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Report to the Chairman, Committee on Governmental Affairs, U.S. Senate

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NUCLEAR WASTE

Improvements Needed in Monitoring Contaminants in Harford Soils

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Resources, Community, and
Economic Development Division

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July 6, 1992

The Honorable John Glenn
Chairman, Committee on
Governmental Affairs
United States Senate

Dear Mr. Chairman:

Since 1943 the Department of Energy's (DOE) Hanford Site in southeastern Washington State has disposed of about 440 billion gallons of liquid waste in the ground and stored about 65 million gallons of waste in underground tanks—66 of which DOE assumes have leaked. Although DOE believes that most of the contaminants in the waste remain in the tanks or in the ground, some of the contaminants have migrated to the groundwater and have reached the Columbia River. Tracking the migration of these contaminants is critical to the success of DOE's 30-year effort to clean up Hanford's 1,500 waste sites and avoid further groundwater contamination.

Given the extent of contamination at Hanford, you asked us to examine DOE's programs to monitor and characterize contamination in the vadose zone—the unsaturated soil layer above the groundwater table. Specifically, we reviewed (1) how effective DOE's existing vadose zone programs have been, (2) how successful DOE's efforts have been to develop a strategy for improving the vadose zone programs, and (3) whether the additional use of electronic radiation detection technology in the vadose zone could save money and reduce health and safety risks during the cleanup.

Results in Brief

Since so much of Hanford's radioactive and hazardous waste has been intentionally disposed of in the ground or has leaked from underground storage tanks, it is important to monitor and characterize the extent of contamination in the vadose zone and determine whether it is migrating toward the groundwater. However, existing vadose zone programs receive limited funding, operate with out-of-date and uncalibrated equipment, and are not comprehensive enough to assess the migration of contaminants from tanks or in the ground.

DOE has not developed a strategy for improving its vadose zone activities. Such a strategy is needed to ensure that adequate money and effort are being placed into improving vadose zone programs and that DOE and contractor efforts are well coordinated. We found that often, the organizations responsible for monitoring and characterizing the vadose zone are unaware of each other's activities and tend not to share data, personnel, or knowledge.

Current plans for cleaning up Hanford's 1,500 liquid waste disposal sites rely heavily on extensive drilling of new wells and analysis of soil samples to characterize the extent of contamination. In the long run, use of electronic radiation detection technology within the vadose zone can cut the costs of environmental cleanup by reducing the need for drilling new wells or extensive soil sampling. For example, the results of one recent study suggest that DOE might save over $300 million by using up-to-date electronic radiation detection technology. This technology can also reduce the risks of contaminating groundwater and exposing workers to radiation during the drilling of wells.

Background

Since 1943 the Hanford Site, managed by the DOE Richland Field Office, has generated billions of gallons of liquid waste that have been treated, stored, and/or disposed of in a variety of ways. Most of this waste was released into nearly 300 waste disposal sites, including trenches, ponds, and cribs (underground structures designed to allow liquid waste to percolate to the soil) that are now inactive and awaiting cleanup. This approach was based on the assumption that the soil particles would hold nearly all of the radionuclides and prevent them from reaching the groundwater. According to DOE estimates, about 440 billion gallons of liquid waste was disposed of in this manner. Another 65 million gallons of high-level, mixed (radioactive and hazardous) waste is stored underground in 28 double-shell storage tanks (clustered into 5 tank farms) and in 149 single-shell storage tanks (clustered into 12 tank farms). DOE assumed, as of March 1992, that 66 single-shell tanks may have leaked and estimated that as much as 1 million gallons of high-level, mixed waste had leaked into the soil.

As a result of past waste disposal practices, the vadose zone and groundwater below large areas of the Hanford Site are already contaminated with radioactive materials and hazardous chemicals. This contamination, according to DOE, is moving toward—and in some cases has reached—the Columbia River. The extent of the vadose zone and groundwater contamination, however, is not fully known.

Currently, according to a DOE hydrologist, Hanford relies primarily on groundwater monitoring to determine the extent of contaminant movement. However, analysis of the vadose zone can provide more complete information about the location and movement of contaminants from waste disposal sites. Depending on the location, the vadose zone at Hanford extends from 1 to 350 feet down to the water table. Evaluating this zone can be accomplished either by extracting and analyzing soil samples as wells are being drilled or by lowering electronic radiation and moisture detection probes—hereafter referred to as vadose zone technology—into existing wells to detect the presence of radioactive materials and moisture. (App. I illustrates a truck using a probe to monitor contamination from cribs.)

The Westinghouse Hanford Company, the DOE Hanford Site operations contractor under the direction of the DOE Richland Field Office, is responsible for Hanford's vadose zone programs. Two DOE organizations—the Tank Farms Project Office and the Environmental Restoration Division—and two Westinghouse groups are responsible for the two principal vadose zone programs—leak monitoring and inactive site characterization. The Westinghouse Tank Farms Surveillance and Data Acquisition Group performs routine vadose zone monitoring to detect leaks from the single-shell tank farms and the 12 active liquid waste disposal cribs. The Westinghouse Environmental Division's Geophysics Team assesses the vadose zone to help characterize the nature and extent of contamination. This effort is needed to help characterize inactive sites so that appropriate cleanup strategies can be developed. Pacific Northwest Laboratories (PNL), a DOE contractor at Hanford, also supports Westinghouse's characterization program. In fiscal year 1991, DOE spent about $2.3 million on Hanford's electronic vadose zone monitoring and characterization programs.

Shortcomings in the Existing Vadose Zone Programs

The existing programs to monitor the single-shell tank farms and the active liquid waste disposal cribs are ineffective. Because of equipment and procedural problems, DOE is not able to detect new leaks quickly or to determine the size of the contaminated area beneath the soil's surface, known as a leak plume. In addition, DOE's effort to characterize the vadose zone, as part of the 30-year cleanup of the Hanford site, has been hampered by the absence of modern vadose zone equipment.

Monitoring Programs Have Been Ineffective

Although Westinghouse's Tank Farms Surveillance and Data Acquisitions Group estimated that nearly $1.1 million was spent in fiscal year 1991 to monitor the single-shell tank farms and 12 active disposal cribs, the radiation-monitoring probes currently being used are not sufficiently sensitive to detect new leaks quickly or to determine the size and composition of the leak plumes. Specifically, the probes are not being properly used and have not been fully calibrated to measure the presence of radioactive material; the data measurements made by the probes have not been adjusted to correct for certain factors, such as the type of well casings used; and the probes are operated at too high a speed. Similar problems exist with the moisture detection probes used at the tank farms to monitor, at least annually, each of its 759 drywells. (See app. II for more details on the problems identified with the presently used monitoring probes.)

Both internal and external reviews of the vadose zone monitoring program have reported many of these problems to DOE. Possibly, the most comprehensive assessment was performed by a DOE Tiger team during May, June, and July 1990. The team's July 1990 report cited inappropriate calibration techniques, wrong logging speeds, and inappropriate use of moisture detection tools as weaknesses in the Hanford tank farm vadose zone monitoring program.

In addition to monitoring the tank farms, from 1954 until 1988, PNL periodically monitored inactive disposal cribs in which large volumes of contaminants had been placed. In a 1988 study, Westinghouse reported that the inactive crib vadose zone monitoring, which PNL was performing for Westinghouse, was ineffective for measuring changes in radioactively contaminated zones for some of the same reasons identified previously for the tank farms. A PNL official said that the PNL inactive crib-monitoring effort was subsequently curtailed and that the effort was refocused to support characterization of the inactive waste disposal sites, including nearly 300 inactive cribs and other liquid waste disposal facilities.

Vadose Zone Technology Is Being Used to a Limited Extent in Site Characterization

In May 1989 DOE, the Environmental Protection Agency (EPA), and the Washington State Department of Ecology signed the Hanford Federal Facility Agreement and Consent Order, commonly referred to as the Tri-Party Agreement. This agreement represents a comprehensive effort to bring the Hanford Site into compliance with the Resource Conservation and Recovery Act of 1976 and the Comprehensive Environmental Response Compensation and Liability Act of 1980. The agreement establishes a 30-year cleanup schedule and contains numerous milestones to ensure DOE's continued progress toward meeting this schedule. Before appropriate cleanup actions can be determined, however, information must be obtained on the composition of the soil beneath the site as well as the nature and extent of contamination.

To obtain this type of information, vadose zone probes are being used to a limited extent. In 1988 Westinghouse purchased a new monitoring system, consisting of a radiation probe and associated equipment mounted in a truck, which replaced the out-of-date PNL monitoring equipment that was being used to monitor the sites.[1] This system uses a spectral gamma probe to measure the energy of gamma-emitting radionuclides, allowing specific radionuclides to be identified and their concentration in the vadose zone to be measured. Although it is still undergoing development and testing, the new system is already being used to help characterize Hanford's 1,500 liquid waste disposal sites (including the nearly 300 inactive disposal cribs and other liquid waste disposal sites into which nearly 700,000 curies of radioactive liquid waste have been placed).[2] However, because there is no backup for either the probe or the truck, the Westinghouse Geophysics Team is unable to meet schedule milestones. To improve its vadose zone monitoring effort, Westinghouse signed a contract for a backup probe in February 1992. Delivery of the backup probe is expected in August 1992. In addition, Westinghouse authorized the purchase of a second truck in March 1992. The second truck is scheduled for acquisition by February 1993.

PNL also supports Westinghouse's inactive site characterization efforts. According to a PNL official, PNL uses 18-year-old equipment to take readings of the naturally occurring radioactivity in the soil to help identify the types of soil in the vadose zone when new wells are drilled. However, we found that only one of the two PNL monitoring trucks at Hanford is being used and that the monitoring probe has not been calibrated since November 1988. PNL's second DOE-owned monitoring truck system has not been calibrated or updated and is not used. According to PNL officials, Westinghouse decided to purchase new equipment for its own program rather than purchase more modern equipment for PNL.

[1]Westinghouse estimates that between January 1992 and September 1992, the new monitoring truck will be used, in part, to help characterize about 30 inactive cribs as part of the site characterization program.

[2]A curie is a measurement of radioactivity, which is equal to 3.7×10^{10} radioactive disintegrations per second.

DOE Has Not Developed a Strategy to Improve Vadose Zone Programs

Because there is no clear requirement to monitor the vadose zone, DOE has not developed a strategy for addressing its various vadose zone activities. As a result, Hanford's vadose zone programs receive little attention and are not well coordinated.

DOE orders require the early detection and identification of contaminants in groundwater. According to DOE officials, no similar requirement exists for detecting and identifying contaminants within the vadose zone. However, in October 1989 Westinghouse issued a Groundwater Protection Management Plan, which requires the development of a sitewide vadose zone monitoring program. To implement this program, a sitewide plan is required that is to include an evaluation of the role of the vadose zone in groundwater contamination and a determination of vadose zone monitoring needs.[3] Although, as of May 1992, no sitewide vadose zone monitoring plan had been funded, Westinghouse had drafted a plan covering the two largest disposal areas at Hanford—those containing the single-shell and double-shell tanks and most of the 300 inactive liquid waste disposal sites. Although this plan provides information on current capabilities at two of seven Hanford areas where liquid waste had been stored and/or disposed of, it does not include an overall approach to managing vadose zone activities, cost data, or timetables for follow-on program activities.

Because DOE requirements for monitoring radioactive wastes in the vadose zone are unclear and no plan has been developed to guide the various vadose zone activities, Westinghouse has not put adequate money and effort into vadose zone programs. We found that often, the DOE and Westinghouse groups responsible for monitoring and characterizing the vadose zone are unaware of each other's activities and their efforts are not well coordinated. They tend not to share data, personnel, or knowledge, but rather they compete with each other for the limited funding that has been made available by Westinghouse. For example, the vadose zone monitoring program does not have adequate calibration facilities. Although DOE paid about $30,000 to ship four calibration models from a DOE facility near Spokane, Washington, to Hanford in August 1989, it has not, after 34 months, designed a facility to house the units and to install them. According to Westinghouse officials, the estimated $210,000 needed to install the models has been approved, and the models should be installed by August 1992. In the interim, according to Westinghouse officials, the monitoring truck has been taken twice to a DOE facility in

[3]Other plan objectives include protecting the groundwater from further contamination, assessing constraints on off-site migration of contaminants, and establishing a process to identify information needs.

Grand Junction, Colorado, for calibration at an estimated total cost of about $63,000.

In a June 1991 study, Westinghouse proposed spending $2.4 million to purchase new vadose zone monitoring equipment, including five trucks with spectral gamma systems for tank farm use in order to identify the specific radionuclides leaking from the tanks. However, this request received a priority too low to be funded. In February 1992, Westinghouse revised its proposal to one truck with a developmental system, estimated to cost $275,000. Westinghouse does not plan to purchase the new system until fiscal year 1994. As of May 1992, funding had not received final approval within Westinghouse.

To improve the coordination of the vadose zone monitoring efforts of the various groups, DOE created a Geophysics Working Committee. According to the DOE representative on the committee, the purpose of the committee is to discuss technical vadose zone questions and gather information for cleanup efforts at Hanford. Committee meetings have featured technical presentations from various government agencies and private contractors. In addition, the committee has exchanged information with other DOE sites. The committee has no funds and no authority to control vadose zone efforts. Westinghouse said that meetings are not the proper vehicle for changing the cost, schedule, or scope of the various vadose zone programs. Furthermore, the Tank Farms Surveillance and Data Acquisition Group—the largest organization with a vadose zone program—had not attended committee meetings because it was unaware of the committee's existence until we told the group about the committee in November 1991. Even after we told officials from the tank farms group about the committee, they did not attend the next four monthly meetings.

Inadequate coordination of vadose zone efforts has contributed to many of the problems we have discussed. For example, to install the calibration models, which would increase the accuracy of all of the vadose zone programs at the site, Westinghouse Geophysics Team officials said that they had had to seek funds from two different Westinghouse organizations involved in vadose zone monitoring, resulting in over 2 years' delay in installing the models. Ineffective coordination is also apparent in the assignment of the Tiger team recommendations for changes in the tank farms monitoring program to the Westinghouse Geosciences Group for action even though this group has no control over the tank farms monitoring program. Until January 1992, the responsible tank farms manager was unaware of the Tiger team findings.

Additional Use of Vadose Zone Technology Could Save Money and Reduce Health and Safety Risks

Current plans for cleaning up Hanford's 1,500 liquid waste disposal sites in a timely manner rely heavily on extensive drilling of new wells and analysis of soil samples to characterize the extent of contamination. A simple 200-foot well currently costs over $150,000, and a full analysis of soil samples every 5 feet costs about $200,000. Given that the estimated cost of spectral gamma analysis is about $2,400 per well, potential savings from using vadose zone technology in existing and new wells as a substitute for physical sampling are large.

An October 1990 Westinghouse study cited the reduced cost of vadose zone technology as an advantage over drilling and taking samples. Similarly, Geraghty & Miller, a groundwater consulting company, reported in 1987 that economic considerations provide an incentive for using vadose zone systems.[4] The report noted that vadose zone technology is generally underutilized and could reduce the number of samples needed. Washington State and EPA officials also believe that vadose zone technology is a promising and cost-effective approach that can help to determine the location, amount, and movement of radioactive and hazardous contaminants so that timely decisions can be made to prevent further migration of materials that represent a threat to the public health and welfare and to the environment. EPA Region X staff said that a sound vadose zone system that made effective use of existing wells could eliminate the need for some new wells and reduce the number of samples that require laboratory analysis. According to DOE officials, Westinghouse has not yet been directed to work with EPA to reduce the number of wells or samples because an adequate vadose zone program is not now available on site.

A March 1992 draft study of the costs and benefits of expanding the use of vadose zone techniques commissioned by Westinghouse concludes that some use of vadose zone technology could cut costs by eliminating the need for some soil and water samples and by reducing the number of new wells to be drilled. We estimate that, if the draft study assumptions are accurate, savings could amount to as much as $130 million for reductions in the number of samples required.[5] In addition, the draft study also suggests that vadose zone technology can be used instead of new wells being drilled for ongoing monitoring. The draft identifies 1,200 potential

[4]Geraghty & Miller, Inc., The Fundamentals of Ground-Water Contamination, 1987.

[5]Hanford's cleanup effort has been divided in the Tri-Party Agreement into 78 areas known as operable units. On the basis of experience with the first six operable units, the draft estimates potential savings at about $1.8 million per operable unit. Projecting this savings to the remaining 72 operable units produces potential savings of $129.6 million.

wells in the tank farms that would not have to be drilled, for a savings of about $180 million.

Besides reducing costs, vadose zone technology can reduce the risks of contaminating groundwater and exposing workers to radiation during the drilling of new wells. In addition, if contaminants in the vadose zone are detected, steps can be taken to prevent the further spread of contamination to the groundwater, thus reducing the potential cleanup costs. For example, in February 1985, PNL discovered that the groundwater below two inactive cribs (216-U-1 and 216-U-2) had been contaminated with some of the 4,000 kilograms of uranium that had been dumped into these cribs from 1957 until 1967. Subsequently, a nearby crib was used to dispose of liquid waste, and this waste flushed the uranium from the other cribs into the groundwater. Westinghouse and PNL officials said that vadose zone monitoring could have detected the problem and the disposal of the liquid waste could have been stopped. During the $1.3-million cleanup operation, about 8 million gallons of groundwater was pumped from the aquifer. However, only about 687 of the 4,000 kilograms of the uranium was removed.

Conclusions

DOE currently lacks reliable information on new tank leaks as well as on the location and movement of contaminants in the soil beneath its Hanford site. Tracking the migration of these contaminants is critical to the success of DOE's effort to clean up Hanford's 1,500 waste sites and avoid unnecessary groundwater contamination. The use of vadose zone technology can help improve DOE's knowledge of the movement of underground contaminants. In addition, as several studies have shown, vadose zone technology could also help DOE save money through reductions in the need for performing laboratory analysis and drilling wells.

Currently, DOE is not using vadose zone technology as effectively as it might to protect public health and the environment. Existing programs receive limited funding, operate with out-of-date and uncalibrated equipment, and are not comprehensive enough to assess the migration of leak plumes from tanks or inactive cribs.

Although DOE acknowledged in its Groundwater Protection Management Plan that vadose zone monitoring could be valuable in assessing the vadose zone, DOE has not developed an overall strategy that would make effective use of vadose zone technology. At present, several different programs and organizations spend vadose zone funds. DOE does not have a plan that would integrate their vadose zone programs to ensure that (1) the programs are adequately funded, (2) available funds are spent efficiently, (3) purchases of new equipment and proposed program improvements are timed to meet the needs of Hanford's 30-year cleanup effort, and (4) the actions of DOE and contractor organizations are coordinated.

Recommendations

To improve the vadose zone monitoring effort, we recommend that the Secretary of Energy direct the Manager of the DOE Richland Field Office to do the following:

- Review and update current monitoring procedures. This effort should require periodic calibration of the monitoring probes, use of appropriate logging speeds, and correction of radiation measurements.
- Develop and implement the vadose zone monitoring plan called for in Hanford's Groundwater Management Protection Plan. This plan should include (1) an integrated management approach; (2) a strategy for modernizing existing vadose zone equipment; (3) a timetable, which should be tied to Hanford's cleanup schedule, for acquiring equipment and implementing program improvements, such as the installation of the calibration models; and (4) an approach for tracking the migration of contaminants from the active and inactive liquid waste disposal sites.

Agency Comments

We discussed the facts in this report with DOE-Richland, Westinghouse, and Pacific Northwest Laboratory officials responsible for managing Hanford's vadose zone programs, who generally agreed that the report was balanced and accurate. As you requested, we did not obtain written agency comments on a draft of this report.

We performed our work between June 1991 and March 1992 in accordance with generally accepted government auditing standards. To assess the vadose zone monitoring programs, we reviewed available studies and interviewed various Westinghouse officials. We also reviewed studies relating to inactive crib monitoring and groundwater monitoring and obtained cost information. (See app. III for a more detailed discussion of our objectives, scope, and methodology.)

Technical assistance in performing this review was provided by Jon Mikesell. Mr. Mikesell is a physicist currently serving as the Chief of the Neutron Activation Project in the Geophysics Branch, Geologic Division, U.S. Geological Survey.

As arranged with your office, unless you publicly announce its contents earlier, we plan no further distribution of this report until 30 days from the date of this letter. At that time, we will send copies to the Secretary of Energy. We will also make copies available to others upon request.

This report was prepared under the direction of Victor S. Rezendes, Director of Energy Issues, who can be reached on (202) 275-1441. Major contributors to this report are listed in appendix IV.

Sincerely yours,

J. Dexter Peach
Assistant Comptroller General

Contents

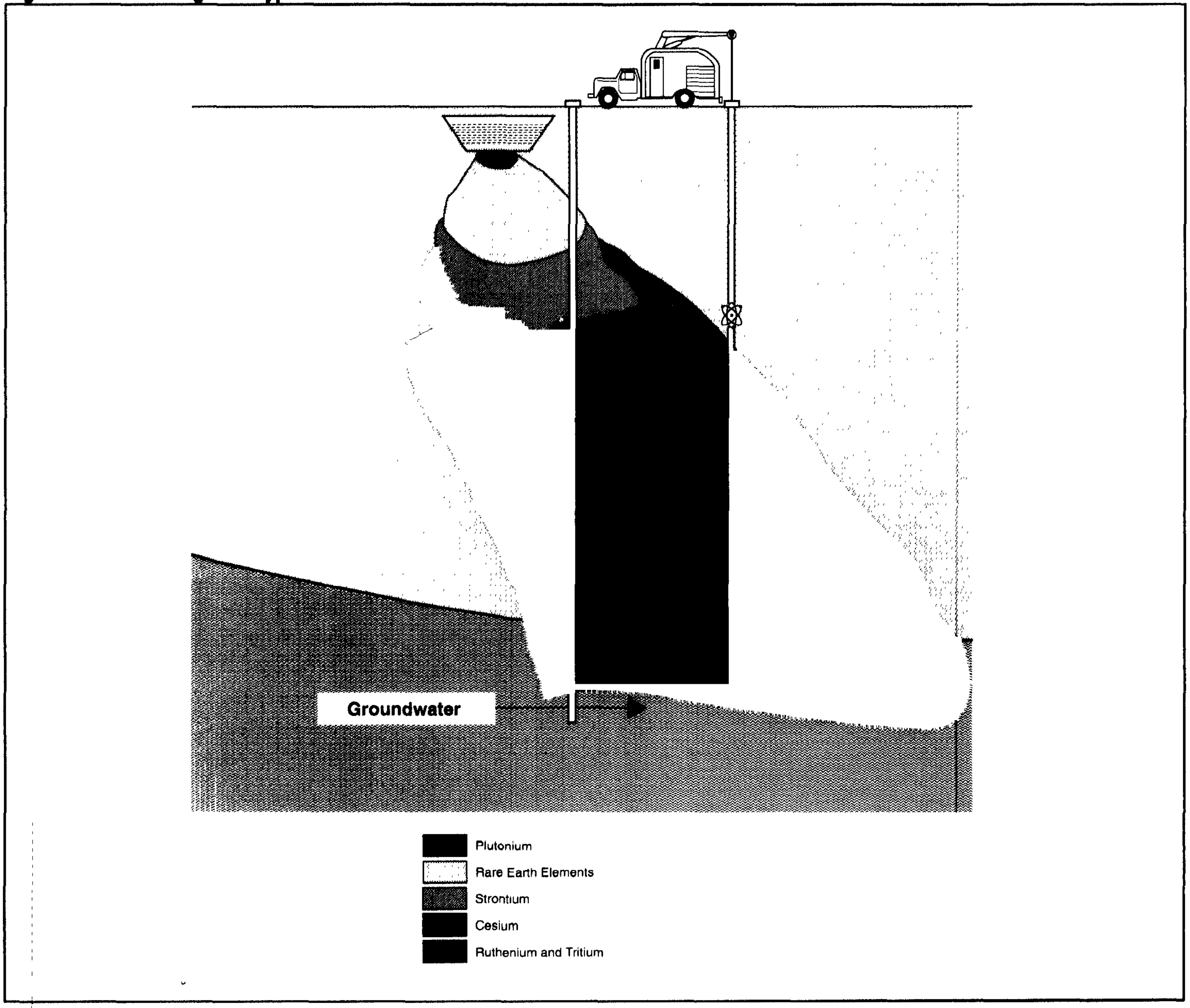
Abbreviations

DOE	Department of Energy
EPA	Environmental Protection Agency
GAO	General Accounting Office
PNL	Pacific Northwest Laboratories

Crib Monitoring

Figure I.1 depicts the vadose zone monitoring of a hypothetical leak plume from a liquid waste disposal crib.

Figure I.1: Monitoring of a Hypothetical Crib Plume



Source: GAO Illustration based on DOE data.

Problems Identified With Current Hanford Site Vadose Zone Probes

The gross gamma measuring probes being used at Hanford are not sophisticated enough to fully characterize leak plumes because they are unable to identify specific radioisotope concentrations and how they change with time.[1] This information is essential to characterizing leak plumes. First, precise knowledge of major and minor radioisotope quantities is essential for inventory purposes. Second, because of the differences in chemical interactions that each radioisotope has with materials in the soil, each radioisotope moves through the ground at different rates of speed. Third, the composition of a plume at any given point in space changes with time both because of the motion of the plume and because of the radioactive decay of some of the shorter-lived radioisotopes.

Furthermore, the measurements being obtained using existing gross gamma and neutron-neutron monitoring probes[2] may not be representative of the radioactivity or moisture in the vadose zone because

- The gross gamma and neutron-neutron probes used to measure the radioactivity and moisture in drywells have not been properly calibrated. The gross gamma probe should be calibrated in a simulated tank farm well which contains a precise amount of a radioactive isotope.
- Radiation measurements have not been corrected for borehole effects, such as the effects of the different types of well casings used.
- The measurements recorded by the gross gamma and neutron-neutron detection probes have not been corrected for dead-time effects. Dead time arises because the detector can respond to only one event at a time and is "blind" to new events occurring while a previous event is being processed. Therefore, dead-time for each probe needs to be experimentally measured annually and all data taken by that probe corrected.
- The speed at which the gross gamma probe is operated in measuring the gamma radiation—commonly referred to as the logging speed—is far too high to permit the early detection of leaks because the high speed reduces the sensitivity of the readings. Moreover, the high logging speeds have no current scientific justification.

[1]Gross gamma probes detect elements that emit gamma particles. The probes indicate only the total activity and do not identify the specific isotopes producing the gamma particles.

[2]Neutron-neutron probes are used to detect the presence of moisture in the surrounding soil, which may indicate that a leak has occurred.

Objectives, Scope, and Methodology

On November 26, 1990, the Senate Committee on Governmental Affairs asked us for information on ground monitoring at DOE's Hanford site. In subsequent meetings and briefings, we agreed to provide a series of reports on ground monitoring. This report focuses on DOE and contractor efforts to monitor the movement of contaminants from the storage tanks and other disposal sites through the soil above the groundwater, referred to as the vadose zone.

To address the Committee's request, we reviewed DOE and Westinghouse reports and files located in Richland, Washington, and at various facilities at the Hanford site. We also obtained information on waste disposal activities from Westinghouse's computerized Waste Information Data System. We did not independently verify the accuracy of the data in the system because the information was only used to determine the types of waste sites at Hanford. We also observed the operation of various vadose zone monitoring activities at Hanford.

We interviewed the DOE staff responsible for overseeing the vadose zone and groundwater programs. We also interviewed current and former staff from Westinghouse and Pacific Northwest Laboratories to determine how the vadose zone monitoring operations had been and were performed, funded, and managed.

To assist us in assessing the technical quality and sufficiency of DOE's vadose zone monitoring program, we obtained the assistance of Mr. Jon Mikesell, a physicist from the U.S. Geological Survey in Denver, Colorado. Mr. Mikesell is currently Chief of the Neutron Activation Project. He has about 15 years' experience in geophysics and vadose zone monitoring.

To determine the regulatory requirements for performing vadose zone monitoring, we discussed regulatory roles with DOE headquarters officials, attorneys from DOE and Westinghouse, EPA Region X officials, and Washington and Oregon State officials. We reviewed various DOE orders and appropriate state and federal regulations.

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