | |
| Pit 6 | Magnetics | 7 | 4.5 | 12.8 | 7.2 | 4 to 7 |
| | Electromagnetic | 4 | 6.8 | 10.5 | 8.3 | |
| Pit 10 | Magnetics | 33 | 3.6 | 17.0 | 7.7 | 6 to 8 |
| | Electromagnetic | 21 | 2.3 | 7.5 | 5.8 | |

a. Harding Lawson Associates (1999).

b. Barnes (1989).

3.6 Summary of Soil Sampling from 1959 to 1970

Studies were conducted at various locations across the INEEL between 1959 and 1970 to determine if radionuclides had migrated from buried waste into the environment. Schmalz (1972) describes these early studies, including several conducted in and around the SDA. Soil core and water samples were collected around Pits 1, 2, and 10 and Trenches 1, 9, and 48, and water samples were collected in 10 cased monitoring holes. Overall, results from the SDA suggested that contamination was detectable beneath some of the areas sampled. Schmalz (1972) hypothesized that periodic flooding of the SDA may have facilitated transport of contamination to a depth of one foot. However, radioanalytical data cited in the report do not include uncertainty values, sample-specific detection limits, laboratory quality control test results, or laboratory blank results; thus, results are not of acceptable quality. Qualitative results from Schmalz (1972) are summarized in Table 3-12.

Table 3-12. Summary of qualitative results from studies conducted at the Subsurface Disposal Area between 1959 and 1970.

| Location | Media Sampled | Sample Location | Findings ^a |
|-------------|---|---|--|
| Western SDA | Water that collected in the bottom of cased boreholes | Ten monitoring holes throughout western part of SDA | Periodic cesium and strontium in some monitoring holes |
| Pit 1 | Soil | Adjacent to Pit 1 | Uranium and plutonium |
| Pit 2 | Soil from two cores (0 to 12 in depth) | Bottom of the Pit 2 | Possible uranium and plutonium |
| | Interstitial sediments taken from between the barrels | In Pit 2, between waste barrels | Possible uranium and plutonium |
| Pit 10 | Soil from a core (0 to 8 ft depth) | 4 ft from edge of Pit 10 | No contamination |
| | Soil from a core (0 to 14 ft depth) | 55 ft from edge of Pit 10 | No contamination |
| | Soil from six cores (0 to 8 in depth) | Bottom and side of Pit 10 | Uranium, plutonium, and americium |
| Trench 1 | Soil | Adjacent to Trench 1 | Possible uranium and fission activation products |
| Trench 9 | Soil | Adjacent to Trench 9 | No contamination |
| Trench 48 | Soil from a core (0-20 ft depth) | 4 ft from edge of Trench 48 | Possible Ce-144, Cs-137, Zr, Nb-95 |
| | Soil from a core (0 to 20 ft depth) | 45 ft from edge of Trench 48 | No contamination |

a. Analytical data were not qualifiable and, therefore, concentrations are not presented.

3.7 Probing in the Subsurface Disposal Area

From December 1999 through November 2001, 337 probes were installed in the SDA to collect monitoring data directly from the waste zone. Unlike any monitoring equipment previously deployed in the SDA, most probes penetrate into buried waste to provide direct or immediately proximal monitoring capabilities. A sonic drill was used to install two kinds of probes, called Type A and Type B probes. Type A probes are hollow, bottom-sealed tubes that allow safe access into the waste zone with nuclear logging instruments. Type B probes are units equipped with various instruments or access ports to provide additional monitoring capabilities in and immediately beneath the waste. Instruments in the Type B probes include tensiometers, suction lysimeters, vapor ports, and soil moisture detectors. A special set of transparent polycarbonate tubes for visual examination of buried waste also is classified as Type B probes.

The following discussions provide information about probing in the SDA. Some information is not yet available in published reports and is provided here in detail, while other topics are summarized. Documents cited in the summaries are listed in Section 3.10. Topics below include descriptions of probing strategy; Type A and Type B probes; probing activities in Pit 9 and five focus areas in Pits 4, 5, and 10 and SVR-12 and -20; soil moisture monitoring; cover and waste zone thicknesses; and continued data collection from the SDA probes.

3.7.1 Probing Background

The probing strategy implemented in Pits 4, 5, and 10 in the SDA is described in the OU 7-13/14 Probehole Plan (INEEL 2000c), which outlined the scope and objectives for the OU 7-13/14 probing. A companion field sampling plan (Salomon 2001) provided specific sampling and monitoring requirements for data collection from Type B probes. The probing in Pit 9 was conducted in accordance with requirements of the Pit 9 Interim Action RD/RA Work Plan (LMITCO 1997). Objectives of the probing, strategy used to site probes to meet objectives, and selection of probing locations and configurations are presented below.

3.7.1.1 Probing Objectives. Data gathered from the probing are being used to support assessment of the following parameters:

- Locations of waste types, distributions of radionuclides in buried waste near the probeholes, and thicknesses of soil and waste layers
- Radiological fingerprints for identifying different waste streams
- Infiltration rates through the cover, buried waste, and underburden soil at the SDA
- Release rate and solubility of uranium
- Release rate of C-14
- Mass of the VOC source remaining in buried waste.

3.7.1.2 Probing Strategy. The overall project strategy was to extract existing information from WasteOScope (INEEL 2001d) to identify candidate locations for waste types of interest (see Section 3.3.3). This information, summarized in the OU 7-13/14 Probehole Plan (INEEL 2000c), was used to select focus areas. Type A probes were installed in some of these focus areas during the first

phase of the SDA probing project. Results from nuclear logging of Type A probes then were used to site most of the clusters of Type B probes in the second phase.

Five probing focus areas were defined for Pits 4, 5, and 10 and two soil vault rows to investigate specific waste types. To increase the likelihood of encountering a target waste stream, Type A probes typically were installed in lines, called transects, across an area of interest. Type A probes subsequently were logged, and the results were used to select optimal sites for clusters of probes. Probe clusters are collocated Type A and Type B probes deployed to study contaminant and moisture conditions in specific focus areas. The primary purpose for installing probes in clusters was to acquire information about the spatial relationships of the source mass, the net infiltration, and the leachate concentrations as a function of time.

3.7.1.3 General Probe Locations and Configurations. The following quantities and types of probes were installed in the SDA:

- 135 Type A probes (excludes 10 probes not logged because of shallow completions less than 1.9 m [6.3 ft] and includes five replacements for the shallow probes)
- 66 tensiometers
- 78 soil moisture probe instruments (51 physical probes, some being multi-instrumented)
- 30 vapor ports
- 18 lysimeters
- 10 visual probes.

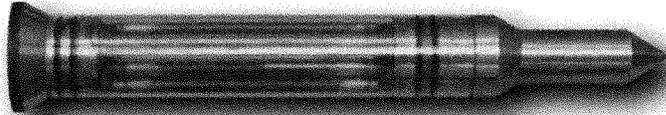
The suite of probes used in this investigation is illustrated in Figure 3-9. The following sections provide more detail about the probe types and the criteria used for selecting their locations, the type of probe installed, and monitoring activities. An entire suite of Type B probes is represented in Figure 3-10; however, most probe configurations, or clusters, did not include every available probe type.

Specific types of probes and various configurations of probe placement in specific areas of the SDA are discussed in the following sections:

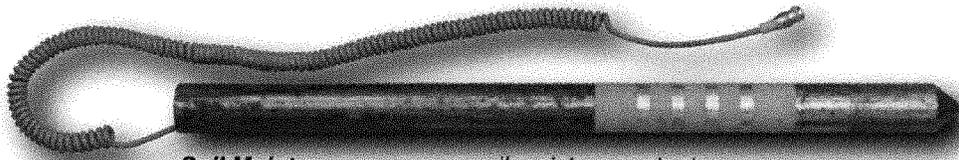
- Section 3.7.4—the Pit 9 study area
- Section 3.7.5—the depleted uranium focus area in Pit 10
- Section 3.7.6—the organic sludge focus area in Pit 4
- Section 3.7.7—the americium and neptunium focus area in Pit 10
- Section 3.7.8—uranium and enriched uranium focus area in Pit 5
- Section 3.7.9—activated metal investigations at SVR-12 and -20
- Section 3.7.10—waste zone moisture monitoring array.



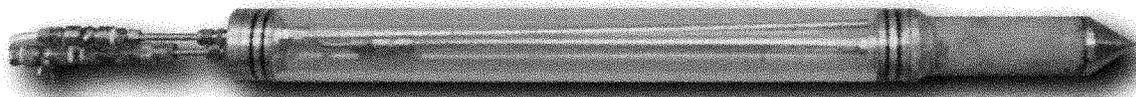
Vapor—detects and collects gas and vapor samples



Visual—allows visual inspection of subsurface conditions (tip section only)



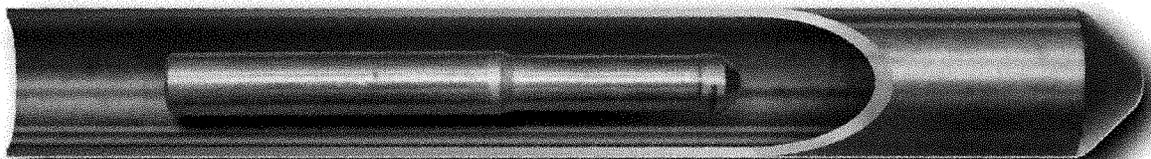
Soil Moisture—measures soil moisture content



Lysimeter—collects water/liquid samples (unit shown is a development model which has clear plastic in place of stainless steel wall components to show probe internals)



Tensiometer—measures movement of water



Type A—accommodates interchangeable logging tools that detect contamination

Figure 3-9. Probe suite used in the Subsurface Disposal Area probing project.

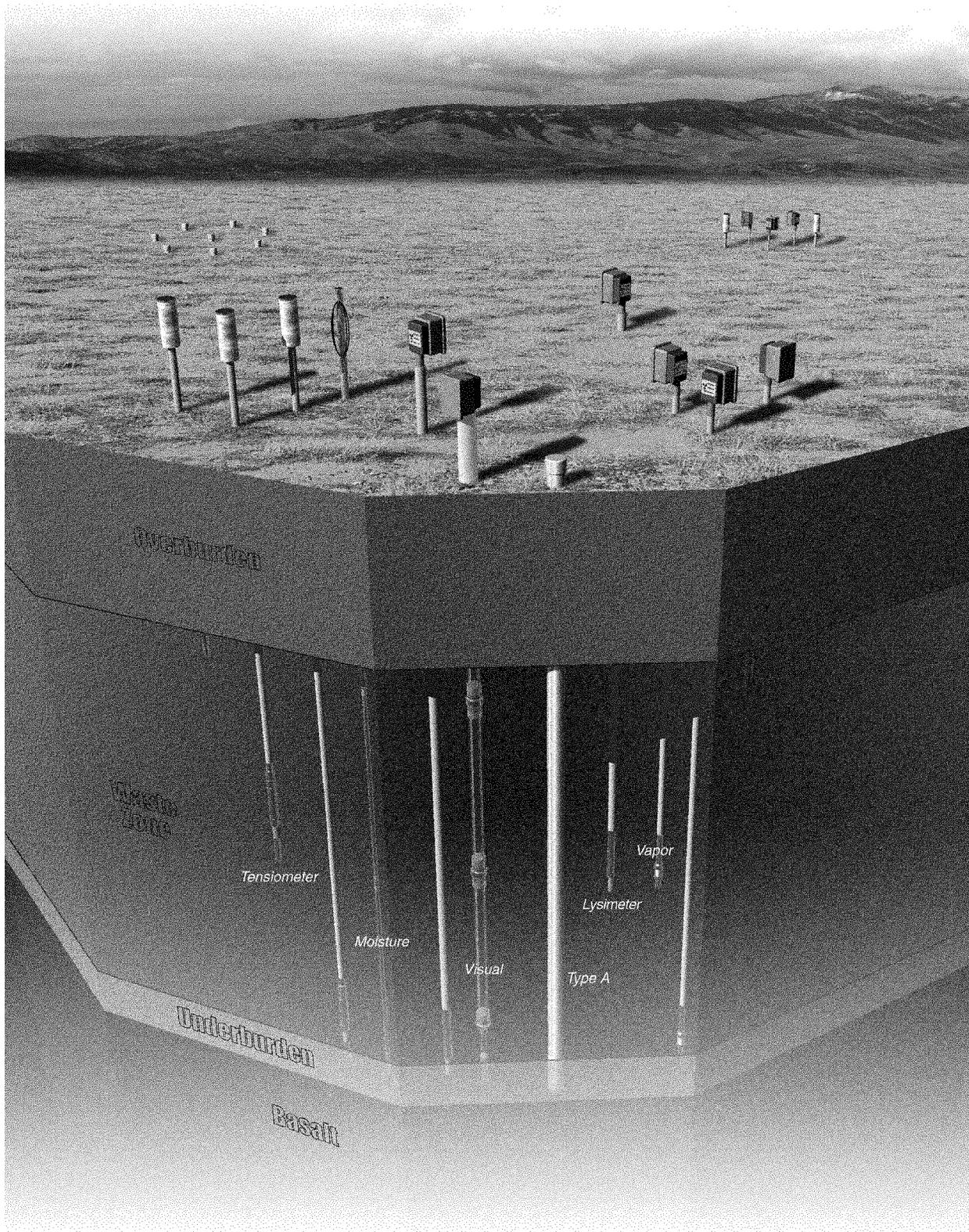


Figure 3-10. View of a typical probe suite deployed in the Subsurface Disposal Area.

3.7.2 Type A Probes and Logging Instruments

Type A probes are sealed, steel casing with a 14-cm (5.5-in.) outside diameter installed directly into the buried waste in the pits. A total of 135 Type A probes were installed in the SDA. The soil and waste adjacent to the Type A probes were characterized with nuclear logging instruments. The first set of Type A probes were placed in lines, called transects, and spaced approximately 1.8 to 2.1 m (6 to 7 ft) apart. Many Type A probes were successfully driven to the underlying basalt while some Type A probes met refusal at an interim depth in the buried waste. Subsequent probe installations included placing Type A probes between some of the original transects to form a grid, and installing close-spaced Type A probes in clusters around original Type A probes to evaluate source characteristics.

Type A probes were monitored with the following five commercially available logging instruments:

- Passive spectral gamma detector for identifying gamma-emitting radionuclides
- Neutron activation instrument to detect prompt gamma rays from neutron activation of Cl-35, an indicator for halogenated hydrocarbons (e.g., chlorine containing volatile organic compounds like carbon tetrachloride)
- Neutron-neutron detector to evaluate soil moisture
- Passive neutron detector for sensing spontaneous fission and alpha-neutron reactions (e.g., TRU constituents)
- Shielded, directional gamma detector to identify azimuthal location of gamma-emitting sources.

Detailed descriptions of these tools and results of the logging are presented in the OU 7-13/14 Probehole Plan (INEEL 2000c). Section 4 contains summaries of the results and interpretations of the nuclear logging in the waste zone for specific contaminants.

3.7.3 Type B Probes and Instrumentation

The installation and monitoring of the Type B probes is described in the Type B Probe Field Sampling Plan (FSP) (Salomon 2001). Type B probes include tensiometers, suction lysimeters, vapor ports, soil moisture detectors, and visual probes. Though geochemical probes were specified in the Probehole Plan (INEEL 2000c), the instruments did not meet development criteria and their deployment was discontinued. Instead, lysimeters and vapor ports will be used to collect data for evaluating oxidation-reduction conditions. The remainder of this section provides a brief description of various Type B probe instruments and types of data generated by the Type B probes.

3.7.3.1 Tensiometers. Tensiometers are used to measure either the matric potential of a porous medium under unsaturated conditions or the pressure head if saturated conditions form. Tensiometers were placed in location to provide data on the variability of moisture in the waste zone, quantify the amount and timing of moisture infiltration, and define the presence and extent of saturated conditions (Salomon 2001). Construction and design specifications of the tensiometers are described in Grover (2001).

A total of 66 tensiometers were installed throughout the SDA in nested groups of three. The upper group was placed near the overburden and upper waste contact, the middle group was placed in the upper third of the waste zone, and the lower group was placed at the underburden and waste contact or in

contact with the underlying basalt, as conditions allowed. In most instances, the tensiometers were paired with soil moisture probes. Data generated by these instruments were collected on data loggers, typically taking measurements at 2-hour intervals.

3.7.3.2 Soil Moisture Probes. Soil moisture probes indirectly measure the moisture content of soil using the relationship between the soil dielectric constant and the moisture content. Probes also perform resistivity measurements of the electrical contrasts between different geologic media and indicate the temperature of surrounding material. Specifications of the soil moisture probes installed for this investigation are detailed in Anderson (2001a).

A total of 51 soil moisture probes were installed in the SDA, with 78 soil monitoring instruments. Some of these soil moisture probes have multiple instruments attached to them. As many as three soil moisture instruments were installed on some probes. In most instances, the soil moisture probes were paired with tensiometers. Probes often were nested in groups of three. The upper instruments were placed near the overburden and waste contact, the middle instruments were placed in the middle of the waste zone, and the lower instruments were placed at the underburden and waste contact or in contact with the underlying basalt, as conditions allowed. Soil moisture probes are being used to describe the following characteristics (Salomon 2001):

- Relative changes in moisture over time to corroborate and supplement matric potential measurements from tensiometers
- Extent of infiltration to corroborate and supplement matric potential measurements
- A lower-bound order of magnitude for net infiltration and drainage at the depth of the probe.

3.7.3.3 Lysimeters. Suction lysimeter probes collect soil moisture samples through application of a partial vacuum to a porous cup that is in contact with soil. Construction and design specifications of the suction lysimeters installed for this investigation are described in Clark (2001a). Lysimeter probes typically were installed in pairs using the following guidance:

- In or just below the targeted waste for that area
- At the waste and underburden contact or at the contact with underlying basalt.

A total of 18 lysimeter probes were installed—16 in Pits 4, 5, and 10 and two near SVR-12. The analytical suites for lysimeter samples are described in the Type B Probe FSP (Salomon 2001). Samples collected from the pits are analyzed for a broad range of radionuclides, VOCs, nonradioactive metals, and other inorganic constituents, depending on available sample volume. Lysimeter samples collected near the soil vaults are analyzed for a smaller suite of radionuclides to focus on those typically associated with activated metallic waste.

3.7.3.4 Vapor Ports. Commercially available vapor ports were combined with Type B probes and installed to collect soil gas from waste zones and the area surrounding soil vaults in the SDA. Specifications of vapor ports installed for this investigation are detailed in Clark (2001b). Vapor ports usually were bundled in threes and installed generally at the following three vertical horizons:

- Just below the overburden and waste contact
- Middle of the waste zone or in close proximity to a desired source in the waste
- Slightly above the waste and underburden contact.

A total of 30 vapor ports were installed—16 in Pits 4, 5, and 10 and 14 near SVR-12 and -20. One vapor port in Pit 4 malfunctioned and subsequently was abandoned. Samples collected from the pits are being analyzed in accordance with the Type B Probe FSP (Salomon 2001). All vapor samples from the pits are analyzed for VOCs. In addition, some vapor samples are analyzed to evaluate subsurface reduction/oxidation (redox) conditions by assessing O₂, CO₂, H₂, and methane. All samples collected from vapor ports surrounding soil vaults are analyzed for C-14. Samples collected at SVR-20 also are analyzed for tritium.

3.7.3.5 Visual Probes. Visual probes were installed to allow observation and investigation of the soil overburden and waste zone. Visual probes are transparent polycarbonate tubes reinforced with an internal steel cage. A miniature video camera is lowered through the visual probe to visually observe the waste and subsurface conditions. The videos are interpreted by personnel familiar with historical waste-generating processes such as at RFP and historical waste disposal operations at the RWMC.

Construction and design specifications of visual probes installed for this investigation are described in Clark (2001c). Visual probe video logs, used in conjunction with other probing data, are used to evaluate conditions in the waste zone. The following subsurface conditions can be observed:

- Location of the top and bottom of the overburden and underlying sediment
- Thickness of sediment beneath the waste
- Relative grain size of the geologic media (i.e., cobbles, pebbles, sand, silt, clay) next to the probe
- Stratification in the sediment beneath the waste or disturbance in the sediment
- Color of sediment beneath the waste for oxidation and reduction indication
- Amount of sediment versus waste adjacent to the tube in the waste zone
- Visual indication of moisture movement
- Evidence of how tightly the tube is sealing
- Condition of the drums
- Void spaces caused by drum placement or lack of material
- Presence of cellulose material (i.e., boxes, wood, paper)
- Waste form identification (e.g., sludge, graphite, combustibles, nitrate salts, or noncombustibles).

Though the video logs improved with each deployment of the video camera, several future improvements have been proposed for visual examination. The improved format and output expected from future digital video-logging activities would greatly expedite interpretation of the videos.

3.7.4 Pit 9 Study Area

Operable Unit 7-10 comprises Pit 9, which was an active disposal pit from November 1967 through June 1969 (see Section 3.2.9). The pit is approximately 4 ha (1 acre) in size and is roughly trapezoidal in shape with areal dimensions of 115 × 40 m (379 × 127 ft) (McClellan, del C. Figueroa, and King 1991).

A total of 49 Type A probes (excluding five probes with shallow penetrations) and three Type B visual probes were installed in Pit 9, as illustrated in Figure 3-11. The approach to probing in Pit 9 is described in the RD/RA Work Plan (LMITCO 1997) and summarized below.

- **Pit 9 Preliminary Campaign**—The Pit 9 preliminary campaign, conducted in June 1999, involved installing and logging three Type A probes outside the southeast Pit 9 boundary. Moisture and n-gamma logging was conducted in these probes to assess general soil conditions with particular emphasis on soil moisture (INEEL 2000c). The Pit 9 preliminary probing campaign was undertaken to help address safety concerns before probe installation in waste areas.
- **Pit 9 40 × 40-ft Campaign**—An area in Pit 9, measuring approximately 12 m (40 ft) on each side was selected for detailed subsurface investigation (see Figure 3-11). Known as the 40 × 40-ft study area, the location was selected based on waste inventory information and surface geophysical data assessed using WasteOScope (INEEL 2001d). Records indicated that the area contained a high percentage of drums containing plutonium from RFP. Twenty Type A probes were installed and logged using the full suite of geophysical logging tools, including several azimuthal logs. The primary objective of logging data analysis was to select a location in the 12 × 12-m (40 × 40-ft) area to perform a limited excavation and waste retrieval (Beitel et al. 2000; Josten and Okeson 2000).
- **Pit 9 Campaign 1**—Pit 9 Campaign 1 involved installing eight additional Type A probes to the north of the 40 × 40-ft area to evaluate conditions in the northern part of the pit. This area was a candidate location for the Pit 9 waste excavation and retrieval. Five probes could penetrate no further than depths of 1.5 m (5 ft) or less and were replaced by new probes located several feet away. All Campaign 1 probes were logged with the full standard logging suite.
- **Pit 9 Campaign 2**—Pit 9 Campaign 2 consisted of two Type A probe arrays, one located in the northern part of Pit 9 and one located along the southeast pit boundary. The northern array included eight probes and was intended to explore for Pu-239-bearing HEPA filters. These probes have “P9-FI-xx” designators in Figure 3-11. The southern array consisted of seven probes and was intended to explore for Pu-239-bearing graphite molds, and have “P9-GR-xx” designators in Figure 3-11. Both search locations were selected by the combined use of waste inventory records and surface geophysical data in WasteOScope. All Campaign 2 probes were logged with the full standard logging suite.
- **P9-20 Investigation**—Six additional Type A probes were installed in a circular pattern around the P9-20 probe. Initial passive gamma logging data from the Type A probe at the P9-20 location indicated a significant zone of Pu-239. This zone had a maximum apparent concentration nearly three times the next highest Pu-239 detection in Pit 9 and an order of magnitude greater than the next highest reading for Pu-239 detection in any other Type A probe in the SDA. The specific objective of the additional six cluster Type A probes was to obtain detailed information needed to evaluate criticality potential.
- Data from the six additional Type A probes showed a decrease of one to two orders of magnitude in Pu-239 levels than observed in P9-20. Furthermore, the data indicated that the Pu-239 source was contained entirely in the circle of probes, and that the source volume and mass are much smaller than previously speculated. The spectral data indicate that a point or small distributed, concentrated source exists. This interpretation of the probe data is consistent with historical WasteOScope records that drums containing graphite molds were disposed of in the area. Graphite molds could have had plutonium fixed to their surfaces or wedged in cracks in the molds.

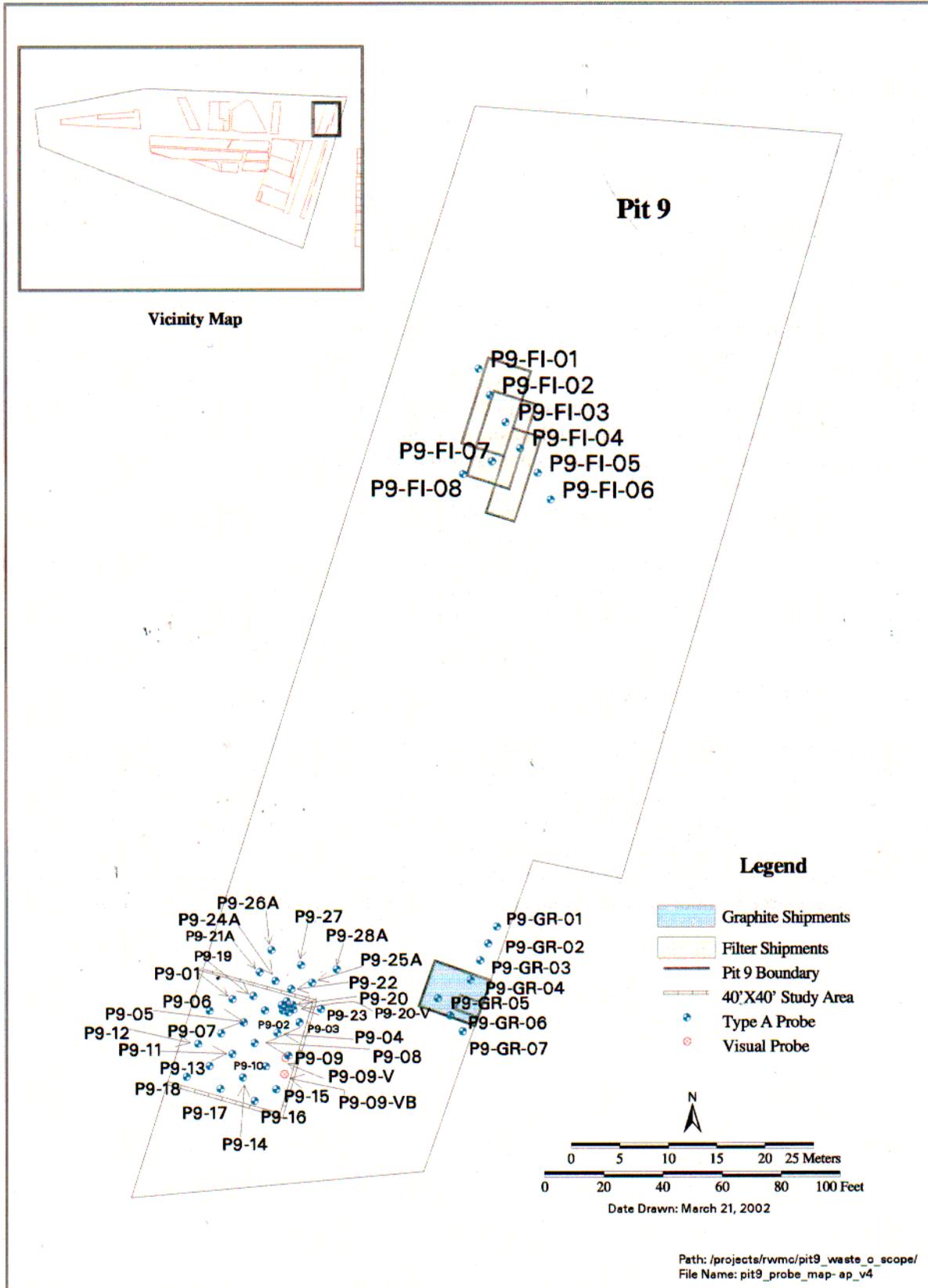


Figure 3-11. Probes installed in the Pit 9 study area.

3.7.5 Depleted Uranium Focus Area

Depleted uranium from RFP is the dominant uranium waste form in the SDA. Depleted uranium material, called roaster oxide, was exposed to a flame and roasted (i.e., oxidized), allowing for safe shipping and storage of this otherwise pyrophoric material. Information from WasteOScope (INEEL 2001d) indicated that the west end of Pit 10 contained depleted uranium. Geophysical surveys indicated that metallic objects were present in this area. Type A probes were first installed along two transects in the depleted uranium focus area and later additional Type A probes were installed between the transects (see Figure 3-12). Probes DU-01 through DU-08 compose the two original probe transects. Interpreted results from these probes are documented in the Type B Probe FSP (Salomon 2001, Appendix D).

Locations for Type B probe clusters were identified from the Type A logging data. The highest concentrations of uranium detected in the depleted uranium focus area were found at locations DU-10 and DU-14, indicating that the locations were optimal for Type B probe clusters. The Type A probes were then logged using a directional gamma detector to identify azimuthal location of gamma-emitting sources in May 2001. A third cluster also was deployed in the depleted uranium focus area because geophysical logging results indicated that it was an excellent site to monitor neptunium waste. This site, DU-08, is described under the discussion on the americium and neptunium focus area in Section 3.7.7.

In addition, a depleted uranium source was identified in the organic sludge focus area in the east end of Pit 4. The highest level of U-238 detected in any Type A probe was found at Probe 743-08. This probe also was selected as the origin of a probe cluster to characterize organic sludge and, thus serves for both depleted uranium and organic sludge characterization. The primary clusters and probes used to characterize depleted uranium waste are listed in Table 3-13, which includes the probes in Probe Cluster 743-08.

3.7.6 Organic Sludge Focus Area

Organic compounds buried in the SDA include carbon tetrachloride, methylene chloride, TCE, TCA, PCE, heavy lubricating oils, polychlorinated biphenyls, chlorofluorocarbons, alcohols, organic acids, ethylenediaminetetraacetic acid (EDTA, also known as Versenes) and nitrobenzene. The primary contributors to potential risk in the IRA (Becker et al. 1998) from organic sludge were carbon tetrachloride, methylene chloride, and PCE. Ninety-eight percent of the CCl_4 was originally contained in RFP 743-series sludge. Information from WasteOScope (INEEL 2001d) indicated that the east end of Pit 4 contained a large number of drums containing 743-series sludge. High VOC soil gas concentrations

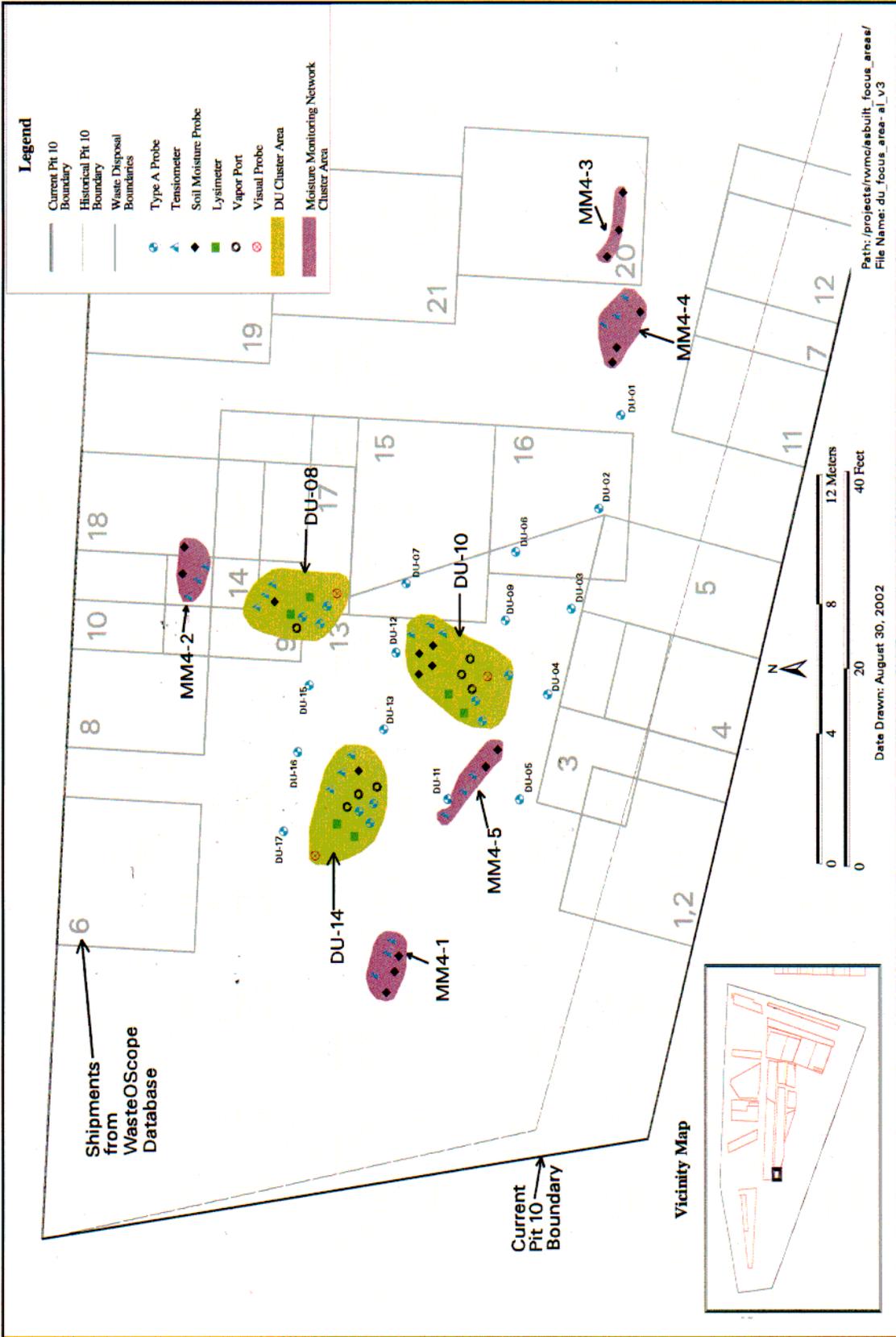


Figure 3-12. Probe clusters installed in and around the depleted uranium focus area in the west end of Pit 10.

Table 3-13. Probe completions, by cluster, in the west end of Pit 10 and the east end of Pit 4 supporting depleted uranium waste assessment.

| Probe Type | | | | | | | | | | | | | | | | | |
|---------------|------------|------------------|------------|-----------------------|------------|------------|-----------------------|------------|------------|-----------------|------------|------------|-----------------|------------|------------|------------------|--|
| Type A Probe | | | | Tensiometer | | | Soil Moisture Probe | | | Lysimeter | | | Vapor Port | | | Visual Probe | |
| Cluster Name | Probe Name | Probe Depth (ft) | Probe Name | Instrument Depth (ft) | Probe Name | Probe Name | Instrument Depth (ft) | Probe Name | Probe Name | Port Depth (ft) | Probe Name | Probe Name | Port Depth (ft) | Probe Name | Probe Name | Probe Depth (ft) | |
| DU-10 | DU-10 | 17.3 | DU-10-T3 | 9.1 | DU-10-M1 | DU-10-M1 | 9.2 | DU-10-L1 | DU-10-L1 | 9.8 | DU-10-VP1 | DU-10-VP1 | 11.5 | DU-10-V | DU-10-V | 7 | |
| | | DU-10-A | 17.0 | DU-10-T2 | 6.7 | DU-10-M2 | DU-10-M2 | 6.6 | DU-10-L2 | DU-10-L2 | 7.0 | DU-10-VP2 | DU-10-VP2 | 10.0 | | | |
| | | DU-10-B | 17.2 | DU-10-T1 | 4.0 | DU-10-M3 | DU-10-M3 | 4.0 | | | | DU-10-VP3 | DU-10-VP3 | 6.2 | | | |
| DU-14 | DU-14 | 17.3 | DU-14-T3 | 15.3 | DU-14-M1 | DU-14-M1 | 15.2 | DU-14-L1 | DU-14-L1 | 16.0 | DU-14-VP1 | DU-14-VP1 | 16.0 | DU-14-V | DU-14-V | 10.5 | |
| | | DU-14-A | 17.5 | DU-14-T2 | 9.0 | DU-14-M1 | DU-14-M1 | 9.8 | DU-14-L2 | DU-14-L2 | 7.9 | DU-14-VP2 | DU-14-VP2 | 11.7 | | | |
| | | DU-14-B | 17.6 | DU-14-T1 | 3.7 | DU-14-M1 | DU-14-M1 | 4.5 | | | | DU-14-VP3 | DU-14-VP3 | 4.9 | | | |
| 743-08 | 743-08 | 25.3 | 743-08-T3 | 22.4 | 743-08-M1 | 743-08-M1 | 22.3 | 743-08-L1 | 743-08-L1 | 23.3 | 743-08-VP1 | 743-08-VP1 | 20.2 | 743-08-V | 743-08-V | 13.6 | |
| | | 743-08-1 | 25.6 | 743-08-T2 | 13.0 | 743-08-M1 | 743-08-M1 | 13.9 | 743-08-L2 | 743-08-L2 | 9.0 | 743-08-VP2 | 743-08-VP2 | 13.4 | | | |
| | | 743-08-2 | 25.0 | 743-08-T1 | 5.6 | 743-08-M1 | 743-08-M1 | 6.6 | | | | 743-08-VP3 | 743-08-VP3 | 4.9 | | | |
| | | 743-08-3 | 26.3 | | | | | | | | | | | | | | |
| | | 743-08-4 | 24.1 | | | | | | | | | | | | | | |
| | | 743-08-5 | 25.0 | | | | | | | | | | | | | | |
| | 743-08-6 | 25.1 | | | | | | | | | | | | | | | |

that have been detected over the east end of Pit 4 corroborated that drums containing 743-series sludge were buried there. The VOC concentration was corroborated further from results of Type A logging. Most of these probes logged with the n-gamma tool indicated elevated chlorine detections across the focus area. Chlorine is indicative of chlorine-bearing wastes such as VOCs and polyvinyl chloride plastic.

Investigation in the east end of Pit 4 was undertaken primarily to collect data to evaluate the mass of VOCs remaining in the buried waste, using a combination of shallow and waste zone vapor probes, nuclear logging of the Type A probes, flux chamber measurements, and modeling. A long transect of Type A probes first was installed in the eastern side of Pit 4 (see Figure 3-13). The area investigated contained a significant quantity of organic sludge. The probe transect was designed to originate in an area where VOC-containing waste drums were heavily concentrated, and extend to an area with minimal VOC-containing waste. The transect passed through 30 delineated waste shipments recorded for the area in Pit 4. Of these disposals, 26 originated from Rocky Flats and contained 743-series sludge, which contains high concentrations of VOCs. The 30 disposals contained approximately 2,819 drums, of which 1,077 (38%) were drums of 743-series sludge (INEEL 2000c). Using WasteOScope, shallow soil gas and geophysical data were used to aid in the placement of the transect.

Figure 3-14 is an example of a recent soil gas survey and shows that high levels of carbon tetrachloride are in the northeast corner of Pit 4, which corresponds well with the disposal records described above. The survey was conducted after placement of the original probe transect and is given here because the data set is more current than the original shallow soil gas survey data. Figure 3-15 represents an electromagnetic geophysical survey conducted over the same area. This survey indicates the presence of metallic objects, probably drums, in a wide area of the eastern section of Pit 4 and also indicates substantially less metallic material in the southern portion of the pit. Data from these types of surveys supported the plan to place probes over a transect covering a high to low concentration of VOC-bearing waste.

Multiple disposals of organic sludge were concentrated in the east end of Pit 4. Accordingly, precision was less important in choosing locations for the Type B clusters. The three primary probe cluster locations were chosen to cover a large areal extent of the transect and also to cover a range of chlorine detections generated from nuclear logging data.

Location 743-03 was chosen as the origin of a probe cluster because it had the highest chlorine signature collected from any Type A probe along the transect. According to WasteOScope, this location also contained numerous organic sludge disposals and previous soil gas surveys indicated elevated VOC concentrations. Location 743-08 was selected for much the same reason. In addition, this location contained the largest detection of U-238 daughter products and, thus, was able to provide valuable information about depleted uranium characteristics in addition to data about the organic sludge. Location 743-18 was selected because it is in the transition area between disposals that contain organic sludge and those that do not. Type A logging data indicated the presence of chlorine, but at substantially lower concentrations than identified at 743-03 and 743-08. The data interpretations used to locate the Type B probe clusters are given in the Type B Probe FSP (Salomon 2001, Appendix D). The types and completion depths of probes used to form clusters in the organic sludge focus area are listed in Table 3-14.

3.7.7 Americium and Neptunium Focus Area

The primary source of Am-241 and Np-237 in the SDA is the RFP 741-series sludge (i.e., first stage wastewater sludge). An area in the central part of Pit 10 was identified as the americium and neptunium focus area. Disposal numbers^g 195, 196, 205, 206, and 207 in that location were of special

g. Disposal numbers are artifacts of early versions of WasteOScope and were applied in probehole planning documents, figures, and other aspects of the probing implementation. These numbers no longer appear in WasteOScope.

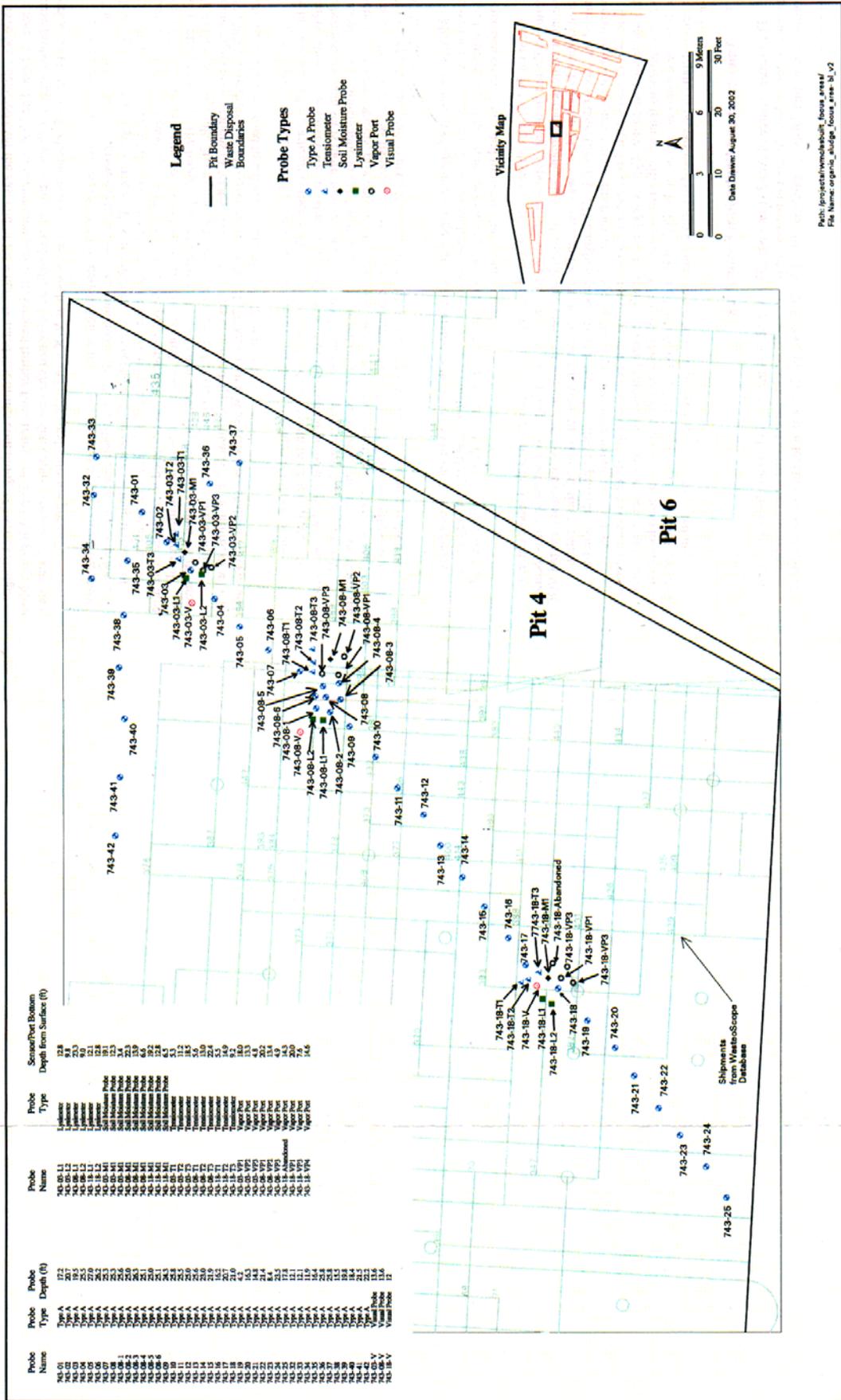


Figure 3-13. Probes installed in the organic sludge focus area in the eastern end of Pit 4.

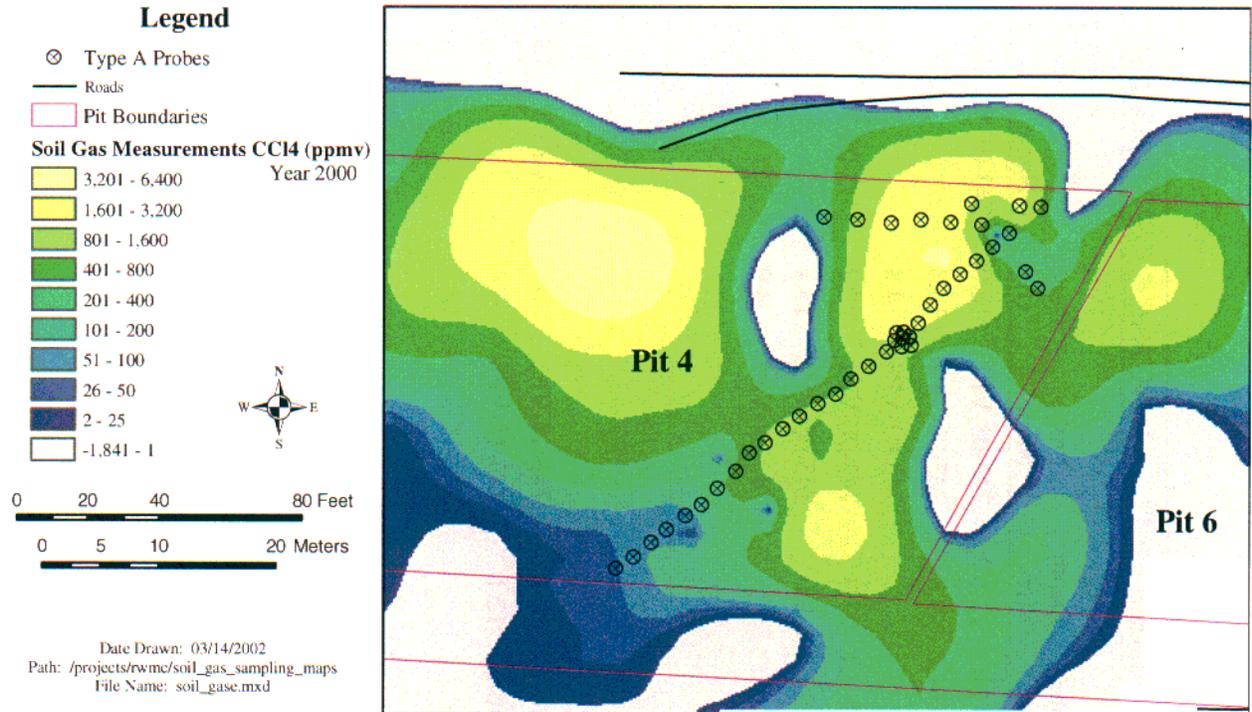


Figure 3-14. Relationship of shallow soil gas survey and Type A probe placement in the east end of Pit 4.

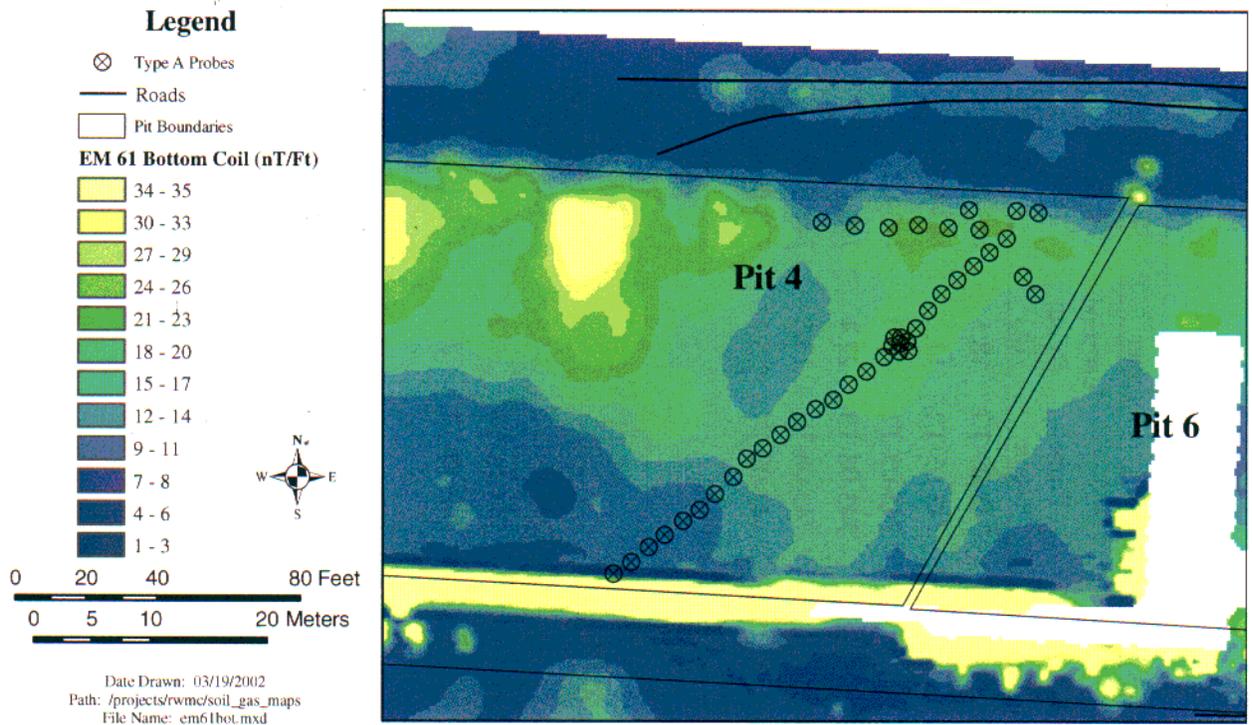


Figure 3-15. Relationship of geophysical survey and Type A probe placement in the east end of Pit 4.

Table 3-14. Probe completions, by cluster, in the organic sludge focus area in the east end of Pit 4.

| Cluster Name | Probe Type | | | | | | | | | | | | | | | | | |
|---------------|--------------|------------------|------------|-------------|-----------------------|------------|-----------------------|------------|-----------------------|------------|-----------------------|------------|-----------------|------------|-----------------|--------------|-----------------|--|
| | Type A Probe | | | Tensiometer | | | Soil Moisture Probe | | | Lysimeter | | | Vapor Port | | | Visual Probe | | |
| | Probe Name | Probe Depth (ft) | Instrument | Probe Name | Instrument Depth (ft) | Probe Name | Instrument Depth (ft) | Probe Name | Instrument Depth (ft) | Probe Name | Instrument Depth (ft) | Probe Name | Port Depth (ft) | Probe Name | Port Depth (ft) | Probe Name | Port Depth (ft) | |
| 743-03 | 743-03 | 19.5 | 743-03-T3 | 18.5 | 743-03-M1 | 19.1 | 743-03-L1 | 12.8 | 743-03-VP1 | 18.0 | 743-03-V | 13.6 | | | | | | |
| | | | 743-03-T2 | 11.2 | 743-03-M1 | 12.3 | 743-03-L2 | 9.8 | 743-03-VP2 | 13.3 | | | | | | | | |
| | | | 743-03-T1 | 5.3 | 743-03-M1 | 3.4 | | | 743-03-VP3 | 4.8 | | | | | | | | |
| 743-08 | 743-08 | 25.3 | 743-08-T3 | 22.4 | 743-08-M1 | 22.3 | 743-08-L1 | 23.3 | 743-08-VP1 | 20.2 | 743-08-V | 13.6 | | | | | | |
| | 743-08-1 | 25.6 | 743-08-T2 | 13.0 | 743-08-M1 | 13.9 | 743-08-L2 | 9.0 | 743-08-VP2 | 13.4 | | | | | | | | |
| | 743-08-2 | 25.0 | 743-08-T1 | 5.6 | 743-08-M1 | 6.6 | | | 743-08-VP3 | 4.9 | | | | | | | | |
| | 743-08-3 | 26.3 | | | | | | | | | | | | | | | | |
| | 743-08-4 | 25.1 | | | | | | | | | | | | | | | | |
| | 743-08-5 | 25.0 | | | | | | | | | | | | | | | | |
| | 743-08-6 | 25.1 | | | | | | | | | | | | | | | | |
| 743-18 | 743-18 | 21.0 | 743-18-T2 | 14.9 | 743-18-M1 | 19.2 | 743-18-L2 | 12.8 | 743-18-VP1 | 20.0 | 743-18-V | 12 | | | | | | |
| | | | 743-18-T3 | 9.2 | 743-18-M1 | 12.8 | 743-18-L1 | 12.1 | 743-18-VP3 | 7.6 | | | | | | | | |
| | | | 743-18-T1 | 5.5 | 743-18-M1 | 6.5 | | | 743-18-VP4 | 14.6 | | | | | | | | |

interest for two reasons: (a) the disposals contain relatively large numbers of 741-series drums, and (b) because the 741-series drums occur in high ratios relative to other types of waste drums in the same disposals. For example, Disposals 195 and 196 contained a total of 301 drums and 169 of those drums contained 741-series sludge. Similarly, Disposals 205, 206 and 207 contained 293 drums, of which 137 contained 741-series sludge. Specific contents of the shipments are listed in the OU 7-13/14 Probehole Plan (INEEL 2000c). The Probehole Plan also gives rationale and figures derived from past geophysical surveys to support placement of the probes in this focus area. Historical disposal information was used to demarcate a general area, then geophysical survey data were used to refine the probe location selection. Initial probe data were evaluated to further refine additional probe locations.

The americium and neptunium focus area was investigated to determine a fingerprint of this high-activity waste stream in the SDA environment. Both Am-241 and Np-237 were identified as COPCs in the IRA (Becker et al. 1998). Though the waste may have contained Np-237 at the time of disposal, some Np-237 is produced through decay of Am-241. The primary waste stream containing Am-241 is the 741-series sludge, which contains more than 80% of the Am-241 buried in the SDA. Disposal of this waste stream occurred from 1954 to 1970.

Locations of probes installed in the americium and neptunium focus area are shown in Figure 3-16. Location 741-08 had higher observed concentrations of Pu-239, Am-241, and Np-237 than other locations in this focus area. In addition, DU-08 in the depleted uranium focus area (see Figure 3-12) contained an excellent source for monitoring neptunium waste. The primary clusters and probes used to characterize the americium and neptunium focus area are listed in Table 3-15.

As noted in Section 3.6.5, the other Type A probe used to establish a probe cluster to study americium and neptunium waste was identified in the depleted uranium focus area. Nuclear logging data from this probe indicated that the highest concentration of neptunium-bearing waste was detected at DU-08. A cluster was installed there to monitor this type of waste. The probes installed at DU-08 are given in Figure 3-12, which shows the depleted uranium focus area in the west end of Pit 10.

3.7.8 Uranium and Enriched Uranium Focus Area in Pit 5

Three areas in Pit 5 were investigated to locate areas of enriched uranium and other uranium waste streams. One area in the north part of Pit 5 was selected based on monitoring data. The other two areas were selected using WasteOScope. The probe names and the location and completion intervals for probes installed in this investigation are provided in Table 3-16 and Figure 3-17. The individual areas probed in Pit 5 are discussed below.

Pit 5-TW1. Type B probes, including a lysimeter, were located in Pit 5 next to lysimeter TW-1, where both U-236 and enriched uranium (i.e., anthropic uranium) had been previously detected in soil moisture collected from a depth of approximately 31 m (102 ft) (Roback et al. 2000). The area surrounding TW-1 also exhibits a topographic depression on the upper basalt surface (see Figure 3-17). This geologic feature may cause local infiltration around Pit 5 and Pad A to move in the direction of TW-1. Therefore, Type B probes were located in this area. The sampling port on the Type B lysimeter Pit 5-TW1-L1 was completed at 3.7 m (12.2 ft) and is assumed to be next to the contact with the underlying basalt. To date, however, the lysimeter has not yielded soil moisture samples.

Pit 5-1. Type A probes were placed in an area shown by WasteOScope to contain two collocated disposals of U-233 waste from RFP Building 881. Building 881 focused on enriched uranium manufacturing and recovery through the mid-1960s. However, Building 881 also housed numerous special projects, some of which involved U-233. Thirty-nine of the 370 drums reported for two disposals

Table 3-15. Probe completions, by cluster, supporting americium and neptunium waste assessment in Pit 10.

| Cluster Name | Probe Type | | | | | | | | | | | | | | | | | |
|---------------|--------------|------------------|-----------------------|-------------|------------------|-----------------------|---------------------|------------------|-----------------------|------------|------------------|-----------------------|------------|------------------|-----------------------|--------------|------------------|-----------------------|
| | Type A Probe | | | Tensiometer | | | Soil Moisture Probe | | | Lysimeter | | | Vapor Port | | | Visual Probe | | |
| | Probe Name | Probe Depth (ft) | Instrument Depth (ft) | Probe Name | Probe Depth (ft) | Instrument Depth (ft) | Probe Name | Probe Depth (ft) | Instrument Depth (ft) | Probe Name | Probe Depth (ft) | Instrument Depth (ft) | Probe Name | Probe Depth (ft) | Instrument Depth (ft) | Probe Name | Probe Depth (ft) | Instrument Depth (ft) |
| DU-08 | DU-08 | 18.7 | DU-08-T3 | 16.4 | DU-08-M1 | 17.9 | DU-08-L1 | 16.1 | DU-08-VP2 | 15.8 | DU-08-V | 17.6 | | | | | | |
| | DU-08-A | 18.1 | DU-08-T2 | 10.2 | DU-08-M1 | 11.5 | DU-08-L2 | 14.1 | | | | | | | | | | |
| | DU-08-B | 17.6 | DU-08-T1 | 5.3 | DU-08-M1 | 6.1 | | | | | | | | | | | | |
| 741-08 | 741-08 | 22.3 | 741-08-T3 | 19.9 | 741-08-M1 | 19.9 | 741-08-L1 | 15.2 | | | | | 741-08-V | 13.5 | | | | |
| | 741-08-A | 20.8 | 741-08-T2 | 10.6 | 741-08-M1 | 11.5 | 741-08-L2 | 7.8 | | | | | | | | | | |
| | 741-08-B | 21.8 | 741-08-T1 | 3.6 | 741-08-M1 | 4.1 | | | | | | | | | | | | |

Table 3-16. Probe completions, by cluster, supporting uranium waste assessment in Pit 5.

| Cluster Name | Probe Type | | | | | |
|------------------|--------------|------------------|---------------------|-----------------------|--------------|-----------------|
| | Type A Probe | | Soil Moisture Probe | | Lysimeter | |
| | Probe Name | Probe Depth (ft) | Probe Name | Instrument Depth (ft) | Probe Name | Port Depth (ft) |
| Pit 5-1 | Pit 5-1-1 | 7.8 | | | | |
| | Pit 5-1-2 | 7.8 | | | | |
| | Pit 5-1-3 | 9.1 | | | | |
| | Pit 5-1-4 | 8.5 | | | | |
| | Pit 5-1-5 | 3.8 | | | | |
| | Pit 5-1-6 | 11.7 | | | | |
| | Pit 5-1-7 | 16.0 | | | | |
| | Pit 5-1-8 | 13.6 | | | | |
| Pit 5-4 | Pit 5-4-1 | 16.5 | Pit 5-4-M | 10.2 | Pit 5-4-L1 | 10.6 |
| | Pit 5-4-2 | 16.4 | Pit 5-4-MB | 8.2 | | |
| | Pit 5-4-3 | 16.3 | Pit 5-4-MB | 2.8 | | |
| | Pit 5-4-4 | 12.7 | | | | |
| | Pit 5-4-5 | 10.5 | | | | |
| | Pit 5-4-6 | 16.5 | | | | |
| | Pit 5-4-7 | 14.1 | | | | |
| Pit 5-TW1 | | | Pit 5-TW1-M | 10.2 | Pit 5-TW1-L1 | 12.2 |
| | | | Pit 5-TW1-MB | 8.2 | | |
| | | | Pit 5-TW1-MB | 2.9 | | |

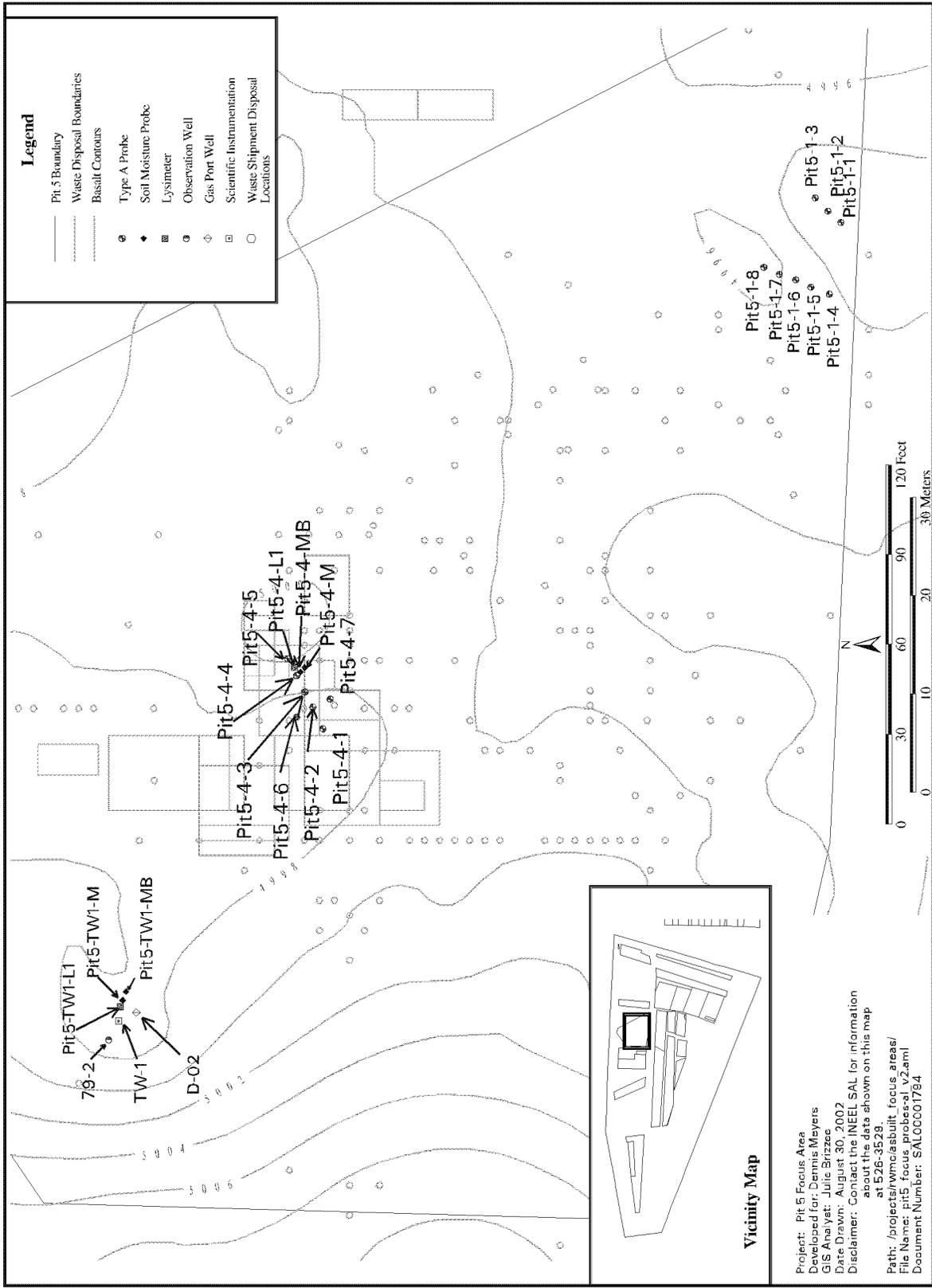


Figure 3-17. Probes installed in the uranium and enriched uranium focus area in Pit 5.

in the area contained U-233 waste from Building 881. Another three drums from these two disposals were reported in WasteOScope (INEEL 2001d) to contain U-233 from Building 771. Another important consideration in selecting this site for investigation is its disposal location along the southern perimeter of Pit 5. Confidence is higher for disposal location information near the pit boundary compared to information for disposals near the center of a large pit like Pit 5. Eight Type A probes were installed along two transects in Pit 5.

Pit 5-4. Type A probes were placed in an area shown by the WasteOScope to contain 14 of 147 drums that originated from RFP Building 886, a building established to perform criticality testing on highly enriched uranyl nitrate. In addition, all but 16 of the drums in this disposal originated from RFP uranium processing facilities (i.e., Building 881, 883, or 886), thus increasing the likelihood of detecting the targeted uranium. Rocky Flats personnel^h indicated that two enriched uranium-contaminated gloveboxes and associated piping were disposed of from Building 886, but the time of disposal could only be described as many years ago. WasteOScope (INEEL 2001d) was queried and a Rocky Flats disposal was found that described glovebox deactivation, decontamination, and decommissioning-type waste and selected combustibles originating from Building 886. This waste likely would contain significant concentrations of enriched uranium. Rocky Flats personnel (see footnote h) also noted that numerous spills containing highly enriched uranyl nitrate occurred in Building 886, and often were mopped up. If these mops, classified as combustible waste, were disposed of, they would contain significant U-235 activity, as well. Seven Type A probes, two soil moisture probes, and one lysimeter were installed in this area.

3.7.9 Activated Metal Investigations

This investigation primarily was focused on evaluation of C-14. Carbon-14, as an activation product, is a byproduct of reactor operations. The amount of C-14 disposed of and its release rate are uncertain. An effort is ongoing to refine the inventory of C-14 in the SDA. Using the current assumptions on the release rate, preliminary evaluations of potential risks from the IRA (Becker et al. 1998) indicate that C-14 amounts still could be above acceptable risk levels.

Most C-14 inventory in the SDA is from disposal of activated metal. Some of this disposal inventory is in the form of reactor core components, including beryllium reflector blocks and end pieces from reactor cores. The remaining activity is mostly in ion exchange resins. Typical C-14-bearing waste was disposed of in the SVRs (or possibly in the trenches) in the earlier years of operation (see Sections 3.1.2.4.2 and 3.2.1).

Type B probes were installed near soil vaults indicated by WasteOScope to contain C-14-bearing waste. These probes were placed to yield information about release and potential transport of C-14 in the subsurface. Carbon-14 can be transported in both vapor and dissolved phases. Moisture monitoring also was conducted near the vaults to assess the moisture state of surrounding soil. Two activated metal disposal sites were evaluated during the probing project investigation. One site, SVR-12, contained activated stainless steel and the other site, SVR-20, contained activated beryllium. Detailed criteria used to select each site for investigation are given in the Type B Probe FSP (Salomon 2001).

3.7.9.1 Activated Metal (Stainless Steel) Investigation at Soil Vault Row 12. Soil vault Row 12 was selected to monitor activated stainless steel because disposal information indicated that the SVR had the target material and did not contain other interfering materials (e.g., beryllium) that could

h. J. Anderson, radiological engineer and current Building 886 facility manager, Rocky Flats Plant, telecommunication with Hopi Salomon, Washington Group International, Idaho Falls, Idaho, November 2000.

greatly complicate subsequent analyses. WasteOScope data (INEEL 2001d) indicated the disposal of highly irradiated waste at this site. Further investigation indicated that the waste contained disposals of highly irradiated stainless steel end pieces from spent Experimental Breeder Reactor II fuel elements (Salomon 2001). This highly irradiated stainless steel probably was disposed of in scrap cask inserts that were open at the top and perforated on the bottom, allowing contact with surrounding soil (Salomon 2001). Because of shallow soil conditions at SVR-12, these disposals were made using an excavator in lieu of an auger rig to create the hole for burying the scrap cask inserts. The disposals of interest were handled remotely, using a free air transfer technique. As a result, exact positioning of the disposed waste was not possible.

Historical information identified in the Type B Probe FSP indicated that the SVR-12 disposal area was no deeper than 2 to 4 m (8 to 12 ft) belowground surface at time of disposal (Salomon 2001). However, because of subsequent flooding, RWMC operations personnel placed approximately 3 m (10 ft) of fill in an area close to where these shipments were buried. Results of the probing did not support this because the greatest depth at which a probe could be installed at SVR-12 was only 3.81 m (12.5 ft) belowground surface (Probe SVR12-2-VP1). Specifics about waste disposal at SVR-12 and the rationale used for selecting probe placement are given in the FSP (Salomon 2001). Probe type and completion intervals for probes placed at SVR-12 are represented in Table 3-17. Physical placement of the probes at SVR-12 is represented in Figure 3-18. Samples collected from vapor ports at SVR-12 are being analyzed for the radioactive gas C-14, while samples collected from lysimeters are being analyzed for gamma spectroscopy and a suite of radionuclides (i.e., C-14, H-3, Nb-94, Ni-59, Ni-63, and Tc-99) to support modeling activated metal release characterization. These results will be used to evaluate the validity of the assumptions used in the IRA.

Table 3-17. Probe completions supporting activated metal assessment.

| Cluster Name | Probe Type | | | | | | | |
|----------------|-------------|-----------------------|---------------------|-----------------------|------------|-----------------|-------------|-----------------|
| | Tensiometer | | Soil Moisture Probe | | Lysimeter | | Vapor Port | |
| | Probe Name | Instrument Depth (ft) | Probe Name | Instrument Depth (ft) | Probe Name | Port Depth (ft) | Probe Name | Port Depth (ft) |
| SVR-12 | | | SVR-12-M | 11.4 | | | | |
| | | | SVR-12-MB | 8.4 | | | | |
| | | | SVR-12-MB | 4.3 | | | | |
| SVR12-1 | SVR12-1-T3 | 10.8 | | | SVR12-1-L1 | 11.1 | SVR12-1-VP1 | 11.7 |
| | SVR12-1-T2 | 8.4 | | | SVR12-1-L2 | 5.8 | SVR12-1-VP2 | 7.6 |
| | SVR12-1-T1 | 3.6 | | | | | SVR12-1-VP3 | 2.7 |
| SVR12-2 | | | | | | | SVR12-2-VP1 | 11.9 |
| | | | | | | | SVR12-2-VP2 | 7.7 |
| | | | | | | | SVR12-2-VP3 | 2.6 |
| SVR12-3 | | | | | | | SVR12-3-VP1 | 11.8 |
| | | | | | | | SVR12-3-VP2 | 7.6 |
| | | | | | | | SVR12-3-VP3 | 2.5 |
| SVR-20 | | | SVR-20-M | 17.4 | | | | |
| | | | SVR-20-MB | 13.8 | | | | |
| | | | SVR-20-MB | 4.4 | | | | |
| SVR20-1 | SVR20-1-T3 | 16.4 | | | | | | |
| | SVR20-1-T2 | 12.7 | | | | | | |

Table 3-17. (continued).

| Cluster Name | Probe Type | | | | | | | |
|----------------|-------------|-----------------------|---------------------|-----------------------|------------|-----------------|-------------|-----------------|
| | Tensiometer | | Soil Moisture Probe | | Lysimeter | | Vapor Port | |
| | Probe Name | Instrument Depth (ft) | Probe Name | Instrument Depth (ft) | Probe Name | Port Depth (ft) | Probe Name | Port Depth (ft) |
| | SVR20-1-T1 | 8.3 | | | | | | |
| SVR20-3 | | | | | | | SVR20-3-VP1 | 6.3 |
| | | | | | | | SVR20-3-VP2 | 12.9 |
| | | | | | | | SVR20-3-VP3 | 15.0 |
| SVR20-5 | | | | | | | SVR20-5-VP3 | 17.2 |

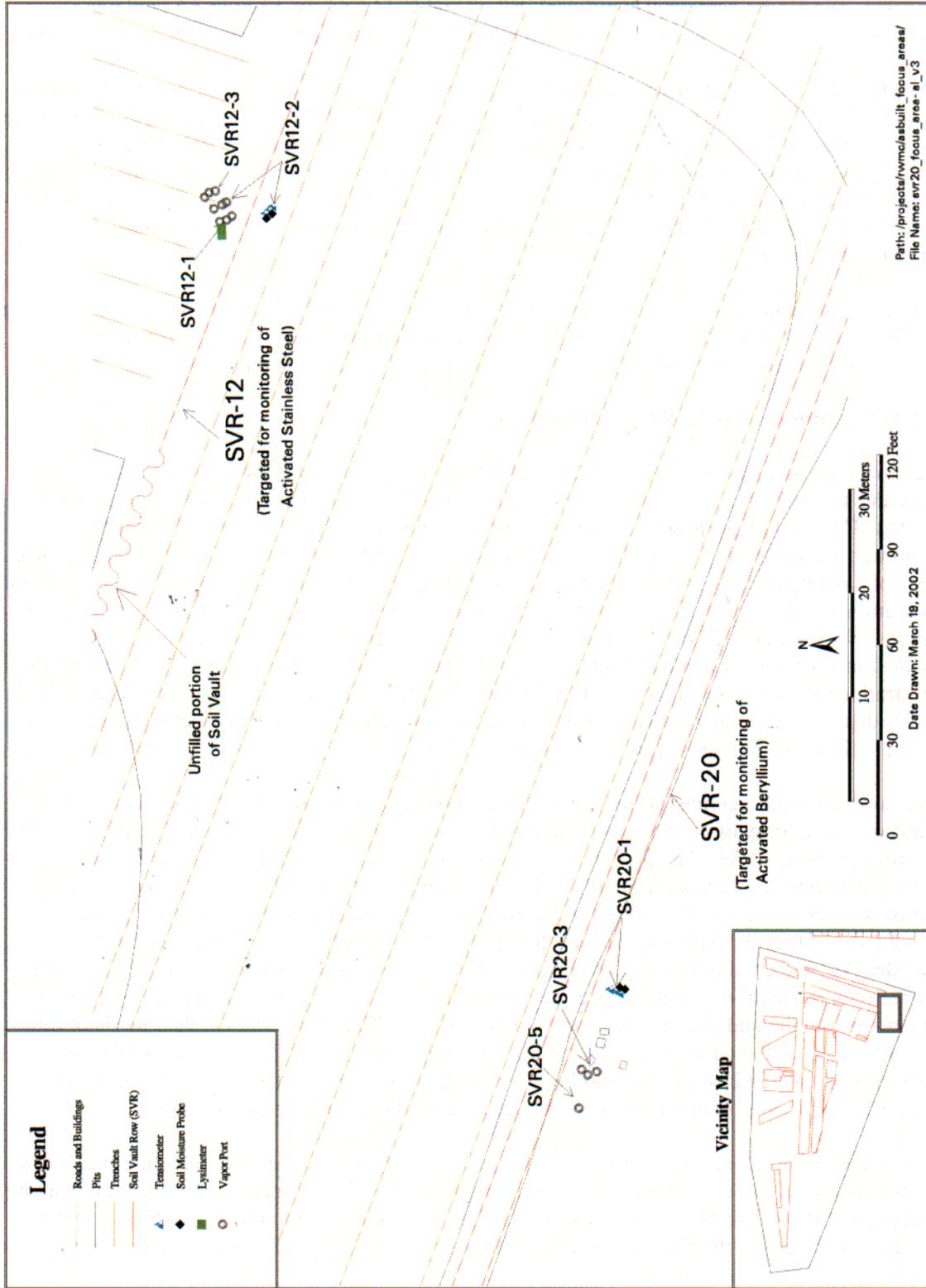


Figure 3-18. Probes installed in the activated metal focus area.

3.7.9.2 Activated Metal (Beryllium) Investigation at Soil Vault Row 20. Six

neutron-activated beryllium reflector blocks from the INEEL Advanced Test Reactor were buried in SVR-20 in 1993. The blocks contained significant tritium and C-14 activity. Section 3.8 contains a summary of beryllium disposals at SVR-20, as well as previous monitoring activities conducted nearby.

Before the SDA probing project, a monitoring array was established to characterize the migration of tritium and C-14 at SVR-20. The monitoring array installed as part of the probing project augments the monitoring that began in 1994. Vapor ports have been installed to enhance lateral monitoring for tritium and C-14 at a greater distance from the source than previously installed vapor ports. Moisture monitoring also is being conducted near the vault because the moisture state of the surrounding soil affects sampling and evaluation of soil gas data. Probes installed for the probing project investigation at or adjacent to SVR-20 are included in Table 3-18 and Figure 3-18.

Vapor ports installed around SVR-20 are being sampled with a dedicated system for tritium sample collection. The system consists of a vacuum pump, control unit, and desiccant-filled moisture traps to monitor tritium in the vapor phase, which was not an objective of sampling at any other site.

3.7.10 Waste Zone Moisture Monitoring Array

Three moisture monitoring transects and an additional array were established by pairing tensiometers and soil moisture probes at various locations and depths in and immediately adjacent to some SDA pits. The primary purposes for these transects were to identify the amount of water that infiltrates through the waste, to investigate the effects of cover material on reducing infiltration, evaluate the influence of existing ditches on moisture movement, and to determine whether local conditions could enhance contaminant release. Results of modeling are extremely sensitive to the infiltration rates used in the simulations. Not only does infiltration provide the mechanism for contaminant migration, it also influences the corrosion rate of metal containers and eventual release from the waste form. Though Site-specific infiltration rates are implemented in this ABRA (see Section 5), the moisture monitoring transects were deployed to further validate the OU 7-13/14 comprehensive RI/FS model parameters and to enhance the infiltration data set for any future analysis of the SDA.

Three north-to-south trending probe transects were installed in and adjacent to the north side of Pit 4, and an additional array of probes was placed in the west end of Pit 10. In each Pit 4 transect, three clusters of probes were installed. The first cluster in each transect was installed near the drainage ditch north of Pit 4, the middle clusters were established near the north boundary of the pit, and the third, (southernmost) clusters were installed well into the waste in Pit 4 (see Figure 3-19). In most probe clusters, three pairs of tensiometers and soil moisture probe instruments were installed to monitor three different depths. As field conditions allowed, a tensiometer and soil moisture detector were paired near the contact between the overburden and waste, near the middle of the waste zone, and near the contact between the waste and the underburden or near the basalt contact. The instruments in the middle of the waste were installed with the tensiometer completed in the upper third of the waste zone and the soil moisture detector completed lower in the middle of the waste zone to increase coverage in the waste. Final instrument completions in the moisture monitoring transects are given in Table 3-18.

The location of the transect known as MM1 was selected to monitor the effect of water that flows through a culvert under the east-west road (see Figure 3-19). The MM2 transect is centrally located along the northern edge of Pit 4. The MM3 transect is located just east of the I-3 monitoring well pair, which showed wet conditions above the B-C interbed at a depth of approximately 27.4 m (90 ft) during previous investigations.

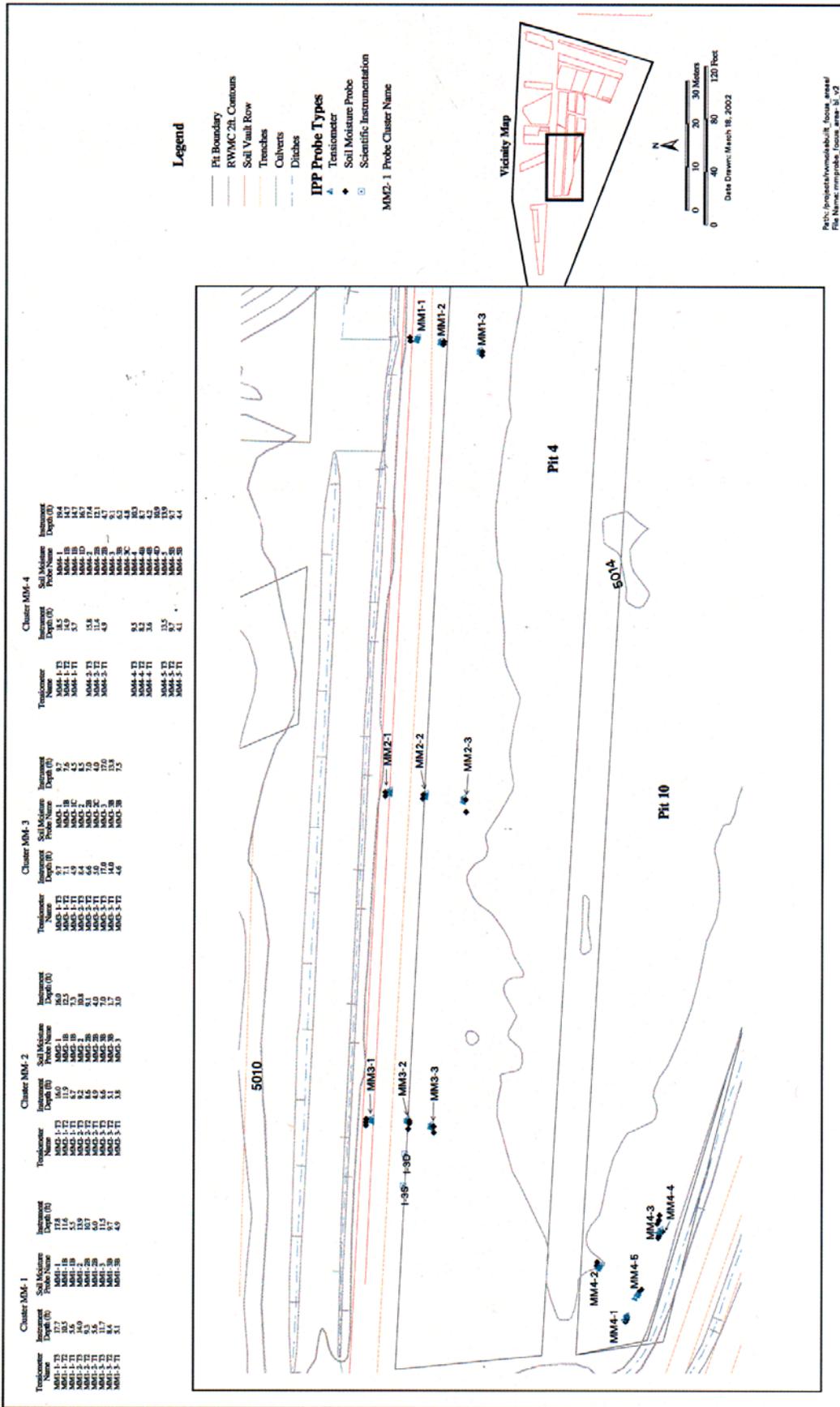


Table 3-18. Probe completions in the waste zone moisture monitoring array at Pit 4 and Pit 10.

| Probe Type | | | | | | | | | | | | |
|--------------|------------|-----------------------|------------|-----------------------|--------------|---------------------|-----------------------|----------------|-----------------------|--------------|-----------------------|------|
| Tensiometer | | | | | | Soil Moisture Probe | | | | | | |
| Cluster Name | Probe Name | Instrument Depth (ft) | Probe Name | Instrument Depth (ft) | Cluster Name | Probe Name | Instrument Depth (ft) | Probe Name | Instrument Depth (ft) | Probe Name | Instrument Depth (ft) | |
| MM1-1 | MM1-1-T3 | 17.7 | MM1-1 | 17.8 | MM3-2 | MM3-2-T3 | 8.4 | MM3-2 | 8.5 | MM3-2 | MM3-2 | 8.5 |
| | MM1-1-T2 | 10.5 | MM1-1B | 11.6 | | MM3-2-T2 | 6.6 | MM3-2B | 7.0 | | MM3-2B | 7.0 |
| | MM1-1-T1 | 5.6 | MM1-1B | 5.5 | | MM3-2-T1 | 5.0 | MM3-2C | 4.0 | | MM3-2C | 4.0 |
| MM1-2 | MM1-2-T3 | 14.0 | MM1-2 | 13.9 | MM3-3 | MM3-3-T3 | 17.0 | MM3-3 | 17.0 | MM3-3 | MM3-3 | 17.0 |
| | MM1-2-T2 | 9.3 | MM1-2B | 10.7 | | MM3-3-T1 | 14.0 | MM3-3B | 13.8 | | MM3-3B | 13.8 |
| MM1-3 | MM1-3-T3 | 11.7 | MM1-3 | 11.5 | MM4-1 | MM4-1-T3 | 18.5 | MM4-1 | 19.4 | MM4-1 | MM4-1 | 19.4 |
| | MM1-3-T2 | 8.4 | MM1-3B | 9.7 | | MM4-1-T2 | 14.9 | MM4-1B | 14.7 | | MM4-1B | 14.7 |
| | MM1-3-T1 | 5.1 | MM1-3B | 4.9 | | MM4-1-T1 | 5.7 | MM4-1B | 6.3 | | MM4-1B | 6.3 |
| MM2-1 | MM2-1-T3 | 16.0 | MM2-1 | 16.0 | MM4-2 | MM4-2-T3 | 15.8 | MM4-2 | 17.4 | MM4-2 | MM4-2 | 17.4 |
| | MM2-1-T2 | 11.9 | MM2-1B | 12.5 | | MM4-2-T2 | 11.4 | MM4-2B | 12.1 | | MM4-2B | 12.1 |
| MM2-2 | MM2-2-T3 | 9.2 | MM2-2 | 10.8 | MM4-3 | MM4-3-T3 | 4.9 | MM4-3 | 4.7 | MM4-3 | MM4-3 | 4.7 |
| | MM2-2-T2 | 8.6 | MM2-2B | 9.1 | | None installed | None installed | None installed | 9.1 | | MM4-3B | 6.2 |
| | MM2-2-T1 | 4.9 | MM2-2B | 4.0 | | None installed | None installed | None installed | 6.2 | | MM4-3C | 4.8 |
| MM2-3 | MM2-3-T3 | 6.6 | MM2-3B | 7.0 | MM4-4 | MM4-4-T3 | 9.5 | MM4-4 | 10.3 | MM4-4 | MM4-4 | 10.3 |
| | MM2-3-T2 | 5.1 | MM2-3B | 1.7 | | MM4-4-T2 | 8.2 | MM4-4B | 8.7 | | MM4-4B | 8.7 |
| MM3-1 | MM3-1-T3 | 9.7 | MM3-1 | 9.7 | MM4-5 | MM4-5-T3 | 13.5 | MM4-5 | 13.9 | MM4-5 | MM4-5 | 13.9 |
| | MM3-1-T2 | 7.1 | MM3-1B | 7.6 | | MM4-5-T2 | 9.7 | MM4-5B | 9.7 | | MM4-5B | 9.7 |
| | MM3-1-T1 | 4.9 | MM3-1C | 4.5 | | MM4-5-T1 | 4.1 | MM4-5B | 4.4 | | MM4-5B | 4.4 |

An additional array of probes, MM4, was installed to form an array around the depleted uranium focus area in the west end of Pit 10. Some probes were located in a potential topographic depression on the underlying basalt surface (Salomon 2001). Several probes in this location are located near a drainage ditch that borders the southwest corner of Pit 10. The MM4-3 cluster is located in a slight topographic depression, while the MM4-2 cluster is located in an area that has higher relative surface elevation with good surface water runoff. This location is biased toward an area of suspected low infiltration to monitor moisture behavior in an area with less favorable infiltration potential.

Additional information concerning upper basalt topography and locations where water tends to accumulate on the surface from snow melt and precipitation (e.g., ditches) was considered when selecting the locations for moisture monitoring. Upper basalt surface topography indicates a possibility for infiltrating water to move laterally toward Pits 4 and 10 from both the north and the south. Areas in the SDA that had significant ponding during a February 1995 thaw are shown in Figure 3-20 (Bishop 1996). This melting and water accumulation pattern was similar to ponding that occurred in 1993, 1994, and 1996. Water temporarily standing in ditches nearly surrounding the perimeter of Pits 4, 6, and 10 is shown in Figure 3-20. Moisture monitoring probes were placed to determine the extent of lateral movement away from these ditches into the waste zone.

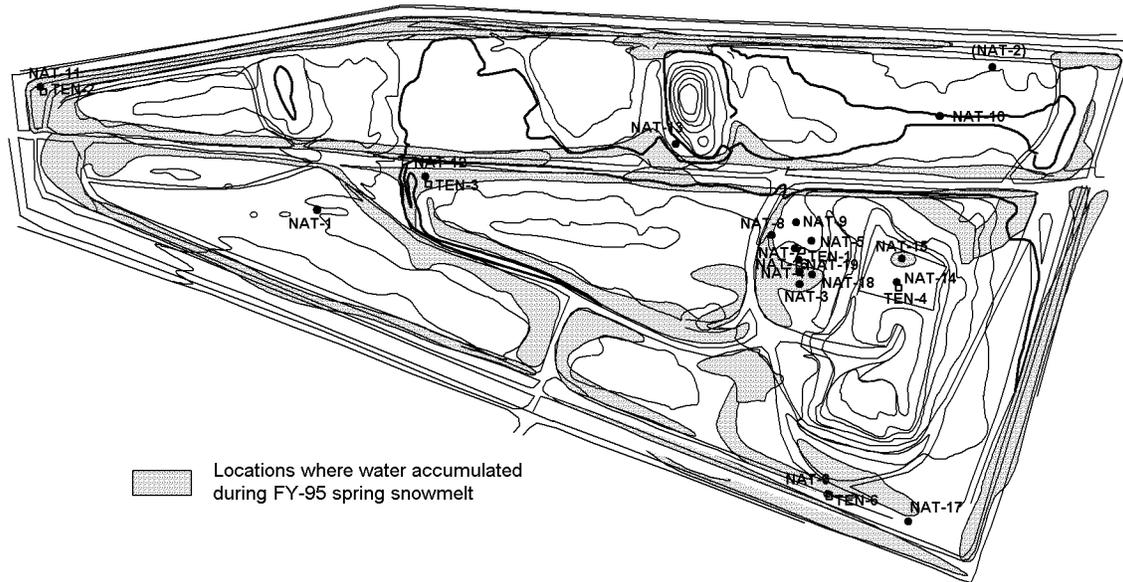


Figure 3-20. Locations at the Subsurface Disposal Area showing significant temporary accumulations of surface water during February 1995.

3.7.11 Type A Logging Results Used to Estimate Cover and Waste Zone Thickness

Results generated from nuclear logging of Type A probes have provided additional information to assess thicknesses of the soil cover and the waste zone. Vertical waste zone thickness and boundaries were interpreted assuming that the waste zone contains less soil, more void spaces, and increased amounts of hydrogen, iron, and chlorine compared with the overburden and underburden soil. Neutron-neutron moisture logging data were used to interpret the top and bottom of the waste zone in each Type A probehole, based on the assumption that low density, void spaces, and the presence of neutron absorbing elements found in typical waste can combine to cause sharp reductions in measured instrument response. Sharp decreases in the moisture tool response were first observed during Pit 9 logging in 1999. The decreased tool response occurred consistently at about the expected depth of the top of the waste zone at 1.2 to 1.8 m (4 to 6 ft) and indicated very low soil moistures of about 0 to 5% by volume below that

depth. In some cases, the moisture tool response was observed to increase sharply near the bottom of the probehole, returning to typical soil moisture values. For these reasons, the neutron-neutron tool response appears to be a valuable aid in determining vertical limits of the waste zone.

Neutron-neutron moisture logging data were the primary data set used to interpret vertical waste zone boundaries. Silicon, calcium, potassium, and thorium levels, measured using other logging tools, also were considered in cases where the moisture tool response was ambiguous. The logging methods used for the various waste zone indicators are shown in Table 3-19. Logging data from each probe were examined for sharp decreases and increases in neutron-neutron tool response. Decreases in response indicate the top of the waste and increases in tool response indicate the bottom of the waste. Depths were chosen at the approximate middle of the decrease or increase and were rounded to the nearest 0.15 m (0.5 ft). Interpreted boundaries then were compared against contamination indicators, such as gross gamma, gross neutrons, and chlorine, to ensure consistency and to recognize signal interference.

Table 3-19. Logging methods used to interpret the vertical waste boundaries.

| Logging Method | Waste Zone Indication |
|----------------------------|--|
| Neutron-neutron (moisture) | Reduced response resulting from low density, void space, and neutron absorbing elements in waste |
| Passive spectral gamma | Reduced response resulting from reduced K-40 and Th-232 compared with native soil |
| Activated spectral gamma | Reduced response resulting from reduced silicon and calcium compared with native soil |

Preliminary evaluations of logging data to determine overburden and waste zone thickness are summarized in Table 3-20. The waste zone thickness estimated in Table 3-20 may be greater than the value indicated because no lower waste boundary was recognized during interpretation of some logging results. In a few cases, the lower boundary of the waste zone was assumed to lie below the maximum logged depth; and, therefore, results are defined as the minimum waste zone thickness. In some logs, no indicators of waste or presence of a waste zone were indicated. Data from these probes were excluded from thickness calculations because the respective data were likely from probes installed at pit boundaries and are not representative.

Table 3-20. Overburden and waste zone thickness estimates from Type A logging data.

| Pit | Number of Probes Used to Determine Estimate | Overburden Thickness (ft) | Minimum Waste Zone Thickness (ft) |
|--------|---|---------------------------|-----------------------------------|
| Pit 4 | 38 | 7.6 | 11.6 |
| Pit 5 | 13 | 5.3 | 7.3 |
| Pit 9 | 47 | 5.2 | 5.8 |
| Pit 10 | 30 | 6.3 | 8 |

The overburden thickness estimates listed in Table 3-20 were compared to previous evaluations conducted to estimate cover or overburden thickness. Section 3.1.5 provides information on overburden thickness summarized from Neupauer (1995) and Barnes (1989). Section 3.1.6 provides geophysical interpretation on overburden thickness estimates at selected pits within the SDA. The cover thickness estimates based on interpretations of Type A logging results correlate well with previously developed estimates.

3.7.12 Continued Data Collection in the Subsurface Disposal Area Probes

Installation of the last SDA probes was completed in November 2001 and the data collection system used to monitor the moisture monitoring array is estimated to be finished during the spring of 2002. Data have been generated from nuclear logging of Type A probes; however, interpretation of these data is still in the preliminary stages. To date, limited numbers of physical samples have been collected. Though water samples have been collected from several lysimeters, the recovered sample volume has been small, typically less than 20 mL per sample, resulting in limited analysis and high analytical detection limits. These small sample volumes are likely the result of relatively dry subsurface conditions in the SDA following installation and initial sampling. Samples collected following the 2002 spring snow melt may provide additional sample volume, which could enhance analytical performance by lowering detection levels and increasing the number of analytical parameters evaluated.

Data generated by ongoing probe sampling and monitoring may be used to validate or refute results of the modeling in this ABRA and, thus, assist in developing remedial decisions for the SDA. Data also could provide additional information useful during RD/RA. Tentative planning for OU 7-13/14 calls for continued probe data collection. Additional tasks could be considered to expand the knowledge generated by the unique monitoring capability that the probes provide. Though not an exhaustive list, the tasks below are tentatively planned for ongoing monitoring and data interpretation for the SDA probes:

- **Contaminant Mass Estimate**—Reevaluate existing nuclear logging data to determine the mass of total VOCs and specific radioisotopes (i.e., Am-241, Np-237, Pu-239/240, U-235, U-238, Th-228, and Th-232) remaining in the buried waste around probe clusters and to support future RD/RA.
- **Waste Type Definition**—Reanalyze existing nuclear logging data to evaluate each spectral peak. Current interpretation has relied on analysis of only seven to ten peaks. However, each probe spectral data file contains upwards of seventy peaks that can be used to assess the presence of different contaminants and waste types. These data would substantially improve confidence in WasteOScope and can be used to support future RD/RA.
- **Moisture Movement**—Evaluate tensiometer and soil moisture probe data to improve understanding of moisture infiltration through the cover soil and the SDA waste zone, validate assumptions on moisture content, define moisture gradients, assess the rates of moisture flux parameters for source release and transport models, and establish future RD/RA performance objective.
- **Contaminant Migration**—Evaluate data generated from lysimeters and vapor ports to obtain specific contaminant concentrations in water and vapor in the waste zone to validate transport models and establish future RD/RA performance objectives.
- **Contaminant Release**—Using Type A and future Type B data, evaluate the mass of contaminant in an area, in combination with the localized moisture state and contaminant concentrations. Information on the waste mass, conditions affecting moisture movement through

the system, and the contaminant concentrations could be used to validate source release modeling and provide data to establish RD/RA performance objectives.

- **Waste Condition**—Improve video logging techniques and review the video logs to enhance understanding of the physical nature of the waste. Subject matter experts, including personnel familiar with historical waste-generating processes and past disposal operations should be consulted to interpret the videos. This information would be used in conjunction with other data to evaluate the waste zone, increase confidence in WasteOScope, and support the development of RD/RA.

3.8 Actinide Retardation Studies

A series of experiments was conducted in laboratories at Clemson University (Fjeld, Coates, and Elzerman 2000) to measure radionuclide retardation parameters for application to risk assessment at the SDA. The experiments focused on the actinide elements uranium, neptunium, plutonium, and americium. Experiments were conducted mainly with composite interbed sediments, with a few studies conducted with basalt. Recently, experiments have been conducted on materials collected from discrete intervals in sedimentary interbeds. Laboratory studies consisted of batch measurements, column elution experiments, and measurement of adsorption isotherms. Test solutions were made up to resemble the chemistry of groundwater near the SDA.

The objective of these experiments was to quantify the partitioning of radionuclides between vadose zone water and sedimentary interbed material from the SDA. Most experiments were designed to measure a linear, reversible partition coefficient referred to as K_d . The K_d parameter is defined as the ratio of the quantity of a contaminant sorbed onto a solid phase, such as sediment or basalt, to the quantity of the contaminant remaining in the water:

$$K_d = \frac{C_s}{C_w} \quad (3-1)$$

where

- K_d = linear, reversible partition coefficient (mL/g)
- C_s = quantity of the contaminant on a solid (pCi/g, mg/g)
- C_w = quantity of the contaminant in water (pCi/mL, mg/mL).

In column experiments, retardation of the movement of a radionuclide relative to the rate of water movement through the column was measured. The retardation of a radionuclide is related to the K_d by

$$R = 1 + \frac{\rho}{\theta} K_d \quad (3-2)$$

where

- R = retardation factor (unitless)
- ρ = bulk density of sediment in the column (gram/milliliter)

θ = water content of the column (milliliter/milliliter).

Rearranging Equation (3-2), K_d can be calculated from

$$K_d = \frac{\theta}{\rho}(1 - R) \quad (3-3)$$

Equation (3-3) is used in this section to calculate K_d values from retardation factors reported from column experiments.

Between 1993 and 1995, a series of batch adsorption experiments and a few column elution experiments were conducted at Clemson University and at the INEEL using uranium, plutonium, and americium (Newman et al. 1996). Nine sedimentary interbed samples from multiple depths in Wells M6S and M7S, which were drilled near the RWMC, were mixed to form a composite interbed material. The composited material was sieved to a size range less than 0.25 mm. A few tests were conducted on a crushed INEEL basalt and an intact core of basalt. Tests were conducted in a synthetic groundwater with a composition similar to groundwater in the Snake River Plain Aquifer near the RWMC (pH = 8.0; $\text{HCO}_3^- = 96.6$ mg/L). Column tests were conducted in packed columns 20 to 25 cm (8 to 10 in.) in length. Batch partition experiments were conducted following American Society for Testing and Materials (ASTM) Method D4319, "Standard Method for Distribution Ratios by the Short-Term Batch Method."

For column tests on basalt, uranium transport was reasonably well explained by a K_d type model, with about 100% recovery. Retardation, as defined in Equation (3-2), was about 2 for uranium, translating to a K_d of about 0.2 to 0.3 mL/g (see Table 3-21). Plutonium (total) and americium showed an enhanced mobility fraction of about 2% with a retardation factor, as defined in Equation (3-2), of about 2 for crushed

Table 3-21. Summary of batch and column measurements of americium, plutonium, and uranium partition coefficients from Newman et al. (1996).

| Isotope | Media | Batch K_d (mL/g) | Column K_d (mL/g) | Enhanced Mobility K_d (mL/g) |
|-------------------|--------------|-----------------------|------------------------------|--------------------------------------|
| Americium | Basalt | 70 to 280 | Greater than 60 ^a | 0.2 |
| Americium | Interbed | 450 to 1100 | Greater than 48 ^a | Present ^b |
| Plutonium(V) | Basalt | 70 to 130 | | |
| Plutonium(V) | Interbed | 5,100 to 7,900 | | |
| Plutonium(V) | Surface soil | 7,800 to 22,000 | | |
| Plutonium(VI) | Basalt | 12 to 24 | | |
| Plutonium(VI) | Interbed | 110 to 690 | | |
| Plutonium(VI) | Surface Soil | 1,800 to 4,900 | | |
| Plutonium (total) | Basalt | | >60 ^a | 0.25 |
| Plutonium (total) | Interbed | | >48 ^a | Present ^b |
| Uranium | Basalt | 4 to 6 | 0.2 to 0.3 | Not present |
| Uranium | Interbed | 3 to 6 | 7 to 10 | Not present |

a. Breakthrough did not occur, and so it is only known that the K_d is greater than the reported value.

b. An enhanced mobility fraction was present, but at too small of a concentration to quantify a K_d .

basalt columns. The remaining 98% of plutonium and americium did not emerge from the crushed basalt column, indicating that retardation exceeded 200. Based on the bulk density and porosity of the column, a retardation value greater than 200 gives a K_d value greater than 60 mL/g (see Table 3-21). In columns containing packed composited interbed sediment, uranium was slightly retarded during transport through the column with 90% to 100% recovery of the tracer. Retardation ranged from 30 to 43, yielding K_d values between 7 and 10 mL/g (see Table 3-21). Plutonium and americium showed a very small fraction of enhanced transport, with more than 99% of the plutonium and americium remaining in the column indicating, a K_d greater than 48 mL/g.

A wide range of K_d values was measured for plutonium in batch adsorption experiments (see Table 3-21). For comparable materials, higher K_d values were measured when the plutonium initial oxidation state was plutonium(V), and lower when the starting oxidation state of plutonium was plutonium(VI) (see Figure 3-21). Most batch partition experiments were conducted at a water-to-solid-weight ratio of 4:1 as specified in ASTM D4319. In the vadose zone, the water-to-solid-weight ratio is closer to 1:5, as calculated with a soil bulk density of 1.5 g/cm³ and a moisture content of 0.3 cm³/cm³ (Barraclough, Robertson, and Jantzer 1976), which is substantially different from the laboratory results. Oxidation state determinations on plutonium in batch experiments showed that when the solid-to-liquid ratio in experiments more closely resembled natural conditions in the vadose zone, plutonium(V) and plutonium(VI) were reduced to plutonium(IV).

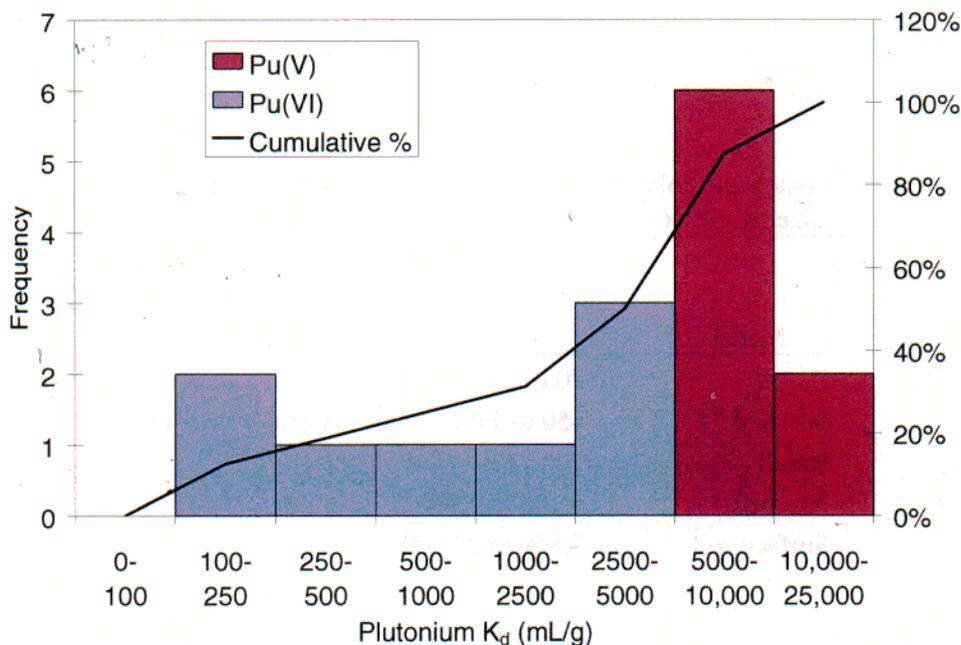


Figure 3-21. Frequency distribution of batch plutonium K_d values measured by Newman et al. (1996) differentiated by the valence state of plutonium in the starting solution.

Additional column studies were conducted at Clemson University on thorium, uranium, neptunium, plutonium, and americium to further define transport mechanisms and parameters (Fjeld, Coates, and Elzerman 2000). These studies were conducted on composite interbed material in synthetic water solution designed to resemble perched water at the RWMC (pH = 8.2; $\text{HCO}_3^- = 750 \text{ mg/L}$). All of the experiments

were column elution experiments. This series of tests included variations in water chemistry to evaluate the effects of actinides complexing with ligands in solution.

Trivalent and quadrivalent actinides, americium(III), thorium(IV), and plutonium(IV) were found to have a very small (less than 0.01%) enhanced mobility fraction with a retardation factor between 1 and 6 and a K_d less than 0.5 mL/g. Americium(III) and plutonium(IV) showed a continuous small breakthrough during the experiment. However, 99.9% of the americium(III), 98.8% of the plutonium(IV) and 99.9% of the thorium(IV) were retained in the columns with a K_d greater than 250 mL/g (see Table 3-22). Plutonium(V) showed the same behavior as plutonium(IV), with a small fraction being released from the column with little retardation, and 99.8% of the plutonium(V) remaining in the column. Plutonium(VI) was not tested.

Neptunium experiments on the column were conducted using neptunium in the neptunium(V) valence state. About half of the neptunium migrated through the columns with a retardation factor of 100 and a K_d of 25 mL/g (Table 3-22). The other half of the neptunium did not emerge from the column. Fjeld and coworkers hypothesized that some of the neptunium was being reduced from the +V to the +IV valence state in the column. A column was oxidized with hydrogen peroxide, and a breakthrough test repeated. All of the neptunium was recovered, indicating that reduction was a factor in neptunium transport. A similar experiment with plutonium(V) did not result in breakthrough of plutonium. Reduction of plutonium in the soil is strong enough that, even after treatment of the soil with hydrogen peroxide, the soil can reduce plutonium(V) to plutonium(IV).

Column experiments were conducted using the hexavalent form of uranium. Uranium(IV) can be expected to have similar geochemical characteristics as the other quadrivalent actinides (Seaborg and Loveland 1990). Under reducing conditions, where uranium(IV) predominates, uranium would be strongly bound to sediments with K_d values greater than 250 mL/g, similar to values measured for thorium and plutonium(IV). Hexavalent uranium was completely recovered from the columns with a retardation factor of 3.2 to 8.2 and a K_d from 0.54 to 1.8 mL/g (Table 3-22). Experiments with water chemistry composition showed that complexing of uranium with carbonate ion was a very important factor in the transport of uranium. When carbonate ions were removed from the synthetic groundwater, the retardation factor jumped to 560 to 690 and the K_d jumped to 140 to 170 mL/g.

Complexing with organic complexing agents also was found to appreciably enhance migration of actinides. Quadrivalent actinides were not mobile in the absence of complexing agents. When EDTA was added to test solutions, 27% to 61% of the quadrivalent actinide became mobile with retardation factors from 16 to 79 and K_d values from 4 to 20 mL/g (see Table 3-22). Organic complexing agents were disposed of in the SDA (INEEL 1998), including unknown quantities of EDTA contained in RFP TRU waste. According to the HDT, a reasonable upper limit on the unknown quantity of EDTA from RFP is $7.1E+04$ kg (LMITCO 1995a, Table 4-1). Hypothetically, the presence of these agents could enhance the mobility of actinides. However, because detections of actinides in the vadose zone are relatively sparse, the hypothesis has not been confirmed by RWMC vadose zone monitoring results (see Section 4).

During the fall of 2000, adsorption isotherms for uranium and neptunium were measured on 14 discrete interbed samples collected from boreholes drilled inside and adjacent to the SDA (Grossman et al. 2001). An adsorption isotherm is measured by a series of batch adsorption experiments carried out with different initial solution concentrations. If adsorption follows a linear adsorption isotherm (K_d), the ratio of sorbed to dissolved concentrations will be the same at all concentrations. Sediment samples from both the B-C and C-D interbeds were assessed. Experiments were again conducted in synthetic groundwater (pH = 8.2; $HCO_3^- = 220$ mg/L).

Table 3-22. Summary of retardation and K_d values measured in column experiments.

| Element | Special Test Conditions | Column Retardation Factor | Column K_d (mL/g) | Fraction of Initial Spike Retained in the Column | Enhanced Mobility (Fraction Released/Pore Volume) | Effective K_d of Enhanced Mobility Fraction (mL/g) |
|---------------|--------------------------------|---------------------------|---------------------|--|---|--|
| Americium | | >1000 | > 250 ^a | 0.999 | 7.9E-5 | 4.5 |
| Americium | With EDTA ^c | 16 | 4 | 0.50 | 7.7E-5 | Continuous ^b |
| Thorium | | >1000 | >250 | 0.999 | 2.6E-5 | Continuous |
| Thorium | With EDTA | 23 | 5.75 | 0.73 | 2.3E-5 | Continuous |
| Plutonium(IV) | | >1000 | >250 | .98 | 6.2E-6 | Continuous |
| Plutonium(IV) | With EDTA | 35 to 79 | 8.8 to 20 | 0.42 | 1.7E-4 | Continuous |
| Plutonium(V) | | >1000 | >250 | .999 | 1.7E-4 | Continuous |
| Plutonium(V) | With EDTA | >1000 | >250 | .999 | 3.6E-5 | Continuous |
| Plutonium(V) | Oxidized sediment ^d | >1000 | >250 | .999 | Not determined | |
| Neptunium | | 97 to 156 | 24 to 39 | 0.32 to 0.60 | 1.5E-4 | 0.3 to 0.9 |
| Neptunium | With EDTA | 58 to 80 | 14.5 to 20 | 0.33 to 0.43 | 1.5E-4 | 0.6 |
| Neptunium | No carbonate ^e | 195 to 310 | 49 to 78 | 0.19 to 0.33 | Not present | N/A |
| Neptunium | Oxidized sediment | 265 to 434 | 66 to 108 | ~0 | Not present | N/A |
| Uranium | | 3.2 to 8.2 | 0.5 to 2 | 0.04 to 0.08 | Not present | N/A |
| Uranium | With EDTA | Not tested | | | | |
| Uranium | No carbonate | 560 to 690 | 140 to 170 | 0.55 | 1.3E-4 | 3 |

EDTA = ethylenediaminetetraacetic acid N/A = not applicable

a. Breakthrough did not occur, and the only conclusion that can be drawn is that the K_d is greater than the reported value.

b. An enhanced mobility fraction was present, but release was more or less continuous, not as a discrete peak.

c. Simulated perched water with EDTA added.

d. Hydrogen peroxide was used to oxidize the sediment column before the test.

e. Carbonate was left out of the recipe when the simulated perched water was mixed.

For neptunium and uranium, isotherms showed distinct nonlinearity. However, a good fit for both actinides was obtained using a Freundlich isotherm (see Figure 3-22). The Freundlich isotherm is defined by the following equation:

$$C_s = K_f C_w^n \quad (3-4)$$

where

K_f = Freundlich adsorption coefficient (mL/g)

n = Freundlich exponential coefficient (unitless).

The K values of the Freundlich isotherm showed a large amount of variation, but exponents of the isotherms n were very similar for all samples (see Table 3-23). When plotted on a log-log graph, the Freundlich isotherm becomes linear with n being the slope of the line. Parallel lines on the log-log plot indicate how similar the Freundlich n values are (see Figure 3-23).

Most of what is known about actinide transport parameters applicable to the RWMC comes from 8 years of work at Clemson University and the INEEL (Newman et al. 1996; Fjeld, Coates, and Elzerman 2000; Grossman et al. 2001). Based on these experiments, the transport of uranium and neptunium occurs in the

dissolved phase in the vadose zone, and can be represented by an adsorption type of conceptual model. Uranium, in particular, demonstrates classic breakthrough curves for column tests suggesting a reversible adsorption mechanism. Neptunium in natural waters is present in the pentavalent(V) valence state (Seaborg and Loveland 1990). An adsorption model for neptunium can be shown to be conservative because at least some of the neptunium is irreversibly adsorbed in column elution experiments. Experimental results from Clemson suggest that reduction of some of the neptunium(V) to neptunium(IV) causes the adsorption. Test results from Clemson indicate that adsorption isotherms for uranium and neptunium are nonlinear. As the uranium and neptunium concentration in solution increases, the partitioning ratio decreases. Sorption will not be as efficient for retarding the movement of uranium and neptunium at higher concentrations as it is at lower concentrations. A Freundlich nonlinear adsorption isotherm would, therefore, be a better approach for uranium and neptunium sorption than a constant K_d approach.

Plutonium(VI) is not stable in natural waters (Seaborg and Loveland 1990; Choppin, Bond, and Hromadka 1997; Runde 2000; Skipperud, Oughton, and Salbu 2000). Plutonium(V) is the stable oxidation state of dissolved plutonium in natural systems; however plutonium(V) is reduced to plutonium(IV) through interaction with solid minerals and soil organic matter in natural systems (Skipperud, Oughton, and Salbu 2000). Based on the findings of the Clemson batch experiments and on a review of the literature, the batch adsorption experiments at high water-to-solid ratios using plutonium(VI) as a starting material are concluded to fail to be representative of conditions expected in the subsurface at the RWMC. Some experiments where plutonium K_d values are measured using plutonium(V) as a starting material, and at low water-to-solid ratios, are more representative of the vadose zone environment. Under those conditions, a plutonium K_d over 5,000 mL/g is indicated.

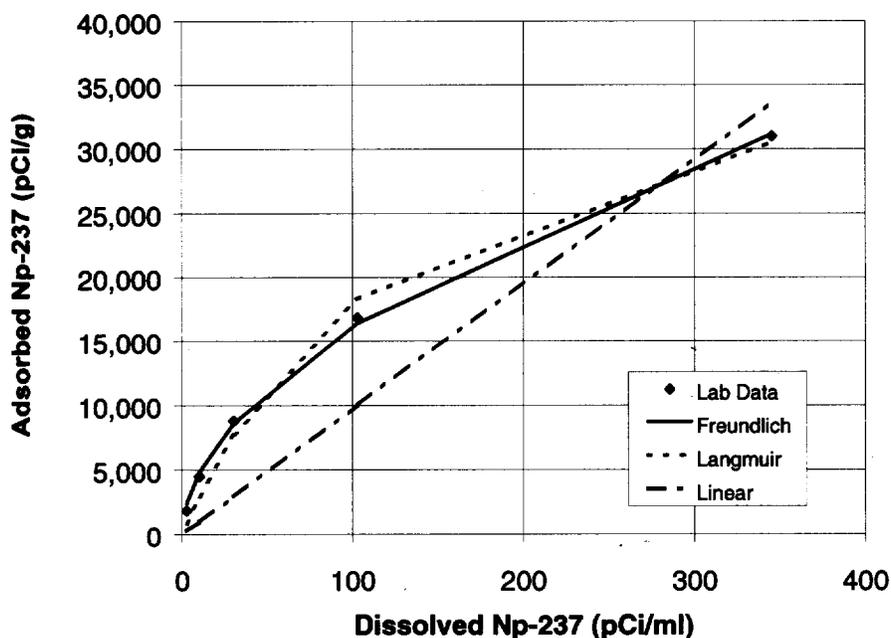


Figure 3-22. Neptunium adsorption on Sample I1S-INEEL-109 comparing the fit of Freundlich, Langmuir, and linear isotherms to the laboratory data.

Table 3-23. Measured Freundlich and linear isotherm parameters for neptunium and uranium (Grossman et al. 2001).

| Sample ID | Neptunium | | | Uranium | | |
|---------------|------------------------|------------------------|------------------------|----------------------|----------------------|----------------------|
| | Neptunium Freundlich K | Neptunium Freundlich n | Neptunium K_d (mL/g) | Uranium Freundlich K | Uranium Freundlich n | Uranium K_d (mL/g) |
| 7DS00101KD | 246 | 0.59 | 100 | 74 | 0.81 | 37 |
| 7DS00301KD | 91 | 0.62 | 27 | 53 | 0.78 | 21 |
| 7DS00901KD | 100 | 0.59 | 25 | 17 | 0.78 | 6 |
| 7DS00701KD | 24 | 0.65 | 6 | 46 | 0.76 | 16 |
| 7DS00501KD | 155 | 0.56 | 37 | 37 | 0.81 | 17 |
| 7DS01701KD | 133 | 0.56 | 34 | 40 | 0.77 | 14 |
| 7DS02301KD | 109 | 0.56 | 28 | 35 | 0.81 | 15 |
| I2S-INEEL-105 | 52 | 0.65 | 15 | 40 | 0.78 | 15 |
| I1S-INEEL-109 | 280 | 0.58 | 98 | 35 | 0.78 | 13 |
| I4D-INEEL-234 | 86 | 0.54 | 16 | 23 | 0.76 | 7 |
| I4D-INEEL-231 | 124 | 0.53 | 27 | 33 | 0.76 | 11 |
| I1D-INEEL-234 | 95 | 0.60 | 25 | 40 | 0.87 | 22 |
| I4D-INEEL-224 | 162 | 0.54 | 41 | 31 | 0.81 | 13 |
| I3D-INEEL-229 | 256 | 0.57 | 85 | 27 | 0.77 | 9 |
| Average | 137 | 0.58 | 40 | 38 | 0.79 | 16 |

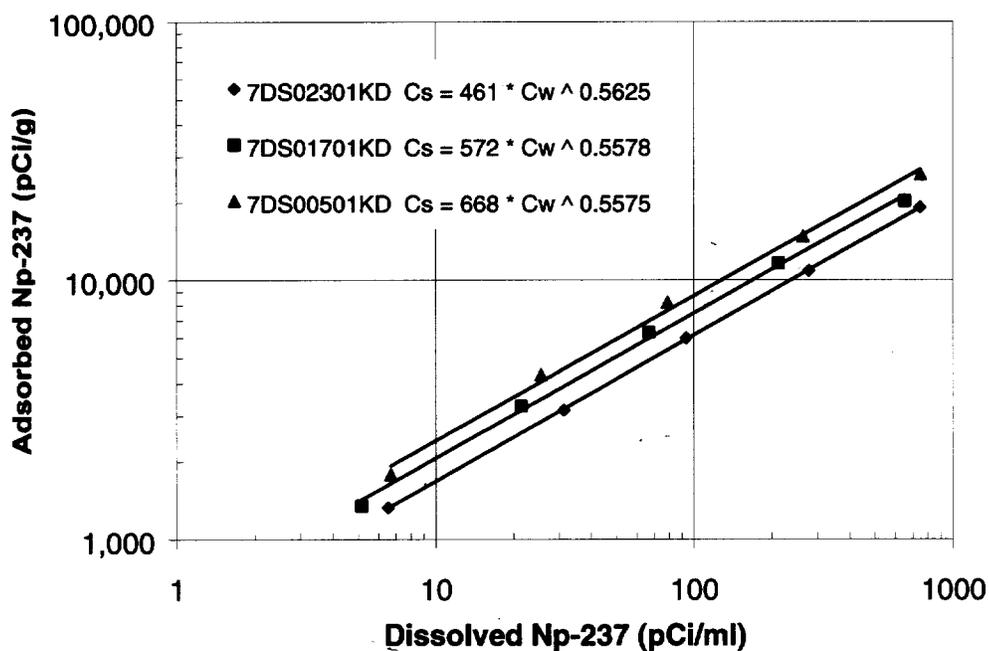


Figure 3-23. Laboratory neptunium adsorption data for three soil samples showing the similar slopes when fit with a Freundlich isotherm.

For americium and plutonium, however, transport in the dissolved phase may not be an important mechanism. Attempts to measure adsorption isotherms for americium and plutonium were unsuccessful because americium and plutonium formed insoluble mineral precipitates and could not be kept in solution in the simulated groundwater. This result is consistent with the solubility of solid plutonium and americium minerals in the synthetic water composition. Without a dissolved aqueous phase, a liquid-solid partitioning coefficient could not be measured. A better conceptual model for americium and plutonium seems to be the formation of an insoluble solid phase that is mostly filtered out of solution during batch adsorption experiments, which gives the appearance of a large K_d value in batch experiments. In column experiments, the particulate material is mostly filtered out of solution by the sediment in the column, also giving the appearance of a large K_d value for more than 98% of the plutonium.

In column experiments, however, small, but continuous release of trivalent and quadrivalent actinides (thorium, plutonium, and americium) occurs, in a particulate form that migrates as fast or almost as fast as the water. This was seen in earlier column experiments conducted by Miner, Evans, and Polzer (1982) as well as in two generations of studies at Clemson University (Newman et al 1996; Fjeld, Coates, and Elzerman 2000). A continuous, slow release of a very small fraction of the actinide occurs over time. Even in the packed sediment columns where material had been sieved to sizes less than 0.25 mm, there is measurable transport of particulate actinides. Because of this characteristic, a tiny fraction of the trivalent and quadrivalent actinides could be moving with little or no retardation through the vadose zone.

A final factor affecting mobility of actinides identified by the Clemson University studies (Fjeld, Coates, and Elzerman 2000) is the effect of organic complexing agents. Laboratory tests using EDTA, an organic complexing agent, showed that EDTA could greatly enhance the mobility of actinides. An inventory of complexing agents (e.g., EDTA) used at RFP (INEEL 1998) indicates that organic complexing agents are likely to be present in the waste. The quantities of EDTA from RFP are reported as unknown, but a reasonable upper limit of $7.1E+04$ kg is suggested in the HDT (LMITCO 1995a, Table 4-1).

3.9 Carbon-14 Characterization

Modeling of release and migration of carbon-14 for OU 7-13/14 has been limited to dissolved-phase approaches. However, C-14 can be released and migrate as a vapor, particularly in carbon dioxide (CO_2). Recent modeling to estimate the quantities and concentrations of radioactivity in beryllium blocks, and monitoring at a beryllium disposal in SVR-20 and an activated metal disposal in SVR-12 are summarized below.

3.9.1 Estimated Activity in Beryllium Blocks Buried in the Subsurface Disposal Area

Research reactors at the INEEL TRA, including MTR, the ETR, and the ATR, use beryllium reflectors. The beryllium is used as a neutron reflector to intensify the neutron flux in the reactor core. The amount of beryllium used as a reflector varies in each reactor (Mullen et al. 2002). The ATR reflector assembly consists of a set of eight beryllium blocks and 16 outer shim control cylinders (Figure 3-24). Each block is 129.5 cm (51 in.) long, approximately 40.6 cm (16 in) square and weighs 81,420 g (179.5 lb). When all eight blocks are assembled, they have a cross section approximately 127 cm (50 in) in diameter. For the ETR, the reflector assembly was essentially four slabs that surrounded the core while the MTR reflector assembly was much more complex.

Historically, reflector assemblies from the test reactors periodically were replaced every 8 to 10 years because of swelling. The majority of irradiated beryllium reflector waste was disposed of in the SDA in three major events: 1976, 1977, and 1993. A total 5,309 kg (11,703 lb) of beryllium was disposed of from the ATR, ETR, and MTR (Table 3-24) (Mullen et al. 2002). Early characterization

efforts of the beryllium blocks relied on modeling alone to develop the isotope inventories, and there was a concern that certain key nuclides were overestimated. In an effort to reduce the conservatism in the inventory estimates samples were taken from stored irradiated beryllium blocks at TRA. The analysis was necessary to determine C-14 content. Limitations on C-14 content for LLW destined for disposal in the SDA are defined in the WAC (DOE-ID 2001) based on the LLW operation Performance Assessment (Maheras et al. 1994, Case et al. 2001). Similar analysis had not been required for previous beryllium disposals because earlier versions of the WAC did not limit C-14.

The sampling showed that the initial models were indeed conservative with regard to C-14 but substantially underestimated Nb-94 (Mullen et al. 2002). The sample results also revealed that trace impurities in the beryllium blocks, when subjected to neutron flux in a reactor, transmute to other elements. Uranium is transmuted into plutonium and other transuranic isotopes, and gold is transmuted into mercury. Modeling based on reactor burn-up histories and estimates of concentrations of impurities in the beryllium has shown that the irradiated beryllium blocks contain sufficient transuranic content to be classified as TRU waste. Table 3-24 provides estimates of the C-14 and transuranic concentrations in beryllium blocks buried in the SDA. Figure 3-25 illustrates the locations of the beryllium blocks in the SDA.

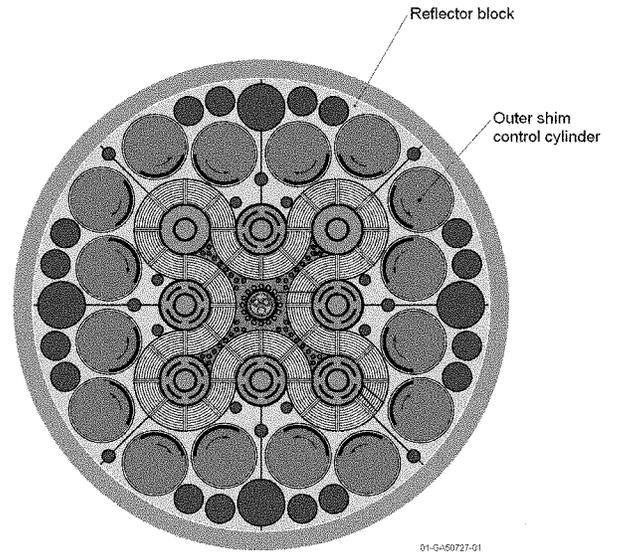
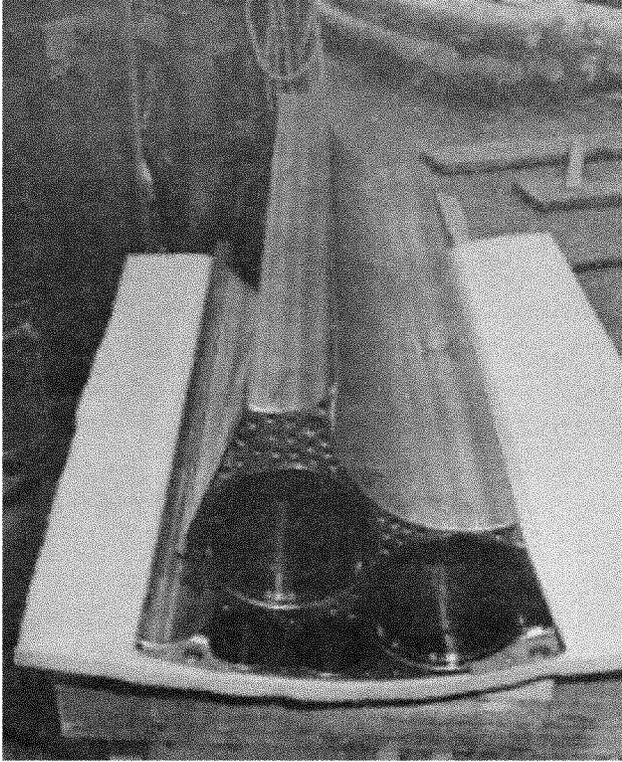


Figure 3-24. Photograph and cross-sectional view of an Advanced Test Reactor beryllium reflector block.



Figure 3-25. Beryllium disposal locations in the Subsurface Disposal Area.

Table 3-24. Summary of the Advanced Test Reactor, Engineering Test Reactor and Materials Test Reactor transuranic and C-14 concentrations in irradiated beryllium reflector waste disposed of in the Subsurface Disposal Area as of the indicated disposal date.

| Reactor and Beryllium Waste Disposed of by Serial Number or Core Position | Initial Irradiated Date | Final Irradiated Date | Core | Reactor Position | Total Core (MWd) | Metal Mass (g) | Metal Volume (m ³) | Disposal Date | Disposal Location ^a | Total C-14 Activity (Ci) | Estimated C-14 Concentration (Ci/m ³) | Estimated Transuranic Concentration (nCi/g) | Total Transuranic Activity per Item (Ci) |
|---|-------------------------|-----------------------|------|------------------|----------------------|----------------------|--------------------------------|---------------------|--------------------------------|--------------------------|---|---|--|
| Materials Test Reactor | 3/31/52 | 7/1/69 | 1 | NA | 108,000 | 2,610,000 | 1.41 | 1977 | BGT 58 3+10-20 to 3+40-50 | 3.78 | 2.68 | 1,000 | 2.61 |
| Engineering Test Reactor | 10/15/57 | 3/1/70 | 1 | NA | 424,313 | 580,500 | 0.3137 | 1970 ^{b,c} | | 3.64 | 11.6 | 575 | 0.334 |
| Advanced Test Reactor | | | | | | | | | | | | | |
| Block NW-L | 2/1/68 | 9/9/72 | 1 | NW | 28,894 | 81,420 | 0.044 | 1976 | BGT 58 200+05-15 | 0.9997 | 22.72 | 321.97 | 0.026 |
| NW-R | 2/1/68 | 9/9/72 | 1 | NW | 28,894 | 81,420 | 0.044 | 1976 | Same as above | 0.9997 | 22.72 | 321.97 | 0.026 |
| NE-L | 2/1/68 | 9/9/72 | 1 | NE | 27,960 | 81,420 | 0.044 | 1976 | BGT 58 200+25-35 | 0.9679 | 22.34 | 321.12 | 0.026 |
| NE-R | 2/1/68 | 9/9/72 | 1 | NE | 27,960 | 81,420 | 0.044 | 1976 | Same as above | 0.9679 | 22.34 | 321.12 | 0.026 |
| SW-L | 2/1/68 | 9/9/72 | 1 | SW | 27,978 | 81,420 | 0.044 | 1976 | Same as above | 0.9683 | 22.01 | 321.13 | 0.026 |
| SW-R | 2/1/68 | 9/9/72 | 1 | SW | 27,978 | 81,420 | 0.044 | 1976 | Same as above | 0.9683 | 22.01 | 321.13 | 0.026 |
| SE-L | 2/1/68 | 9/9/72 | 1 | SE | 28,017 | 81,420 | 0.044 | 1976 | Same as above | 0.9696 | 22.04 | 321.23 | 0.026 |
| SE-R | 2/1/68 | 9/9/72 | 1 | SE | 28,017 | 81,420 | 0.044 | 1976 | BGT 58 200+25-35 | 0.9696 | 22.04 | 321.23 | 0.026 |
| Block NE-L | 2/5/73 | 4/11/77 | 2 | NE | 23,625 | 81,420 | 0.044 | 1977 | BGT 58 3+10-20 | 1.264 | 18.61 | 191.90 | 0.016 |
| NE-R | 2/5/73 | 4/11/77 | 2 | NE | 23,625 | 81,420 | 0.044 | 1977 | Same as above | 1.264 | 18.66 | 191.90 | 0.016 |
| SW-L | 2/5/73 | 4/11/77 | 2 | SW | 36,285 | 81,420 | 0.044 | 1977 | Same as above | 1.254 | 28.50 | 197.52 | 0.016 |
| SW-R | 2/5/73 | 4/11/77 | 2 | SW | 36,285 | 81,420 | 0.044 | 1977 | Same as above | 1.254 | 28.50 | 197.52 | 0.016 |
| SE-L | 2/5/73 | 4/11/77 | 2 | SE | 24,357 | 81,420 | 0.044 | 1977 | Same as above | 0.8441 | 19.18 | 193.52 | 0.016 |
| SE-R | 2/5/73 | 4/11/77 | 2 | SE | 24,357 | 81,420 | 0.044 | 1977 | BGT 58 3+40-50 | 0.8441 | 19.18 | 193.52 | 0.016 |
| Block 018L | 8/9/77 | 2/2/86 | 3 | NW | 53,924 | 81,420 | 0.044 | 1993 | SVR 20 0+315 | 1.853 | 42.11 | 387.15 | 0.032 |
| 013R | 8/9/77 | 2/2/86 | 3 | NW | 53,924 | 81,420 | 0.044 | 1993 | Same as above | 1.853 | 42.11 | 387.15 | 0.032 |
| 015L | 8/9/77 | 2/2/86 | 3 | NE | 47,259 | 81,420 | 0.044 | 1993 | Same as above | 1.627 | 36.98 | 406.25 | 0.032 |
| 019L | 8/9/77 | 2/2/86 | 3 | SW | 60,205 | 81,420 | 0.044 | 1993 | Same as above | 2.066 | 46.95 | 370.37 | 0.032 |
| 014R | 8/9/77 | 2/2/86 | 3 | SW | 60,205 | 81,420 | 0.044 | 1993 | Same as above | 2.066 | 46.95 | 370.37 | 0.032 |
| 011R | 8/9/77 | 2/2/86 | 31 | SE | 72,984 | 81,420 | 0.044 | 1993 | Same as above | 2.497 | 56.75 | 340.98 | 0.032 |
| Nine Outer Shim Control Cylinders | 2/5/77 | 4/11/77 | 1/21 | NA | 165,928 ^d | 489,881 ^e | 0.2648 ^f | 1987 | SVR 17 0+10, 0+18, 1+00, 1+56 | 15.91 | 60.08 | 377.54 | 0.185 |
| Total | | | | unknown | | 5,308,781 | | | | 49.8272 | | | 3.625 |

RWMC = Radioactive Waste Management Complex
 a. Coordinates refer to the distance from the disposal unit boundary monument.
 b. The disposal date and location at the SDA could not be determined from available records.
 c. The final irradiation date is assumed to be the SDA disposal date.
 d. Total exposure for nine outer shim control cylinders (OSCCs).
 e. Total mass for nine OSCCs.
 f. Total volume for nine OSCCs.

NA = not applicable
 BGT = burial ground trench
 SDA = Subsurface Disposal Area
 L = left
 R = right
 SRV = soil vault row
 TRU = transuranic
 NW = northwest
 NE = northeast
 SW = southwest
 SE = southeast

3.9.2 Beryllium Reflector Block Monitoring

Six beryllium reflector blocks from the Advanced Test Reactor were buried in SDA Soil Vault Row (SVR)-20 in 1993 (see Figure 3-18) (Ritter and McElroy 1999). The blocks contained a total of 293,000 Ci of tritiated hydrogen gas and approximately 20 of C-14. Both radionuclides form mobile compounds. About one-fifth of the total C-14 inventory in the SDA is associated with the beryllium. Carbon-14 was identified as a COPC in the IRA (Becker et al. 1998) and as a risk driver in the RWMC Performance Assessment (Case et al 2000) and the INEEL Composite Analysis (McCarthy et al. 2000). Tritium, though not a risk driver, was identified as a contaminant of interest because of its potential as a model calibration target for vapor phase transport.

Dedicated monitoring to characterize the migration of tritium and C-14 from beryllium reflector blocks buried began in 1994. Results of environmental monitoring characterizing releases and environmental conditions around the beryllium blocks in SVR-20 are summarized below.

3.9.2.1 Airborne Tritiated Water Vapor. Ambient air samples were collected 30 cm (1 ft), 1 m (3.3 ft), and 2 m (6.6 ft) aboveground near SVR-20 (see Figure 3-18) during summer and early fall of 2000 and 2001. Samples were collected weekly because the emission rate can vary substantially over relatively short periods. Passive airborne tritium samplers are used to collect the samples. Prior to 2000, samples were collected by several organizations, including the INEEL and Idaho State University for the INEEL Oversight Program. Results for all beryllium sampling are shown in Figure 3-27. Typically, the concentration of tritiated water vapor (HTO) in air ranged over several orders of magnitude each year with the peak concentrations occurring in late summer. Usually the maximum concentrations persisted over a period of a few weeks each year, but the peak concentration occurred over a period of only 4 days during 1997. The estimated annual tritium release to the atmosphere range from less than 1 Ci in 1998 to over 100 Ci in 1995 and 1996. The variation is probably caused by year-to-year differences in soil conditions that affect gas phase permeability and by possible changes in the rate of release of tritium from the blocks by corrosion. Monitoring data do not show any long-term trend in air concentration or emission, though the seasonal variability of the emission rate is evident.

3.9.2.2 Tritiated Water Vapor in Soil Gas Samples. Since 1996 soil gas samples have been collected approximately 60 to 100 cm (23 to 39 in.) from the buried beryllium blocks in SVR-20. Soil gas data through June 28, 2001, are summarized in Figures 3-28, 3-29, and 3-30. The maximum concentrations of HTO in soil moisture were 3.4, 0.28, and 0.70 $\mu\text{Ci/mL}$ at depths of 2.7, 4.5, and 6.2 m (9, 15, and 20 ft), respectively. Correlation of the concentrations at 4.5 and 6.2 m (15 and 20 ft) is depicted in Figure 3-31. The concentration of HTO in soil moisture appears to fluctuate over the course of each year, with lower concentrations occurring during cool months.

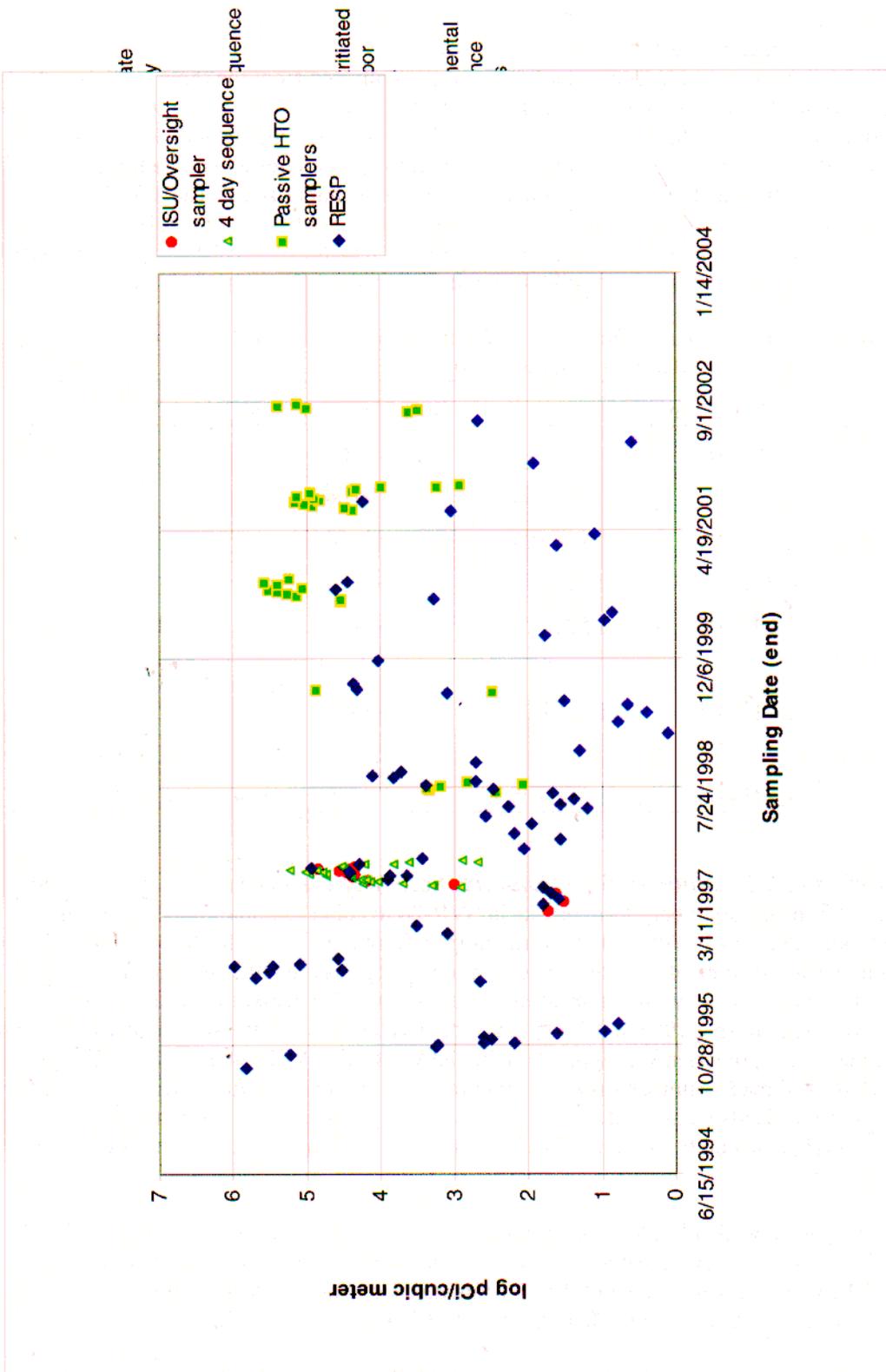


Figure 3-27. Concentrations of airborne tritiated water vapor above the beryllium blocks buried in Soil Vault Row 20.

3.9.2.3 Carbon-14 in Soil Gas. The specific activity of C-14 in CO₂ (i.e., the C-14 activity per gram of total carbon) was measured in grab samples of soil gas collected from the three GSP-1 ports and SVR20-5-VP3 at various depths. Samples collected through 1997 used a caustic solutions in bubblers and samples collected after 1997 used the Tedlar bag method. The two sampling methods are assumed to produce comparable data; however, the bag sampling and analysis procedures and calibration are still in development, and will be finalized in FY-2003. Sample results are summarized in Table 3-25. Based on a review of all results for the 1999 to 2002 monitoring, C-14 specific activity (pCi of C-14 per gram of carbon in CO₂) in soil gas near buried beryllium has increased by a factor of 5 to 10 since the late 1990s. A similar increase in HTO concentrations in soil water is evident over the same period.

Table 3-25. Summary of carbon-14 specific activity (pCi of carbon-14 per gram of carbon) in carbon dioxide in soil gas samples collected at Soil Vault Row 20.

| Date | GSP-1 at 2.7 m | GSP-1 at 4.5 m | GSP-1 at 6.2 m | SVR20-5-VP3 at 5.4 m |
|------------|----------------|----------------|----------------|----------------------|
| 6/5/1996 | 1.70E+04 | | 2.30E+04 | |
| 7/2/1996 | | 3.40E+04 | 2.50E+04 | |
| 12/12/1996 | 1.30E+05 | 4.20E+04 | 3.30E+04 | |
| 11/12/1997 | 4.40E+04 | 2.00E+04 | 1.20E+04 | |
| 11/15/2001 | 3.64E+05 | 1.58E+05 | 2.45E+05 | 8.28E+04 |
| 2/20/2002 | | | | 2.85E+04 |
| 5/2/2002 | 1.71E+05 | 1.45E+05 | 1.33E+05 | |
| 5/23/2002 | | | | 3.10E+04 |
| 8/23/2002 | 1.34E+05 | 1.33E+05 | 1.37E+05 | 3.67E+04 |

3.9.2.4 Chloride and Bromide in Soil Moisture. Suction lysimeters were installed at depths of 2 and 6 m (7 and 20 ft) near buried beryllium blocks in SVR-20 to collect samples of soil moisture for chemical and radiological analysis. Attempts to draw samples from the 2-m (7-ft) -deep lysimeter have been unsuccessful because of limited sample recovery. The vapor ports are either plugged or the soil surrounding the vapor ports has very low permeability. Samples were successfully collected from the 6-m (20-ft) -deep lysimeter during 1997 and 2000. Chloride was tested for in the sample analysis because magnesium chloride dust suppressant was applied on the SDA roadways in 1984 and 1985, and again in 1992 and 1993. Dissolved magnesium chloride in soil pore water would accelerate corrosion of the buried beryllium. Bromide analysis also was conducted on the 2000 sample because dust suppressant was found to have a relatively high, constant bromide-to-chloride ratio, thus being a further indicator of the impact of the dust suppressant.

The 1997 sample showed chloride concentrations in soil moisture near the beryllium blocks of about 650 ppm. This is substantially greater than the 20 to 30 ppm chloride concentrations expected in soil moisture at INEELⁱ, but less than the 2,650 ppm estimate used to derive the beryllium corrosion rate for the RWMC Performance Assessment (Maheras et al. 1994). Elevated chloride concentrations

i. Hull, Laurence, Interdepartmental personal communication with Paul Ritter, Idaho National Engineering and Environmental Laboratory, Bechtel BWXT Idaho, LLC, Idaho Falls, Idaho, March 2002.

measured around the beryllium blocks in 1997 are interpreted to be related to use of magnesium chloride dust suppressant on the SDA roads.

The chloride concentration in the 2000 sample was 35.5 ppm, and the reported bromide concentration, 0.2 ppm, was below the detection limit for the analysis (Ritter and McElroy 1999). Results suggest that the chloride-bearing water present near the lysimeter in 1997 migrated downward or laterally and was replaced by water with near-background chloride concentrations.

3.9.2.5 Type B Probes. Several Type B probe vapor ports were installed at SVR-20 in 2001 to augment the three existing sampling locations at the GSP-1 borehole (Figure 3-18). Only Type B probe SVR20-5-VP3 is currently functioning. Type B Probe SVR20-5-VP3 is approximately 3.5 m (15 ft) from the centerline of the buried beryllium with vapor ports at a depth of 5.4 m. This probe is farther from the buried beryllium than the preexisting monitoring points at GSP-1 and is expected to provide useful information concerning the lateral migration of tritium and C-14. As of March 2002, several sets of soil vapor samples have been collected for C-14 analysis as part of method development for long-term C-14 monitoring.

3.9.3 Activated Metal Monitoring

A large fraction of the total SDA inventory of C-14 is present in activated steel. The rate of release of C-14 from activated steel, accelerated by corrosion, is being studied at Soil Vault Row (SVR)-12 (Figure 3-18). Because SVR-12 is parallel to the interior perimeter road along the east edge of the SDA, it is not likely to be affected by roadway activities such as snow clearing or $MgCl_2$ dust suppressant. The area is not in an obvious runoff path, and there is little vegetation.

Highly-irradiated, activated stainless steel end pieces from spent Experimental Breeder Reactor II (EBR-II) fuel elements were disposed of in SVR-12. Spent fuel elements from EBR-II were sent to the INTEC for processing after use. The stainless steel end pieces were physically separated from the fuel in underwater basins at INTEC and sent to the SDA in 10 shipments. Personnel familiar with the subject disposals indicated that the end pieces were placed in open-top cask inserts that were perforated at the bottom to allow for draining upon removal from the storage basin (Salomon 2001).

Type B probes with vapor ports were installed near SVR-12 in 2001 (Figure 3-18). The Type B probes at SVR 12 include both vapor sampling ports and tensiometers. Tensiometers were installed to measure soil matric potential near activated metal in SVR-12 to determine hydraulic gradients, and the direction and rate of flow of soil moisture. Vapor ports were installed to provide information that could be used to characterize release and lateral migration of C-14 from the activated steel. Soil gas samples have been collected quarterly from the SVR-12 Type B probes since November 2001. In general, the specific activity of C-14 in CO_2 near the activated steel is at least 2 orders of magnitude less than the specific activity measured near activated beryllium in SVR-20. Compared to beryllium, activated stainless steel corrodes slowly and is a much less intense source of C-14.

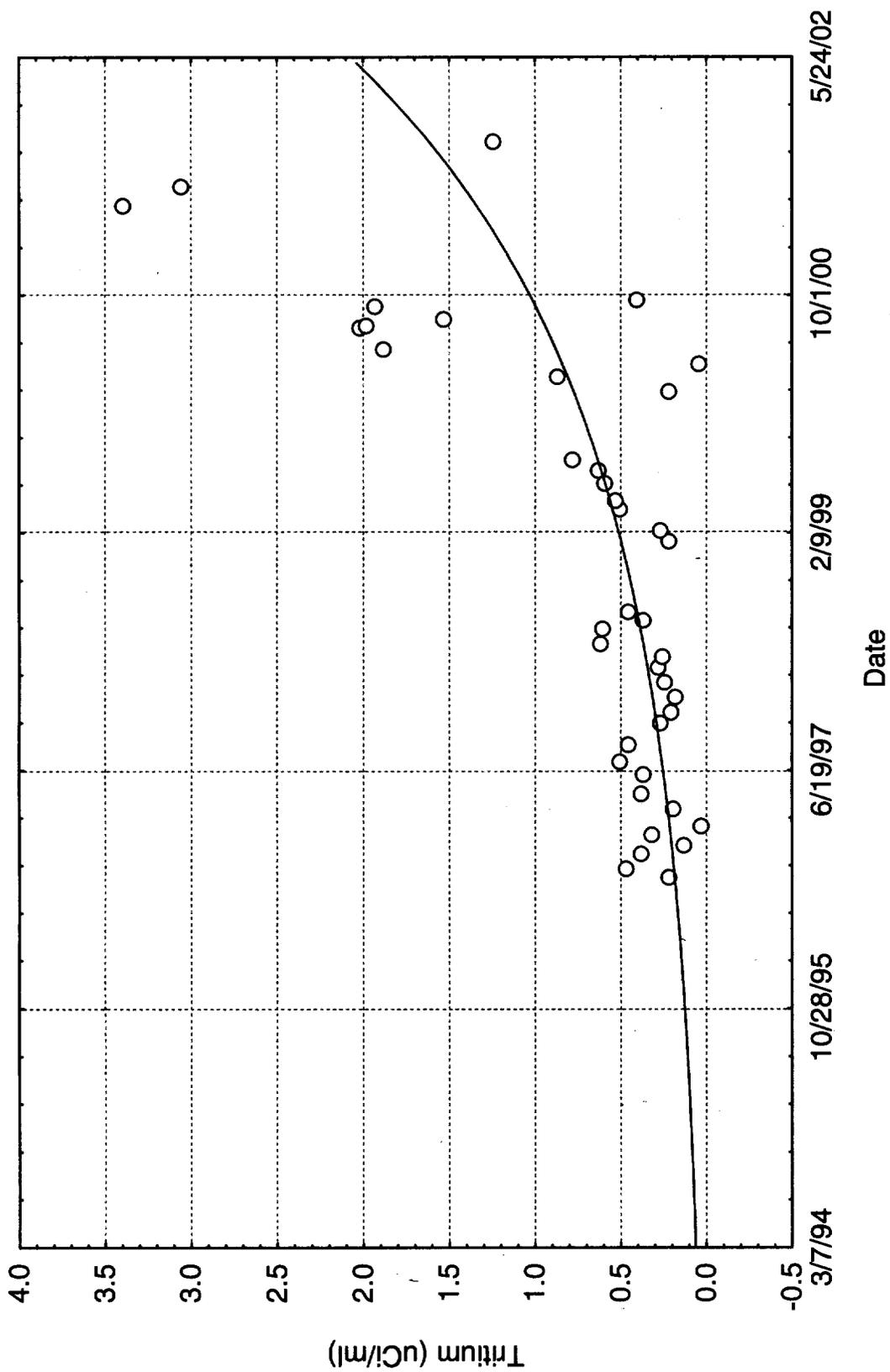


Figure 3-28. Concentrations of tritiated water in soil moisture collected from a depth of 2.7 m (9 ft) near activated beryllium in Soil Vault Row 20.

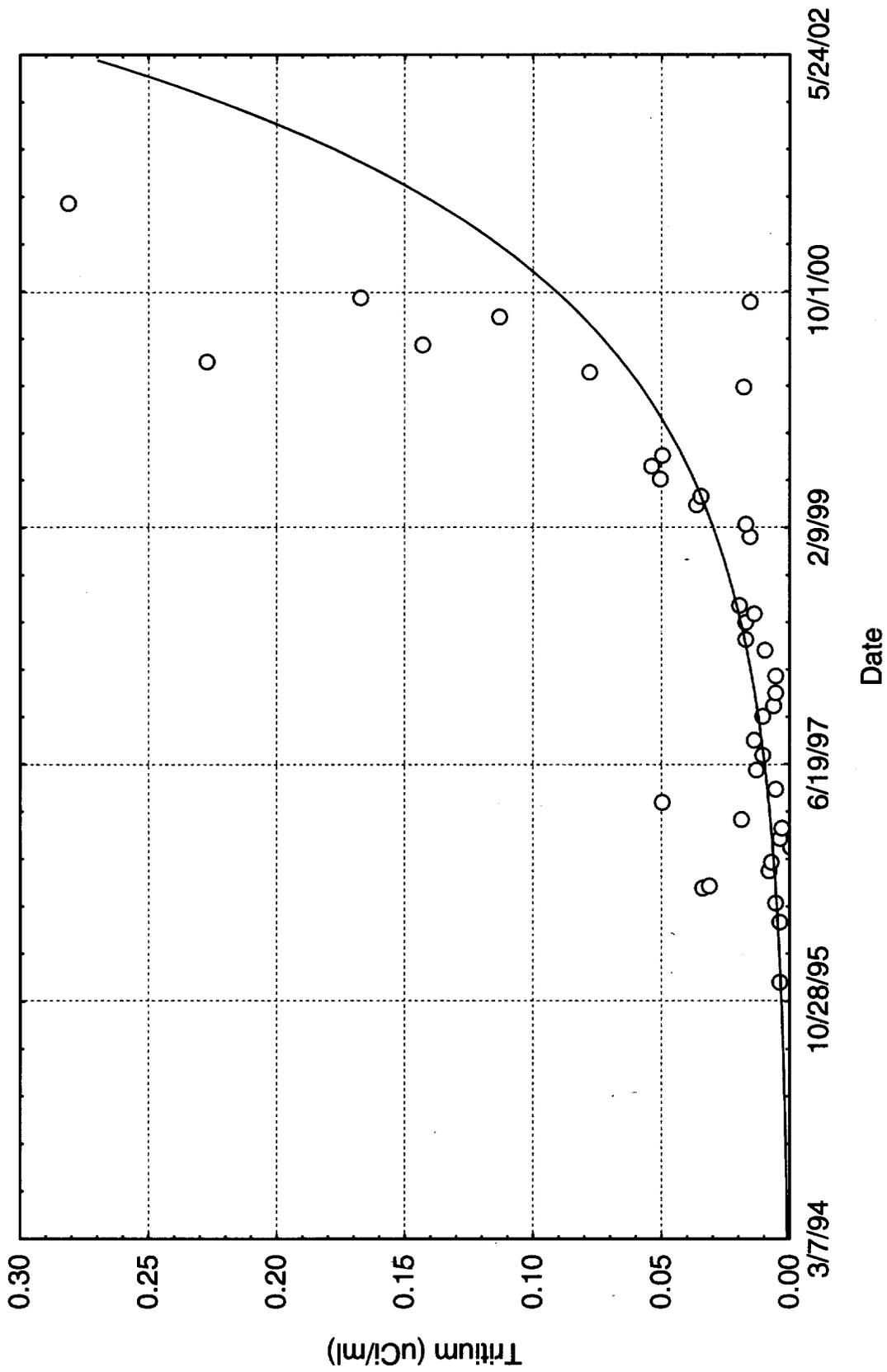


Figure 3-29. Concentration of tritiated water in soil moisture collected from a depth of 4.5 m (15 ft) near activated beryllium in Soil Vault Row 20.

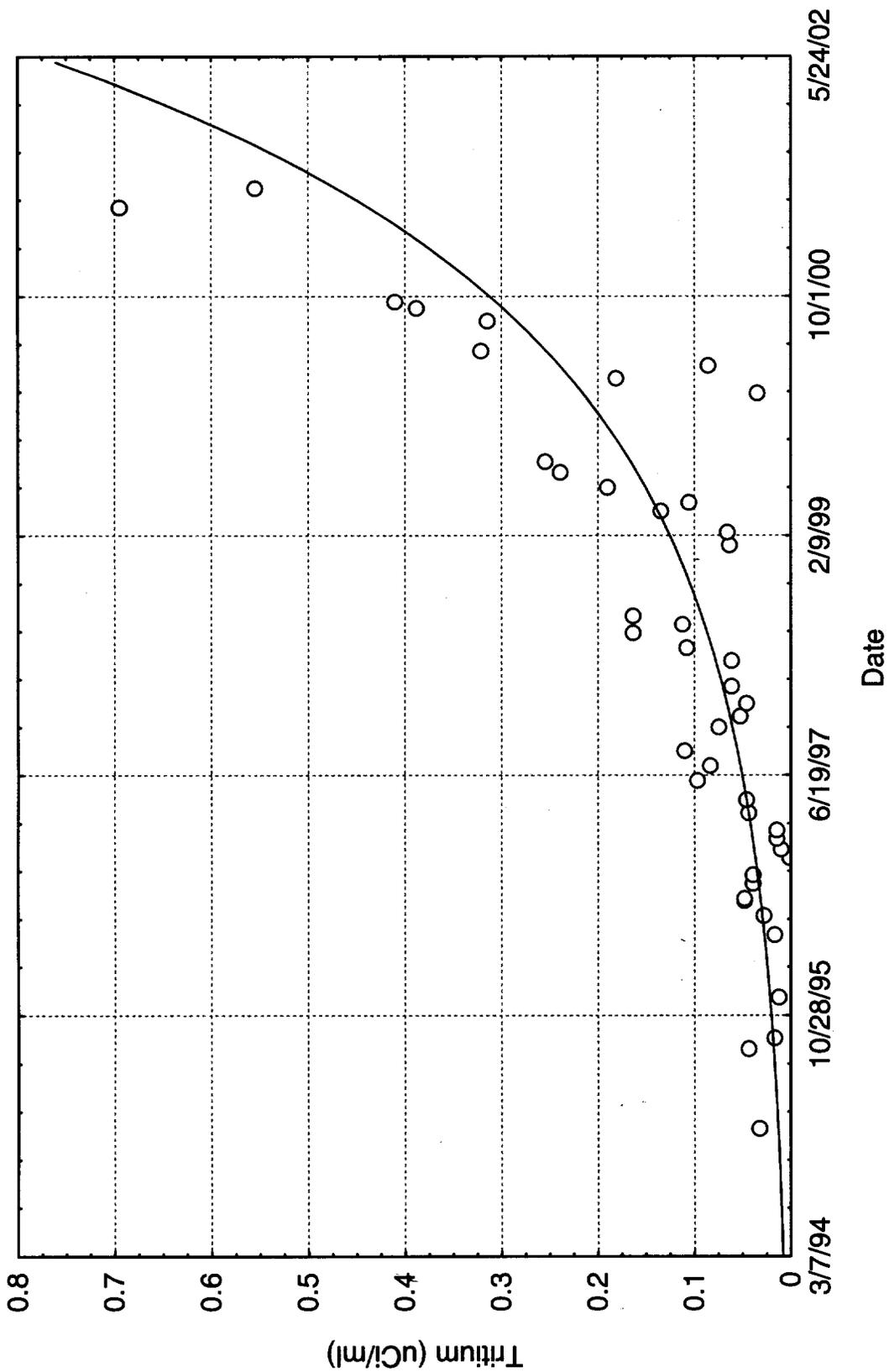


Figure 3-30. Concentration of tritiated water in soil moisture collected from a depth of 6.2 m (20 ft) near activated beryllium in Soil Vault Row 20.

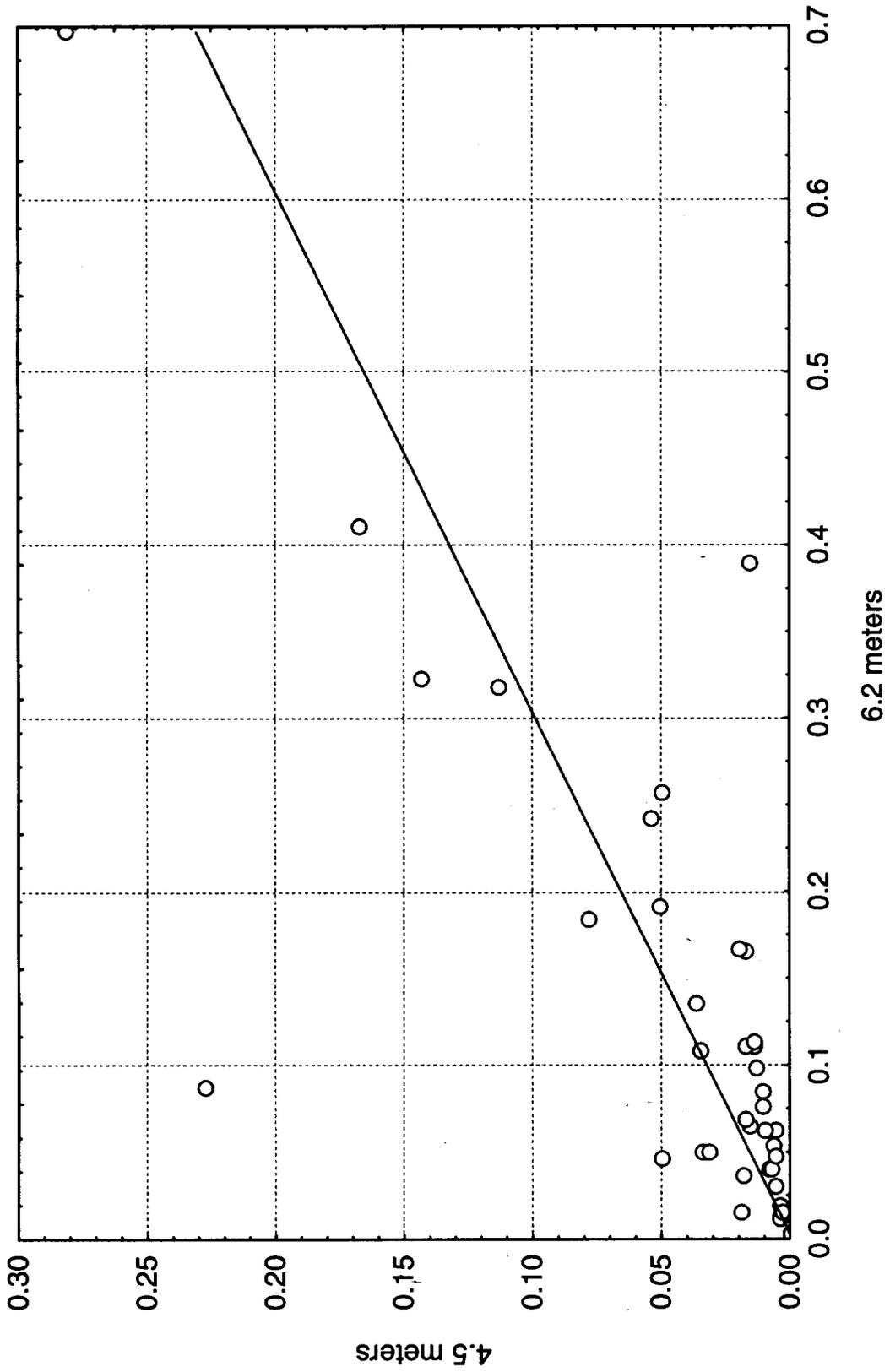


Figure 3-31. Correlation of concentrations of tritiated water in soil moisture collected from depths of 4.5 and 6.2 m (15 and 20 ft).

3.10 Preliminary Criticality Analysis for the Radioactive Waste Management Complex

The Criticality Safety Study^j of the SDA was prepared to support the OU 7-13/14 comprehensive RI/FS. The study was performed in 2001 to assess postulated plutonium criticality scenarios in the SDA. The study was designed to first define waste configurations that would enhance the probability of a criticality event, then to assess sensitivity of critical configurations to various parameters affecting critical systems.

Criticality is the condition in which a nuclear fission chain reaction becomes self-sustaining. Certain isotopes will fission more readily than other isotopes do. Isotopes that tend to fission easiest are often called fissile. Plutonium is a fissile isotope that was buried in the SDA. An approximate cumulative total of 1,100 kg of Pu-238, Pu-239, and Pu-240, with an approximate combined activity of 9.9E+04 Ci was buried in the SDA. The criticality analysis was initiated because of the random manner that waste was disposed of at the SDA and the uncertainty if a criticality (a self-sustaining nuclear reaction) could occur in the buried waste.

A criticality occurs under an extremely limiting set of circumstances. Large masses of fissile material in the appropriate configuration and in the presence of a moderator (i.e., water or some other substance that slows neutrons to enhance fission) can cause a nuclear chain reaction. Parameters affecting criticality in a fissile system include (a) the mass of fissile material present, (b) the presence of moderating material, (c) the geometric configuration, (d) the presence of diluents and neutron poisons, (e) the reflection conditions around the system, and (f) the concentration and distribution of the fissile material in the waste. Each of these parameters and the effects they have on reactivity were evaluated.

Most of the plutonium waste contained in the SDA was received from RFP. No criticality concerns would exist if the buried waste complied with the fissile material disposal limits that were set at RFP. The limits were 200 g of fissile material per drum or 5 g of fissile material per cubic foot with a total loading not to exceed 350 g per box. However, SWEPP assays of stored waste at TSA indicated that some RFP drums exceed the disposal limits, or are overloaded, with respect to plutonium (Ravio et al. 1995).

Three RFP waste streams were chosen for analysis based on the perception that they could contain enough plutonium to result in a criticality in the SDA. The waste streams were identified based on limited historical SWEPP assay data from stored waste at TSA and engineering judgment, and included glovebox HEPA filters, graphite molds, and magnesium oxide waste. The HEPA filters were chosen because overloaded drums containing this waste matrix have been discovered in the aboveground storage operations at TSA. In addition, HEPA filters historically have higher fissile loading. Graphite molds were chosen based on historical data indicating the possibility of high fissile loading and on the moderation properties of graphite. Graphite is a good neutron-moderating material in large systems that consist of somewhat homogeneous distributions of fissile material. Magnesium oxide also was chosen because overloaded waste drums containing this waste matrix have been discovered in the aboveground storage operations at TSA.

Sludge waste from RFP was not considered because of the sludge waste forms and the historically low fissile loading in the sludge matrices. Most of the sludge contains a large amount of carbon tetrachloride, which is a very good neutron poison. The chlorine in the carbon tetrachloride is an excellent

j. The study, document INEEL/EXT-01-01294, is still undergoing expert review and will be released in 2003.

neutron absorber that effectively lowers reactivity of the system by removing neutrons, thus reducing the likelihood of criticality. In addition, sludge inhibits the optimum conditions required for the formation of a critical system.

The analysis considered combinations of dumped containers and stacked containers with mass and geometry defined to enhance the probability of criticality. Regular stacking of containers would provide a more reactive geometry than randomly dumped containers, according to the analysis. Following the analysis of geometry, the amounts of moderation, neutron reflection, and neutron poison were varied to assess the potential for a configuration that could achieve criticality. The extremes of perfect neutron reflection and perfect moderation were assessed. None of the configurations analyzed was conducive to spontaneous criticality. The postulated configurations analyzed were designed to create near ideal conditions and are more reactive than the actual waste conditions within the SDA.

In summary, to achieve criticality with minimal mass, several conditions must occur simultaneously:

- The mass of plutonium must be larger than 520 g
- Water must be present in sufficient amounts to initiate a reaction
- The plutonium must be homogeneously distributed within the fissile volume
- Diluting material or neutron poisons cannot be present in the system.

Clearly, within the SDA, the optimal system for criticality does not occur. The waste is intermixed with neutron poisons, such as chlorinated solvents, sludges, and other waste debris. The geometry is not optimal because the plutonium present in the waste is in isolated small masses. Substantial quantities of water necessary to moderate and sustain a reaction are not present. In addition, the metallic plutonium originally contained in the waste when it was buried would not remain in the metallic form but would transform to plutonium oxide in the environment, diminishing the likelihood of a criticality even further. Soil mixed with the waste would dilute the plutonium concentrations and the soils contain additional neutron poisons.

3.11 References

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