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—Regulatory Updates
—Performance Assessment
—Understanding Remedial Action Efforts

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VOLUME I

REGULATORY UPDATES

PERFORMANCE ASSESSMENT

UNDERSTANDING REMEDIAL ACTION EFFORTS

Prepared by the
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Idaho National Engineering Laboratory
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Idaho Falls, Idaho

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Volume I

REGULATORY UPDATES

PERFORMANCE ASSESSMENT

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REGULATORY UPDATES

Development of a Mixed Waste Management Facility at the Nevada Test Site: An Update

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ABSTRACT

The U.S. Department of Energy (DOE) produces some radioactive low-level wastes (LLW) which contain hazardous components as identified by Title 40 Code of Federal Regulations (CFR) Part 261. By definition, the management of those mixed wastes (MW) at the Nevada Test Site (NTS) requires compliance with U.S. Environmental Protection Agency (EPA) and state of Nevada regulations for hazardous wastes, and DOE regulations for LLW. In 1988, the DOE Nevada Operations Office (NV) began receiving MW at the NTS under interim status, as authorized by the state of Nevada. MW operations are currently limited to receipt of pondcrete and saltcrete from Rocky Flats Plant and retrievable disposal in an existing pit while operating under interim status.

Preparations for operation of a separate Mixed Waste Management Unit (MWMU) in the 1990s are underway. The 167-acre MWMU will be a part of the 732-acre Area 5 Radioactive Waste Management Site (RWMS). The MWMU is being developed in response to a DOE Office of Defense Waste and Transportation Management need to provide enhanced capabilities and facilities for safe, secure, and efficient disposal of defense-related MW in accordance with DOE, EPA, and state of Nevada requirements.

Planned activities relating to the development of the MWMU include completing National Environmental Policy Act (NEPA) requirements; responding to any notices of deficiencies (NODs) on the NTS Part B Permit application; conducting generator audits as part of the NTS MW certification program; optimizing the design and operation of the vadose zone monitoring system; developing protocols for the sampling and analysis of MW, and facility construction.

INTRODUCTION

U.S. Department of Energy activities, in support of Defense Programs, result in the generation of MW which contains both radioactive and hazardous components. In further support of Defense Programs, DOE/NV is developing a facility at NTS which can receive and dispose of a portion of the MW generated by DOE defense operations. The MWMU is being developed in response to a DOE Office of Defense Waste and Transportation Management need to provide enhanced capabilities and facilities for safe, secure, and efficient disposal of defense-related MW in accordance with DOE, EPA, and state of Nevada requirements.

This paper describes the permitting and regulatory environment, the specific application of the permit process to the NTS, and the phased development of an MWMU at the NTS.

SITE CHARACTERISTICS

The Area 5 RWMS is located on the NTS in Frenchman Flat, a basin and range province intermontane valley with no external surface drainage or surface water resources. The RWMS is located on alluvial fan material derived from the Tertiary volcanics of the Massachusetts Mountains located to the northwest. The valley fill is poorly sorted and only loosely stratified. It contains clay- to boulder-sized materials and is composed of tuff, limestone, dolomite, quartzite, granite, basalt, and other lithologic remnants in various proportions.

Annual estimated precipitation is calculated to be 5.5 in (14 cm); and the soil moisture content, to a depth of 20 ft (6 m), was found to be approximately eight percent. Potential evapotranspiration greatly exceeds the yearly precipitation. The Ash Meadows groundwater basin underlies the RWMS and is an interbasin flow system which occupies the lower portion of the Cenozoic alluvial fill and the basement Paleozoic carbonates. It is relatively independent of the topographic boundaries of Frenchman Flat. Depth to the water table at the waste site is approximately 800 ft (240 m) with the direction of flow generally south to southwest.

REGULATORY REQUIREMENTS

Mixed waste contains both radioactive and hazardous components as defined respectively by the Atomic Energy Act (AEA) and the Resource Conservation and Recovery Act (RCRA). Radioactive components of MW are regulated by DOE under the AEA. Hazardous components of MW are subject to RCRA regulations as enforced by the state of Nevada and approved by the EPA.

A. Resource Conservation and Recovery Act Requirements

The RCRA regulations govern facility development and operation, and prescribe a multitude of administrative and technical requirements. Compliance with these requirements must be demonstrated by documentation which specifically addresses each of the requirements.

Regulations for permitting MW operations are contained in Title 40 CFR Part 264, "Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities," and include the following: General Facility Standards, Preparedness and Prevention, Contingency Plan and Emergency Procedures, Manifest System, Recordkeeping and Reporting, Releases from Solid Waste Management Units, Closure and Post-Closure, and Landfills.

The state of Nevada adopted the RCRA regulations and is an authorized state for hazardous waste regulation. As such, the state regulations are at least as stringent as the RCRA regulations. The state of Nevada is authorized to regulate in accordance with the pre-Hazardous and Solid Waste Act Amendments (HSWA) RCRA regulations for MW. EPA Region IX is reviewing the state applications and could issue a decision in 1989.

B. DOE Requirements

The MWMU must meet all DOE regulations relating to radiation safety, environmental compliance, and waste disposal. Those requirements include disposal site performance, waste analysis, and waste acceptance criteria. In support of those regulations, a radiological performance assessment of all activities at the RWMS was conducted and is in the final review process. Based on that draft performance assessment, operation of the MWMU will meet all required radiological performance objectives. NVO-325 "Nevada Test Site Defense Waste Acceptance Criteria, Certification, and Transfer Requirements" contains the requirements for certifying MW for acceptance at the NTS.

C. National Environmental Policy Act Requirements

An Environmental Assessment (EA) of the impact of MW disposal operations at the Area 5 RWMS was prepared in 1988. That assessment included the results of the draft radiological performance assessment of all radioactive waste management operations at the Area 5 RWMS. Based upon the results of the EA, operations at the Area 5 RWMS, including the disposal of MW, will not have a significant environmental impact. The EA was reviewed by DOE Headquarters and may need to be expanded to address non-NTS related issues such as transportation of MW to the NTS.

APPLICATION OF THE PERMIT PROCESS SPECIFIC TO THE NTS

Pit 3, the existing disposal unit to be used for the retrievable disposal of MW during interim status, is located in the northeast corner of the Area 5 RWMS. Its dimensions are roughly 380 ft x 1080 ft (115.8 m x 329.2 m) and 30 ft (9 m) in depth. It has previously been used as a repository for LLW. However, the present quantity of LLW disposed in Pit 3 is small in comparison to the pit dimensions, and this waste will not interfere with the retrievable disposal of MW.

Because of the extreme conditions of the NTS environment, NV has requested a permit waiver on the use of disposal unit liners, leachate collection systems, and groundwater monitoring wells as required by RCRA.

In accordance with Title 40 CFR 265.90(c) and 40 CFR 264.90(b)(4), documentation of the low potential for migration of hazardous components to groundwater was developed and included in the Part B Permit application. That determination was necessary to operate under interim status without groundwater monitoring.

For permitted status operations, the interim status waiver, in conjunction with the vadose zone monitoring system, will support the waivers from groundwater monitoring wells and trench liners. The state has verbally indicated their expected concurrence with this approach; however, the EPA has not offered a position on the waiver request.

FACILITY MONITORING

A typical monitoring system utilizing groundwater monitoring wells is inappropriate at the NTS. The travel time of a contaminant, from the near surface to the water table (calculated to take in excess of 100,000 years) precludes the use of monitoring wells as a detection system. In addition, wells could create accelerated transport pathways for the migration of water contaminants from the near surface to the water table. For those reasons, a system has been designed for monitoring the vadose zone beneath the MW disposal units.

The methods selected as most appropriate for monitoring MW at the NTS are (1) neutron logging, (2) soil air sampling, and (3) gamma logging. MW consists of both hazardous and radioactive components. Accordingly, both components should be included in the monitoring plan. Because water movement through the unsaturated zone is the major vehicle for the transport of waste components, neutron logging will provide long-term spatial monitoring of soil moisture conditions within and beneath the disposal unit. Soil air sampling will indicate the presence and concentration of volatile hydrocarbon components, while gamma logging will identify radioactive components in the soil.

The vadose zone monitoring system has been installed in the MW dedicated portion of Pit 3 for use during interim status operations. Refinements to the vadose zone monitoring system will continue to be made during interim status in order to improve specificity and sensitivity of the system. During permitted operations, the vadose zone monitoring system will be used as an alternative to conventional groundwater monitoring.

FACILITY OPERATIONS

A. Interim Status

On November 8, 1985, DOE/NV provided the NTS RCRA Part B Permit application for the RWMS to EPA Region IX and the state of Nevada in support of developing an MWMU. On September 17, 1987, the state of Nevada Department of Conservation and Natural Resources granted DOE/NV interim status for the receipt and disposal of hazardous waste. Subsequent discussions with the state confirmed that interim status authorized the NTS to accept MW which can only be disposed in the existing LLW disposal unit, Pit 3. However, until such a time as the EA is approved by DOE/HQ, the waste must be easily retrievable, hence the new term retrievable disposal. The state of Nevada has RCRA authority and has applied for authority to regulate MW. In anticipation of the state receiving MW authority, a revised Part B Permit application was submitted to the state of Nevada in October 1988.

The MWMU will be operated in four phases which coincide with the permitting process. Phases I and II (retrievable disposal and disposal, under interim status, respectively) occur under interim status authorization. Phases III and IV (construction and operation of the MWMU, respectively) occur under permitted status authorization. The operations corresponding with each of these phases follow:

1. Phase I - Retrievable Disposal

Although interim status has been granted to DOE/NV, current operations under Phase I only include the receipt and placement of Rocky Flats Plant (RFP) pondcrete and saltcrete into retrievable disposal in Pit 3. Disposal will not occur until a Finding of No Significant Impact (FONSI) is issued to satisfy National Environmental Policy Act (NEPA) requirements. NEPA requirements for retrievable disposal are covered by the DOE memorandum to file, "Temporary Storage of Rocky Flats Waste at NTS." Upon issuance of the FONSI, operations will shift from retrievable disposal to complete or final disposal (Phase II).

In accordance with NVO-325, waste generators must operate under a Waste Certification Program Plan which addresses the elements described therein. Initial approval and annual audits of generators' certification programs will be conducted jointly by DOE/NV and Reynolds Electrical & Engineering Co., Inc. (REECo) audit teams. Upon demonstration of satisfactory compliance with the audit findings and observations, a generator would be approved for a specific MW stream. Each MW stream will be subject to the audit process. In order to receive RFP pondcrete under Phase I, an audit of the RFP waste certification program was conducted at the RFP in December 1987 and followup meetings held during 1988.

2. Phase II - Disposal Under Interim Status

Once NEPA requirements have been satisfied with the issuance of the FONSI, disposal of the RFP waste streams in Pit 3 will commence and additional selected mixed waste streams may be accepted from approved generators. Waste disposal operations will be conducted in accordance with the requirements of Title 40 CFR Part 265. Review of the Part B Permit application by the state of Nevada, and responses to any NODs, will be completed during Phase II.

B. Permitted Status

1. Phase III - Procurement and Construction

Once the state of Nevada issues the Part B Permit, MWMU construction activities will commence. Site construction activities include construction of the flood control dike, completion of new road work, excavation of the first disposal unit, installation of onsite utilities and fire protection systems, and installation of the vadose zone monitoring system. Disposal cells in the MWMU will be 100 ft x 300 ft x 20 ft. Average disposal life of each cell will be under five years.

Until the construction of the MWMU is complete, waste operations will continue in Pit 3. This transitional period includes state reviews of "as-builts" and verification inspections at the site. Upon approval by the state, placement of MW in the new disposal unit (Phase IV) will proceed.

2. Phase IV - Permitted Disposal

Upon completion of the MWMU, disposal of MW from approved generators will commence in accordance with the conditions of the Part B Permit. Generators' waste certification activities will be audited for conformance with the MW acceptance criteria outlined in NVO-325. No generator waste streams will be authorized for disposal until compliance with NVO-325 is demonstrated.

In addition to the waste certification program, random examination of package contents will be conducted at a Waste Examination Building (WEB) which should become operational at approximately the same time as the MWMU. Initially the WEB only will utilize real-time radiography to verify compliance with the waste acceptance criteria of NVO-325. Future waste verification activities will include intrusive sampling and analysis of package contents.

CURRENT PLANS

Mixed waste operations at the NTS are currently in the Phase I stage with waste from RFP being retrievably disposed in Pit 3 at the Area 5 RWMS. The Part B Permit has been submitted and is under review by the state of Nevada. Generator certification audits are being performed and protocols are being developed for sampling and analysis of the MW. The vadose zone monitoring system is being refined for in situ monitoring. DOE/NV anticipates moving ahead into Phase II upon receipt of the appropriate approvals.

Environmental Protection Agency Update on Mixed Waste Regulations

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This paper is divided into discussions of the following four basic areas: (1) dual regulation, a reality that is here to stay; (2) the state role; (3) an overview of current agency activities; and (4) current issues.

The first area, dual regulation of mixed waste, requires the cooperation between regulatory agencies, whether federal or state, for managing the chemical and radioactive aspects of mixed waste. Dual or joint regulation of mixed waste is now a well established fact. The jurisdictional divide is clear. The radioactive component of the waste is regulated by the U.S. Department of Energy (DOE) or the Nuclear Regulatory Commission (NRC), under the authority of the Atomic Energy Act (AEA), and the hazardous waste component of the waste is regulated by the U.S. Environmental Protection Agency (EPA), under the auspices of the Resource Conservation and Recovery Act, known as RCRA.

The regulatory jurisdiction of mixed waste is not always clearly understood or accepted. Historically, jurisdictional confusion centered around the exclusionary provision in RCRA for source, special nuclear, and byproduct material. These classes of radioactive material are under the jurisdiction of the AEA. The regulatory status of waste containing both RCRA hazardous waste and AEA radioactive material was not clearly defined until dual regulation was established.

Two Federal Register publications established the dual regulatory framework. First, EPA published a notice on July 3, 1986, announcing that the RCRA exclusion applies only to the radioactive component of solid waste;

the hazardous waste component is regulated under RCRA. Secondly, on May 1, 1987, DOE published an order that defined byproduct material. DOE stated that only the actual radionuclides in radioactive waste are considered byproduct material and that any other constituents, such as the hazardous constituents, are not byproduct material and are therefore not excluded from RCRA regulation. Within the dual regulatory framework, if the application of both regulatory regimes proves conflicting in specific instances, that is, where compliance with one set of regulations would cause noncompliance with the other, the Atomic Energy Act requirements take precedence. As a result of dual regulation of mixed waste, we are assured that the health and environmental hazards posed by both the chemical and the radioactive components of mixed waste are adequately addressed.

The second area is state involvement. Dual regulation involves not only the EPA, DOE, and NRC, but also state authorities. RCRA is implemented for the most part by the individual states. Congress intended that the states be the primary implementers of RCRA and created provisions in the Act to authorize state programs. An authorized state program means that a state has developed a set of regulations which are at least as stringent as the federal regulation and that EPA has approved the state program and authorized the state to implement this hazardous program within its own jurisdiction. In effect, the state program operates in lieu of the federal government. As a result, authorized states implement their programs. State RCRA programs must be equivalent to, and may in fact, be more stringent or broader in scope, than the federal RCRA program.

This means that the states can impose more stringent requirements for mixed waste than for other hazardous waste. For example, states could develop separate mixed waste regulations. We expect, however, that as most states become authorized for mixed waste, they will simply expand their hazardous waste programs to include mixed waste. This seems to be the case even now. At the moment there are nine states authorized to regulate mixed waste. They are the States of Washington, Colorado, South Carolina, Georgia, Ohio, Utah, Minnesota, Tennessee, and Kentucky. Major DOE facilities are located in many of these states and are being regulated by the appropriate state authority. There are an additional 36 states that have authorization for their hazardous waste programs, something referred to as base RCRA authorization. However, these base RCRA-authorized states have yet to receive authorization to regulate mixed waste.

Consequently, federal RCRA regulations do not apply to mixed waste handlers in these states. However, there may be non-RCRA independent authority under state law to regulate mixed waste. Base RCRA-authorized states must revise their hazardous waste programs to include the regulation of mixed wastes.

EPA expects to authorize an additional 14 to 15 states in the next six to eight months. For these newly authorized states, mixed waste will come under the authority of the appropriate state agency. It's also important to note that there are 11 unauthorized states and territories in which EPA administers the federal RCRA program. Federal RCRA regulations do not apply to mixed waste handlers in these states. These states are Idaho, Iowa, Alaska, Puerto Rico, Wyoming, Connecticut, the northern Marianas Islands, the Virgin Islands, American Samoa, California, and Hawaii.

Because of the state authorization process and the current status of authorized and unauthorized states, there may be varying requirements nationwide for mixed waste as states adopt hazardous waste regulations that are either broader in scope or more stringent than the federal RCRA program. This fact has led EPA to realize that there is a need for strong and centralized guidance regarding the regulation of mixed waste.

The third area discussed in this paper is concerned with EPA's progress on current issues. EPA has progressed on several promises to create strong centralized guidance. One of the first tasks that EPA and NRC performed was a detailed comparison of NRC's low-level waste requirements and EPA's corresponding regulations. This was to determine whether the fact of the dual regulatory framework was workable. NRC and EPA wanted to be assured that there were no insurmountable inconsistencies between the two regulatory programs. In fact, no inconsistencies were found between the two sets of regulations. What we mean by no inconsistencies is that they had found no instances where compliance with one set of regulations would cause noncompliance with the other. There may be some difficulty in the current implementation aspects of those sets of regulations. EPA recognizes that, in implementing the regulations and site-specific situations, there is potential for conflict. But such problems, we believe, are not insurmountable. EPA and NRC produced three joint guidances to address the identification of mixed wastes, and the following two perceived implementation problems: the criteria to be considered when siting mixed waste units and the conceptual design of the mixed waste disposal units.

In addition to these joint guidances, EPA hosted a workshop on mixed waste in Denver, Colorado in July of 1988. The workshop participants included representatives from EPA, DOE, and NRC, as well as many state agencies involved in the overall regulation of mixed waste activities. Feedback confirmed that the workshop was successful in communicating ideas, issues, and questions among the primary regulatory agencies. There was also a great degree of interaction at the workshop. For the first time, key players in the regulation of mixed waste were convened to share their experience and concerns. EPA believes that a good deal of profitable information was exchanged and has undertaken further projects which have resulted from issues raised at the Denver workshop.

In September 1988, EPA published a clarification in the Federal Register, regarding RCRA interim status with facilities handling mixed waste. The notice extended the deadline for facility owner/operators in unauthorized states, so they could comply with procedures allowing them to qualify for interim status. The Federal Register notice also explained that the deadline for facility owners and operators in authorized states would be inspected in accordance with state law, that is, after the state received RCRA authorization for mixed waste. These two actions ensured that the newly regulated mixed waste facilities can legally continue to operate under RCRA until their permits are issued.

Finally, EPA and NRC developed a clarification of waste testing requirements for mixed waste. This clarification, which was expected to be issued in October, emphasizes that, under RCRA regulations, testing is not required in order to determine if a waste is hazardous. Generators are required to determine whether the waste is RCRA hazardous. However, testing particularly for listed waste may not be necessary. The hazardous waste determination may be based on the generator's knowledge of the materials in process. Owners and operators of facilities that treat, store, or dispose of hazardous waste, must then obtain sufficient information to manage the waste in a safe and appropriate manner. The owner or operator may use information that came from the generator for this purpose.

However, in order to accurately characterize the waste, it may also be necessary to conduct representative sampling. It is important to note here that when sampling and testing are needed, it is not necessary to sample every container. Furthermore, routine testing of waste shipments is not required. After initial characterization, waste must be analyzed only if the owner or operator has reason to believe the process of generating waste has changed or that the characteristics of the waste do not match the accompanying manifest or shipping papers. Clarifying when testing and sampling are necessary to ensure that appropriate management of mixed waste will enable facilities to minimize the instances when they test. EPA is confident that, by identifying when testing and sampling are necessary and by requiring the use of appropriate sampling procedures, the hazards associated with the testing of mixed waste will be maintained within acceptable limits. EPA recognizes that some issues, however, such as sampling representativeness and testing protocols require further consideration, and is considering acceptable resolutions to these problems.

Fourth and finally, there are many issues outstanding and some may have direct specific significant impact on DOE facility operations.

One issue is the status of state authorizations. As I mentioned to you earlier, RCRA is designed to be implemented by the states. Authorized states must revise their programs to include mixed waste. Because so few states are currently authorized to regulate mixed waste, there is a checkerboard regulatory situation among the states. This patchwork authorization often leads to public and political criticisms. This type of inconsistency will disappear as states continue to receive authorization for mixed wastes.

The second issue is the storage of mixed waste. This is troublesome because of the limitations of storing any RCRA hazardous waste. RCRA allows unpermitted on-site storage of hazardous waste by the generator for up to 90 days. For storage longer than 90 days, the generator must apply for a permit as a storage facility. Once the state receives authorization for mixed waste facilities, including generators, to store mixed waste on site for longer than 90 days, they will be required to apply for a RCRA permit and would be allowed to operate under interim status pending final permit determination or issuance. These storage limitations and time frames, clearly will affect the day-to-day management of mixed waste at DOE facilities.

Perhaps the biggest outstanding issue is how the land disposal restrictions, also referred to as the LDRs or LANDBAN, will affect the treatment, storage, and disposal of mixed waste at DOE facilities. The Hazardous and Solid Waste Amendments (known as HSWA or HASWA) to RCRA were enacted on November 4, 1984. A major provision of HSWA requires EPA to evaluate all hazardous waste to determine whether or not land disposal is protective of human health and the environment.

For wastes which are restricted from land disposal, EPA is to set levels of treatment standards that will substantially reduce the waste toxicity. EPA sets the treatment standards based on the best demonstrated available technology, known as BDAT. HSWA describes an ambitious schedule requiring EPA to consider all hazardous waste by May 8, 1990. To ensure that the final schedule is adhered to, HSWA set interim schedules and established soft and hard hammers. What that effectively means is that, in the law, Congress said to EPA "By such-and-such a date, you will do the following." If EPA fails to set a treatment standard for scheduled waste by its statutory deadline, the soft hammer restrictions apply. Soft hammer restrictions allow the continued disposal of untreated waste, provided the receiving unit meets the minimum technology requirements. If treatment for the soft hammer waste is practically available, the generator must use the best practical available treatment to treat waste before disposal.

If EPA fails to set treatment standards for any listed hazardous waste by May 8, 1990, the hard hammer falls, meaning that the land disposal of such waste is banned. The unusual structure of the land disposal restrictions and the schedule and the hammers set forth in HSWA have been driving the Agency efforts now for some time.

To date, final rules in planning the land disposal restrictions have been promulgated for solvents and dioxin wastes; these were issued on November 8, 1986. The California listed waste was published on July 8, 1987, and the "first third" and "second third" of all remaining listed waste on August 17, 1988 and June 23, 1989, respectively. Through these rules, if the hazardous component of a mixed waste is spent solvent, a dioxin-containing waste, or California listed waste, the mixed waste is subject to the applicable land disposal restriction treatment standards.

The "first third" rule deferred consideration of scheduled mixed waste until the final third of the schedule waste, that is until May 8, 1990. As a result, mixed waste other than spent solvents, dioxin-containing waste, or California listed waste, will not be subject to the land disposal restrictions until May 8, 1990.

Under certain conditions, however, variances for the extensions of the effective date of the land disposal prohibitions are available. The November 8, 1988 rule established four types of variances or extensions. The first one is the variance from the land treatment standard, the second a two-year national capacity variance, the third a case-by-case extension, and the fourth a no-migration petition.

A petition must be filed with the Agency for an extension or variance, with the exception of the two-year national capacity variance, which EPA grants at the time the rule is promulgated. It is important to note that any extensions or variances granted under the land disposal restrictions framework will not alter the eventual need for sufficient capacity between stored and disposed mixed waste.

EPA recognizes that this is a particularly difficult provision--the difficult nature of the land disposal restrictions in the context of mixed waste. When we are testing the waste to ensure compliance (and in testing the waste we are in compliance with the treatment standards), generators must determine either by testing or process knowledge whether or not their waste is restricted from land disposal, and whether their waste meets the applicable treatment standards. A waste analysis must be conducted if there is any reason to believe that the waste composition or the generating process has changed such that reliance on process knowledge could prove to be insufficient. Treatment facilities must test the treatment residue using the Toxicity Characteristic Leaching Procedure (TCLP) to determine whether or not it meets the level specified by the applicable treatment standards. Again, if there is any reason to believe that the waste composition or a treatment process has changed, treatment facilities must conduct a waste analysis.

Land disposal facilities are responsible for ensuring that only wastes meeting the treatment standards are land disposed. Owners and operators of land disposal facilities should note that, while reliance on generator-supplied waste analysis data is allowable under the land disposal restrictions, use of such data does not relieve owners or operators of liability under the terms of the land disposal restriction requirements.

The land disposal restrictions have generated a flurry of activity at both EPA and DOE. DOE has applied for a no-migration petition for its Waste Isolation Pilot Plant near Carlsbad, NM. The facility is to be a repository for transuranic waste, and will be important, providing DOE with the necessary capacity for managing transuranic waste.

In the area of future activities, EPA has several activities already underway or in the planning stages to address some of these particular issues. EPA is developing a storage guidance document, which will be comparable to NRC storage guidance, and will address current RCRA storage requirements, corrective action, and closure requirements, and the use of storage to consolidate waste prior to treatment for disposal.

One of the conclusions from the workshop in Denver was that there is a strong need for cross training within the regulatory agencies. EPA RCRA staff need to have an overview of the NRC and DOE requirements that apply to mixed wastes and they need to be trained in the principles and hazards of radioactivity in order to increase their ability to recognize the special problems caused by radioactive waste, while integrating solutions to these problems within the RCRA regulatory framework. Currently, EPA is designing a mixed waste training force to prepare those RCRA permit writers and inspectors to deal with the particular health and safety and regulatory aspects of mixed wastes. We will be pilot testing this force in September or in early October, and will be delivering the full force soon thereafter.

Also under development by the Office of Waste Programs Enforcement within EPA's Office of Solid Waste and Emergency Response is a guidance document on inspecting mixed waste facilities. This guidance is planned to be issued in early 1990. In order to clarify EPA's role in mixed waste regulation at federal facilities, EPA and DOE are negotiating a memorandum of understanding (MOU). The MOU will seek to clarify RCRA applicability to DOE mixed waste, and all DOE mixed waste facilities will be subject to the terms and conditions of the MOU.

Last, EPA is planning another mixed waste workshop for sometime in the spring of 1990, which will be open to the public as well as to all the regulatory agencies. The success of the first workshop was so overwhelming that EPA believes the sharing of information and exchanging of ideas that occurred in Denver should be repeated. Additional progress can be reported then. Also, new issues that have arisen can be brought to the fore and resolved.

In conclusion, I'd like to say that dual regulation is, from EPA's perception, working well, and EPA will be undertaking even more efforts over the next two years to make it part of the mixed waste regulatory framework. We will seek to make it workable and practical for the generators, treaters, storers, and disposers of mixed waste.

NRC REGULATORY INITIATIVES

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INTRODUCTION

The U.S. Nuclear Regulatory Commission (NRC) is addressing several low-level waste disposal issues that will be important to waste generators and to States and Compacts developing new disposal capacity. These issues include Greater-Than-Class C (GTCC) waste, mixed waste, below regulatory concern (BRC) waste, and the low-level waste data base. This paper discusses these issues and their current status.

GREATER-THAN CLASS C WASTE

The Low-Level Radioactive Waste Policy Amendments Act of 1985 (Amendments Act), which was signed into law in January 1986, makes disposal of GTCC waste the responsibility of the Federal government. The Amendments Act also requires the NRC to license the disposal facility for commercial GTCC wastes.

In February 1987 the Department of Energy (DOE) published "Recommendations for Management of Greater-Than-Class C Low-Level Radioactive Waste" (DOE/NE-0077). In this report DOE accepted responsibility for the disposal of GTCC waste, but did not address disposal options. Rather, DOE stated that disposal recommendations could not be made until the NRC and the Environmental Protection Agency (EPA) first addressed a number of regulatory actions. The NRC, however, responded that DOE need not wait to make a decision on a disposal option and pointed out that, if DOE were to decide to dispose of commercial GTCC waste in a high-level waste geologic repository, many of DOE's concerns would be eliminated.

DOE did offer to store GTCC waste until disposal capacity could be developed. They expected to have a program in place for accepting GTCC waste for storage within two years. In the interim DOE would consider requests for acceptance of commercial GTCC on a case-by-case basis. DOE is currently considering the location for an interim storage facility and the scheduling of the availability of a dedicated GTCC waste storage facility and a GTCC waste disposal facility.

On May 25, 1989 NRC published in the Federal Register (54 FR 22578) a final rule amending 10 CFR Part 61 to require disposal of GTCC waste in a deep geologic repository, unless disposal elsewhere has been approved by the Commission.

Currently, the NRC staff continues to support DOE efforts to establish storage capacity for GTCC wastes. The NRC staff considers that interim storage of sealed sources and other material exceeding the Class C concentrations is clearly in the public interest to help prevent possible unauthorized use or loss of control of these radioactive materials. The NRC staff is working to characterize the quantities of GTCC waste being generated, particularly the number and charactistics of unneeded sealed sources.

BELOW REGULATORY CONCERN WASTES

Section 10 of the Amendments Act requires that, within six months, the NRC establish standards and procedures, and the technical capability to act in an expedited manner on petitions to exempt specific waste streams from regulation. NRC responded with three actions.

First, On August 29, 1986 the NRC published in the Federal Register (51 FR 30839) a Commission Policy Statement and Staff Implementation Plan. These two documents provide guidance to potential rulemaking petitioners outlining the decision criteria the Commission intends to use to expeditiously process petitions.

Second, the IMPACTS-BRC computer code for calculating radiological impacts from unregulated disposal was adapted for personal computer use and a draft user guide was published in July 1986 (Volume 2 of NUREG/CR-3585). Subsequently, the NRC staff contracted with Sandia National Laboratory for technical assistance to critique, validate, and verify the computer code.

Third, on December 2, 1986 the NRC published in the Federal Register an advanced notice of proposed rulemaking (ANPR) (51 FR 43367) requesting comments on the development of a generic BRC level for wastes. Over 90 comments were received in response to the ANPR reflecting diverse views on how the NRC should proceed. Many commenters opposed the concept of any level of radioactivity being BRC and others urged NRC to proceed promptly on the generic rulemaking. In March 1988 the Commission delayed the rulemaking and directed the staff to first prepare for Commission consideration options for a broad policy statement that establishes a generic limit for exposures that are below regulatory concern.

The policy statement addresses BRC issues not only for waste management but for all licensing applications including consumer products, existing exempt quantity limits, and effluent releases. This policy statement would provide for more efficient and consistent regulatory actions in connection with exemptions from specific NRC requirements. A draft policy statement was prepared and discussed at the International Workshop on Rules for Exemption from Regulatory Control sponsored by the NRC and the Nuclear Energy Agency in October 1988. An advance notice of a policy statement was issued for public comment in the Federal Register on December 12, 1988 (53 FR 49886). The Advance Notice recommended a 10 mRem/yr dose level as a floor for ALARA based on consideration of the variations in background, risk perceptions, BRC versus de minimis distinctions, the linear non-threshold hypothesis, and practical implementation. The policy and the comments received are currently being considered by the Commission. We expect the Commission to take action this summer.

The NRC expects to receive a petition for rulemaking from the Nuclear Management and Resources Council (NUMARC) to have specific commercial reactor waste streams designated as BRC. The petition, which is being prepared on behalf of 54 nuclear utilities, is expected to be submitted to the NRC in August 1989. NUMARC has indicated that the potential BRC wastes considered in the petition represents 20 to 30 percent by volume and 0.018 percent of the activity of low-level wastes generated by commercial reactors. The various waste streams addressed in the petition are considered as one large waste stream characterized by certain bounding physical and radioactive properties. The petition would exclude wastes with the potential for recycle.

MIXED WASTE

Mixed waste continues to be a very controversial and confusing area for States and commercial waste generators. Under the Resource Conservation and Recovery Act (RCRA), the EPA has jurisdiction over the management of solid wastes with the exception of source, byproduct, and special nuclear material, which are regulated by the NRC under the Atomic Energy Act (AEA). Low-level radioactive wastes contain source, byproduct, and special nuclear material, but they may also contain chemical constituents that are hazardous under EPA regulations promulgated under Subtitle C of RCRA. Consequently, under Federal law mixed wastes are subject to both NRC and EPA regulations with the NRC having jurisdiction over the radioactive component and the EPA having jurisdiction over the hazardous chemical component of the waste. Due to the nature of dual jurisdiction over mixed wastes, organizations that treat, store, or dispose of mixed wastes will need both a license for possession and use of the radioactive material issued under the AEA and a treatment, storage, or disposal permit issued under RCRA.

While both RCRA and the AEA are intended to protect public health and safety and the environment, both laws take different paths to achieve their goals. For example, the AEA is a very general, performance-oriented law while RCRA provides prescriptive requirements including detailed disposal facility design requirements. RCRA was also never intended to address a radiation hazard in hazardous chemical wastes. This has resulted in implementation issues that in some cases involve higher occupational exposures than would occur under only the AEA.

To minimize confusion resulting from dual jurisdiction, the EPA and NRC staffs have prepared three joint guidance documents. These documents address the definition of mixed waste, mixed waste disposal facility siting, and mixed waste disposal facility design. The EPA and NRC received seven comments on the joint definition document and have revised the document. This revision makes no substantial changes in the mixed waste definition but does clarify several areas of confusion raised by the commenters. The final definition document has been signed by EPA and is in concurrence at the NRC.

The EPA and NRC staffs are also developing additional joint guidance documents. Joint guidance documents on waste characterization, inspection, and storage are currently under development. The characterization guidance will address the need for consideration of occupational exposures during testing. A final draft characterization document is currently under review and is scheduled for completion October 1989. The inspection guidance will provide NRC Regional, Agreement State, EPA Regional, and Authorized State inspectors with background information on mixed waste licensing and permitting, inspection planning and coordination, cross-training, and the conduct of mixed waste inspections. A draft inspection document is currently under review and is scheduled for completion in January 1990. The storage guidance will combine the NRC radioactive waste storage recommendations with EPA storage requirements. A draft storage document is being prepared by an EPA contractor.

One of the major issues in the mixed waste area is the Land Disposal Restrictions (LDR). The LDR require that wastes be treated prior to disposal and prohibit storage of wastes except to accumulate sufficient quantities for treatment. The LDR requirements are being implemented in a time phased program. However, because licensed treatment capacity of radioactive waste is limited, waste generators are placed in a situation where they cannot dispose of their wastes nor can they treat them nor can they store them. The EPA staff is currently developing a statement designed to clarify this issue.

The NRC staff is also supporting an initiative by the DOE Energy Information Agency (EIA) to obtain a data base on mixed waste. The EIA is considering a survey of mixed waste generators to obtain information on mixed waste generation, the volume in storage, and projected generation rates in the future. This program could be very important to States and Compacts that are developing capacity projections for mixed waste disposal units. Although this EIA program is currently at a conceptual stage, the EIA hopes to initiate it next year.

LOW-LEVEL WASTE DATA BASE

The NRC has inititated a rulemaking to ensure that adequate technical information on low-level wastes is available and in a form that can be used for performance assessments, technical analyses, and other activities needed to ensure the low-level waste disposal is conducted in a manner that protects public health and safety. This rulemaking will amend 10 CFR Parts 20 and 61 to --

1. Augment and improve information contained in manifests accompanying shipments of low-level wastes to disposal facilities

2. Require that operators of disposal facilities store portions of this manifest information in computer recordkeeping systems.

3. Require that operators periodically submit, in an electronic format, reports of shipment manifest information.

The NRC staff intends to incorporate the submitted electronic data into a large computerized waste disposal data base to be operated by DOE under the provisions of the Amendments Act.

The NRC staff has scheduled a proposed rule to be published in the Federal Register in June 1990.

DECOMMISSIONING

On June 27, 1988 the NRC published in the Federal Register (53 FR 24018) a final decommissioning rule amending its regulations to set forth technical and financial criteria for decommissioning nuclear facilities. These new regulations address decommissioning planning, timing, financial assurance, acceptable funding methods, and license termination procedures. These regulations affect both reactor and materials licensees.

To implement the regulations the NRC is preparing a series of guidance documents in the areas of funding, cost estimating, recordkeeping, facilitation of decommissioning, termination procedures, and the content of decommissioning plans.

In July 1989 the NRC received for review of the Pathfinder reactor dismantlement plan and the Fort St. Vrain preliminary decommissioning plan. The Pathfinder reactor is a 66 Mwe experimental boiling water reactor located in Sioux Falls, SD. This plant will be the first NRC power reactor licensee to be dismantled. Fort St. Vrain is a 330 Mwe high temperature gas cooled reactor located in Platteville, CO. This facility will be placed in SAFSTOR.

OVERVIEW OF EPA's ENVIRONMENTAL STANDARDS FOR THE LAND DISPOSAL OF LLW AND NARM WASTE - 1989

by

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ABSTRACT

The Environmental Protection Agency (EPA) program to develop proposed generally applicable environmental standards for land disposal of low-level radioactive waste and certain naturally occurring and accelerator-produced radioactive wastes has been completed. The elements of the proposed standards include the following: (1) exposure limits for pre-disposal management and storage operations, (2) criteria for other regulatory agencies to follow in specifying wastes that are Below Regulatory Concern (BRC), (3) post-disposal exposure limits; (4) ground water protection requirements; and (5) qualitative implementation requirements. In addition to covering those radioactive wastes subject to the Atomic Energy Act (AEA), the Agency also intends to propose a standard to require the disposal of high concentration, Naturally occurring and Accelerator-produced Radioactive Materials (NARM) wastes exceeding 2 nCi/g, excluding a few consumer items, in regulated LLW disposal facilities.

1.0 INTRODUCTION

In August 1983, EPA published an Advanced Notice of Proposed Rulemaking (ANPRM) [1], stating the Agency's intention to develop generally applicable environmental standards for the land disposal of low-level radioactive waste (LLW).

These standards are being developed under the authority of the Atomic Energy Act of 1954, as amended [2], and Reorganization Plan No. 3 of 1970 [3]. The intent is that they must be met by facilities that dispose of LLW, whether the facilities are licensed and regulated by the Nuclear Regulatory Commission (NRC) or their Agreement States, or are owned and operated by the Department of Energy (DOE).

Comments in response to our ANPRM and at public outreach meetings, especially from State representatives, strongly recommended that the Standard should also cover certain wastes from Naturally occurring and Accelerator-produced Radioactive Materials (NARM). As a result, and since EPA is the only Federal Agency with authority to regulate NARM waste disposal, it was decided to include a proposed NARM waste disposal standard.

We are using the Toxic Substances Control Act [4] for the necessary NARM authority. Section 6 of this Act provides that if the Administrator determines that an unreasonable risk exists, he may promulgate regulations on the disposal of a chemical mixture or substance to mitigate such risks.

LLW Disposal Standard

The EPA LLW Standard is intended to cover disposal of all AEA materials not covered by other EPA disposal standards, i.e., all radioactive waste that is not high-level and transuranic radioactive waste or spent nuclear fuel, as defined in 40 CFR Part 191, and not uranium mill tailings that are subject to 40 CFR Part 192. Coverage of certain "regulated NARM" wastes is proposed in 40 CFR Part 764. The standards will have several important and closely related elements:

(a) Low-level waste pre-disposal management and storage. This would include limits on radiation exposure to individuals during processing, management, and storage of LLW.

(b) Definition of radiation exposures related to low-level radioactive waste disposal that are sufficiently small that they do not need to be regulated regarding their radiation hazard (i.e., a level "below regulatory concern").

(c) Limits on radiation exposure to individuals after the disposal site is closed, i.e., after it stops receiving wastes.

(d) Ground water protection requirements for both pre- and post-disposal phases.

(e) Other areas will include qualitative implementation requirements.

NARM Waste Disposal Standard

The regulation of certain NARM waste is proposed under the Toxic Substance Control Act (TSCA) since the AEA does not apply to NARM. Since the proposed NARM regulation would require the disposal of regulated NARM in an AEA authorized LLW disposal facility, such NARM wastes would become subject to the AEA post-disposal requirements of that facility.

2.0 LLW STANDARDS RATIONALE

Individual Radiation Exposure Limits

During Management and Storage (Pre-Disposal)

This element would limit annual effective dose equivalent from all environmental pathways to any member of the public from facilities which process, manage, or store LLW. This would include the operational phase of regulated LLW disposal facilities, i.e., while they are receiving and emplacing waste; and "away from generator" LLW management, processing and storage facilities. NRC-licensed Uranium Fuel Cycle Facilities also process LLW, but are covered under 40 CFR Part 190 (5).

With the advent of NRC's 10 CFR Part 61 rulemaking [6] on licensing requirements for land disposal of LLW, all higher activity commercial wastes must be solidified and packaged with the intent to add retention and structural strength to the waste package. Waste generators are also now opting for volume reduction, waste processing, and packaging, not only to meet NRC requirements, but as methods to reduce disposal costs and to stay within reduced out-of-State volume limits imposed by host States for existing LLW disposal facilities under the Low-Level Radioactive Waste Policy Amendments Act of 1985 [7].

We are, therefore, confronted with growing trends to create a large number of diverse facilities for treating and processing LLW, plus the potential for facilities that would be dedicated to the storage of LLW for periods beyond our previous perception. These circumstances then create a possible gap in the pathway coverage of EPA's waste related standards. Processing and storage done at a power reactor site would be covered by the

Uranium Fuel Cycle Standards, 40 CFR Part 190 [5] as well as the Clean Air Act requirements of 40 CFR 61 [8,12]. Exposure from atmospheric releases at all other LLW processing and storage facilities would be covered by the Clean Air Act radionuclide emission regulations (40 CFR Part 61) [8, 12]. However, exposure through other pathways from processing operations and long-term storage at LLW disposal facilities and at "away from generator" LLW processing facilities would not be covered.

Most of the exposures from these facilities would be expected to result from airborne releases, but there is also the potential for exposures from direct gamma radiation, water pathways and from releases caused by spillage and similar incidents. Our analyses indicate that control of these exposures should require no more increment of effort than maintaining processing and storage vessels away from public access and the good housekeeping practices necessary to eliminate or cleanup spillage.

The Agency, therefore, deems it prudent to include limits on these potential exposures in our Standard. This would also make the EPA LLW Standard more parallel and consistent in structure with those the Agency promulgated for High-Level Radioactive Waste, 40 CFR Part 191, Subpart A (9). The Office of Radiation Program's analyses indicate a standard around 25 millirem per year from all pathways would be consistent with the technology and other similar standards.

"Below Regulatory Concern" Criteria

We intend to establish criteria for identifying LLW with sufficiently low levels of radioactivity to qualify as "Below Regulatory Concern" (BRC) waste. Any waste meeting these criteria could be disposed of as a non-radioactive waste. However, if it had Resource Conservation and Recovery Act (RCRA) hazardous characteristics, it would have to be disposed of in compliance with RCRA regulations. The EPA would not be involved in identifying or selecting specific LLW types which qualify as BRC wastes, the NRC, States and DOE would implement the use of our criteria.

If the BRC criteria are implemented as we envision, most wastes identified as BRC wastes, and not having RCRA hazardous characteristics, would be disposed of as garbage or trash in a municipal landfill or be incinerated and subsequently so disposed. Our risk analyses show that with careful selection and segregation of waste, the population, individual and on-site worker risks can be quite low.

In arriving at a proposed BRC level, EPA carefully weighed and considered many factors. Foremost, was protection of the public and the development of an exposure level with assurance of no undue risk. Also, considered were other daily risks encountered, ability to demonstrate compliance, guidance for similar exemptions by other governmental and scientific groups, consistency with other regulated risk levels, general population health risks, and the maximum annual exposures to critical population groups.

Our economic analyses show that the use of a BRC criteria to eliminate certain low-activity radioactive wastes from the full LLW regulation and disposal process is very cost effective. EPA estimates that approximately 35 percent by volume of all commercial and DOE LLW could be reclassified as BRC with a resulting maximum annual effective dose equivalent to an individual of less than 4 millirem per year and potential savings of more than 700 million dollars over 20 years.

Individual Radiation Exposure Limits for Post-Disposal

Our standard will establish limits on exposure through all pathways to members of the public from the land disposal of LLW.

EPA's post-disposal limit would apply to any DOE or NRC/State-licensed LLW land disposal method or facility constructed after the effective date of the rule. The requirements would apply to existing disposal facilities requiring them to conform to the standards within a certain time frame, on the order of five years. EPA is proposing an all pathways limit of 25 millirem per year annual effective dose equivalent from the land disposal of LLW.

Ground Water Protection

The protection of the Nation's ground waters is of major importance in EPA and such a consideration is particularly appropriate in waste disposal standards. The Agency's Groundwater Protection Strategy [10] calls for the protection of ground water commensurate with its value and use, along with the development of a ground water classification system. Our approach to ground water protection is developed in this context.

Two sets of ground water protection requirements will be proposed and public comments solicited. In both proposals Class I ground waters require the highest levels of protection. This class represents those ground waters that are highly vulnerable to contamination <u>and</u> serve as irreplaceable sources of drinking water for large populations. It is appropriate to give these ground waters the highest level of protection, i.e., non-degradation. The two proposals differ only with respect to the protection levels for Class II ground waters which represent all non-class I present or potential sources of drinking water. The first proposal would protect Class II ground waters from high yield aquifers (which are or could be a community water supply) to an annual effective dose equivalent of 4 millirem, while Class II ground waters from low yield aquifers (which generally could not provide a community water supply) would be protected as a part of the 25 millirem per year all pathways pre- and post disposal performance standards. The second proposal would protect all Class II ground waters, which is by far the largest category of ground waters, to an annual effective dose equivalent of 4 millirem. This level is comparable to the 4 millirem per year Maximum Contaminant Level (MCL) for man-made beta particle and photon radioactivity established for public water supplies by EPA's drinking water standards under the Safe Drinking Water Act [11].

Finally, both proposals recommend the same levels of protection for Class III ground waters. Such ground water is not a source of drinking water but may have other beneficial uses. Class III A ground waters are protected to the level applicable to the highest class of ground water to which it is interconnected. Class III B ground waters would be protected as a part of the 25 millirem per year all pathways pre- and post-disposal performance standards.

This is an area where we are particularly interested in receiving public comment as to the impact of these two alternatives. The evaluation of these comments will have a major influence on the final standard.

Qualitative Requirements

Another area of coverage in the Standard that is being considered is the matter of qualitative requirements. Such requirements would make clear the context and assumptions within which we expect the Standard to be implemented.

These requirements would address areas not appropriate for quantitative requirements and compensate for the uncertainties that necessarily accompany plans to isolate radioactive wastes from the environment for a long time. They would include: (a) limiting the dependence on active institutional controls (such as guarding, maintenance or clean-up of releases) after disposal to no more than 100 years; (b) providing passive institutional measures (such as permanent markers, records or archives or government ownership) which should reduce the chance of inadvertent human intrusion beyond the active institutional control period, (c) requiring monitoring during disposal and post-disposal phases which should be done with techniques that would not jeopardize the isolation of the wastes; and (d) suggesting site location away from areas containing materials not widely available from other sources (such as certain minerals and fuels).

3.0 NARM COVERAGE

The considerations for the regulation of NARM are to:

(a) Assure the same disposal of discrete high activity NARM wastes as for similar AEA wastes,

(b) Provide for a manifest system that will track the NARM waste from generator to disposal.

An important point on the NARM coverage of an EPA standard is specifically which NARM wastes are to be covered. We have used the nomenclature of discrete, non-diffuse, low volume, high concentration NARM waste to describe our intention. We presently are excluding those high volume diffuse wastes such as mine over-burden and beneficiation residuals. That is not to say that these latter wastes are not deserving of some type of regulation. We are merely saying they are not appropriate for coverage under these LLW Standards, which are focused on regulated disposal sites for LLW operated by State compacts or the Federal government.

NARM waste proposed for regulation includes any NARM waste whose radioactivity concentration exceeds 2 nanocuries per gram, but exempts certain consumer items. Individually, such items, such as watches, contain small amounts of radioactivity and are typically widely dispersed in society. The primary criterion of the proposed NARM regulation requires the disposal of regulated NARM in an AEA authorized LLW disposal facility. Such facilities are either NRC or Agreement State licensed or authorized under DOE regulations. This subjects regulated NARM waste to the post-disposal requirements described earlier.

4.0 1989 ACTIVITIES

We are now on track, to what we see as the final approach to proposing the LLW and NARM waste standards in early 1990. We are presently preparing a series of regulatory support documents which will be available when the proposed standard is published in the Federal Register. They will include a draft environmental impact statement which will consist of two major documents: (a) a Draft Background Information Document (BID) -- providing a technical treatise on the risk assessment including sources of radiation exposures, routes of exposures, methodology of assessments, individual and population risk estimates, and an evaluation of model sensitivity and uncertainties; and (b) a Draft Economic Impact Assessment (EIA) -- providing a complete presentation of the costs of the controls and cost-effectiveness of the regulatory options. In addition, the Federal Register notice will include the proposed standard listing the requirements discussed earlier; and a preamble to the rule which discusses the Agency's decision-making procedure and the rationale for its regulatory judgements. For the final rulemaking (probably a year or two after the proposed rule is issued) an additional volume will be added which summarizes the Agency's response to public comments.

EPA forwarded a revised draft Federal Register notice (preamble and standard) to the Office of Management and Budget in April 1989. This draft preamble and standard clarified certain technical issues raised by NRC and DOE. In particular, the level of 4 millirem per year specified for certain classes of ground water applies only to man-made radionuclides. Remaining issues to be resolved relate primarily to policy issues associated with ground water protection.

Our program for the next few months includes finalizing these documents, review by the Office of Management and Budget, and subsequent publication in the Federal Register.

5.0 CONCLUSION

The EPA low-level radioactive waste management program staff believes the Standards covering the above described areas would provide adequate protection of members of the general public with a reasonable balance of risks and costs. However, we recognize that we are somewhat isolated from the front line of waste disposal activity. The public process that we will be going through, which includes a formal notice of proposed rulemaking, public comment, and public hearings will, we hope, provide a mechanism for receiving a perspective from the "front line." However, it is never too early to get your viewpoint heard. We hope that this presentation will encourage some early response and comments on the areas of coverage we are considering for the EPA Low-Level Radioactive Waste Standard.

REFERENCES

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The Environmental Protection Agency's Proposed Regulation of Low Level Radioactive Waste (40 CFR Part 193): A Department of Energy Overview[1]

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The Department of Energy (DOE) manages one of the world's largest programs for storage, treatment, and disposal of low-level radioactive wastes. This system with facilities located at sites across the nation has evolved over some forty years in response to changing needs, technologies, and increasing public awareness and concerns for environmental protection. The DOE has operated in a self regulatory mode in most aspects of its low-level waste (LLW) programs. It has been DOE's policy and practice to provide at least the same level of safety and protection for the public, DOE and contractor employees, and the general environment, as that required by the Nuclear Regulatory Commission for commercial operations. DOE's policies have been implemented through a management system that historically has been highly decentralized so as to be responsive to the needs of DOE sites which generate a wide variety of wastes at some 25 locations.

In addition to concerns with the LLW that it manages, DOE has an interest in the U. S. Environmental Protection Agency's (EPA) promulgation of 40 CFR Part 193 because of its responsibilities under the Low Level Radioactive Waste Policy Amendments Act (LLRWPAA) to manage certain classes of waste and to assist and encourage the development of interstate compact-managed regional low-level waste disposal sites. The Department also has an interest in this rulemaking because of its overall responsibilities for national commercial nuclear power generation and its associated uranium fuel cycle, and DOE's overall concerns with any implications for the national energy supply. The availability of commercial disposal capacity is also of interest to DOE because of its role in the use of a variety radioisotopes in industry, medicine, and research.

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1. The material and discussion in this paper reflect, in part, the work of an internal Department of Energy (DOE) Steering Group composed of DOE staff and that of a Technical Review Group made up of technical experts representing DOE contractor organizations who manage low-level wastes. The Steering Group's role is to develop and coordinate the official DOE response to the Environmental Protection Agency's (EPA) proposed rulemaking. The Technical Review Group is providing technical and economic evaluation of EPA proposals and will participate in the development of DOE official comments. Comments and observations contained in this paper should be viewed as preliminary and subject to change pending the publication of the EPA proposed rule in the Federal Register.

2. Chief, Air, Water and Radiation Protection Unit, Environmental Guidance Division, US Department of Energy.

The emphasis in this presentation is on the implications of the rule for DOE owned and managed low-level waste facilities.

HISTORY.

The nuclear research and development activities and nuclear defense programs of the DOE have their beginnings in several predecessor Federal agencies. The Manhattan Engineer District of the Army Corps of Engineers was created early in World War II to develop nuclear weapon capability. In January, 1947, Congress created the Atomic Energy Commission (AEC) to continue nuclear defense activities and to additionally develop peaceful applications of nuclear energy.

At the early development and deployment stages of commercial application of nuclear energy and material it made sense, from a technology and national security perspective, to regulate and control nuclear programs and activities under the AEC. However, with the continued and rapid growth of the commercial nuclear industry, a national consensus was reached to separate the regulation of commercial applications of nuclear energy and materials from the development function and national defense nuclear programs. In January 1975 the AEC was abolished. The Energy Research and Development Administration (ERDA) was created and to it was assigned, among other responsibilities, nuclear defense and development of commercial applications of nuclear energy. The Nuclear Regulatory Commission (NRC) was given the charge to regulate the commercial sector. Finally with the creation of the DOE in October of 1977, ERDA was abolished, and its responsibilities for defense and civilian nuclear activities were transferred to DOE.

PAST AND CURRENT LOW-LEVEL WASTE MANAGEMENT.

LLW has been generated and disposed of at DOE facilities for over forty years. Historically these wastes have been managed on an ad hoc basis within criteria established by internal DOE Directives. Disposal has been predominantly on site at these facilities, typically by shallow-land burial. When commercial LLW disposal facilities became available in the 1960's, a small fraction of DOE's LLW was disposed of in these commercial facilities. However, by 1979, this practice ended, and all LLW is now disposed of at DOE facilities.

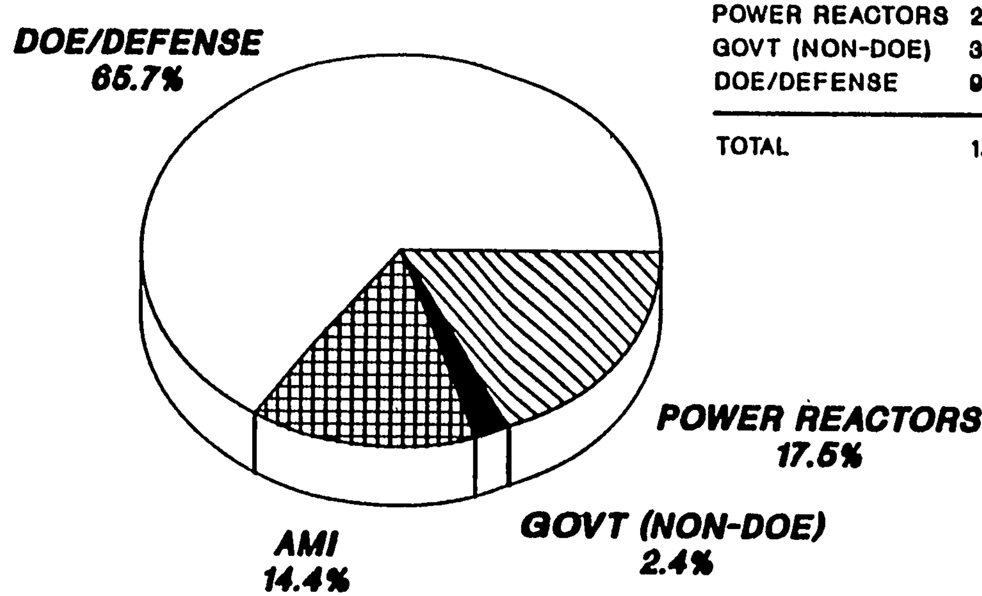
DOE facilities produce large quantities of LLW from nuclear defense production and research and development activities. The amount of DOE wastes and its share of the overall national disposal is shown in Figures 1 and 2. These wastes are treated, where required, within the DOE system and disposed of at DOE disposal facilities. Where space limitations or unacceptable site conditions do not allow for disposal at the generating facility, the waste is shipped offsite to one of the principal DOE LLW disposal facilities. DOE operates eleven disposal sites and maintains five inactive sites. Five of the active sites are small and are used solely for disposal to support local plant operations. The location and status of DOE's LLW disposal facilities are shown in Table 1.

THE DOE LOW-LEVEL WASTE SYSTEM.

All DOE generated LLW is currently disposed of at DOE disposal sites. A number of waste-generating sites do not have disposal facilities either because there

ORNL DWG 88-9119

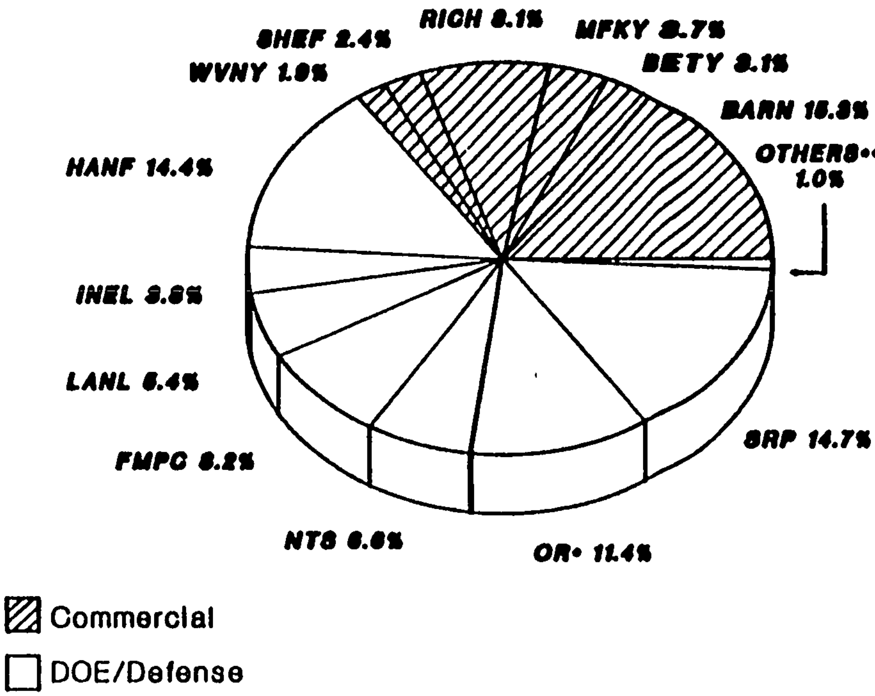
SOURCE	CUBIC METERS
AMI[a]	2.19E+04
POWER REACTORS	2.66E+04
GOVT (NON-DOE)	3.70E+03
DOE/DEFENSE	9.95E+04
TOTAL	1.52E+05



[a]ACADEMIC/MEDICAL/INDUSTRIAL (AMI)

Fig. 1. Volume of LLW buried and disposed in 1987.

ORNL DWG 88-9120



SITE	CUBIC METERS
BARN	5.58E+05
BETY	1.11E+05
MFKY	1.35E+05
RICH	2.95E+05
SHEF	8.83E+04
WVNY	6.99E+04
HANF	5.23E+05
INEL	1.40E+05
LANL	1.95E+05
FMPC	2.99E+05
NTS	2.41E+05
OR*	4.13E+05
SRP	5.35E+05
OTHERS**	3.57E+04
TOTAL	3.64E+06

*Includes contributions from ORNL, Y-12, and ORGDP.

**Includes contributions from PANT, SNL, LLNL, BNL, PAD, PORTS, and WVDP.

Fig. 2. Total volume of buried and disposed LLW through 1987.

is no suitable disposal location or the waste produced is small or has special characteristics. Waste generators with no disposal facilities ship wastes to active DOE disposal locations. While all of the six major DOE disposal sites have received offsite wastes for disposal in the past, the major receivers of waste at this time are the Nevada Test Site and the Hanford Reservation in Washington. A list of DOE LLW generators and the disposal site that accepts that waste is presented in Table 2.

The four major disposal sites located in arid regions: the Los Alamos National Laboratory(LANL), Nevada Test Site (NTS), Idaho National Engineering Laboratory (INEL), Hanford (HANF), have been projected to have adequate disposal capacity for the next 25 to 100 years. The two major disposal sites located in the humid southeast: Savannah River Site (SRS) and Oak Ridge National Laboratory (ORNL), are critically short of capacity. SRS currently has capacity to provide uninterrupted disposal service through early 1991. Additional capacity is being developed. ORNL is already having to store some wastes and may run out of capacity by 1996.

DOE ORDER 5820.2A.

Until recently the DOE LLW management program could be characterized as highly decentralized. The reasons for this condition are many and are rooted in the historical development of the mission of the DOE and its predecessor agencies. In 1986, the Department launched an effort to revise it's internal Order on all radioactive waste management activity. The objective of the revision was to make DOE Order 5820.2A more prescriptive and detailed in response to criticisms that the existing Order was too general and did not support a system wide management approach. The new directive, DOE Order 5820.2A, that was issued in September, 1988, mandates requirements in chapters that specifically address High-Level Waste (HLW), Transuranic (TRU) Waste, Low-Level Waste (LLW), Naturally Occurring or Accelerator Produced Radioactive Material (NARM), and Decommissioning of Radioactively Contaminated Facilities.

Of interest are the revisions contained in Chapter III, Management of Low-Level Waste. This chapter received the most revision and was written to be consistent with, to the extent practicable, those requirements contained in the NRC regulation of LLW 10 CFR Part 61. Performance objectives, including ground water protection are articulated. Performance assessments for all waste management operations are required. A peer review panel is to review, assess, and comment upon radiologic performance assessments for all disposal sites. Additional requirements include waste minimization, waste characterization and establishing waste acceptance criteria which must be met by waste generators/shippers. As required by the Order, all waste managers covered by the Order have recently prepared implementation plans that have been submitted for evaluation by DOE headquarters program officials. Completion of this evaluation should allow for improved system wide management and decisionmaking. The Peer Review Panel has been established. EPA and NRC representatives have been selected to participate in the peer reviews. One initial information exchange has been conducted and a tentative schedule for covering all planned LLW project peer reviews over the next several years has been established.

It should be noted that DOE 5820.2A is limited to managing radioactive wastes. It simply recognizes the anticipated need to comply with EPA and state

TABLE 1. DOE SITES FOR LLW DISPOSAL

Site	Location	Status
Los Alamos National Laboratory	Los Alamos, New Mexico	Active
Brookhaven National Laboratory	Brookhaven, New York	Inactive
Sandia National Laboratories	Albuquerque, New Mexico	Active
Idaho National Engineering Laboratory	Idaho Falls, Idaho	Active
Nevada Test Site	Las Vegas, Nevada	Active
Feed Materials Production Center	Fernald, Ohio	Inactive
Bechtel National	Niagara Falls, New York	Inactive
Oak Ridge Gaseous Diffusion Plant	Oak Ridge, Tennessee	Inactive
Oak Ridge National Laboratory	Oak Ridge, Tennessee	Active
Oak Ridge Y-12 Plant	Oak Ridge, Tennessee	Active
Paducah Gaseous Diffusion Plant	Paducah, Kentucky	Active
Portsmouth Gaseous Diffusion Plant	Piketon, Ohio	Active
Weldon Springs	St. Charles County, Missouri	Inactive
Hanford Site	Richland, Washington	Active
Savannah River Site	Aiken, South Carolina	Active
Lawrence Livermore National Laboratory	Livermore, California	Active

TABLE 2. LOCATION OF LLW DISPOSAL FACILITIES FOR DOE GENERATORS

Organization	Disposal Facility
Ames Laboratory	---
Argonne National Laboratory	INEL
Argonne West	INEL
Battelle Columbus Laboratory	WHC
Bettis Atomic Power Laboratory	SRS
Brookhaven National Laboratory	WHC
Feed Materials Production Center	NTS
Fermi National Accelerator Laboratory	WHC
Grand Junction	Grand Junction
Idaho Chemical Processing Plant	INEL
Idaho National Engineering Laboratory (INEL)	INEL
Knolls Atomic Power Laboratory	---
Lawrence Berkeley Laboratory	WHC
Lawrence Livermore National Laboratory	LLNL Site 300, NTS
Los Alamos National Laboratory (LANL)	LANL, NTS
Lovelace Research Institute	NTS
Mound	NTS
Nevada Test Site (NTS)	NTS
Oak Ridge Gaseous Diffusion Plant	Y-12
Oak Ridge National Laboratory (ORNL)	ORNL, K-25
Pacific Northwest Laboratory	WHC
Paducah Gaseous Diffusion Plant	ORNL
Pantex	NTS
Pinellas	SRS, NTS
Portsmouth Gaseous Diffusion Plant	ORNL
Rockwell, Rocketdyne	WHC, NTS
Rocky Flats Plant	NTS
Sandia National Laboratory	LANL
Sandia National Laboratory-Livermore	NTS
Savannah River Laboratory	SRS
Savannah River Site (SRS)	SRS
Stanford Linear Accelerator Center	---
University of California - Davis	---
University of California - Los Angeles	---
University of California - San Francisco	---
Westinghouse Hanford Company (WHC)	WHC
West Valley	INEL, West Valley

requirements for hazardous waste management and disposal, and any criteria or standards established for protecting ground water.

THE PROPOSED REGULATION - 40 CFR PART 193.

We are now approaching the fifth anniversary of EPA's announcement of a proposal to regulate LLW. During that time considerable progress has been made in shaping a workable rule. During this same time frame, new and fast moving legislation and regulations have appeared, including hazardous waste management and ground water protection, which have a bearing on regulating LLW. DOE is particularly grateful for the cooperation and assistance received from EPA and their willingness to accommodate certain DOE concerns in their internal drafting efforts. We commend EPA for making its most recent draft publically available. However we have continuing concerns with this latest draft, particularly in the areas dealing with ground water protection. Discussion in this paper will focus primarily on this part of the proposed regulation. The proposed Environmental Standard for Naturally Occurring Accelerator-Produced Waste, 40 CFR Part 764 is not addressed at this time.

Subpart A - Environmental Standards for Management and Storage.

With the exception of section 193.03(b) dealing with Below Regulatory Concern (BRC), this section appears to be consistent with NRC's 10 CFR Part 61 regulation and DOE 5820.2A, Chapter III. The standard of 25 mrem/yr effective dose equivalent is the standard in the DOE directive. DOE is concerned about the application of the ground water protection standards of Subpart C to Subpart A facilities, (See discussion below).

The proposal to establish a BRC level is responsive to a need recognized by the Congress in the LLRWAA of 1985, and to a broader need for similar approaches in regulating radioactivity generally that has been expressed by the nuclear community for many years. EPA has responded by taking the initiative contained in the proposal. The discussion and analyses for developing a defensible BRC level contained in the Supplementary Information Section is extensive. However, EPA concludes that the selection of a numerical standard, in the final analysis, is subjective. EPA then has selected 4 mrem/year as the BRC while also noting that a standard within this range is the current drinking water standard - 4 mrem/year. The selection of the same numerical standard for a BRC level to be the same as the drinking water standard has the potential for confusion and misinterpretation that there is a direct relationship between the two standards. If the EPA selection of 4 mrem/year is appropriate, then why not select 5 mrem/year? This would at least be consistent with the recent United Kingdom and Canadian recommendations, be within the EPA range,and would avoid any possible interpretation of a nexus to the drinking water standard.

Subpart B - Environmental Standards for Land Disposal

The proposed standard of 25 mrem/year effective dose equivalent is consistent with the NRC's 10 CFR Part 61 and the requirements of DOE 5820.2A, Chapter III. The requirements for implementation, including the analysis through "Performance Assessment" are consistent with the approaches included in DOE 5820.2A, and as discussed previously, have begun to be implemented by DOE in its LLW management programs.

Subpart C - Ground Water Protection Standards

DOE is concerned that the ground water protection provisions as currently drafted by EPA may pose insurmountable siting problems for DOE waste management and disposal facilities. As a practical matter DOE site selection opportunities are much more circumscribed than those of the commercial sector. These provisions also create the potential for costly relocation of existing facilities. It is questionable as to whether special ground water provisions, including a standard of 4 mrem/year, are necessary since other parts of the standard limit the total dose from all pathways, including all ground water. The following comments reflect the preliminary evaluations of the potential impacts of implementing this Section of the most recent EPA draft.

Dual Standard.

The need for dual dose-limiting standards of 4 mrem/year for the ground water pathway and 25 mrem/year for all pathways combined is not clear. Both standards would govern the same waste management or disposal activity. However, EPA has not provided either a health-based or cost-benefit rationale for the separate ground water protection provision.

According to the EPA analysis, a standard of 4 mrem/year would cost an additional $2.5 billion over current expenditures, resulting in 13 additional health effects averted over 10,000 years, or about $200 million per health effect averted. This represents an almost 50 fold increase over current conventional practice. It would appear that this large cost increase is not warranted when considering the relatively small increase in health effects over 10,000 years.

Use of EPA Draft Guidances for Ground Water Classification as the Basis in Establishing a National Environmental Standard by Rulemaking.

The use of a complex groundwater classification system with far reaching national implications for management of ground water resources should be subject to a rulemaking process. Promulgation of a standard for a rather small, although important, section of overall waste management activity in this country, founded on a system that has not been formally adopted by rulemaking is questioned. The degree and mechanisms for protecting our ground waters continues to be nationally debated. Recently, EPA has announced that they are undertaking an agency-wide review of current policies and practices. In view of this widespread concern, it may be premature to adopt the classification approach that is proposed in Subpart C.

Complexity and Judgmental Aspects of EPA's Classification System.

As an exercise for purposes of evaluating the proposed standard, DOE made a trial effort to classify ground waters at several locations using EPA's "Guidelines for Ground Water Classification under the EPA Ground Water Protection Strategy," Final Draft 1986. Problems encountered included the need for more detailed interpretation guidance as we went through the various steps contained in the EPA guidance. Additionally, it appears that the guidance requires an extraordinary application of professional judgment so as to raise questions of consistency in classification and to make any classification decision subject to technical and possible legal challenge. Table 3 summarizes the standard scenarios for different ground water classifications as proposed in the 1989 EPA draft.

DOE Classification of Ground Water at DOE LLW Facilities.

Because the standard would be implemented by NRC and DOE under their respective authorities contained in the Atomic Energy Act, it would appear to be efficient for DOE to be responsible for establishing the classification at its facilities as suggested by EPA, should the ground water classification scheme be included in the final rule making.

Application of the 4 mrem/year Proposed Standard and Ground Water Classification.

As indicated previously, DOE performed a preliminary classification of ground waters at selected DOE locations using the draft 1988 EPA guidance. It appeared that the major DOE sites are located above Class II high-yield aquifers. Under both the 1988 and 1989 draft EPA proposals, the presence of those aquifers would limit the effective dose equivalent to any individual to 4 mrem/year from drinking 2 liters of ground water per day. As proposed by EPA in 1988, the dose equivalent was intended to be a cumulative limit; that is, it includes the combined impact of current and future operations, natural background, and radioactive contamination in ground water from past operations. If the existing water quality would provide 3 mrem/year, for example, the LLW facility could contribute only 1 mrem/year. The standard is silent as to what requirements would apply if the existing drinking water dose exceeded 4 mrem/year, however conversations with EPA staff indicate that no increase at all would be permitted. Application of this standard could result in relocation of existing facilities.

To further evaluate the impact of the proposed standard recent monitoring information on background concentrations and existing contamination levels within a classification review area were reviewed at several DOE sites. The review concluded that the potential range of doses from natural background radiation was from 0.1 to 2.0 mrem/year; however several existing radioactive contamination plumes from past operations were identified. It was estimated that ingestion of water from these plumes would result in doses in excess of 4 mrem/year. The 1989 EPA draft is helpful in that it appears to exclude natural background radioactivity from the calculation for meeting the standard. However, the rationale for distinguishing between natural and man-made radioactivity is unclear. The standard should exclude any consideration of existing radioactivity in defining the standard.

It is anticipated that new DOE LLW facilities will continue to be located at major existing DOE installations. For a variety of siting and waste management reasons, it is not unlikely that a new LLW disposal facility may be located in close proximity to, or in the predicted migration path of an existing subsurface plume of radioactive contamination. DOE needs the flexibility to meet a 4 mrem/year standard without the calculation that adds the dose from man made contamination. An important consideration in choosing to locate a LLW facility near a "contaminated" area would be the preference not to locate the facility in a new or "pristine" area. Including man made doses in the

TABLE 3. PROPOSED SUBPART C GROUNDWATER PROTECTION STANDARDS

Groundwater Classification	Increased Radiation Allowed, mrem/year* Option 1	Option 2
Class I	0	0
Class II (high-yield)	4**	4**
Class II (other)	25	4**
Class IIIA***	0, 4, or 25	0, 4, or 25
Class IIIB	25	25

* All 4 mrem/y standards apply to man-made radionuclides through the drinking water pathway only assuming 2 L/d consumption and include a 5 pCi/L concentration limit on radium. All 25 mrem/y standards apply to all radionuclides via all pathways combined.

** 4 mrem/y from man-made radionuclides and a limit for radium of 5 pCi/L. The 4 mrem/y limit appears to include ambient levels of man-made radionuclides, and the radium limit appears to include background levels of radium.

*** 0 if hydrodynamically connected to Class I; 4 if connected to Class II high-yield aquifer under Option 1 or any Class II under Option 2; and 25 if connected to non-high-yield aguifer Class II under Option 1 or any other Class IIIB under either Options 1 or 2.

arithmetic of the standard could also result in relocating existing disposal facilities away from existing plumes prior to using the full capacity of a facility.

Additional potential negative impacts from adoption of the ground water protection standard as proposed in the 1989 EPA draft are; (1) interruption of operations, or unscheduled closure of production facilities; (2) perpetual dedication of additional land for radioactive waste disposal; and (3) additional transportation risks from shipping wastes to alternate sites.

Location of the Point of Compliance.

The proposed 4 mrem/year standard in Subpart C is adapted from the National Primary Drinking Water Regulations (40 CFR Part 141) in which a maximum contamination level (MCL) is defined as that level which is delivered to the free flowing outlet of the ultimate user of a public water supply system. As proposed in 40 CFR Part 193, the point of compliance is directly below and nominally within two miles of the disposal facility and is applicable regardless whether the water is being used at that time or in the future for drinking water purposes. In contrast, the Subparts A and B standard of 25 mrem/year is deemed sufficient for the health protection of the individual in the general environment who may or may not be within two miles from a waste management or disposal site. This demonstrates the problem with attempting to mechanically apply the EPA ground water protection strategy to radiation protection standards which are indirect standards (dose) based on modeling and calculated health effects, rather than direct measurement of the concentration of a hazardous substance.

Standard for Class I Ground Water.

Section 193.23(b) states: " The management and disposal of low-level radioactive waste and NARM, as defined in 40 CFR Part 764, cannot result in any increase in the levels of radioactivity for all Class I ground waters." DOE understands this to mean that no radionuclides from waste may reach Class I water, regardless of the concentration in the intruding plume or receiving water. DOE sites may have some Class I ground water. This provision would, in effect, prevent DOE from establishing or continuing waste management or disposal operations at these locations since it is impossible to demonstrate that not a single radioactive atom from waste will ever reach the ground water. DOE believes that it is unnecessary to apply this section to waste management (Subpart A) because operational spills can be cleaned up and are covered by other regulations (CERCLA). For disposal sites, the standard should apply to increases in concentration of radionuclides. This would not likely enable DOE to dispose of waste at Class I sites, but would facilitate and clarify the nature of the compliance analysis.

Time for Compliance for Existing LLW Management and Disposal Sites.

Although DOE has informally advised EPA that a five year compliance period would be adequate, funding uncertainties and other environmental program and waste management demands warrant a waiver provision in the event that additional time is needed.

The Future - the DOE Environmental Restoration and Waste Management Five Year Plan.

DOE has recently completed and published its first annual Environmental Restoration and Waste Management Five Year Plan that establishes an agenda and program for compliance and cleanup at DOE facilities. The span of the program will cover all aspects of environmental management. A major component is the management of all wastes in compliance with all applicable regulations and the cleanup of past waste disposal sites to meet todays requirements. The management and disposal of LLW is included in the Five Year Plan. Key elements of the Five Year Plan include a prioritization of identified environmental projects and programs, and funding decisions based on prioritization. Site specific LLW management and disposal decisions will be integrated with all site waste management and restoration that are included in the Five Year Plan.

SUMMARY.

The DOE owns and operates one of the world's largest LLW management and disposal systems. In order to make short term and long range management plans and undertake designs within a time frame that will allow for efficient and environmentally responsible management, promulgation of a standard would be beneficial. As a governmental agency, DOE faces an extended budgetary horizon for waste management projects and therefore requires a stable standard upon which projects can be conceived. The resolution of waste disposal siting issues also affects waste management and storage decisions since the latter are ultimately dependent on the location of the disposal facilities. While acknowledging the need for the issuance of a standard, DOE is concerned that the most recent draft EPA proposal may be unnecessarily conservative with respect to achieving reasonable health protection goals and could have the unintended consequences of limiting LLW siting options. The effort to establish a below regulatory concern limit for LLW management and disposal is welcome.

POTENTIAL IMPACTS OF 40 CFR 193 ON THE DEVELOPMENT OF LOW-LEVEL RADIOACTIVE WASTE DISPOSAL FACILITIES

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Since the publication of the Advanced Notice of Proposed Rulemaking in August, 1983, the proposed environmental regulations regarding low-level radioactive waste have become a serious uncertainty in the development of new low-level radioactive waste disposal facilities. The proposed rule has been discussed on several occasions by the Technical Coordinating Committee and the purpose of this paper is to present the results of the Committee's discussions regarding the proposed rule. The comments included in this paper are based upon a draft of the proposed Environmental Protection Agency rule that was made available earlier this year. Because the rule has yet to be published it is possible that the rule will be changed before it is published for comment. However, the basic concepts will probably not change significantly, and the position taken by the Technical Coordinating Committee is addressed to the basis of the rule as well as the actual standard.

The proposed standard has several closely related elements. The rule would prescribe limits on radiation exposure to individuals during processing, management and storage of low-level radioactive waste. It would set BRC levels and also set dose standards for the period following site closure. An important (and potentially the most significant) portion of the standard, as far as developing new facilities, is the ground water protection standard. The comments received during development of 40 CFR 193 has also led the Environmental Protection Agency to propose 40 CFR 764 governing the disposal of naturally occurring radioactive material or NORM.

The principal issues discussed by the committee are:

1. The pre-disposal radiological exposure limits during "management" functions.
2. The calculation methodology for the radiological dose.
3. The groundwater protection requirements.
4. The impact of BRC rules on waste volumes and disposal practices.
5. NORM waste.

The steadily increasing costs of disposal and the stability requirements of Part 61, have increased the use of off-site waste processors has increased, driven in particular by the need to reduce waste volume and to stabilize Class B and Class C waste materials. This has resulted in the potential for greater population doses to members of the general public from these commercial waste processing facilities. The EPA proposes to include standards in this area to close what is perceived to be a gap in the regulatory scheme.

The pre-disposal radiological dose requirements do not appear to have any significant impact on the development of new disposal facilities. However, if processing facilities are to be co-located at the disposal site the impact of these facilities will require independent pathways analysis.

The proposed standards incorporate a dose calculation methodology different from that specified in 10 CFR 61. The Environmental Protection Agency dose limits are specified as "effective whole body dose equivalent" (ICRP 26 and 30). Current NRC/Agreement State regulations specify "whole body dose equivalent" (ICRP 2). The existing facility assessments will have to be re-evaluated using this methodology and state regulations may require changes to ensure that the calculated doses are arrived at in a consistent manner.

The groundwater protection requirements have a significant impact on the performance criteria which must be met. The 10 CFR 61 dose limits apply to the dose summed from all pathways; any one pathway being able to contribute the maximum dose, provided no other pathways contribute. The draft Environmental Protection Agency standards, however, place more stringent limits on the dose from the groundwater drinking water pathway for certain aquifers. The specific limits apply to aquifers that are ecologically vital or that are existing or potential drinking water supplies for at least 500 people. The Environmental Protection Agency designates such aquifers as Class I or Class II, high yield.

For the Class I (irreplaceable) aquifers, the standards stipulate zero degradation from radionuclides migrating from a disposal facility. Because of the difficulty in demonstrating compliance, the groundwater protection requirements may preclude the siting of low-level radioactive waste disposal facilities in areas that are over a near-surface, or otherwise vulnerable Class I aquifer. An additional potential problem is the position that if a Class II or Class III aquifer is hydrologically connected to a Class I aquifer, the nondegradation standard will apply. The analysis of aquifer hydraulics can be complicated and the determination of whether or not an interconnection exists is not a simple problem in many cases.

For the Class II, high-yield, (replaceable) aquifers there are two options in the draft proposed standards. One of these options is to be selected in the final standard. One option limits radiological degradation to the equivalent of 4 mrem/yr from the drinking water pathway. This approach is consistent with the drinking water standard for naturally occurring radionuclides in drinking water promulgated pursuant to the Safe Drinking Water Act. The other option has a limit of 25 mrem/yr. These limits include doses from background radioactivity or previous contamination in the aquifer. The limits would apply to existing facilities five years after promulgation as final rule.

The potential impacts of this rule also include the effect on ongoing or completed site selection efforts in the various states. While all states have used criteria for siting facilities intended to minimize the potential for groundwater contamination, most have not considered the concept of zero release. Generally, the studies have assumed that the total dose to the public could come from any one pathway if all other pathways were zero. This change in the regulatory framework can also influence disposal site design if total containment becomes a design criteria.

In the area of Below Regulatory Concern wastes, the EPA is considering a dose limit of 4 mrem/yr from all pathways, both pre-disposal and post-disposal. The standard would apply to all state BRC waste disposed of at a sanitary landfill. Because the NRC currently is using a higher value in the determination of BRC impacts, the adoption of this rule would result in significant changes to the BRC review process. States such as Texas which have adopted BRC rules using lower values might be pressured to re-evaluate their existing rules against the new standard.

The BRC standard could affect in a positive way the mixed waste issue. If a large portion of the mixed waste currently produced could be classified as BRC, the wastes could be disposed of in accordance with existing hazardous waste regulations. Since the quantity of mixed waste is small, the cost for disposal in a dedicated mixed waste unit will be high. If this material could be disposed of in the existing system for hazardous waste, a cost savings could be realized. On the other hand, a significant reduction in waste volumes shipped for disposal at low-level radioactive waste disposal sites could have a very significant impact on disposal fees, if the current volume pricing scheme is to be maintained.

While not being considered as a portion of 40 CFR 193 the proposed standard for NORM disposal can also have significant impacts on the development of new disposal sites. If, as is being considered, NORM waste above 2000 picocuries/gram is required to be disposed of in licensed low-level radioactive waste disposal sites, the source term for new facilities could be significantly expanded. In Texas, our current estimates for NORM waste potentially requiring disposal in the facility could amount to as much as 35,000 cubic feet per year. This waste, generated principally as a result of oil and gas production and rare earth extraction from uranium/thorium ores would become the single largest type of waste requiring disposal. The long half-lives of the isotopes involved change the character of the source term and require the analysis of additional biological pathways.

In conclusion, the proposed rules could have very significant impacts on the development of new facilities. The most serious impact, however, is not that the new standards will require changes. It is that there is no standard and that siting and designing to speculation and conjecture is inefficient and expensive. It is in the best interests of all involved to see the regulations published as soon as possible, so that, no matter what the standard is, it will be a firm fixed standard against which we can develop a facility.

PERFORMANCE ASSESSMENT

A PRELIMINARY PERFORMANCE ASSESSMENT FOR NEAR-SURFACE LAND DISPOSAL OF LOW-LEVEL RADIOACTIVE WASTES

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1. INTRODUCTION

This paper discusses a preliminary performance assessment of facilities for near-surface land disposal of low-level radioactive wastes. The analysis assumes environmental conditions representative of the Oak Ridge Reservation (ORR). However, the assessment is not intended to provide realistic predictions of the performance of currently operating disposal facilities on the ORR or facilities that will be developed in the future, because the analysis is largely generic and involves many presumably conservative assumptions that often are used in the absence of data for specific sites and facilities and validated models of system performance. Rather, the assessment is intended primarily as a screening tool in planning for new disposal facilities on the ORR and in identifying important radionuclides for which a more realistic analysis is needed.

The Department of Energy (DOE) Order 5820.2A [1] has established performance objectives for low-level waste disposal that will apply to new facilities on the ORR. These performance objectives include limits on annual effective dose equivalent of 25 mrem for members of the public beyond the boundary of the disposal site and 100 mrem for continuous exposures of inadvertent intruders onto the disposal site following loss of active institutional control, which is assumed to occur at 100 years after facility closure. In this paper, dose estimates for off-site individuals and inadvertent intruders are compared with the performance objectives to identify the principal radionuclides of concern.

Two types of waste disposal facilities are assumed: shallow trenches or above-grade tumuli. However, no credit is taken in the analysis for the waste-isolation capabilities of engineered disposal facilities and waste forms following loss of active institutional control. The analysis for the two types of facilities differs only in the model assumed for transport of radionuclides by water pathways. For trench disposal, radionuclides are transported to an underlying aquifer by infiltrating precipitation; for tumulus disposal, radionuclides are transported to nearby surface water by overland runoff.

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2. RADIONUCLIDE COMPOSITION OF WASTES

Table 1 presents the assumed generation rates of radionuclides requiring disposal. These estimates are based on disposal records for the ORR over the last decade. For those radionuclides generated at more than one site on the ORR, separate estimates for each site are given. We particularly note that the generation rate of unidentified activity is nearly as large as the combined generation rates of the important fission products Sr-90 and Cs-137. The potential impacts of such large quantities of unidentified activity on the dose estimates for off-site individuals and inadvertent intruders are considered in this analysis. Estimates of current inventories of stored Tc-99 and isotopes of uranium at two sites on the ORR are given in Table 2, and Table 3 gives the estimated volumes of generated and inventoried wastes at the three sites.

Estimates of average radionuclide concentrations in the wastes prior to disposal are obtained from the data in Tables 1-3. For Tc-99 and isotopes of uranium, which are both generated and stored, the average concentrations in all wastes are based on the assumption that the operating lifetime of the disposal facility is 10 years. In estimating average radionuclide concentrations after disposal, the concentrations prior to disposal are reduced by a factor of four to account for mixing of the wastes with soil and the presence of void spaces [2]. The resulting estimates of radionuclide concentrations in the disposal facility at the time of facility closure, which ignore radioactive decay during the operating lifetime of the facility, are given in Table 4.

3. RADIONUCLIDE CONCENTRATIONS IN WATER IN DISPOSAL FACILITY

Mobilization and release of radionuclides from the disposal facility is assumed to result from infiltration of precipitation and leaching of the radionuclides from solid waste into solution. Estimates of the concentrations of radionuclides in water in the disposal facility are based on the following assumptions:

- No water enters the disposal facility during the period of active institutional control.

- All barriers to infiltration of precipitation fail completely upon loss of active institutional control, which occurs at 100 years after facility closure [1].

- All radionuclides in the waste are completely immersed in water at the time of facility failure.

- Most radionuclides are completely soluble in water, and the resulting concentration in water is obtained directly from the concentration in the waste. For selected radionuclides, the concentration in water is based on the solubility limit given in Table 5.

The assumptions regarding facility failure presumably are unreasonably conservative for engineered facilities and waste forms that will be used for future disposals on the ORR. However, even if all barriers to contact of waste by water were to fail completely at 100 years after closure, the model described above probably results in considerable overestimates of the concentrations in water that would occur for some radionuclides. For example, for radionuclides in activated metal (e.g., Be-10 and isotopes of europium), it is highly unlikely that all activity would be immersed in water and go into solution immediately following facility failure. In addition, application of the solubility limits in Table 5 to Be-10, Zr-93, and Sn-121m does not take into account the appreciable (but unknown) concentrations of stable isotopes of these elements.

Table 6 gives the estimated concentrations of radionuclides in the solid waste at the time of facility failure, as obtained from the results in Table 4 corrected for radioactive decay during the 100-year period of active institutional control, and the estimated concentrations in the leachate in the disposal facility obtained from the assumptions described above. The unidentified activity is assumed to be a mixture of Sr-90 and Cs-137 in the same proportions as the estimated generation rates of these isotopes in Table 1 and, thus, to have a half-life of about 30 years. This assumption probably results in overestimates of the concentrations of unidentified activity at the time of facility failure, because this activity presumably contains substantial quantities of shorter-lived isotopes. Results for short-lived radionuclides in Table 4 that decay to innocuous levels within 100 years are omitted from Table 6.

Two additional points concerning the results in Table 6 should be noted. First, for Tc-99 and isotopes of uranium, the concentrations arising from operations at the three sites on the ORR are reported separately and are not combined to obtain an average concentration for all wastes. Such a separation can be useful in planning for waste management at the different sites. Second, in estimating the concentrations in solution for isotopes of uranium and plutonium on the basis of the solubility limits in Table 5, the amount of each isotope in solution must be apportioned by mass in the solid waste rather than by activity.

4. ENVIRONMENTAL TRANSPORT VIA WATER PATHWAYS

This section describes the estimates of radionuclide concentrations in ground water for disposal of wastes in shallow trenches and in surface water for disposal in above-grade tumuli.

4.1 Trench Disposal

For disposal in shallow trenches, the waste leachate is assumed to infiltrate downward through a layer of unsaturated soil to an underlying aquifer which is used as a water supply for off-site individuals and inadvertent intruders. The assumptions used in estimating the maximum concentrations of radionuclides in the aquifer are summarized as follows:

- The waste leachate generated in the disposal facility enters the soil below the trenches essentially immediately upon facility failure.

- The waste leachate infiltrates through the unsaturated soil at an average rate of 1.4 m per year to an aquifer located an average distance of 15 m below the trenches [2].

- Half of the infiltrating precipitation passes through the waste trenches and becomes contaminated. As a result, radionuclides that are not retarded and do not decay appreciably during transport through the unsaturated soil have maximum concentrations in the aquifer that are one-half the concentrations in the waste leachate in the disposal facility given in Table 6.

- Radionuclide transport in the unsaturated soil is subject to retardation, which is proportional to the equilibrium distribution coefficient Kd.

- Waste leachate that reaches the underlying aquifer is not diluted further within the aquifer, and retardation of radionuclides during transport in the aquifer is not considered. As a result, the concentration of radionuclides in water drawn from a well by off-site individuals or inadvertent intruders does not depend on an assumed location for the well.

In estimating the effects of radionuclide retardation during transport in unsaturated soil on the concentrations in the aquifer, the radionuclides are divided into six groups according to their assumed values of Kd. The assignment of radionuclides to these groups and the associated Kd values are given in Table 7. The Kd values for each group are obtained from ref. [2], and the group assignments for Be, Co, Ni, Sn, Sm, Eu, Th, Np, Pu, and Am are based on data given in Fig. 2.31 of ref. [3]. Uranium is assigned to Group 2 when the concentration in the solid waste exceeds the solubility limit in Table 5. This assignment is based on the observation of a strongly decreasing Kd with increasing solution concentration for uranium sorption in soil from the ORR [4].

For each group of radionuclides, Table 7 also gives estimates of the maximum concentration in the aquifer relative to the concentration in the trench leachate, assuming no radioactive decay during transport, and the time after facility failure at which the maximum concentration occurs. These results are based on the assumptions described above and model calculations summarized in Figs. 5 and 6 of ref. [2].

Two aspects of the model for transport of radionuclides from shallow trenches are questionable. First, downward infiltration of waste leachate in the unsaturated zone may occur in preferential flow paths, rather than a homogeneous porous medium, at a rate considerably greater than the assumed value. Second, the assumed effects of retardation may not properly describe radionuclide transport in unsaturated soil.

4.2 Tumulus Disposal

For disposal in above-grade tumuli, the waste leachate is assumed to be transported to nearby surface water by overland runoff essentially immediately upon facility failure. Further, we assume no dilution of the leachate during overland transport and no loss of contaminants due to infiltration of water into soil or sorption of radionuclides onto soil particles. The latter two assumptions probably are conservative for above-grade disposal on the ORR.

With these assumptions, the radionuclide concentrations in surface water relative to the concentrations in the waste leachate are given by the ratio of the flow rate of water from the tumuli to the flow rate of surface water. For this analysis, we assume a dilution factor of 110 in estimating radionuclide concentrations in surface water. This assumption is based on average overland flow rates for portions of the ORR [5] and our estimate of the minimum flow rate of surface water that is sufficient to provide a continuous water supply for individuals. Thus, a radionuclide concentration in surface water is obtained by dividing the corresponding solution concentration in Table 6 by this dilution factor. No further dilution during transport in surface water to locations accessed by off-site individuals or inadvertent intruders is assumed. This model presumably overestimates radionuclide concentrations in surface water relative to the solute concentrations in the disposal facility. As opposed to the case of trench disposal, the maximum concentration of all radionuclides in surface water occurs at the same time, i.e., essentially at the time of facility failure.

5. DOSE ANALYSIS FOR WATER PATHWAYS

The dose analysis for radionuclides transported from the disposal facility by water pathways is the same for off-site individuals and inadvertent intruders. The assumed exposure pathways include ingestion of contaminated drinking water, either from ground water for trench disposal or from surface water for tumulus disposal, and ingestion of milk and meat from dairy and beef cattle that drink contaminated water from the same sources. Use of contaminated water to irrigate food crops consumed by the individuals is neglected, because rainfall is usually abundant on the ORR and irrigation is not commonly practiced. The annual effective dose equivalents per unit concentration of radionuclides in water for the drinking water, milk, and meat pathways combined were calculated as described in Appendix A of ref [6]. For most radionuclides, the drinking water pathway is by far the most important [6].

The results of the dose analysis for the water pathways for trench and tumulus disposal are given in Tables 8 and 9, respectively. Each table gives the maximum concentrations in water estimated as described in Sections 3 and 4 (for trench disposal, radioactive decay during transport to the underlying aquifer is also taken into account), the factors for converting radionuclide concentrations in water to annual effective dose equivalents obtained from Table A-20 of ref. [6], and the estimated maximum annual effective dose equivalents.

The results in Table 8 for trench disposal indicate that only a few radionuclides would reach the aquifer in concentrations sufficient to give estimated annual effective dose equivalents greater than 1 mrem. The very small estimated doses for the other radionuclides result from such factors as the half-life and assumed concentration in the solid waste, retardation factor during transport to the aquifer, or solubility limit. The unimportance of the unidentified activity results from the assumption that this activity is a mixture of Sr-90 and Cs-137. Again, however, we caution that the model for infiltration of waste leachate and radionuclide retardation in the unsaturated zone described in Section 4.1 could be inappropriate.

For trench disposal, we again note that the maximum concentrations in the aquifer for H-3, C-14, Tc-99, and isotopes of uranium do not all occur at the same time (see Table 7). Thus, the total dose would not be the sum of the doses from each radionuclide. The estimated annual dose in Table 8 for Tc-99 from the K-25 site exceeds the performance objectives of 25 mrem for off-site individuals and 100 mrem for inadvertent intruders [1], and the estimated annual doses for isotopes of uranium from each of the X-10, K-25, and Y-12 sites exceed the performance objective for off-site individuals. The total dose from uranium would not be the sum of the contributions from the isotopes generated at each site because a solubility limit was applied to this element (see Table 5). For all other radionuclides, the annual dose for the ground water pathway from trench disposal is less than either performance objective.

For tumulus disposal, the total dose would be the sum of the doses from all radionuclides, because no retardation was assumed during transport from the disposal facility to surface water. The estimated annual doses in Table 9 for Sr-90, Cs-137, and Am-241 exceed the performance objectives for off-site individuals and inadvertent intruders, and the estimated annual doses for Tc-99 from the K-25 site, Eu-152, and Cm-244 exceed the performance objective for off-site individuals. As in the case of trench disposal, the total dose from uranium would not be the sum of the contributions from the isotopes generated at the three sites.

Again, the dose estimate for the unidentified activity in Table 9 is based on the assumption that this activity is a mixture of Sr-90 and Cs-137. The high maximum annual dose in comparison with the performance objectives for off-site individuals and inadvertent intruders indicates the potential importance of the unidentified activity in evaluating compliance of the disposal facility with the performance objectives.

6. DOSE ANALYSIS FOR INTRUSION INTO SOLID WASTES

The dose analysis for inadvertent intruders into the disposal facility following loss of active institutional control is the same for shallow trenches and above-grade tumuli. Intrusion is assumed to occur at 100 years after disposal, at which time all wastes are assumed to be in solid form and indistinguishable from native soil. Exposures of inadvertent intruders to the solid wastes are assumed to occur according to an intruder-homesteader scenario. In this scenario, the following exposure pathways are assumed:

- ingestion of vegetables grown in soil contaminated by mixing of wastes with uncontaminated soil on the disposal site;

- ingestion of contaminated soil from the vegetable garden in conjunction with vegetable intakes;

- external exposure to contaminated soil during indoor residence on the site and while working in the vegetable garden; and

- inhalation of suspended activity from contaminated soil during indoor residence on the site and while working in the vegetable garden.

The annual effective dose equivalents per unit concentration of radionuclides in the disposal facility for all pathways combined were calculated as described in Appendix A of ref. [6].

The results of the dose analysis for direct intrusion for both trench and tumulus disposal are given in Table 10. The radionuclide concentrations in the solid waste at the time intrusion occurs were obtained from Table 6, and the factors for converting radionuclide concentrations to annual effective dose equivalents were obtained from Table A-21 of ref. [6]. The estimated annual effective dose equivalents exceed the performance objective of 100 mrem [1] for Sr-90, Tc-99 from the K-25 site, Cs-137, Eu-152, Th-232, and U-235 from the X-10 site. The dose estimate for Be-10 is the same as the performance objective, and the estimate for U-238 from the X-10 site is nearly the same. Finally, the dose estimate for the unidentified activity far exceeds the performance objective if this activity is assumed to be a mixture of Sr-90 and Cs-137. The total dose would be the sum of the estimated doses from all radionuclides.

7. SUMMARY

This paper has presented a preliminary performance assessment of facilities for near-surface land disposal of radioactive wastes. The assessment is not intended to provide realistic predictions of the performance of disposal systems. Rather, the analysis involves a number of generic and presumably conservative assumptions which are used in the absence of data and validated models for specific sites and disposal facilities, and the analysis investigates the effect of these assumptions on the acceptability of low-level waste disposal on the ORR according to the performance objectives established in DOE Order 5820.2A [1].

For transport of radionuclides by water pathways, the most important assumptions that likely result in overestimates of doses to off-site individuals and inadvertent intruders are summarized as follows:

- All radionuclides are solubilized in water immediately upon loss of institutional control over the disposal facility at 100 years after disposal. For all radionuclides except those listed in Table 5, the concentration in solution thus is determined by the concentration in solid waste regardless of its physical and chemical form.

- For disposal in shallow trenches, radionuclide retardation is taken into account only during transport of waste leachate from the disposal facility through unsaturated soil to an underlying aquifer but not during transport in the aquifer to a well used by off-site individuals or inadvertent intruders.

- The dilution factor for transport of radionuclides from shallow trenches to an underlying aquifer is only a factor of two, and no further dilution during transport in the aquifer is considered.

- For disposal in above-grade tumuli, transport of waste leachate by overland runoff to nearby surface water essentially occurs instantaneously and without infiltration into soil or retardation due to sorption of radionuclides onto soil particles.

We have also emphasized, however, that the model for infiltration of waste leachate to the underlying aquifer and radionuclide retardation in transport through unsaturated soil may not be appropriate.

For exposure of inadvertent intruders into the disposal facility following loss of institutional control, the most important assumptions that likely result in overestimates of dose are summarized as follows:

- Intrusion into the solid wastes occurs immediately upon loss of institutional control.

- At the time of intrusion, all wastes in the disposal facility are indistinguishable from native soil regardless of their physical form at disposal, and an intruder-homesteader exposure scenario occurs with a probability of unity.

In essence, the assumptions in the dose analysis do not take into account any long-term waste isolation capabilities of engineered disposal systems or waste forms as they would affect transport of radionuclides by water pathways or exposure of inadvertent intruders to the solid wastes.

Comparison of the dose estimates with the DOE's performance objectives indicates that only a few of the many radionuclides in wastes generated on the ORR are of concern. The important radionuclides in the dose analysis are summarized as follows:

- for exposures of off-site individuals and inadvertent intruders by the ground water pathway from disposal in shallow trenches: Tc-99 and isotopes of uranium;

- for exposures of off-site individuals and inadvertent intruders by the surface water pathway from disposal in above-grade tumuli: Sr-90, Tc-99, Cs-137, Eu-152, Am-241, and Cm-244; and

- for exposure of inadvertent intruders from direct intrusion into shallow trenches or above-grade tumuli: Be-10, Sr-90, Tc-99, Cs-137, Eu-152, Th-232, and isotopes of uranium.

In addition, the analysis shows that unidentified activity in the waste is potentially of great importance. By assuming that this activity is a mixture of Sr-90 and Cs-137, which probably results in overestimates of potential doses from these materials, the doses from the surface water pathway for tumulus disposal and from direct intrusion into the solid wastes far exceed the applicable performance objectives. Therefore, it is clearly important to reduce the amount of unidentified activity in characterizing waste streams on the ORR.

8. CONCLUSIONS

Although the dose analysis in this paper involves many unrealistic and presumably conservative assumptions, it should be emphasized that the degree of overestimation of doses to off-site individuals or inadvertent intruders probably depends on the particular radionuclide. For example, it is likely that the estimated dose from Eu-152, either for the surface water pathway for tumulus disposal or as a result of direct intrusion into solid waste, is much greater than doses that actually would be received, because this radionuclide occurs in activated metal which is relatively insoluble [2] and the waste probably would not be accessible to an intruder according to the assumptions for the intruder-homesteader scenario until the activity has decayed to innocuous levels. That is, the particular physical form in which this isotope occurs in conjunction with its half-life renders the dose estimates highly unlikely. We also believe that the estimated dose to inadvertent intruders from Be-10 is unreasonably high, partly because this isotope also occurs in a relatively insoluble activated metal [2] and partly because the reported inventory (400 Ci in a single disposal) seems unrealistic. It also seems unlikely that Cm-244 would be of concern in a more realistic dose analysis for tumulus disposal due to its relatively short half-life.

On the other hand, Th-232 is very long-lived and expected to be quite immobile in the environment [2]. Thus, the dose estimate for inadvertent intruders based on the assumed homesteader scenario may be reasonable at times far into the future even if the performance of engineered disposal facilities and waste forms were taken into account, because the engineered barriers probably would degrade well before the activity has decayed significantly. Similar considerations could apply to long-lived isotopes of uranium if a substantial fraction of these materials were immobile.

We also emphasize that the type of analysis presented in this paper, even though probably unrealistically conservative for many radionuclides, provides a useful screening tool in planning for disposal facilities and in identifying radionuclides of importance to a more realistic performance assessment. For example, it is probably reasonable to assume that doses to inadvertent intruders and off-site individuals can be prevented for the first 100 years after disposal by use of active institutional control, collection of any waste leachate, and environmental monitoring near the disposal facility. Therefore, most radionuclides for which the doses were found to be very small in this analysis (e.g., less than 1 mrem per year) probably can be neglected in a more realistic performance assessment, provided the estimated concentrations of these radionuclides in the wastes are representative of actual waste compositions. A realistic performance assessment then can focus on a relatively few radionuclides.

We believe that the principal radionuclides of concern to low-level waste disposal on the ORR include Sr-90, Tc-99, Cs-137, and isotopes of uranium, and that Eu-152, Th-232, and Am-241 also warrant attention in a more realistic performance assessment. Site-specific data on long-term performance of engineered disposal systems and waste forms clearly will be important for many of these radionuclides. This is particularly the case for such radionuclides as Sr-90, Cs-137, and Eu-152 which have relatively short half-lives and for which engineered disposal systems and waste forms could be very effective in reducing doses to off-site individuals and in limiting the types of exposure scenarios and resulting doses that could occur for inadvertent intruders. A more realistic treatment of mobilization and transport of radionuclides via water pathways also is needed. Such an analysis could significantly reduce estimated doses for some of the important radionuclides but could increase estimated doses for other waste constituents. Finally, consideration of the long-term stability of the geologic environment is needed. Changes in the geologic environment over time could increase the potential for mobilization and transport of such important long-lived radionuclides as Th-232 and isotopes of uranium.

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Table 1. Estimated generation rates of radionuclides for disposal in low-level waste facility[a]

Nuclide	Half-life (y)	Curies per year	Nuclide	Half-life (y)	Curies per year
H-3	12.28	8.4E2	Eu-155	4.96	3.4E3
Be-10	1.6E6	4.4E1	Th-232	1.405E10	3.4E-1
C-14	5730	2.7E1	U-233	1.592E5	2.5E1
Na-22	2.602	1E-2	U-234	2.445E5	4.8E-1[b]
Fe-55	2.7	1E-1			2.9[c]
Co-60	5.271	4.3E3	U-235	7.038E8	1.1E1
Ni-63	100.1	1E-4			3.0E-2[b]
Sr-90	28.6	3.3E2			1.4E-1[c]
Zr-93	1.53E6	1.8	U-238	4.468E9	2.2E1
Tc-99	2.13E5	4.1			1.2E-1[b]
		6.1E1[b]			2.1[c]
Ru-106	1.01	1E2	Np-237	2.14E6	1E-4
Cd-113m	13.7	1E-4	Pu-238	87.75	1E-3
Sn-121m	55	1.1	Pu-239	24131	1.3E-2
Cs-134	2.062	8.6	Am-241	432.2	3E-1
Cs-137	30.17	5.6E2	Am-243	7.38E3	2E-5
Pm-147	2.6234	1E1	Cm-242	0.447	1E-1
Sm-151	90	6.3	Cm-244	18.11	2.7
Eu-152	13.6	5.7E3	Bk-249	0.88	1E-5
Eu-154	8.8	8.1E3	Cf-252	2.639	1E-3
			UNID[d]	–	8.1E2

[a]Values are for wastes generated at X-10 site, except as noted.

[b]Value for wastes generated at K-25 site based on operations prior to placing plant in standby mode.

[c]Value for wastes generated at Y-12 site.

[d]Denotes unidentified activity.

Table 2. Estimated stored inventories of radionuclides for disposal in low-level waste facility

Nuclide	Site	Curies
Tc-99	K-25	4.3E2
U-234	K-25	1.1
	Y-12	5.4E1
U-235	K-25	6.0E-2
	Y-12	2.5
U-238	K-25	8.0E-1
	Y-12	5.2E1

Table 3. Estimated volumes of generated and inventoried wastes for disposal in low-level waste facility

Site	Generation rate (m^3 per year)	Inventory (m^3)
X-10	2.4E3	-
K-25	1.1E3[a]	2.2E4
Y-12	1.5E4	1.5E4

[a]Based on operations prior to placing plant in standby mode.

Table 4. Estimated average concentrations of radionuclides in disposal facility at time of facility closure[a]

Nuclide	Half-life (y)	$\mu Ci/m^3$	Nuclide	Half-life (y)	$\mu Ci/m^3$
H-3	12.28	8.8E4	Eu-155	4.96	3.5E5
Be-10	1.6E6	4.6E3	Th-232	1.405E10	3.5E1
C-14	5730	2.8E3	U-233	1.592E5	2.6E3
Na-22	2.602	1.0	U-234	2.445E5	4.5E1[b]
Fe-55	2.7	1.0E1			1.2E2[c]
Co-60	5.271	4.5E5	U-235	7.038E8	1.1E3
Ni-63	100.1	1.0E-2			2.7[b]
Sr-90	28.6	3.4E4			5.7[c]
Zr-93	1.53E6	1.9E2	U-238	4.468E9	2.3E3
Tc-99	2.13E5	4.3E2			1.5E1[b]
		7.9E3[b]			1.1E2[c]
Ru-106	1.01	1.0E4	Np-237	2.14E6	1.0E-2
Cd-113m	13.7	1.0E-2	Pu-238	87.75	1.0E-1
Sn-121m	55	1.1E2	Pu-239	24131	1.4
Cs-134	2.062	9.0E2	Am-241	432.2	3.1E1
Cs-137	30.17	5.8E4	Am-243	7.38E3	2.1E-3
Pm-147	2.6234	1.0E3	Cm-242	0.447	1.0E1
Sm-151	90	6.6E2	Cm-244	18.11	2.8E2
Eu-152	13.6	5.9E5	Bk-249	0.88	1.0E-3
Eu-154	8.8	8.4E5	Cf-252	2.639	1.0E-1
			UNID[d]	-	8.4E4

[a]Values are for wastes from X-10 site, except as noted.

[b]Value for wastes from K-25 site.

[c]Value for wastes from Y-12 site.

[d]Denotes unidentified activity.

Table 5. Assumed limits on solubility of elements in water[a]

Element	Solubility (mol/L)
Beryllium	6E-10
Zirconium	7E-12
Tin	2E-14
Thorium	8E-15
Uranium	4.5E-5
Plutonium	1E-12

[a]Values obtained from Table A.2 of ref. [2].

Table 6. Estimated average concentrations of radionuclides in solid waste and solution at time of facility failure[a]

Nuclide	Half-life (y)	Solid (μCi/m^3)	Solution (μCi/L)
H-3	12.28	3.1E2	3.1E-1
Be-10	1.6E6	4.6E3	1.3E-4[b]
C-14	5730	2.8E3	2.8
Co-60	5.271	8.7E-1	8.7E-4
Ni-63	100.1	5.0E-3	5.0E-6
Sr-90	28.6	3.0E3	3.0
Zr-93	1.53E6	1.9E2	1.6E-8[b]
Tc-99	2.13E5	4.3E2	4.3E-1
		7.9E3[c]	7.9[c]
Sn-121m	55	3.2E1	1.3E-4[b]
Cs-137	30.17	5.9E3	5.9
Sm-151	90	3.0E2	3.0E-1
Eu-152	13.6	3.6E3	3.6
Eu-154	8.8	3.2E2	3.2E-1
Eu-155	4.96	3.0E-1	3.0E-4
Th-232	1.405E10	3.5E1	2.1E-13[b]
U-233	1.592E5	2.6E3	4.0E-3[b]
U-234	2.445E5	4.5E1[c]	1.1E-2[b,c]
		1.2E2[d]	4.1E-3[b,d]
U-235	7.038E8	1.1E3	1.7E-3[b]
		2.7[c]	6.6E-4[b,c]
		5.7[d]	1.9E-4[b,d]
U-238	4.468E9	2.3E3	3.4E-3[b]
		1.5E1[c]	3.7E-3[b,c]
		1.1E2[d]	3.7E-3[b,d]
Np-237	2.14E6	1.0E-2	1.0E-5
Pu-238	87.75	4.7E-2	5.0E-7[b]
Pu-239	24131	1.4	1.5E-5[b]
Am-241	432.2	2.7E1	2.7E-2
Am-243	7.38E3	2.1E-3	2.1E-6
Cm-244	18.11	6.1	6.1E-3
UNID[e]	-	8.4E3	8.4

[a]Values are for wastes from X-10 site, except as noted; concentrations are corrected for radioactive decay assuming facility failure at 100 years after disposal.

[b]Value based on solubility limit in Table 5.

[c]Value for wastes from K-25 site.

[d]Value for wastes from Y-12 site.

[e]Denotes unidentified activity which is assumed to decay with half-life of 30 years.

Table 7. Assumptions regarding transport of waste leachate from shallow trenches through unsaturated soil to underlying aquifer

Group	Elements	Kd[a] (L/kg)	Concentration ratio[b]	Time[c] (y)
1	H	0	5.0E-1	7
2	Tc, U	1	4.5E-2	90
3	C, Np	10	4.1E-3	800
4	Be, Co, Ni, Sr, Sn, Sm, Eu, Am	690	6.0E-5	50,000
5	Cm	1,200	3.4E-5	80,000
6	Zr, Cs, Th, Pu	11,000	3.7E-6	800,000

[a]Equilibrium distribution coefficient.

[b]Concentration in underlying aquifer relative to solution concentration in disposal facility assuming no radioactive decay during transport to aquifer.

[c]Time after facility failure at which maximum concentration in underlying aquifer occurs.

Table 8. Results of dose analysis for groundwater pathway for disposal in shallow trenches[a]

Nuclide	Maximum concentration[b] (μCi/L)	Dose factor[c] (rem per μCi/L)	Maximum annual dose (mrem)
H-3	1.0E-1	3.2E-2	3
C-14	1.0E-2	9.3E-1	10
Tc-99	2.0E-2	6.4E-1	12
	3.6E-1[d]		230[d]
U-233	1.8E-4	1.1E2	20
U-234	5.0E-4[d]	1.1E2	55[d]
	1.9E-4[e]		20[e]
U-235	7.7E-5	9.8E1	8
	3.0E-5[d]		3[d]
	8.6E-6[e]		1[e]
U-238	1.5E-4	9.9E1	15
	1.7E-4[d]		17[d]
	1.7E-4[e]		17[e]
Others			<1

[a]Results are for wastes from X-10 site, except as noted, and apply to off-site individuals or inadvertent intruders.

[b]Concentration in aquifer at point of use.

[c]Annual effective dose equivalent per unit concentration in water obtained from Table A-20 of ref. [6].

[d]Value for wastes from K-25 site.

[e]Value for wastes from Y-12 site.

Table 9. Results of dose analysis for surface water pathway for disposal in above-grade tumuli[a]

Nuclide	Maximum concentration[b] (μCi/L)	Dose factor[c] (rem per μCi/L)	Maximum annual dose (mrem)
C-14	2.5E-2	9.3E-1	23
Sr-90	2.7E-2	5.7E1	1,500
Tc-99	3.9E-3	6.4E-1	3
	7.2E-2[d]		46[d]
Cs-137	5.4E-2	2.6E1	1,400
Eu-152	3.3E-2	2.4	80
Eu-154	2.9E-3	3.5	10
U-233	3.6E-5	1.1E2	4
U-234	1.0E-4[d]	1.1E2	11[d]
	3.7E-5[e]		4[e]
U-235	1.5E-5	9.8E1	1
	6.0E-6[d]		<1[d]
	1.7E-6[e]		<1[e]
U-238	3.1E-5	9.9E1	3
	3.4E-5[d]		3[d]
	3.4E-5[e]		3[e]
Am-241	2.5E-4	1.6E3	400
Cm-244	5.5E-5	8.5E2	47
UNID[f]	7.6E-2	4.0E1	3,000
Others			<1

[a]Results are for wastes from X-10 site, except as noted, and apply to off-site individuals or inadvertent intruders.

[b]Concentration in surface stream at point of use.

[c]Annual effective dose equivalent per unit concentration in water obtained from Table A-20 of ref. [6].

[d]Value for wastes from K-25 site.

[e]Value for wastes from Y-12 site.

[f]Denotes unidentified activity which is assumed to be mixture of Sr-90 and Cs-137.

Table 10. Results of dose analysis for inadvertent intrusion into waste disposal facility[a]

Nuclide	Maximum concentration[b] (μCi/m^3)	Dose factor[c] (rem per μCi/m^3)	Maximum annual dose (mrem)
H-3	3.1E2	3.9E-6	1
Be-10	4.6E3	2.2E-5	100
C-14	2.8E3	1.1E-6	3
Co-60	8.7E-1	3.7E-3	3
Sr-90	3.0E3	2.9E-4	870
Tc-99	4.3E2	9.4E-5	40
	7.9E3[d]		740[d]
Cs-137	5.9E3	8.2E-4	4,800
Eu-152	3.6E3	1.6E-3	5,800
Eu-154	3.2E2	1.8E-3	580
Th-232	3.5E1	4.5E-3	160
U-233	2.6E3	1.2E-5	31
U-234	4.5E1[d]	1.2E-5	<1[d]
	1.2E2[e]		1[e]
U-235	1.1E3	1.4E-4	150
	2.7[d]		<1[d]
	5.7[e]		1[e]
U-238	2.3E3	3.5E-5	81
	1.5E1[d]		<1[d]
	1.1E2[e]		4[e]
Am-241	2.7E1	7.0E-5	2
UNID[f]	8.4E3	5.6E-4	4,700
Others			<1

[a]Results are for wastes from X-10 site, except as noted, and apply to shallow trenches or above-grade tumuli.

[b]Concentration in solid waste at time of intrusion.

[c]Annual effective dose equivalent per unit concentration in solid waste obtained from Table A-21 of ref. [6].

[d]Value for wastes from K-25 site.

[e]Value for wastes from Y-12 site.

[f]Denotes unidentified activity which is assumed to be mixture of Sr-90 and Cs-137.

PERFORMANCE ASSESSMENT FOR FUTURE LOW-LEVEL WASTE DISPOSAL FACILITIES AT ORNL

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1. INTRODUCTION

Until recently, low-level radioactive waste disposal performance assessments within the Department of Energy (DOE) have focused primarily on shallow-land burial with lesser consideration of specific site characteristics and engineered disposal technologies. The concept of waste disposal by shallow-land burial was based on the notion that a suitable site could be defined and analyzed using methodologies that were predominantly generic. This approach was difficult to apply at Oak Ridge National Laboratory (ORNL) because the potential sites for disposal are in complex geohydrologic settings and a generic methodology does not address many of the relevant site and waste characteristics [1]. An approach to waste management, emphasizing site and waste characteristics, has evolved at ORNL requiring the development of a site-specific performance assessment for ensuring the appropriate protection of public health and the environment.

This paper discusses the strategy for waste management on the Oak Ridge Reservation (ORR) and the approach to preparing future performance assessments that has evolved from previous performance assessment studies of low-level radioactive waste disposal on the ORR. The strategy for waste management is based on the concept that waste classification should be determined by performance assessment rather than the sources of waste. This dose-based strategy for waste classification and management places special importance on the preparation and interpretation of waste disposal performance assessments for selecting appropriate disposal technologies and developing waste acceptance criteria. Additionally, the challenges to be overcome in the preparation of performance assessments are discussed.

2. BACKGROUND

Preliminary performance assessments for radioactive waste disposal facilities on the ORR provided estimates of the doses to an off-site individual and an inadvertent intruder [1]. Several assumptions were necessary in preparing these analyses that were considered to be extremely conservative. The results of the analyses indicate that shallow-land burial or above-grade disposal technologies without engineered features could be associated with potentially significant doses to an off-site individual who uses groundwater or surface water or to an inadvertent intruder. For the ORR, radionuclides of concern include isotopes of Sr-90, Cs-137, Tc-99 and

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uranium. Other radionuclides that could exceed the performance objectives of DOE Order 5820.2A [2] for protection of off-site individuals or inadvertent intruders include Eu-152, Eu-154, Am-241, Th-232, Be-10, and Cm-244. As discussed in ref. [1], these radionuclides may not be associated with high doses from disposal once sufficient data are available to justify removing those assumptions that are demonstrated to be unnecessarily conservative. Even with better data, however, the doses attributable to Cs-137, Sr-90, Tc-99, and uranium probably will be of concern in satisfying the performance objectives for wastes generated on the ORR because of the high concentrations present in some wastes.

Generic methodologies for performance assessment are difficult to apply to the ORR because of the extremely complex geohydrologic regime and the diverse wastes generated by DOE operations on the ORR. Adaptations of generic methodologies have been shown to be inappropriate because required input data are not available, reasonable representations of the site are not included in the available models, and waste characteristics affecting disposal facility performance unique to the ORR are not addressed.

With preliminary pathways analyses indicating potential concerns related to public health and the environment with the application of shallow-land burial and tumuli for the disposal of radioactive wastes, a strategy for waste management was needed that would demonstrate appropriate protection of public health and the environment. Since the preliminary performance assessments took no credit for waste form and disposal technology performance, but relied totally on the performance of the site, the identification of waste forms and disposal technologies to complement site performance was suggested. As the strategy evolved, combinations of particular sites, technologies, and types of waste were developed that conceptually addressed the vast majority of radioactive wastes generated on the ORR. The salient feature of this process was the use of dose-based performance objectives to aid in defining the appropriate combinations of site, technology and waste. As a consequence, the strategy is responsive to the capability of the disposal environment on the ORR to accept wastes instead of having the wastes as generated define the wastes to be disposed of on the ORR. Thus, some wastes naturally emerged as being unsuitable for disposal on the ORR. These wastes are to be segregated for storage and disposal at an alternative site or subjected to additional treatment to render them suitable for disposal. With several different types of wastes, sites, and disposal technologies, a waste classification system was developed that formed the core of the waste management strategy on the ORR.

3. ORR WASTE MANAGEMENT STRATEGY

The waste management strategy for the ORR [3] was prepared prior to the issuance of DOE Order 5820.2A; however, the final version of the Order required only minor changes to the strategy. The strategy identifies a "trigger dose" of 10 mrem annual effective dose equivalent to an off-site individual or an intruder as the basis for facility design. This reduced dose level compared to the performance objectives of DOE Order 5820.2A was selected because of the difficulty and uncertainty in predicting site and facility performance. By setting a lower dose for the purposes of design, data gathered during facility monitoring would allow for remedial actions prior to any unanticipated adverse impacts on public health and the environment.

Having defined the limits for protecting public health and the environment, the available sites on the ORR were reviewed [4]. Potential sites on the ORR for waste disposal are of two types: 1) thick soils and deep aquifers with karst terrain and uncertain geotechnical conditions and 2) thin soils and shallow aquifers with stable geotechnical conditions. The former were considered as potential sites for wastes with low contamination levels at the time of disposal and the latter as potential sites for wastes with higher levels of contamination that would require long-term stability to protect public health and the environment. Given the shallow aquifers at sites with stable conditions, groundwater protection was identified as critical to developing an acceptable waste management system.

Wastes with higher levels of contamination include those subject to radioactive decay (e.g. Sr-90, Cs-137, and Eu-152) and those with long half-lives (uranium and Tc-99). To protect groundwater, wastes subject to decay were considered for isolation using disposal technologies that would limit releases to the environment until the wastes had decayed sufficiently for the trigger dose limit to be satisfied. Wastes with long half-lives were considered for treatment to remove the soluble fraction from the wastes prior to permanent disposal, with intruder protection included in the disposal system to reduce the potential for exposure of inadvertent intruders. This conceptual structure led to the identification of suitable technologies for waste management that were compatible with the available sites for disposal.

Classification of wastes from consideration of the sites, available technologies, and waste characteristics resulted in four classes of radioactive waste for management on the ORR. Each class of waste is associated with concentration limits to be established by performance assessment. Class I waste is composed of slightly contaminated materials that are to be disposed of at sites with deep soils using industrial landfill technology acceptable to the State of Tennessee. Concentration limits would be determined such that an off-site individual or an inadvertent intruder would not receive an annual dose in excess of 10 mrem at any time after the closure of the facility. Class II waste is composed of wastes that would not result in doses to an off-site individual or an inadvertent intruder in excess of 10 mrem at the end of institutional control (active and passive). Class II wastes are largely fission-product wastes that will decay over the period of institutional control and are to be disposed of using tumulus technology with a solidified waste form on sites with stable geotechnical conditions. The facility is to be designed for zero release of contamination and will incorporate monitoring systems to provide early detection of any unforseen releases of contamination from the facility. Class III waste is composed of waste subjected to treatment to remove the soluble fraction of contamination prior to disposal. Following disposal the waste disposal facility would be provided with intruder protection to minimize the potential for inadvertent intrusion. This class of waste is composed largely of uranium wastes. The treatment methods for removing the soluble fraction of the contamination from Class III wastes are under development awaiting a better understanding of the characteristics of wastes included in this waste class. Sites for disposal of Class III wastes have stable geotechnical conditions. Since groundwater would be protected as a result of the waste treatment step, any exposures to off-site individuals would be minimized; however, these wastes are expected to require an intruder protection barrier to limit potential doses from inadvertent intrusion to the performance objective of 10 mrem. Class IV wastes are those wastes requiring further treatment prior to disposal on the ORR as Class I, II, or III wastes, or those to be disposed of at another facility not on the ORR. Off-site alternatives for the disposal of Class IV wastes have not been identified, so these wastes will be stored until an acceptable method for disposal can be developed.

4. PERFORMANCE ASSESSMENT FOR NEW ORR FACILITIES

The strategy for waste disposal on the ORR poses many questions and challenges in the preparation of performance assessments for new facilities. The process of selecting sites and technologies for waste disposal has been developed with the intent of using technology to achieve waste treatment and isolation. Previous assessments did not take credit for any improvements in performance resulting from waste form, disposal technology, or waste type, and waste disposal was addressed in the context of an assumed intruder-homesteader scenario which assumed that all wastes are subject to transport in groundwater or surface waters. This approach to performance assessment is reasonable for Class I wastes but is not consistent with the waste forms and disposal technologies associated with Class II and Class III wastes. Since performance assessment will be used to define the concentration limits for each waste class as well as in demonstrating compliance with the performance objectives of DOE Order 5820.2A, performance assessment must address the benefits to be derived from using advanced waste forms and disposal technologies. Consequently, valid data are needed for describing waste characteristics, site characteristics, disposal technology performance, and the methodology for performance assessment of engineered systems needs to be considered with care to provide reasonable and defensible results.

Simplistic assumptions and scenarios for the performance of waste forms and disposal technologies tend to negate the potential benefits to be derived from technology improvements. Since improvements in waste form and technology are costly, the commitments of resources associated with their implementation should be justifiable in a performance assessment. Likewise, the methodology for establishing scenarios for intruder behavior should take account of the nature of the waste disposal technology and the waste form. For example, the inadvertent intruder in the intruder-homesteader scenario is assumed to excavate waste in the process of constructing a house and not be capable of distinguishing the native soil from the waste. Following the excavation, the intruder is assumed to grow vegetables and other foodstuffs in contaminated soil. This scenario becomes suspect for some time period after the loss of active institutional control, as engineered facilities and waste forms are introduced that are not likely to degrade to the extent they are either suitable for excavation or indistinguishable from soil. The inherent acceptance in performance assessment of rapid leachate formation from wastes is also subject to doubt if wastes are treated to remove the soluble fraction prior to disposal. While the presumption that all contamination remaining in the waste after treatment will never be subject to groundwater or surface water transport is also suspect, the proper approach to analysis awaits the development of defensible data to support a performance assessment.

A critical part of preparing a performance assessment is the modeling of the behavior of the disposal site environment. Given the site-specific nature of the waste management strategy and the complex geohydrologic regime of the ORR, the task of modeling site performance becomes much more challenging if the results are to be reasonable representations of the site. Modeling of specific sites requires that the model not only be verified as being mathematically correct but validated as being representative of the site. Validation of site behavior has been addressed [5]. The results emphasize the need for comprehensive data in performance assessment and illustrate the misleading results that could result if generic approaches were applied without site-specific interpretation. Using the experience gained in model validation, performance assessment on the ORR will utilize models that are compatible with the completeness of the data describing the facility. At this time, many portions of the model structure for each disposal facility are poorly understood, so that simplistic models are being utilized for the purposes of preliminary analysis. The results from these simple analyses are being used to guide the development of additional data describing the system. Noting that performance assessment is a process, the evolution of performance assessment for the ORR supports the notion that performance assessment can guide the implementation of a waste management strategy that protects public health and the environment.

Since the ORR is a complex geohydrologic setting, uncertainties in calculations are likely to be large. A facet of performance assessment yet to be undertaken is the approach towards performing an uncertainty and sensitivity analysis of results. Initial observations suggest that uncertainties in the environmental conditions and the long-term performance of highly engineered facilities will result in large uncertainties in estimated doses to off-site individuals and inadvertent intruders. The expectation is that modeling results and the associated uncertainty analysis will require a substantial degree of interpretation in order to support conclusions that are reasonable and defensible representations of facility performance. For results to be defensible, conservative interpretations are appropriate, but reasonableness necessitates that extremely conservative interpretations be avoided. The emphasis in the interpretation of modeling results will be demonstration of compliance with the performance objectives of DOE Order 5820.2A rather than simulation of the expected performance of the disposal facilities.

5. CONCLUSIONS

Guidance for the preparation of performance assessments has been issued [6,7], but site-specific performance assessments will be difficult to prepare when highly engineered disposal facilities are used in complex environmental settings. Since waste management on the ORR will rely on the proper classification of wastes, performance assessment needs to be performed with the understanding that compliance with DOE Order 5820.2A and justification of the waste classification system for the selected sites, waste and disposal technologies are necessary. To be responsive to these needs, disposal site characterization seeks to identify both the site characteristics that are advantageous and disadvantageous for waste disposal, and waste characterization must address the needs for modeling and supply sufficient insight to guide technology selection. Wastes not suitable for disposal that may emerge from the performance assessment process will be a subject of special concern. As the characteristics of wastes, sites and disposal technologies are integrated by the performance assessment process, selected disposal technologies will emerge that are defensible on site- and waste-specific bases. For the ORR, which has variable site and waste characteristics, this observation yields a range of technologies identified for waste management that contrasts with the historical practice of using a single technology at a single site for all wastes.

The focus on site-specific analysis on the ORR provides a challenge to preparing defensible performance assessments as well as determining the acceptability of waste disposal at a specific site. The credibility to be attached to any site-specific analysis will be dependent on the validity of the models used for analyzing site performance. The determination of performance assessments that will be both technically adequate and consistent with assessments for other DOE facilities lies ahead, but a sound basis has been developed to proceed with waste management on the ORR that is protective of public health and the environment in the near term and the long term.

Defensible and reasonable estimates of site behavior and waste form and disposal unit performance for the duration of time that wastes constitute a hazard to human health and the environment are the central challenges for performance assessment on the ORR. As part of this effort, certification of wastes will be critical to ensure that actual operations are representative of predictions. The skill that is demonstrated in forecasting the performance of disposal facilities will largely influence not only the acceptability of waste disposal in the future but also the costs of disposal. Performance assessments that are excessively conservative are certain to yield waste management systems that are unnecessarily expensive. However, assessments that provide best forecasts of performance could yield such an optimistic estimate of facility performance that waste management systems might fail to provide acceptable protection to public health and the environment. Against this challenge of balancing acceptable and affordable waste management systems, the validation of predictive results assumes a new level of significance. The uncertainties associated with providing reasonable estimates of performance for the distant future while striving to comply with fixed performance objectives emphasizes the importance of interpreting results in the formulation of conclusions. Providing reasonable and valid assessments of facility performance will ultimately define the nature of disposal systems in the future.

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Model Validation Lessons Learned: A Case Study at Oak Ridge National Laboratory

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ABSTRACT

A groundwater flow and contaminant transport model validation study was performed to determine the applicability of typical groundwater flow models for performance assessment of proposed waste disposal facilities at Oak Ridge, Tennessee. Standard practice site interpretation and groundwater modeling resulted in inaccurate predictions of contaminant transport at a proposed waste disposal site. The site's complex and heterogeneous geology, the presence of flow dominated by fractured and weathered zones, and the strongly transient character of shallow aquifer recharge and discharge combined to render assumptions of steady-state, homogeneous groundwater flow invalid.

The study involved iterative phases of site field investigation and modeling. Prior to initial modeling, which involved conventional applications of a porous medium code, the site geology and geohydrology were intensively characterized and a groundwater dye tracer test was performed to obtain data against which model results could be compared to test accuracy. The initial site groundwater model incorporated the assumptions of horizontally layered, homogeneous but anisotropic aquifer materials. Simulations using this approach failed to accurately simulate the dye tracer behavior because of poor resolution of the heterogeneous site conditions.

Subsequent modeling activities focused on generation of a model grid incorporating the observed site geologic heterogeneity, and on establishing and using model boundary conditions based on site data. Time dependent water table configurations, and fixed head boundary conditions were used as input to the refined model in simulating groundwater flow at the site.

This study demonstrates that in the Oak Ridge setting conventional porous medium modeling provides only low resolution results when compared to an aquifer tracer test. Site specific geologic factors which influence groundwater flow must be incorporated in the model to achieve high resolution model results.

Introduction

Modelling groundwater flow in the Appalachian orogenic belt presents numerous challenges in site characterization, data collection and interpretation, and model application. Reliable performance assessment of sites proposed for land disposal of solid waste depends on the

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combination of a properly implemented site characterization program, development of an accurate conceptual model of site geohydrology, and use of a numerical model and grid combination which incorporate the site data and conceptual model.

A groundwater flow and contaminant transport model validation study was performed to determine the applicability of typical groundwater flow models for performance assessment of proposed waste disposal facilities at Oak Ridge, Tennessee. Previous experience with standard practice site characterization methods, data interpretation, and groundwater modelling resulted in inaccurate prediction of contaminant transport at a proposed waste disposal site. The site's complex and heterogeneous geology, the presence of flow dominated by fractured and weathered zones, and the strongly transient character of shallow aquifer recharge and discharge combined to render assumptions of a horizontally layered, homogeneous but anisotropic aquifer and steady-state groundwater flow invalid.

Overview

This study was designed to integrate geologic and geohydrologic concepts and data with setup and application of a numerical groundwater flow and contaminant transport model through an iterative feedback system. Site characterization investigations were guided by hypothesis testing which sometimes incorporated model simulation of alternative hypotheses. The geohydrologic conceptual model evolved continually as site testing and modelling efforts progressed and hypotheses were proven, modified, or abandoned. In addition to the battery of field tests and routine data collection, a natural gradient groundwater tracer (Rhodamine-WT) migration test was performed and monitored for more than fifteen months. This test was performed in a quantitative mode with parts per billion resolution tracer analyses performed on groundwater samples from more than three dozen wells in and near the plume. Tracer migration behavior was documented and used as a bench mark against which model results were compared.

Site Characteristics

The study site encompasses about an acre of hillside terrain underlain by weathered interbedded calcareous siltstones, limestones, and shales of the uppermost Maryville Limestone and lowermost Nolichucky Shale of the Upper Cambrian Conasauga Group. Individual bed thicknesses range from about 1 to 50 cm and lithologic units (limestones, shales, and siltstones) range from less than 1 m to several meters in thicknesses. Bedrock dips southeast at about 45 degrees and strikes northeast-southwest consistent with regional structure.

The goal of site characterization was to obtain quantitative measurements of subsurface conditions which control groundwater flow. Detailed site characterization is an intrusive process which may significantly alter subsurface conditions, consequently altering groundwater flow characteristics. All drilling was performed either by augering or using water as the drilling fluid to reduce the artificial dilation of fractures which often occurs when high pressure air is used as the drilling fluid. Geologic and geohydrologic characterization studies at the site included: rock core drilling, lithologic logging, and geophysical logging; core hole packer testing of hydraulic conductivity and static head; construction of individual and cluster wells; performance of two pump tests drawing water from different aquifer zones; single well hydraulic conductivity testing; continuous and periodic water level monitoring in site wells. Detailed characterization tests at the study site extended to a depth of about 30 meters below ground surface.

Table 1. Estimated hydraulic conductivity data from falling head and straddle packer testing

Test number	Test interval (ft. below g.s.)	Hydraulic conductivity estimate (cm/s)
GW-499Q-1[1]	16.70 - 20.36	5.67E-6
GW-499Q-2[2]	20.00 - 23.66	2.23E-5
GW-499Q-3	29.20 - 32.86	3.19E-5
GW-499Q-4[3]	32.00 - 35.66	7.17E-5
GW-499Q-5	37.60 - 41.26	8.71E-5
GW-499Q-6[4]	39.80 - 43.46	1.24E-5
GW-499X-1*	2.80 - 5.30	1.23E-5
GW-499X-2*	6.10 - 8.30	1.94E-6
GW-499X-3*	5.10 - 8.30	7.03E-4
GW-499X-4*	7.70 - 10.50	NA
GW-499X-5*	7.20 - 10.50	9.0E-4
GW-499X-6	9.00 - 12.50	8.56E-6
GW-499X-7	12.00 - 14.50	6.65E-5
GW-499X-8	14.00 - 16.50	2.07E-5
GW-499X-9	16.00 - 18.50	3.86E-5
GW-499X-10	18.00 - 20.50	3.83E-5
GW-499X-11	20.00 - 22.50	5.05E-5
GW-499X-12	22.00 - 24.50	1.11E-4
GW-499X-13[1]	24.00 - 26.50	4.55E-5
GW-499X-14[2]	26.00 - 28.50	2.77E-5
GW-499X-15	28.50 - 31.00	4.90E-5
GW-499X-16	33.70 - 37.36	NA
GW-499X-17	37.40 - 41.06	3.21E-4
GW-499X-18[3]	41.00 - 44.66	5.18E-5
GW-499X-19	45.00 - 48.66	9.02E-5
GW-499X-20[4]	50.00 - 53.66	3.51E-5
GW-499X-21	53.70 - 57.36	1.01E-5

Tests GW-499X-1 through GW-499X-8 are vadose zone tests.
Tests GW-499X-1 through GW-499X-15 are falling head tests performed in saprolite; all other tests are straddle packer tests in unweathered bedrock.
Correlative superscript numbers refer to tests performed in correlative stratigraphic intervals.
* - Ground surface heaving and bore wall blowouts observed during testing renders these test results unreliable.
NA - Data unsuitable for analysis.

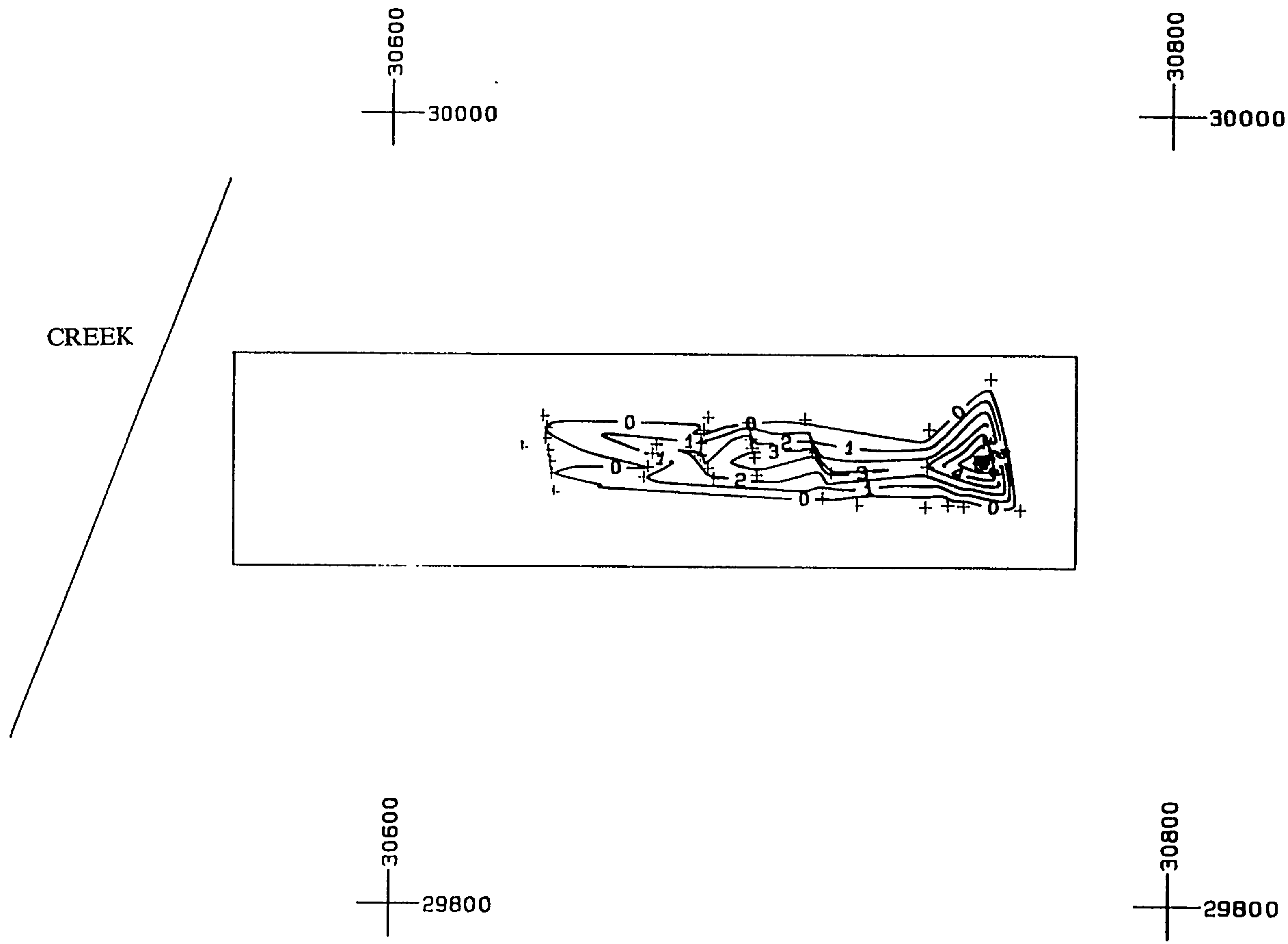


Fig. 1. Log tracer concentration (ppb) contour plot within model grid boundary rectangle. Crosses denote detection wells, square denotes tracer injection well at right, and slanted line at left represents creek. Scale: 1" = 40'.

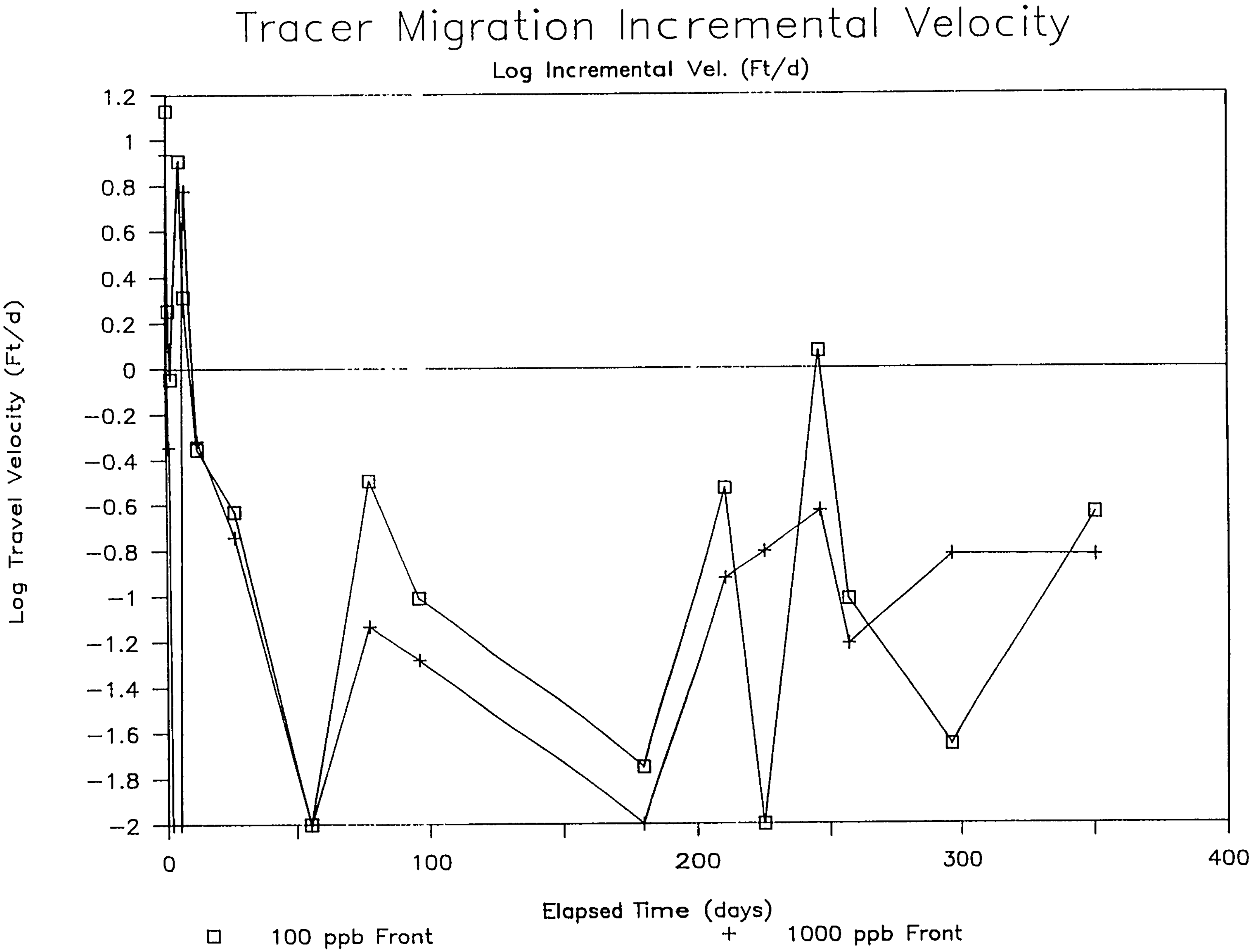


Fig. 2. Log tracer migration incremental velocity for 100 and 1000 ppb isopleths.

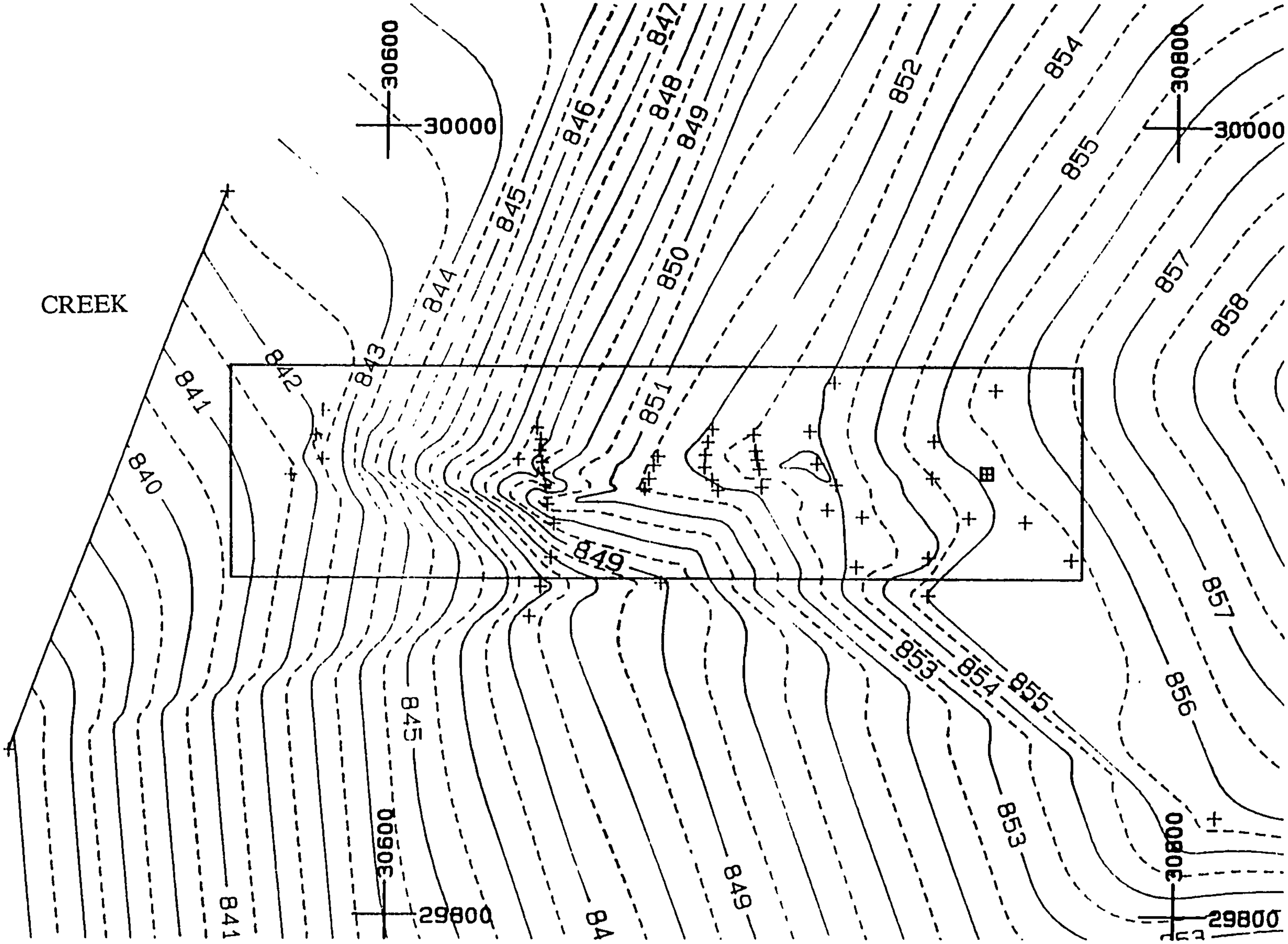


Fig. 3. Water table configuration at tracer site. Crosses denote detection wells, square denotes injection well, and slanted line at left represents creek. Contour interval 0.5 '. Scale: 1" = 40'.

Initial working hypotheses of geologic and hydrologic factors which may control groundwater flow at the site were developed on the basis of early core drilling and packer testing results. These hypotheses are generalized in two categories: 1) geologic structures and differential weathering may control groundwater flow and are related to individual lithologies which vary at the meter scale, and 2) the variable tracer migration rate observed at the site was caused by a decrease in hydraulic gradient associated with seasonal water table decline.

Field tests performed to evaluate these hypotheses included: 1) falling head and straddle packer tests at the 0.6 to 1.1 m thickness scale in two nominal 20 m deep boreholes to test the relationship of hydraulic conductivity to lithology and structure, and 2) collection of tracer concentration (nominal monthly frequency) and water elevation data (biweekly frequency). Conductivity test intervals were selected by inspection of rock core to coincide with discrete lithologic and structured intervals. Fifteen falling head tests were performed in weathered bedrock, and 12 straddle packer tests were performed in unweathered bedrock. Data from two of the test intervals were unsuitable for analysis, and deteriorating bore wall conditions rendered results of 5 vadose zone tests invalid. Four tests were performed in correlative stratigraphic intervals, 2 within unweathered bedrock and two above and below the weathering interface. Estimated hydraulic conductivity values of falling head and straddle packer test data are presented in Table 1.

Interpretation of the hydraulic conductivity test results revealed no consistent relationship between conductivity and lithology or with degree of rock weathering when stratigraphically correlative intervals were tested above and below the weathering interface. The apparent determinant of conductivity was degree of fracturing. Based on the discrete zone tests, the hydraulic conductivity was found to range randomly from about 1 E-4 to 5 E-5 cm/s with the mean conductivity about 5.3 E-5 cm/s. This range of conductivity is generally consistent with results of the numerous other single well, pump test, and packer test results obtained at similar depths in the area. Aquifer conductivity anisotropy was determined on the basis of aquifer pump test behavior with maximum conductivity parallel to geologic strike.

Analysis of tracer migration and water table fluctuation data indicates that tracer migration rate and direction are strongly controlled by local geologic structural features. The direction of tracer migration (Fig. 1), parallel to geologic strike, is consistent with aquifer anisotropy and oblique to the overall site hydraulic gradient, indicative of the dominance of fractures in controlling local groundwater movement. Early time (the first month) tracer migration was quite rapid (0.6-5 m/d) with migration of a narrow (2-3 m), high concentration plume for about 15 m. Subsequent migration occurred at rates less than 0.5 m/d and measured migration velocity was observed to vary over one order of magnitude in relation to variations in precipitation. Fig. 2 illustrates the incremental velocity of tracer migration over a period of 1 year.

Water elevation contours indicate the pathway of maximum tracer concentration is coincident with a fracture-related water table anomaly (Fig. 3). The anomaly appears as a water table high under drought conditions and a water table low under elevated water table conditions. Rather than migrating in a direction normal to the gradient, the center of mass of the tracer plume remains on the axis of a strike-parallel water table divide. The transient rate of tracer migration is unrelated to seasonal fluctuations in the hydraulic gradient.

Neither the long nor short-term rate of tracer migration is closely dependent on the overall site hydraulic gradient. The rapid migration rate early in the test is coincident with nearly the lowest and flattest measured hydraulic gradient (square symbol in Fig. 4). Short-term perturbations in tracer concentration are apparently closely related to a threshold precipitation accumulation over periods of several days which total a minimum 1.3 cm, depending on the time of year. In combination the tracer migration and water table configuration and fluctuation data indicate the presence of a fracture-controlled conduit through which initial flow occurred. Later time tracer migration data show fingering and lateral spreading of tracer within the aquifer. Other conduits are inferred from tracer and water table data.

Modelling Method

The site was modelled using standard concepts of groundwater flow through porous media. The underlying assumptions in this approach are that the velocity field is determined by Darcy's Law and contaminant transport is controlled by advection and dispersion processes. The numerical model used for site simulation was driven by shallow aquifer hydraulic data and tracer migration data collected from April 1988 through June 1989.

Modelling proceeded in the following steps.

1. A detailed two-dimensional grid was constructed based on the heterogeneous site geology. This grid incorporated elements representing the 1 m variations in lithology. Grid elements were aligned parallel to geologic strike and flow was assumed to occur in a horizontal aquifer 3 m thick.

2. An initial boundary value problem was formulated and solved for this grid configuration to simulate a steady-state theoretical head distribution and time dependent concentration distribution. Grid boundary hydraulic head data (Dirichlet data) were developed using the fit of a quintic spline to measured water table elevations at wells within the test area.

3. The hydraulic conductivity field assigned to the grid was based on conductivity measurements previously discussed. Conductivity was randomly assigned for each grid node with the overall conductivity distribution in the model grid consistent with the measured conductivity distribution from field data. Flow and transport simulations using the purely randomized grid showed transport behavior similar to the tracer behavior but underestimated early time migration velocity. To enable the model to simulate the early rapid migration, a line of elevated conductivity (1 E-4) nodes, equivalent to the observed rapid flow slot, was superimposed on the grid.

4. Transport was assumed to be primarily advection driven based on observed concentration/time tracer behavior, and consequently dispersivity parameters in the model were held at moderate values. It was assumed that the tracer was non-reacting and not subject to retardation.

5. Flow and transport computations were made using the USGS Method of Characteristics computer program. The problem was solved repeatedly with variation in input parameter values to optimize parameter input and arrive at a combination of parameters which allowed the code to most closely simulate the observed tracer migration behavior.

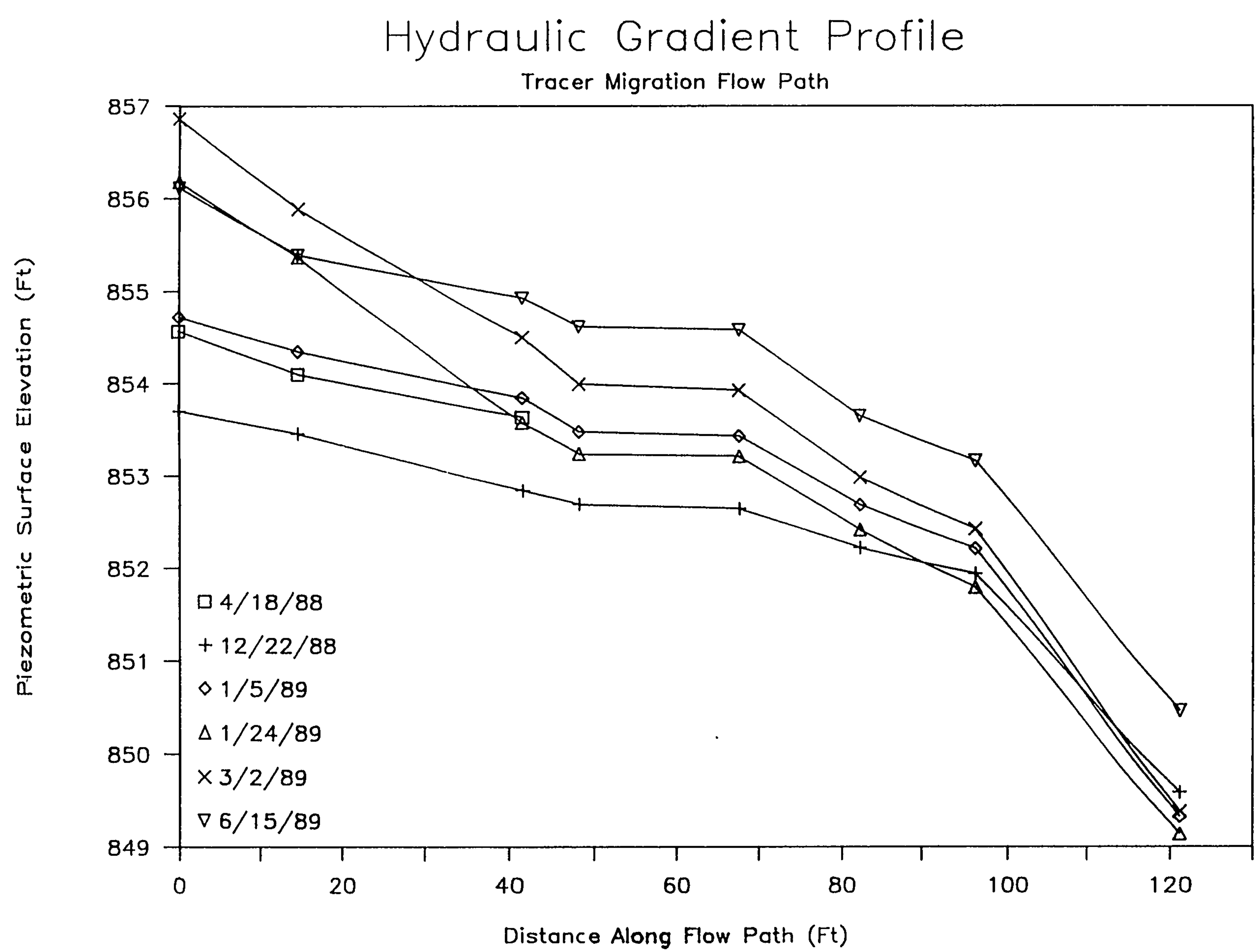


Fig. 4. Representative hydraulic gradient profiles at tracer site. Tracer injected on 4/20/88.

The range within which input parameters were allowed to vary was constrained to that defined by field data.

Performance of the computer simulations established the following points:

1. When isotropic porous medium conditions with randomly distributed conductivity are assumed, the simulations show migration of tracer directly down hydraulic gradient at a rate of about 0.1 m/d.

2. When randomly distributed conductivity conditions with conductivity parallel to strike 10+ times that perpendicular to strike are assumed, the simulated tracer migration is essentially parallel to strike. The actual plume migration velocity is best simulated when an anisotropy of 30+ is used and a line of elevated conductivity nodes is superimposed on the grid to simulate the rapid migration zone observed in the tracer test (Figs. 5, 6, and 7). Aquifer anisotropy values as high as 30 have been measured by pump testing in the Conasauga Group at Oak Ridge. Use of a permeable slot in simulation is indicated based on water table and tracer migration behavior measured at the site.

3. For the purpose of simulating the effects of a larger scale source, a solute line source was input at the North/South grid row equivalent to the tracer injection well location. Several simulations were performed including no discontinuous high conductivity conduits and one conduit. Simulation results suggest that flow in these cases results in local fingering of solute with little effect on the long term (12 month), long distance (50+ m) transport rate. Multiple closely spaced but discontinuous conduits act as continuous preferential conductors of solute which can greatly affect transport rate.

Discussion

Based on analyses of site data and flow and transport model simulations, a geohydrologic conceptual model for the shallow aquifer has evolved from this study. Hydraulic conductivity values vary randomly within approximately 1.5 orders of magnitude, and apparently discontinuous, narrow conduits of comparatively high hydraulic conductivity provide preferred pathways for tracer migration. The rate of local tracer migration is dependent upon the presence of conduits and independent of the overall site hydraulic gradient. The pathway of maximum tracer concentration is coincident with the axis of a strike-parallel water table divide. This water table anomaly is considered to represent a fracture-controlled zone of preferred aquifer discharge (and presumably recharge at higher elevations).

Conclusions

This study demonstrates the fundamental influence of geologic structure on groundwater flow at the site. By incorporating a systematic approach to site characterization and conceptual model formulation and testing with development of a groundwater flow simulation model, it was possible to numerically simulate a field tracer test using rational model input parameters derived from the interpretation of site data. While mathematical simulation of aquifer behavior using the concept of porous medium flow can provide an approximation of observed groundwater flow and contaminant transport, the field test results clearly demonstrate that much of the significant

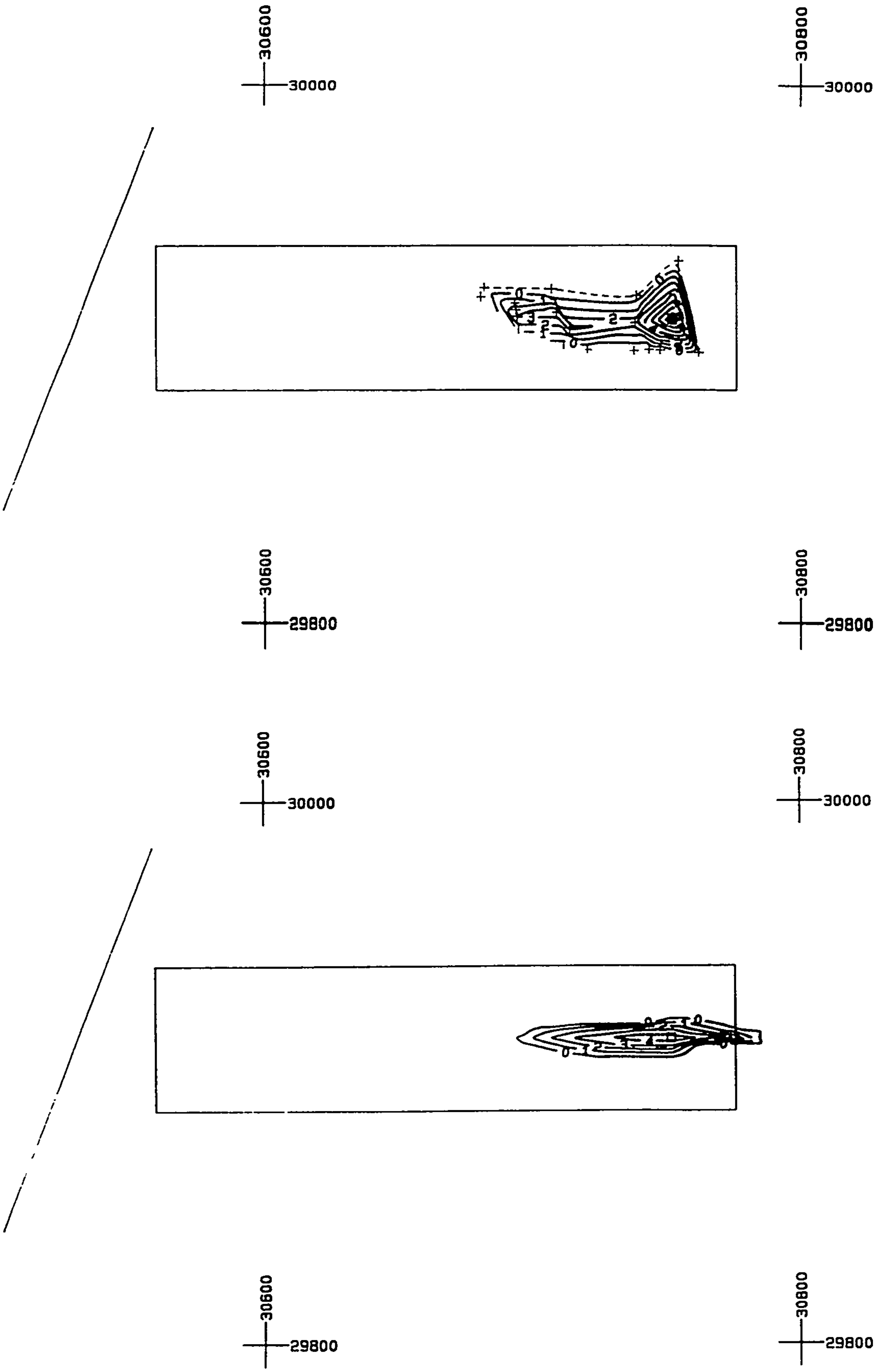


Fig. 5. Comparative plots (log ppb) of measured tracer concentration (top) and model generated plume (bottom) 1 month after tracer injection.

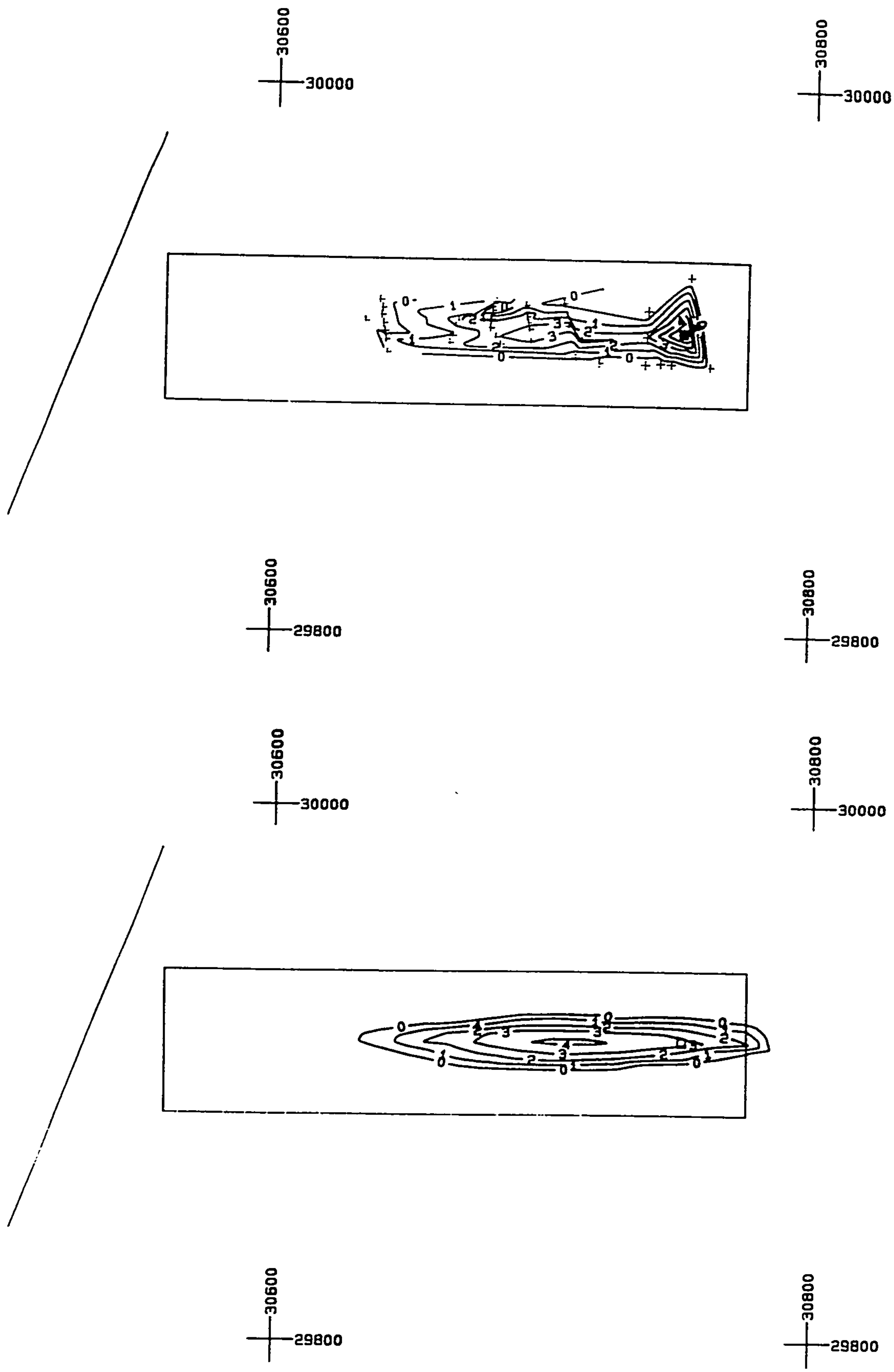


Fig. 6. Comparative plots (log ppb) of measured tracer concentration (top) and model generated plume (bottom) 6 months after tracer injection.

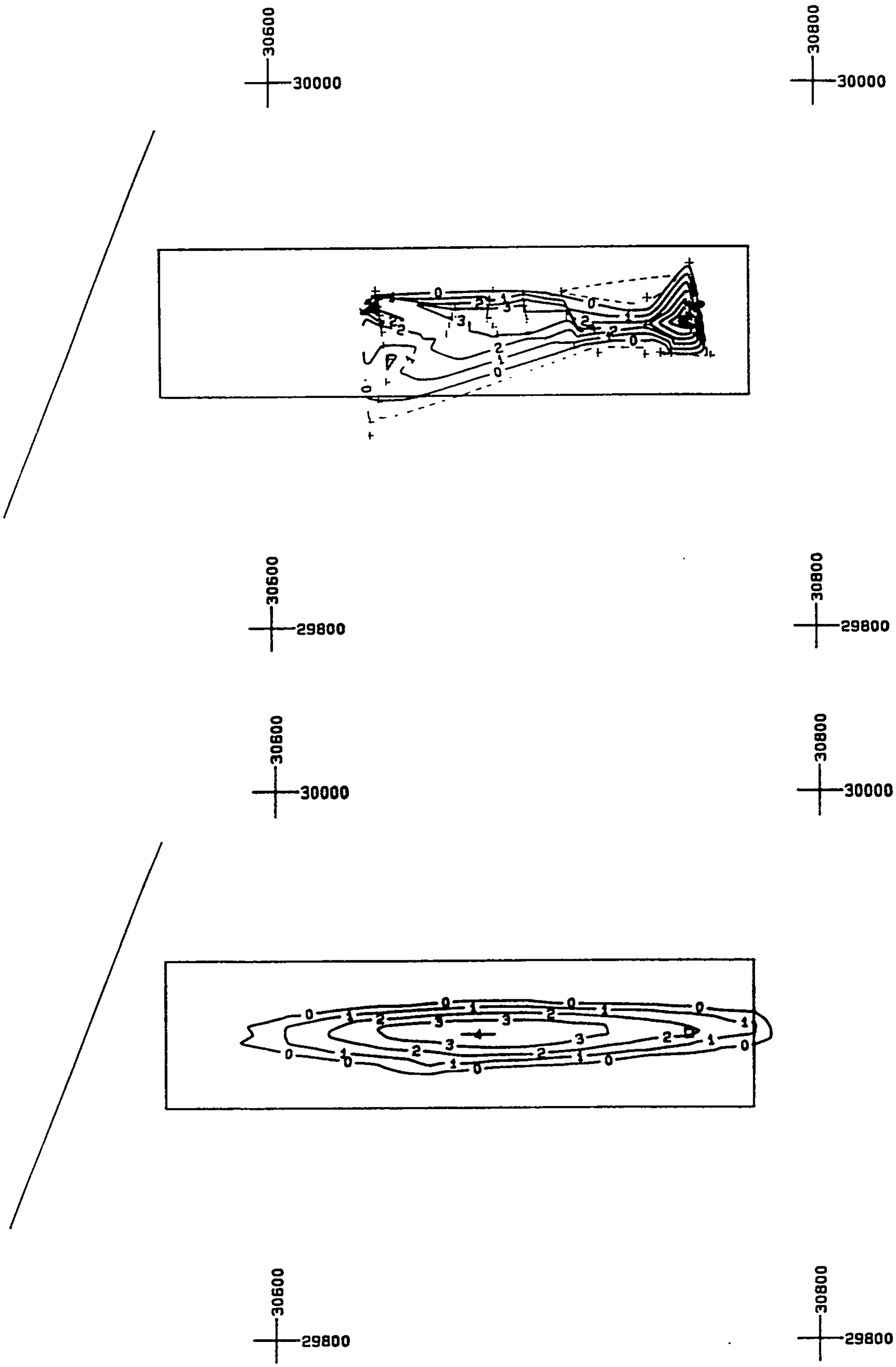


Fig. 7. Comparative plots (log ppb) of measured tracer concentration (top) and model generated plume (bottom) 12 months after tracer injection.

transport activity occurs through mechanisms of fracture flow. The methods used in model grid specification can and will be used in development of scaled up site groundwater models in support of a comprehensive waste disposal program at Oak Ridge.

Radiological Environmental Pathway Screening Analysis For The Feed Materials Production Center (FMPC)

By

Roy Eckart,[1] Dennis Carr,[2] Bob Conner,[2] Randy Janke[1] and Robert Janke[1]

Introduction

The University of Cincinnati is working with the Westinghouse Materials Company of Ohio (WMCO) to develop remedial action residual radioactive material soil guidelines for the Feed Materials Production Center (FMPC).

As a first step in developing these soil guidelines, a radiological environmental pathway screening analysis was performed. The purpose of the pathway screening analysis was to identify the radionuclides and environmental pathways that would lead to the highest exposure or dose to humans from residual radioactivity in the soil at the Feed Materials Production Center (FMPC). In addition, the screening analysis identifies those pathways that are critical to a particular radioisotope.

A remedial investigation and feasibility study (RI/FS) was initiated in 1987. The purpose of this RI/FS is to assess the impact and extent of any release of hazardous and radioactive substances at or from the FMPC, and to develop and recommend remedial action cleanup strategies to protect public health and the environment from any determined releases (WMCO, 87).

The Environmental Protection Agency (EPA), through various RI/FS guidance documents, has recommended that remedial action cleanup strategies, known as remedial action alternatives, can be broadly classified into two types of actions: 1) source control measures and 2) management of migration measures

(EPA, 85). Source control measures are classified as those designed to prevent or minimize the migration of contaminants from the source. Management of migration measures are those designed to mitigate the impact of contamination that has migrated into the environment. We believe that the pathway screening analysis, when characterized for the FMPC site, will provide a significant technical contribution to the process of selecting remedial action alternatives.

Since most results of this analysis are in terms of a quantity called the dose-to-source ratio (DSR), it seems prudent to review this term and its importance. The dose-to-source ratio is a measure of the effective dose equivalent from external radiation plus the committed effective dose equivalent for internal radiation. The dose-to-source ratio is in units of millirem of dose per picocurie of radioactivity in the soil (mrem/pCi). Even though the environmental pathways are complicated and the internal dosimetry complex, the dose to humans is always linearly proportional to the radionuclide concentration in the soil. For example, assume the dose-to-source ratio (DSR) for radium-226 was 20 mrem/yr per pCi/gr in the soil and that the soil was found to contain 5 pCi/gr. The resulting dose to an individual in the public would be five times the DSR value or 100 mrem per year. This linearity permits the pathway analysis to proceed without knowing the exact radionuclide concentration in the soil. The screening study can also use the dose-to-source ratios as an indicator of the pathways and radionuclides that would be of most concern.

The pathway screening analysis was not used to calculate or even estimate soil guidelines for the FMPC. It was a generic pathway screening analysis, and conservative assumptions were used to calculate the DSR values. The DSR values were calculated at their maximum value and therefore do not occur at the same time. The screening study helped us to understand "how" to analyze the site in terms of distinguishing important site parameters, pathways, and radionuclides. It can not be used to calculate or even estimate soil guidelines.

The pathway screening study utilized the methodolgy, equations, and other data from the DOE manual, "A Manual for Implementing Residual Radioactive Material Guidelines" (Gilbert, 88). The Manual, as it will be referred to, describes the pathway analysis procedure for a generic site. Site specific data for the FMPC was utilized wherever possible to provide insight to the problems associated with this assessment. A pathway analysis, as described in the Manual, consists of four major parts: 1) a source analysis, 2) a human scenario analysis, 3) an environmental pathway and transport analysis, and 4) a calculation of dose to source ratios. We also used a computer program called ONSITE/MAXI1 (Kennedy 1986) developed by Pacific Northwest Laboratory (PNL). Future work will use GEN II, (Napier 1988), a new computer system also developed by PNL.

Source Analysis

The source analysis is still underway at the FMPC site by other contractors. The screening study was performed for the radionuclides identified as present on site by the Characterization Investigation Study (Weston, 1987). For the purposes of the screening study, the radionuclides were conservatively assumed to be uniformly and homogeneously distributed over a large area.

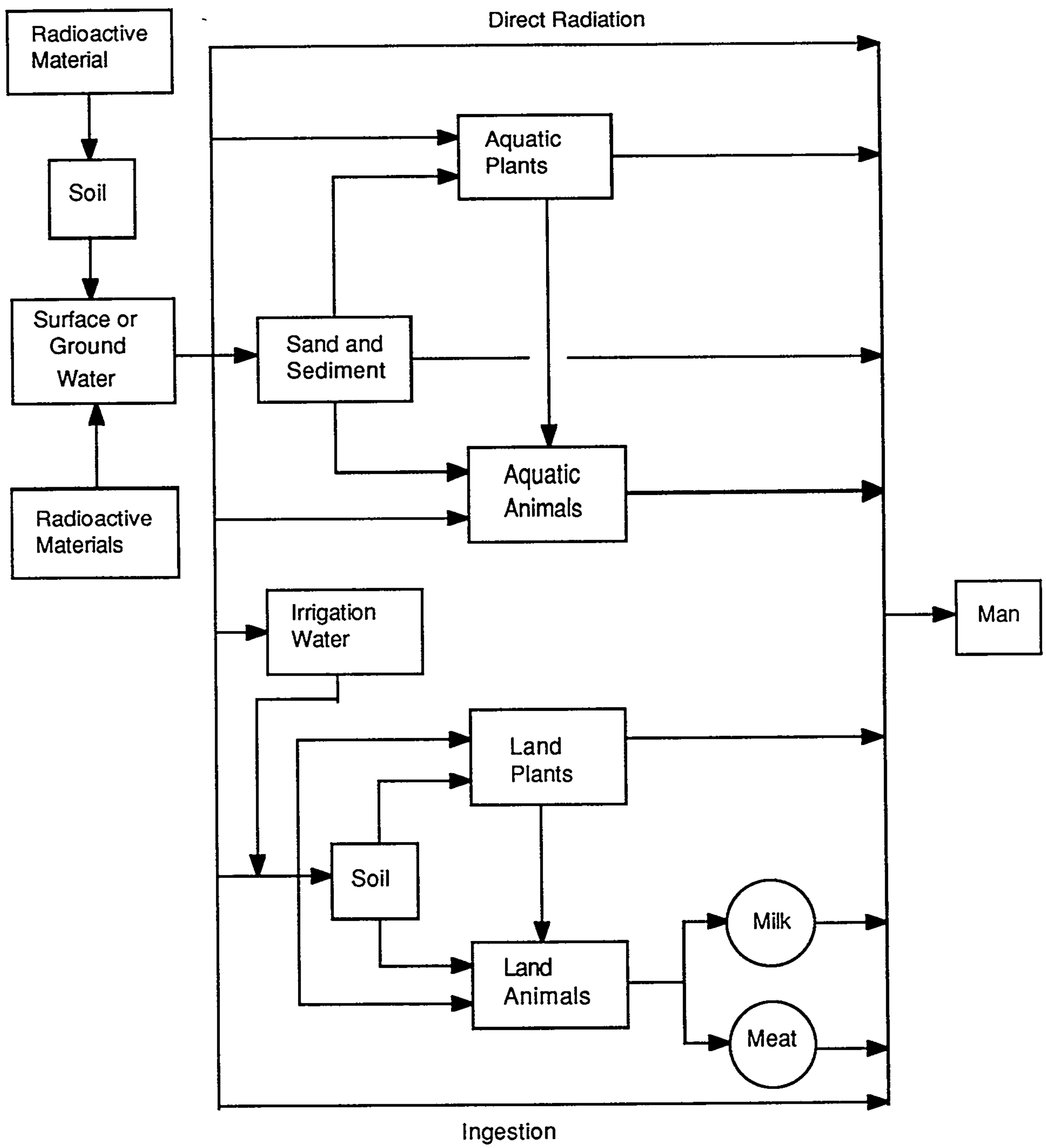
Human Activity Scenario

Since the FMPC is surrounded by large farms, the resident farm scenario was selected as the human activity model that would best fit the environment in and around the FMPC site. In this scenario, a resident farm family is assumed to establish their farm on the FMPC site within a minimum of one year after decommissioning and decontamination. This family is assumed to grow all their food products on site. This includes water from an on site well and meat and milk from cattle grazing on site.

Pathway Analysis And Environmental Transport

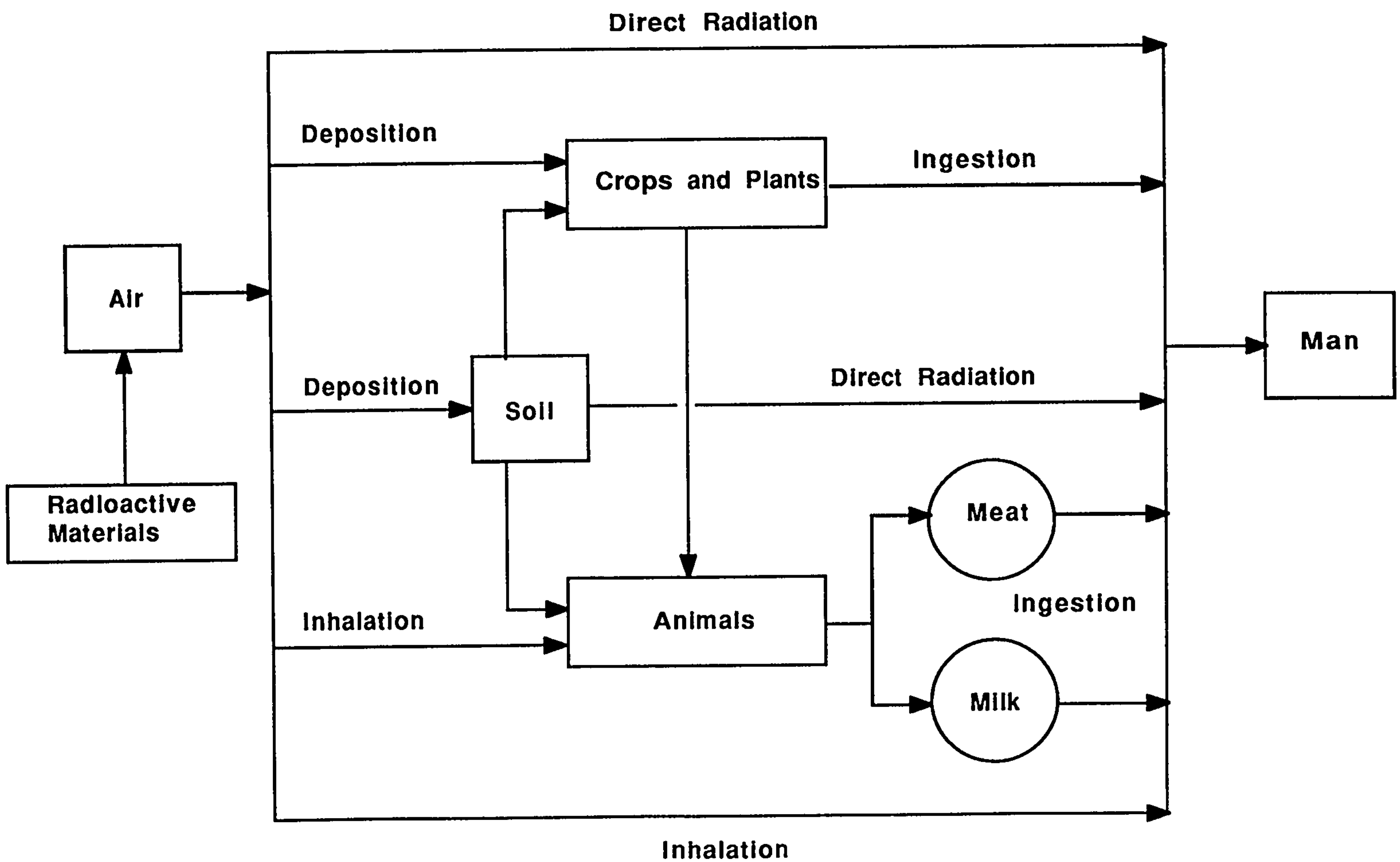
The environmental pathways were developed from the generalized models presented in Figures 1 and 2. Figure 1 illustrates the generalized liquid pathway schemes and Figure 2 illustrates the generalized gaseous pathway routes. A preliminary evaluation eliminated many of the pathways illustrated in these generalized models to arrive at the ten pathways/subpathways which form the basis of the screening study. These ten pathways/subpathways were analyzed in detail. These pathways are listed in Table 1.

FIGURE I: GENERALIZED LIQUID PATHWAYS TO MAN



This figure was adapted from U.S. EPA, 1972.

FIGURE 2: GENERALIZED GASEOUS PATHWAYS TO MAN (U.S. EPA, 1972)



Dose-to-Source Ratios

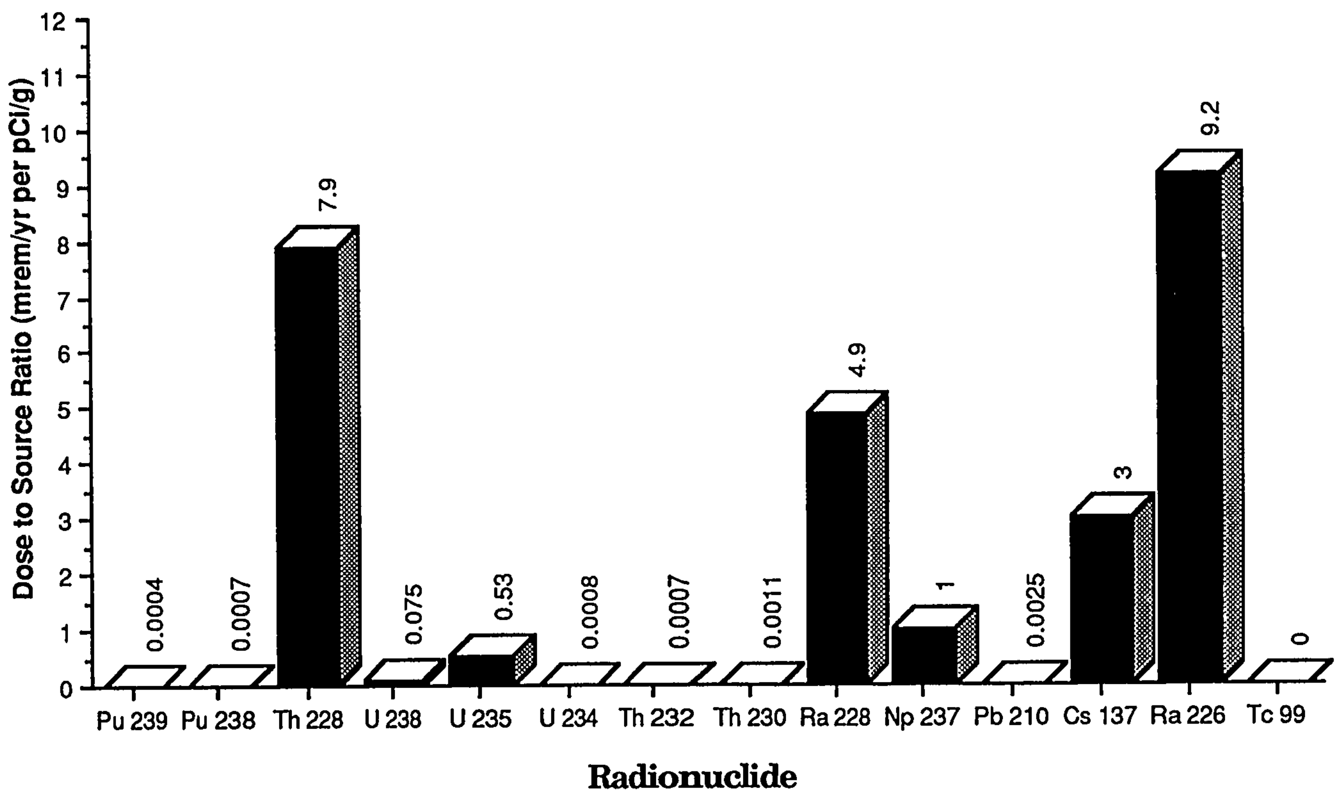
The dose-to-source ratio, DSR, was calculated for each radionuclide in each of the ten sections (pathways). This paper presents the dose-to-source ratio results for the pathways listed in Table 1.

The dose-to-source ratios for all of the radionuclides in a typical pathway, specific pathway, are shown in figures 3, 4, and 5. The dose-to-source ratio is shown as the ordinate value in each figure, and represents the dose equivalent from external radiation plus the committed effective dose equivalent from internal radiation (hereafter called dose) in units of millirem per picocurie of the given radionuclide in the soil.

Figure 3, shows the DSR for each radionuclide in the direct radiation pathway. The dose in this pathway is from gamma emitting radionuclides in the soil. The radionuclides of primary concern are shown in Figure 3 to be radium-226, thorium-228, radium-228, cesium-137, neptunium-237, and uranium-235. Since the dose-to-source ratio for 1 picocurie of radium-226 in the soil is 9.2 mrem/yr per pCi/g, if the soil contained 10 pCi of radium-226 per gram, the dose would be 92 mrem per year.

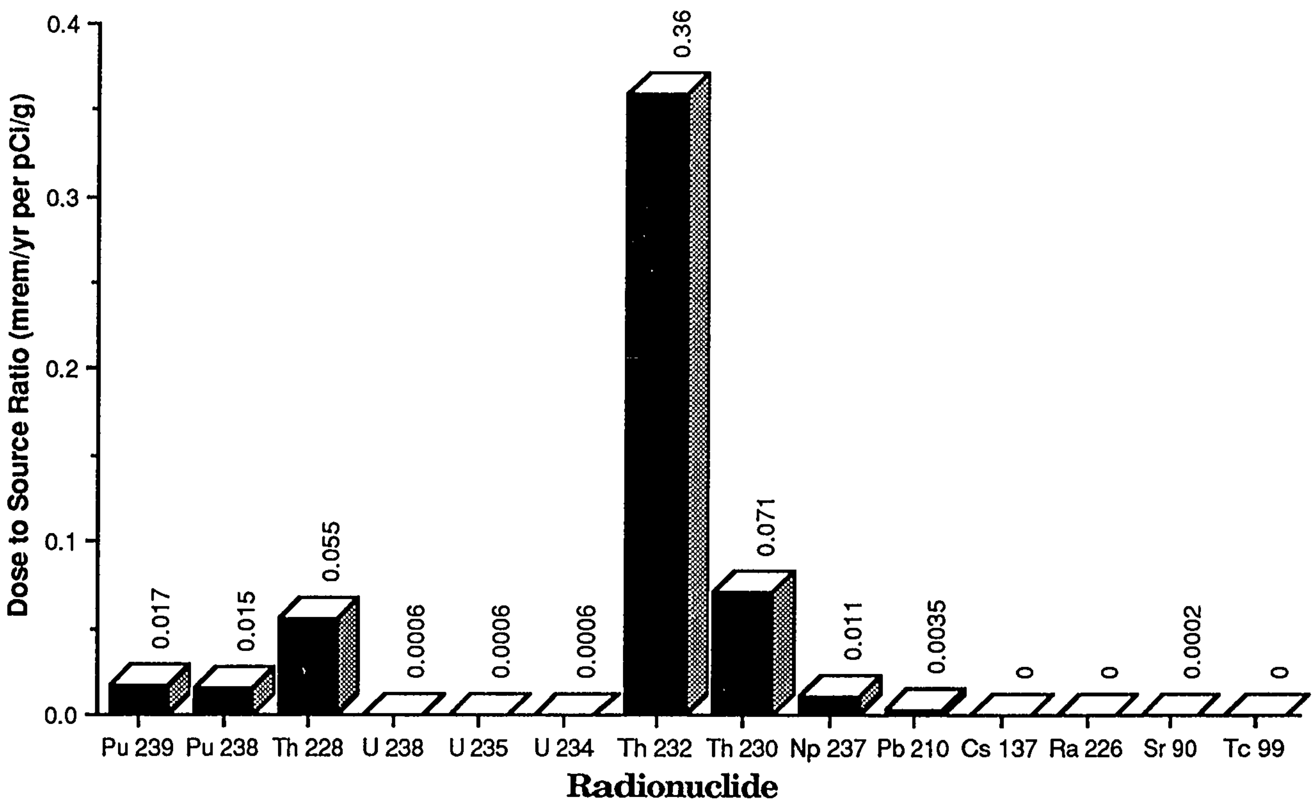
Typical results for other pathways analyzed in the screening analysis are shown in figures 4 and 5. Each figure identifies the radionuclides that have the highest dose-to-source ratio for a particular pathway or subpathway. Figure 4, for example, shows that thorium-232 would be of particular concern in the dust inhalation pathway. Please note that in order to make these figures useful, the ordinate range (DSR) was varied in each figure.

Figure 3: Direct Radiation Pathway



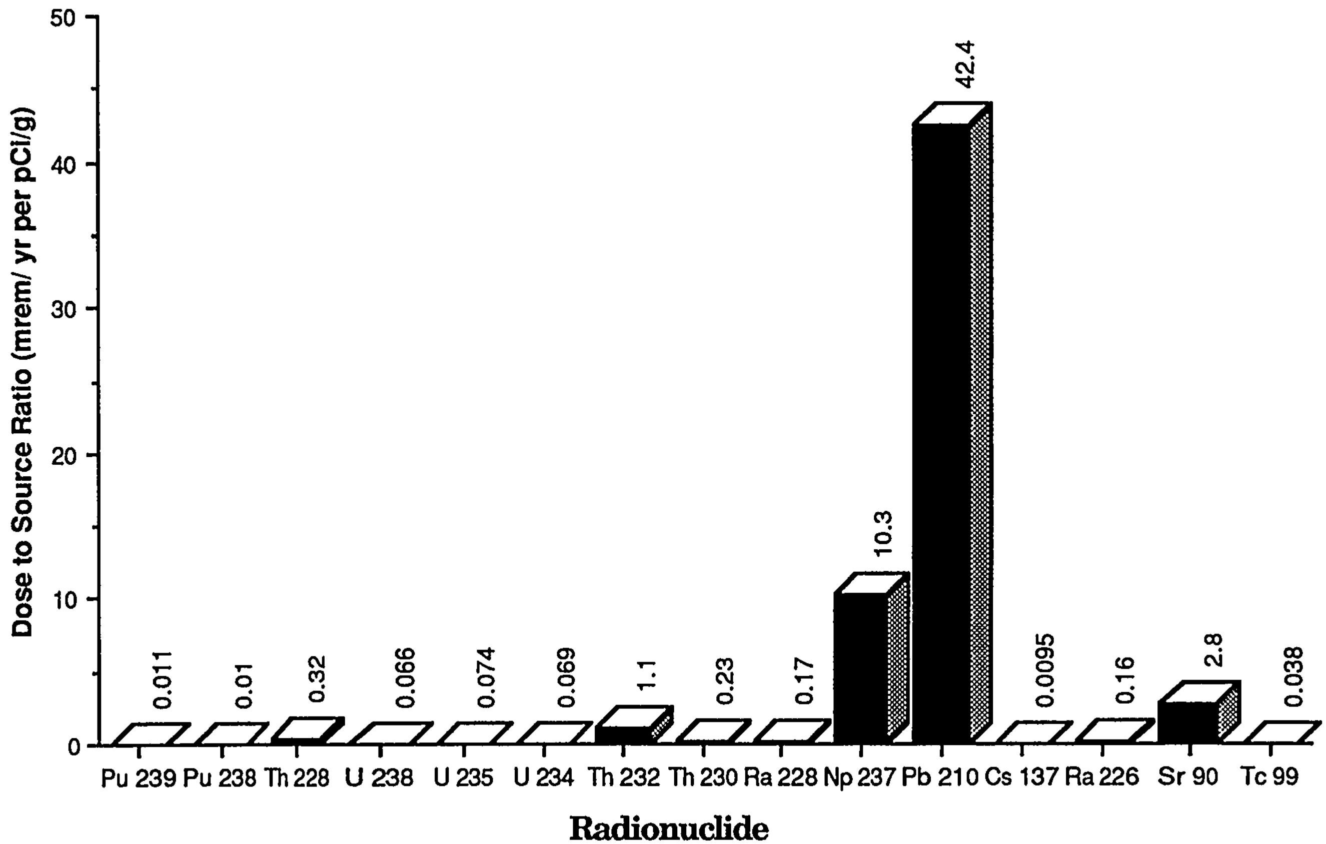
Note: The Ordinate Scale Varies From Figure To Figure.

Figure 4: Inhalation Of Contaminated Dust Pathway



Note: The Ordinate Scale Varies From Figure To Figure.

Figure 5: Dose-To-Source Ratios For The Ingestion of Crops And Plants Root Uptake Subpathway



Note: The Ordinate Scale Varies From Figure To Figure.

Table 1

Pathways/Subpathways Analyzed In The Screening Analysis

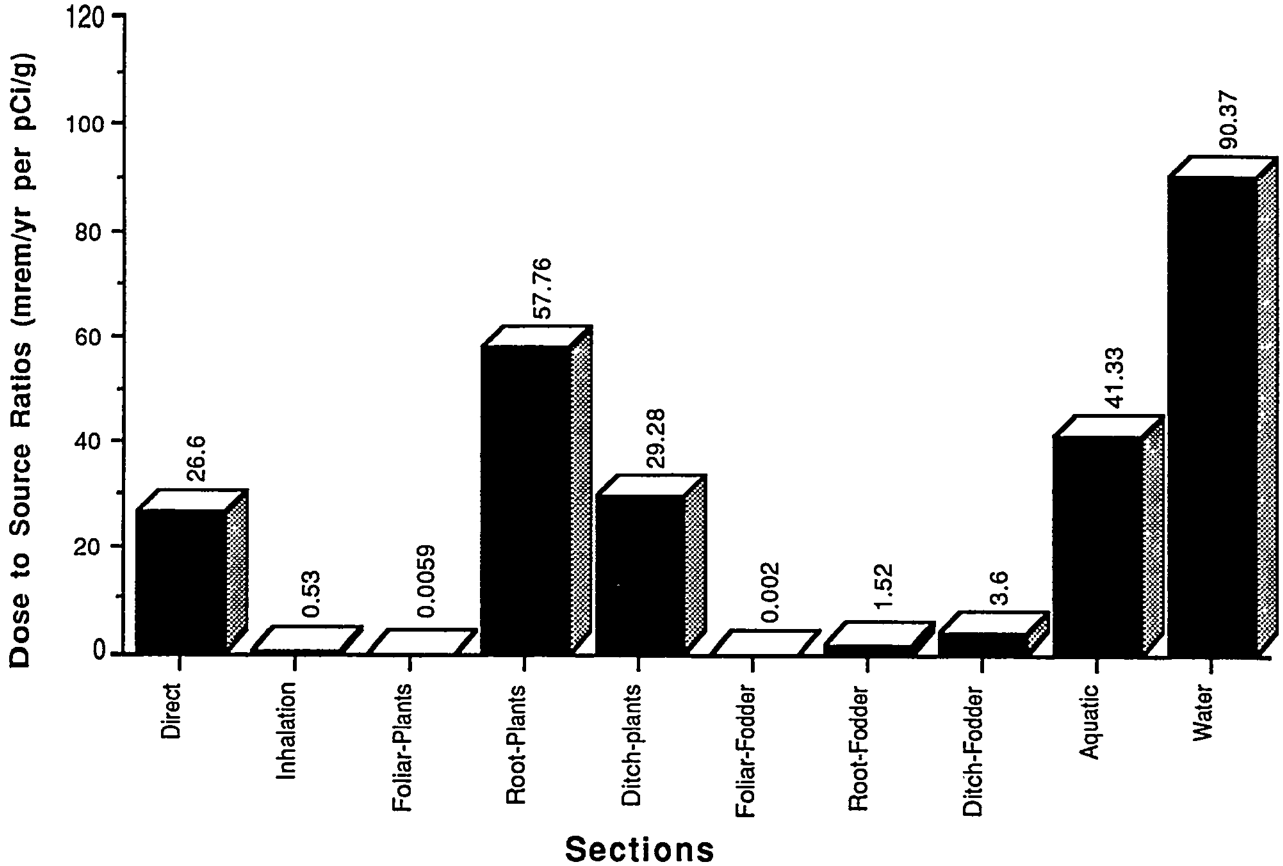
Direct Radiation
Inhalation of Contaminated Dust
Ingestion of Contaminated Drinking Water
Ingestion of Plants/Crops by Contaminated Foliar Deposition
Ingestion of Plants/Crops by Contaminated Root Uptake
Ingestion of Plants/Crops by Contaminated Ditch Irrigation
Ingestion of Meat/Milk by Contaminated Foliar Deposition
Ingestion of Meat/Milk by Contaminated Root Uptake
Ingestion of Meat/Milk by Contaminated Ditch Irrigation

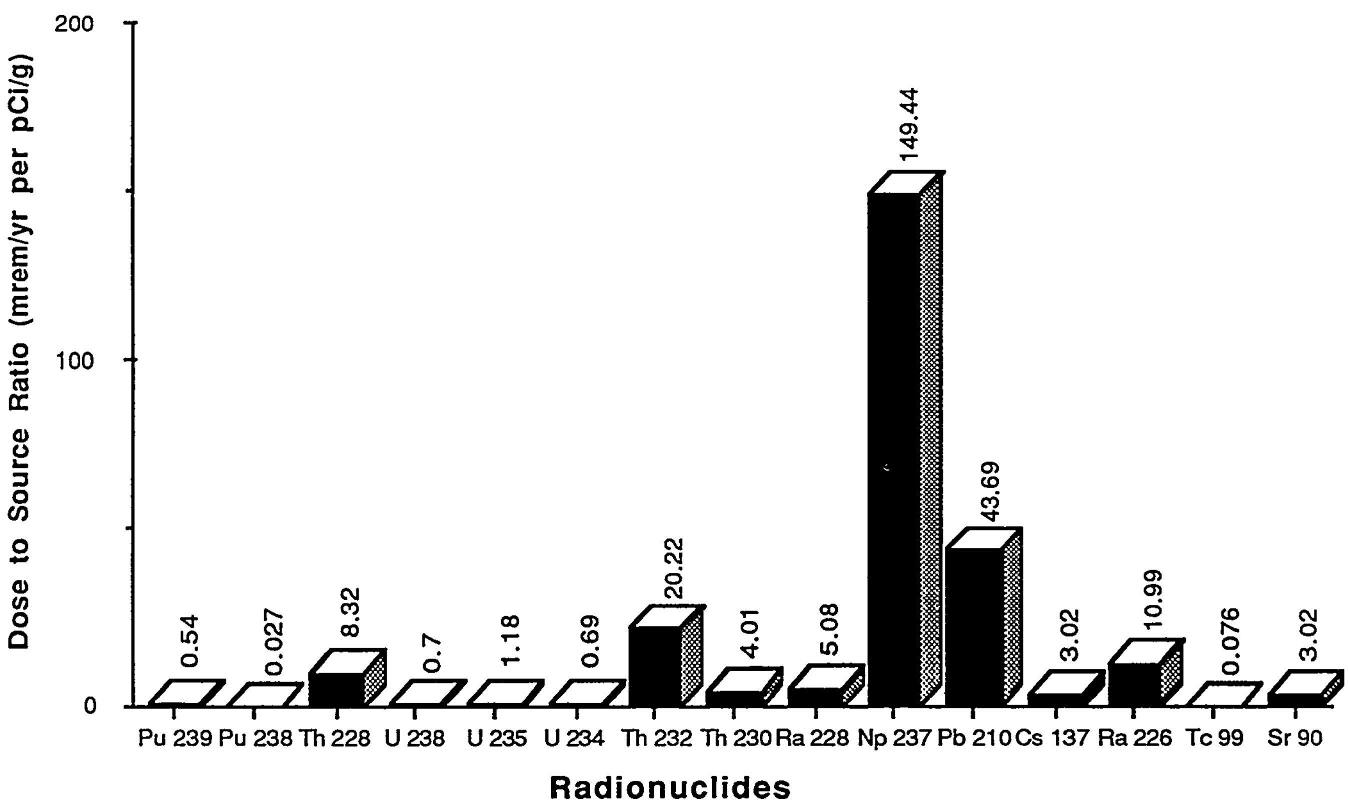
Analysis And Discussion Of The Results

Figure 6 summarizes the results of the pathway screening analysis, displayed by illustrating pathway and radionuclide totals. One can identify, from this figure of results, the most significant environmental pathways and radionuclides. This figure establishes a hierarchy of relative importance for each of the pathways and subpathways and also for the radionuclides. The dose-to-source ratios were calculated at the time where their maximum value was obtained and do not correspond to identical time frames.

Figure 6

DSR Values For Pathways And Radionuclides





Discussion Of Significant Pathways

Table 2 identifies the pathways that would lead to the highest dose to the resident farmer from residual radioactive material in the soil. The food ingestion pathway of particular concern is the ingestion of plants and crops. Lead-210 is the most significant radionuclide in this pathway, primarily through root uptake to foods. Once in the GI tract, the fraction of lead-210 transferred from the small intestine to the blood system is relatively large. Strontium-90 and the thorium isotopes are also significant in this pathway.

Table 2

Important Environmental Pathways
Drinking Water
Direct Radiation From Soil
Inhalation Of Resuspended Dust
Food Ingestion-Crops And Plants

Direct radiation from the soil constitutes another important pathway. The gamma emitting radionuclides are the main concern in this pathway: radium-226, thorium-228, radium-228, cesium-137, and uranium-235.

The drinking water pathway is always important in a pathway analysis. In this screening analysis, the migration model given in the Manual allows for rapid, non-dispersive movement of the radionuclides from the contaminated zone to the aquifer. The family well on the farm taps the aquifer for the drinking water. This is a highly conservative analysis. Using this type of analysis, there are a number of radionuclides that contribute to the dose in this pathway: thorium-232, thorium-230, radium-226, uranium-234, 235 and 238, and plutonium-239.

The fourth and final pathway identified as important is the inhalation of resuspended dust. The dose-to-source values for this pathway are lower than one might expect. These lower values are the result of the addition of a depth factor into the analysis in recent Manual revisions. The depth factor assumes a mixing occurs in the near surface ground layers, acting as a dilution mechanism. We believe this pathway could be significant. The dose from this pathway is dependent on a number of parameters that need better site-specific values, such as the actual dust loading in the air around the FMPC, the distribution of the dust particle sizes, and the chemical forms of the radionuclides. These parameters will be more fully investigated as the work progresses. Thorium-232 is a significant radionuclide in this pathway. The other isotopes of thorium, 228 and 230, and the plutonium isotopes, 238 and 239, are also important.

Important Radionuclides

Table 3 lists those radionuclides that were found to be most significant by the screening analysis. Generally, the most important radionuclides are those that are highly mobile in the environment (such as neptunium-237), have a high root uptake from the soil (such as lead-210) or decay with significant gamma activity (such as thorium-232). In some cases, combinations of these parameters occur. The final analysis for the remedial action soil guidelines study will incorporate the best data and analysis techniques available in the assessment of each of the radionuclides considered.

Table 3

Important Radionuclides
Neptunium-237
Lead-210
Thorium-232
Radium-228
Thorium-228
Thorium-230
Cesium-137
Strontium-90
Uranium-235
Uranium-238
Uranium-234

Action Plan Recommended By The University Of Cincinnati For Developing Soil Guidelines

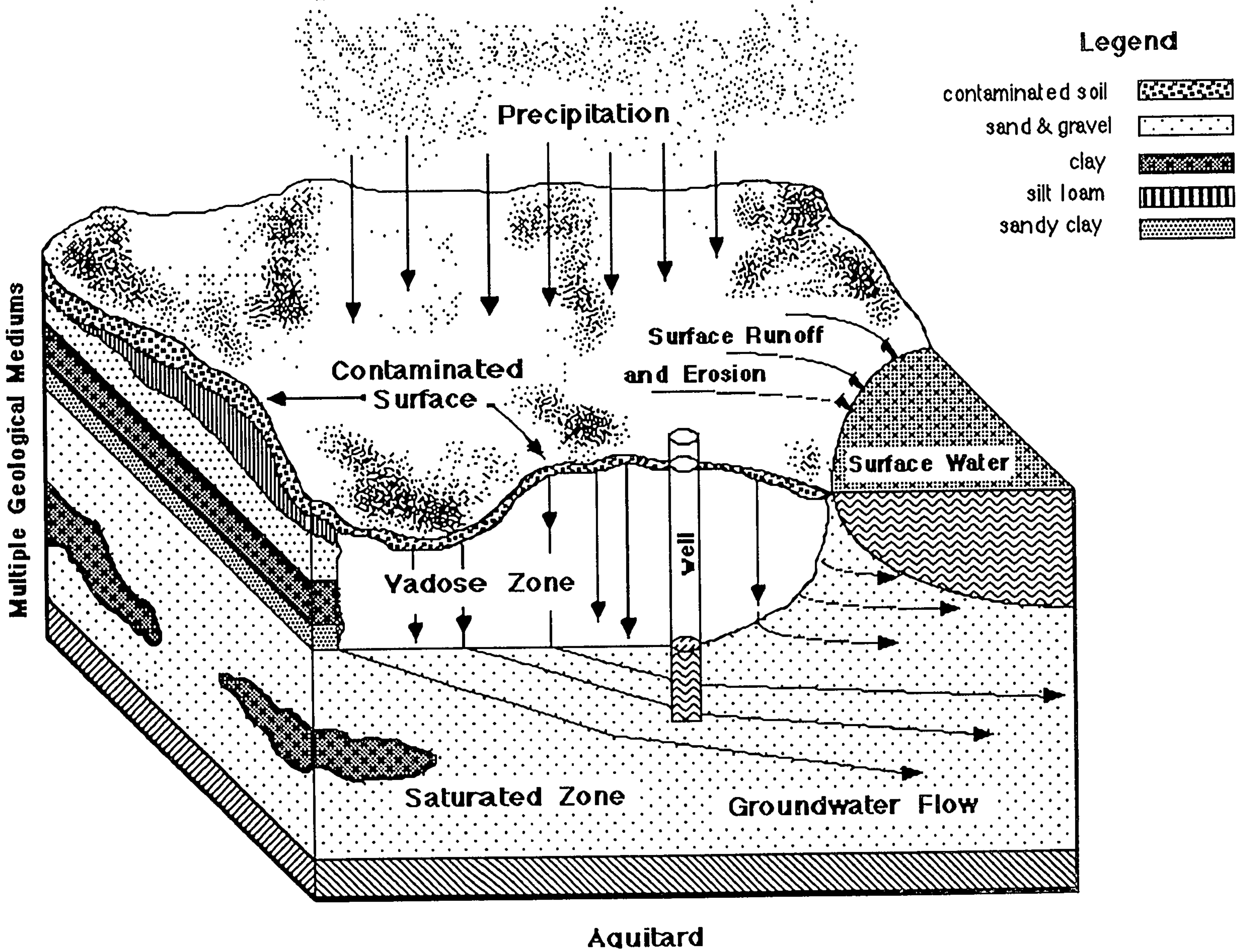
Based on the results of the pathway screening analysis and the development of the radionuclide migration models at the FMPC, one possible action plan has been formulated by the University of Cincinnati to determine the soil guidelines for the FMPC. The completion of the soil guidelines will facilitate the development of remedial action alternatives.

The screening analysis provided valuable insight into a methodology for developing residual radioactive material soil guidelines. The soil guidelines are established either by the conditions which occur at the initial release of the site or are determined by the time required for the radionuclides to migrate from the contaminated zone at the surface through the vadose zone to the aquifer. It is thus imperative that site hydrogeology be well understood before establishing soil guidelines. We now have a better understanding of the FMPC site hydrogeology. As a general rule, site hydrogeology plays the most important role in developing soil guidelines.

The FMPC site will be divided into analysis regions based on the hydrogeological properties of the site, particularly the characterization of the vadose zone. Figure 7 is a generalized view of the water pathways at the FMPC site. This figure illustrates the vadose zone and surrounding mediums through which radionuclides are transported to the groundwater.

We are convinced that for the FMPC site, a site located on top of a major aquifer, the transport of radionuclides through the vadose zone will be the key to establishing the soil guidelines. The screening study utilized a simplified model to

Figure 7 Water Pathways Segments (General)



approximate the water pathways. For this analysis, the vadose zone is composed of three layers or mediums that vary in their hydrogeological properties. The vadose zone was assumed to be 10 meters in depth with a 1 meter contaminated region near the surface. This simplified model was used to evaluate the significance of the water pathways as they applied to the FMPC.

The evaluation of the soil guidelines will require an indepth and extensive assessment of the FMPC site in terms of the hydrogeological parameters. The analysis will be based on the thickness of the vadose zone and the type of material contained there. The site will be divided into analysis zones of approximately equal vadose thickness. A conceptual view of the hydrogeological zone analysis is presented in Figure 8. In this way, the hydrogeological model applied to each zone will be consistent, yielding values of the Water-to-Soil Ratio (WSR) that are of a specific time and position within the FMPC site. Preliminary review of the hydrogeology of the site indicates there will be at least five zones considered. The zones range in thickness from 1.5 to 12 meters. By assessing the water pathways based on vadose zone thickness, the soil guidelines can be determined for each zone separately, with the transport time to the aquifer as the critical parameter in each case. Zones with greater vadose zone thickness would have higher values for soil guidelines and require less remediation.

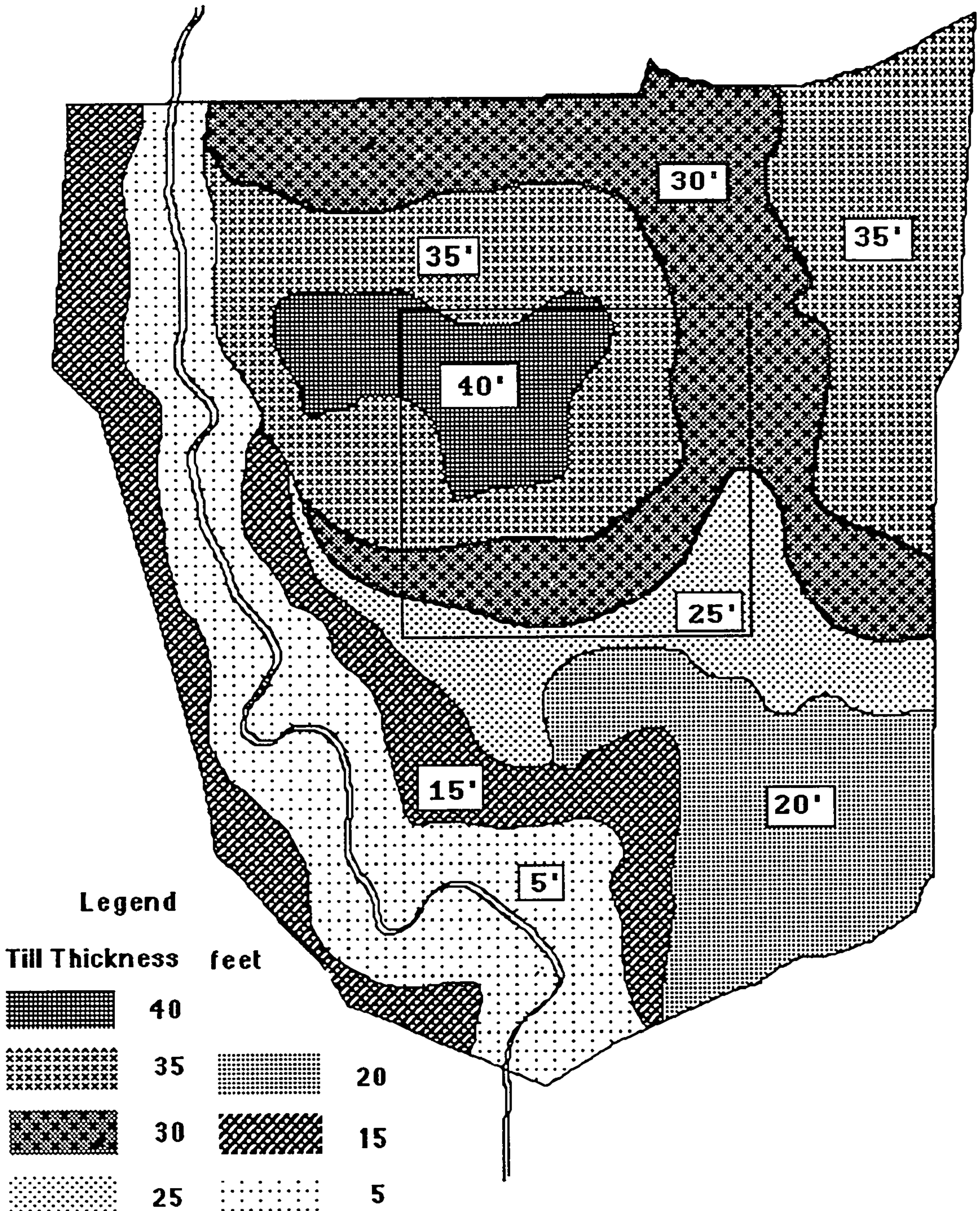


Figure 8
Hydrogeological Zone Analysis Map
For The FMPC

The DSR values calculated as a part of this screening study were developed using only one model (previously described) for the water pathways. The soil guidelines will be evaluated for all the hydrogeological zones. The DSR values calculated in the area of the site where the vadose zone is 2 meters or less in thickness will be significantly different than those reported in this paper due to the time required for radionuclide migration. In this area the soil guidelines may be an order of magnitude lower than for the zone where the vadose thickness is 12 meters. We conclude that this analysis technique (consisting of several sets of soil guidelines based on vadose zone thickness) for the FMPC could conceivably save millions of dollars in remedial action cleanup costs.

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PERFORMANCE ASSESSMENT ON GROUTED DOUBLE-SHELL TANK WASTE AT HANFORD

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J. M. ALLISON
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SUMMARY

The low-level fraction of liquid waste stored in double-shell tanks at Hanford will be solidified in a cementitious matrix (grout) and disposed in subsurface vaults. This paper discusses activities related to the preparation of a site-specific performance assessment as required by DOE Order 5820.2A.

A draft performance assessment has been prepared for the planned grout disposal system at Hanford using site-specific data. The assessment estimates the incremental increase in the dose to future populations who, after loss of institutional control at the site, use groundwater downgradient of the disposal site. Increases in nonradiological species in water from a hypothetical well are also estimated. Two-dimensional transport models were used to estimate contaminant concentrations in groundwater. Based on diffusional release from the waste package, the projected radiological dose to an individual on a hypothetical farm using water from a well at the disposal facility boundary is estimated at less than one percent of the 25 mrem/yr standard in Order 5820.2. Technetium accounted for about 95% of the dose. Nitrate was the principle chemical contaminant at 0.3% to 0.5% of apportioned drinking water standards. Sensitivity studies on various parameters are in progress. This performance assessment will be updated as additional data become available.

INTRODUCTION

It is planned to dispose of 44 million gallons of low-level liquid wastes at Hanford by solidifying the waste in a cementitious (grout) matrix[1]. The Grout Treatment Facility at Hanford, which will be used to produce the grout, was constructed from 1986 through 1988. The facility consists of the Dry Materials Facility, Transportable Grout Equipment, a waste feed tank, and disposal vaults[2]. Waste from a million-gallon feed tank will be mixed with grout formers, creating a slurry that will be pumped to below-grade vaults. Each vault will hold 1.4 million gallons of the slurry and will take about one month to fill. The slurry will harden within several days after production. After the grout has set, any excess liquid will be pumped from the vault and the remaining void will be filled with non-radioactive grout. A closure cover will be placed over the vaults, and eventually, a long-term protective barrier will be placed over the entire disposal site.

(a) Pacific Northwest Laboratory is operated for the U.S. Department of Energy by Battelle Memorial Institute under Contract DE-AC06-76RLO 1830.

This paper discusses the performance assessment process that has been carried out to guide the disposal system design and to meet the requirements of the Department of Energy (DOE) Order 5820.2a.

PERFORMANCE ASSESSMENT PROCESS

Performance assessment is an iterative process, as depicted in Figure 1. A disposal system is defined based on conceptual or definitive designs. The performance of the system, or the long-term environmental impacts, are estimated based on scenarios prescribed by regulations or dictated by the proposed environmental setting. The estimated long-term impacts are compared with regulations. If the estimated impacts are significantly below regulatory criteria and the assessment is defensible, then the plans for disposal can proceed. If not, there may be options to improve the design of the disposal system, improve performance of the waste form, and reduce conservatism in modeling. Reduction of conservatism in models usually requires more complex codes and additional data.

At Hanford, the first scoping analysis for the disposal of the low-level fraction of double-shell tank wastes used one-dimensional models with many estimated parameters because better defined data were not available. As additional data became available, subsequent, the performance analyses became more sophisticated, using two-dimensional models.

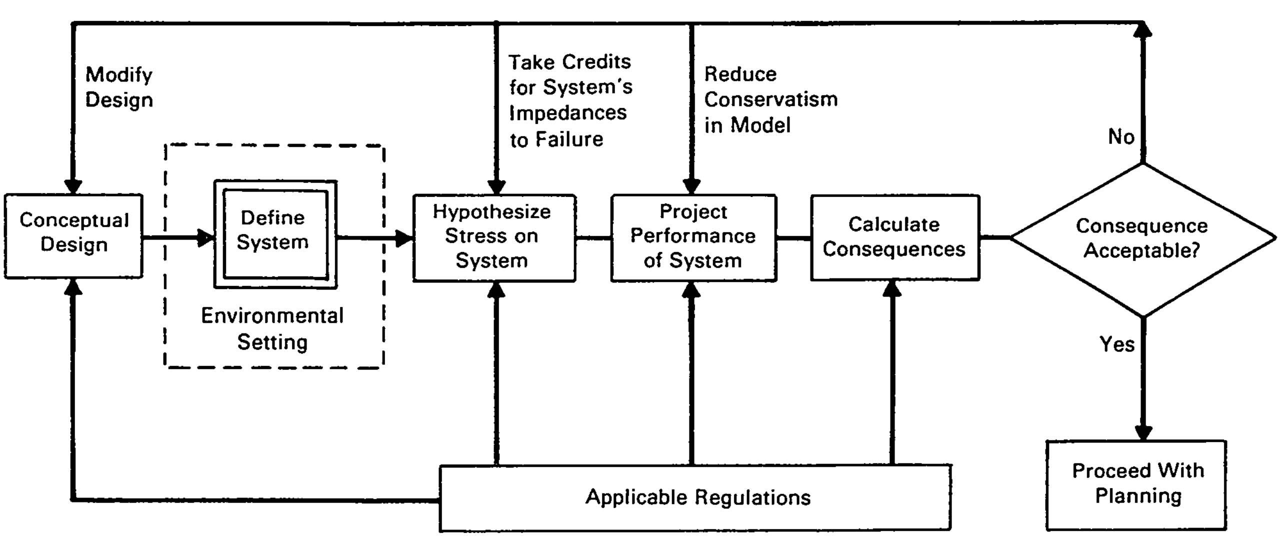

Figure 1. The Performance Assessment Process

In 1987, a performance assessment was prepared for the disposal of very low activity wastes from N Reactor operations at Hanford[3]. Following this evaluation, the same methodology for performance assessment was used to evaluate a simplified grout disposal system for the projected 44 million gallons of low-level wastes. In this evaluation, diffusional release of contaminants from the grout was modeled. Using one-dimensional flow and transport models, contaminant concentrations as functions of arrival times at hypothetical down-gradient groundwater receptor points were determined for various contaminants. The dose to potential users of the groundwater was calculated.

Results of this scoping analysis showed that an improvement in system performance was required. The addition of a long-term infiltration barrier was projected to cause some reduction in peak doses and significant retardation of the contaminant plume. However, the reduction of the peak contamination still did not meet proposed release criteria. Thus, an additional engineered feature was proposed to reduce the release of contaminants from the vault. This feature, called a diffusion barrier, would isolate the vaults from advecting water in the surrounding soil. It was also believed that some improvement could be realized by using more complex models, which could eliminate conservative assumptions that were needed in the one-dimensional analysis. These combined enhancements combined were anticipated to allow a comfortable margin of safety in meeting release goals.

Since the initial performance evaluation in 1987, efforts were initiated to obtain the required data and computer codes to provide a more refined projection of the disposal system performance. An updated projection of long-term performance of the grout disposal system has been drafted and will be submitted to the DOE later this year.

DISPOSAL SYSTEM DESIGN

The Hanford Reservation is in a semi-arid environment in the state of Washington. The surface of the disposal site for grouted low-level waste is about 90 meters above the water table. The soils at the disposal site are primarily sands and silty sands.

The disposal system consists of grout, grout vaults, diffusion barriers, interim barriers, and a protective barrier (Figure 2). Each component will be discussed further.

The reference grout consists of liquid waste and grout-forming solids blended at a ratio of 9 lb of solids per gallon of waste. The major waste components are sodium hydroxide, sodium nitrate, and sodium nitrite. The grout-forming solids are 47 wt% blast furnace slag, 47 wt% class F flyash, and 6 wt% portland I-II cement. Prior to each production campaign, the processability of waste in the feed tank and the acceptability of the product will be verified in laboratory tests.

The disposal site will consist of a projected 44 concrete grout vaults. Internal dimensions of the vaults are 125 ft long by 50 ft wide by 34 ft deep. The base of a vault is about 4.5 ft thick, the top is 2 ft thick, and

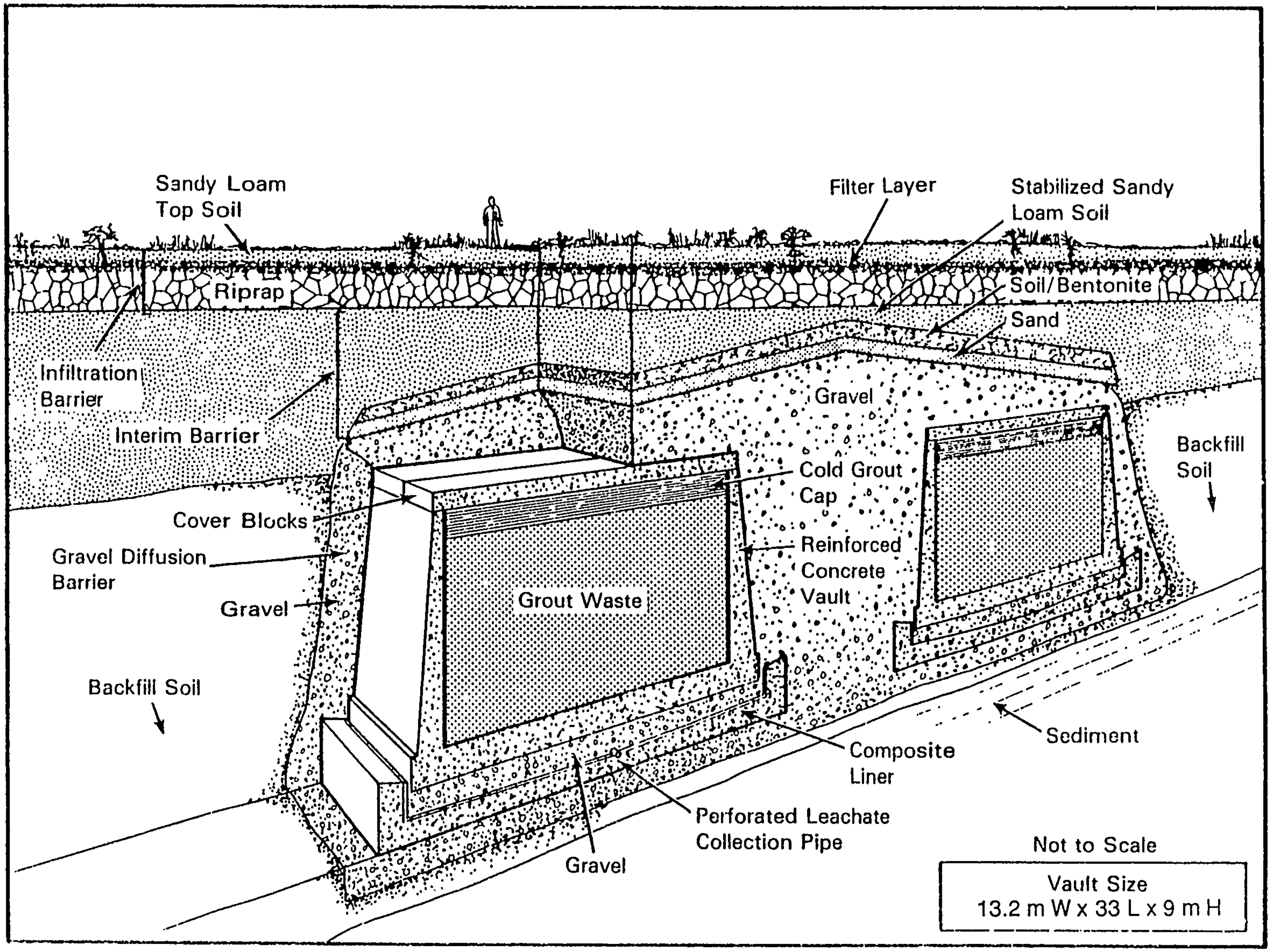

Figure 2. Disposal System Conceptual Design

the thickness of the sides varies from 2 to 4 ft. Under each vault is a lined concrete catch basin to satisfy requirements stipulated by the Resource Conservation and Recovery Act (RCRA). Each vault will be filled with grouted waste to about the 30-ft level. The remaining space will be filled with grout produced using uncontaminated water.

A continuous layer of open-graded gravel, which serves as a diffusion barrier and a water barrier, will surround each vault. The relatively high unsaturated conductivity of the soils surrounding the coarse material will divert liquid around the vault and essentially eliminate advecting water flow to the vault. The gravel will be coated with asphalt to provide a long-term hydrophobic surface, thus assuring a very low surface moisture content in the gravel. The low moisture content results in a low effective diffusion coefficient across the surface of the gravel.

Above a pair of vaults is a clay/soil barrier, which meets the RCRA requirements and diverts advecting water away from the gravel diffusion barrier.

Finally, a long-term protective barrier[4] is planned for placement above the entire disposal site to provide low infiltration rates and to resist intrusion by animals and plant roots. To deter human intrusion, the protective barrier will include large granite monuments with warning markers at various intervals along the border, as well as ceramic disks with warnings buried in the top surface of the barrier.

SCENARIOS/CRITERIA

Two exposure scenarios are being considered: future population's use of water from a hypothetical downgradient well (full-graden scenario), and future population's use of water from the Columbia River. Each scenario is discussed below.

Full Garden Scenario - This scenario estimates the impacts to a maximum-exposed individual who resides just downgradient of the grout disposal site and uses well water for drinking, irrigating of crops for humans and livestock, and watering livestock. His garden provides 25% of his food intake. This scenario has been justified based on the significant amount of farming by irrigation in the region around Hanford. Estimates from this scenario are compared with the standard of 25 mrem/year (all pathways) prescribed by the DOE order. Water from the well is also compared with existing and proposed drinking water standards. To account for potential impacts of other disposal actions at Hanford, grout disposal has been apportioned 20% of the dose and drinking water standards.

River Scenario - This scenario estimates the impacts to future populations that use the Columbia River for drinking water, agriculture, fishing, and recreation. The criterion for this scenario is also the 25 mrem/year all-pathways dose.

DATA

The data used in the performance assessment has come from numerous experiments, chemical analyses, radiological analyses, and data available in the open literature. In addition, some assumptions were necessary in the performance assessment because experiments have not been completed or long-term performance isn't known. Strategy for key data are described.

Inventory - The inventory of contaminants consists of those in the waste and dry materials used for solidification. The waste inventory is based on a projected total waste volume of 44 million gallons. At this time, analysis of three million gallons of waste has been completed[5]. The bounding inventory for the performance assessment is calculated based on the average measured waste concentrations adjusted by statistical methods. As additional samples of waste are analyzed, the average concentrations, standard deviations, and projected upper bound waste inventory will be revised. If the inventory of key species increases during this process, the impacts to the performance assessment will be determined.

The inventory of contaminants in the dry blend is based on analyses of the various components. As materials for each production campaign are received, additional analyses will be performed to reduce the uncertainty of this portion of the inventory.

The preliminary assessment conducted in 1987 and the one just drafted have identified technetium-99 as the most controlling radionuclide in the inventory. Selenium-79 and iodine-129 also make small contributions. The controlling chemical is nitrate, assuming that all the nitrite is converted into nitrate in the soil column and the groundwater. All of these species of concern are anionic in the grout waste form with little or no tendency to sorb onto Hanford sediments. Inventories of key radionuclides are listed in Table 1 and the total chemical inventory is listed in Table 2. Organics are also accounted for in the performance assessment, however, impacts due to organics are extremely low and therefore are not discussed here.

Grout - The principal data on the grout used in the performance assessment is the diffusivity of various contaminants within the grout. These data have been collected over several years on grouts made using both actual and simulated double-shell tank waste. In addition, a data base is being built for numerous species in other types of grouts to help support the values used in the performance assessment[6]. These data have been collected via leach tests such as the ANS 16.1[7] and MCC 1[8].

Diffusion Barrier - The effective diffusivity of components through the diffusion barrier is a key parameter in the performance assessment. Effective diffusivity has been determined for gravels and asphalt-coated gravels using an electrical conductivity technique. Additional long-term verification tests are proposed in the future.

TABLE 1. Radionuclide Inventory for Grouted Waste[5]

Radionuclide	Mean Concentration,(a) Ci/L	Upper-Bound Inventory,(b) Ci
^{14}C	8.4E-07	1.9E+02
^{60}Co	1.1E-05	4.7E+03
^{79}Se	6.7E-06	4.2E+03
^{90}Sr	6.6E-03	1.9E+06
^{94}Nb	1.0E-05	5.8E+03
^{99}Tc	7.7E-05	1.5E+04
^{106}Ru	4.3E-03	2.8E+06
^{129}I	1.7E-07	5.1E+01
^{134}Cs	1.2E-03	7.8E+05
^{137}Cs	3.1E-01	6.1E+07
^{234}U	1.2E-08	5.4E+00
^{235}U	7.0E-10	3.5E-01
^{238}U	8.2E-09	2.7E+00
^{237}Np	5.8E-08	3.5E+01
^{238}Pu	4.3E-07	1.3E+02
$^{239/240}Pu$	9.0E-07	2.9E+02
^{241}Am	1.4E-06	3.4E+02
^{244}Cm	7.7E-08	4.1E+01

(a) Based on mean composition of three tanks.
(b) Based on 95% confidence level; 167 million liters (44 million gallons) of waste.

TABLE 2. Summary of Inorganic Chemicals in Grouted Waste

	Waste		Dry Blend		Total Inventory
	kg	% of Total	kg	% of Total	kg
Ag	<1.7E+3	79	<4.2E+2	21	2.2E+3
As	<1.5E+4	87	2.1E+3	13	1.7E+4
Ba	<1.5E+3	1	2.7E+5	99	2.7E+5
Cd	6.5E+3	92	<5.6E+2	8	7.2E+3
Cl	6.7E+5	100	0.0E+0	0	6.7E+5
Cr	1.3E+5	90	1.5E+4	10	1.5E+5
Cu	1.5E+3	7	2.2E+4	93	2.3E+4
F	1.8E+5	100	0.0E+0	0	1.8E+5
Fe	5.5E+3	0	4.7E+6	100	4.7E+6
Hg	3.6E+3	91	<3.7E+2	9	4.0E+3
Mn	3.6E+3	1	6.5E+5	99	6.6E+5
NO_2	9.4E+6	100	0.0E+0	0	9.4E+6
NO_3	3.1E+7	100	0.0E+0	0	3.1E+7
Pb	3.8E+4	94	2.3E+3	6	4.0E+4
Se	<1.6E+4	98	3.4E+2	2	1.7E+4
SO_4	7.0E+5	16	3.6E+6	84	4.3E+6
Zn	<3.4E+3	18	1.5E+4	82	1.9E+4

The ability of the diffusion barrier to divert water from the grout waste form is also essential for the long-term performance of the disposal system. The capacity to divert advecting water has been studied in physical tests and also with computer models.

Infiltration barrier - Data on the performance of the infiltration barrier is being collected under a separate, long-term program. The goal of the program is to develop a barrier that limits infiltration to an average rate of 0.05 cm/year. The value used in the baseline case for performance assessment is 0.1 cm/year. Sensitivity to this parameter is being examined.

Sorption - Many components in the grouted waste are adsorbed by Hanford soils. Because of the relatively deep soil column and the low infiltration rate, short-lived fission products such as cesium and strontium will decay to insignificant levels before they can diffuse from the grout and travel through the soil column to the groundwater. The transuranics also strongly sorb to the soils. The combination of slow release from the waste form, due to solubility control, and sorption once released, makes the transuranic elements insignificant factors in the pathways involving groundwater. Data on sorption has come from batch sorption tests and sorption tests with grout leachates flowing in columns of soil.

Hydrologic parameters - The hydrologic properties of the soil and gravel components in the system have been determined from conventional permeability tests and water retention tests. The soils were obtained from one split-spoon sampler coring at the grout disposal site. Additional cores will be obtained to supplement the database.

COMPUTER CODES

As stated earlier, initial performance assessment activities revolved around relatively simple models. The release of contaminants from the grout inventory was modeled as either a diffusion- or solubility-controlled process. If a diffusion barrier was present, the release through the diffusion barrier was determined based on an analytical solution of the combined system assuming pseudo-steady-state concentration profiles.

The release term was then plugged into a 1-dimensional flow/transport code called TRANSS[9], which provided contaminant arrival profiles at the saturated zone. The contaminants in the saturated zone were transported using VTT[10] to the receptor point. Contaminant concentrations in the water at the receptor point were determined and doses to users were calculated for various scenarios using the codes DITTY[11] and MAXI[12].

The most recent analyses have used more sophisticated 2-dimensional models for unsaturated flow and transport. The flow code used was TRACR3D, which was developed at Los Alamos National Laboratory[13]. This code was shown to be capable of solving flow problems that were prone to numerical instability due to the large differences in hydraulic properties of various components of the system. Verification and validation of this code is in progress at LANL.

The unsaturated transport code selected was S-301, which was developed at the Winrith Atomic Energy Establishment[14]. This code was selected over several other codes because it was shown to compare most favorably to both advection- and diffusion-dominated problems with analytical solutions.

Output from the unsaturated transport code is used to provide contaminant fluxes for modeling the aquifer. The flow and transport in the aquifer were analyzed using a three-dimensional code called SLAEM[15].

Finally, contaminant concentrations in the well water for the full garden scenario and contaminant fluxes into the Columbia River are input to the radioligical dose code, GENII[16].

RESULTS

The results of the performance assessment are not final at this time. It is anticipated that results in a draft performance assessment will be submitted to the DOE in the fall. However, preliminary results for the baseline case are discussed below.

Full Garden Scenario - In the baseline case, the 70-year effective dose equivalent to an individual was calculated to be 9 mrem and 15 mrem at 10,000 and 15,000 years respectively. These values correspond to less than 0.2

mrem/year, well below the 5 mrem/year (apportioned) standard. Technetium-99 provides 90% to 95% of this dose; iodine-129 and selenium-79 provide the remainder. The principle chemical contaminant was nitrate, at 0.3% to 0.6% of existing and proposed (apportioned) drinking water standards.

Columbia River - In this scenario, insignificant exposures occur to users of the river water. Exposure to radioactive contaminants potentially released to the river from the grout disposal site results in a cumulative population dose of 0.56 person-rem over the first 10,000 years after disposal. This value can be compared to the nearly 3 billion person-rem that the same population would receive from exposure to background sources. The maximum lifetime population dose received is estimated at 0.013 person rem for the population and 6E-6 mrem for the maximally exposed individual.

SENSITIVITY AND UNCERTAINTY

Areas of uncertainty primarily include assumptions regarding performance of various components of the system over the long-term. Some of the specific assumptions that have been made are that the grout properties remain stable for 10,000 years, the diffusion barrier remains effective over 10,000 years in diverting advecting water from the grout, non-isothermal characteristics of the disposal system will not considerably alter the performance of the system, and the infiltration barrier remains effective over 10,000 years. Experiments are being conducted to help support some of these assumptions.

The sensitivity of the system performance to various parameters is essential to understand the relative importance of various components of the system and to help defend long-term performance assessment. The sensitivity of results in the full garden scenario to variations in the effective diffusivity of species in the diffusion barrier, the effective diffusivity of species in the grout, well location, and water infiltration rates is being analyzed. Results will included in the next draft performance assessment document.

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UNDERSTANDING REMEDIAL ACTION EFFORTS

RCRA CLOSURE OF MIXED WASTE IMPOUNDMENTS

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Abstract

A case study of a RCRA closure action at the Rocky Flats Plant is presented. Closure of the solar evaporation ponds involves removal and immobilization of a mixed hazardous/radioactive sludge, treatment of impounded water, groundwater monitoring, plume delineation, and collection and treatment of contaminated groundwater. The site closure is described within the context of regulatory negotiations, project schedules, risk assessment, clean versus dirty closure, cleanup levels, and approval of closure plans and reports. Lessons learned at Rocky Flats are summarized.

Introduction

The Department of Energy (DOE) Rocky Flats Plant (RFP) is a government-owned contractor operated facility. The RFP has operated solar evaporation ponds for the disposal of waste residues since 1953. These ponds were used to store and evaporate low level radioactive process waste solutions containing high nitrate concentrations. During their use, these ponds received additional wastes such as sanitary sewage sludge, lithium metal, sodium nitrate, ferric chloride, sulfuric acid, ammonium persulfates, hydrochloric acid, nitric acid, hexavalent chromium and cyanide solutions. Solvents and other organics were not routinely discharged to the ponds because of the potential for organics to lead to algal growth. Algal growth would diminish the effectiveness of solar evaporation. However, low concentrations of solvents may have been present as a minor constituent in other wastes. Sludges were present in the ponds due to the precipitation of contaminants. These ponds are currently undergoing Resource Conservation and Recovery Act (RCRA) closure.

RCRA closure of a waste management unit is a procedure by which wastes are removed from the unit and steps are taken to prevent threats to human health and the environment. Closures are known as clean or dirty depending upon the condition of the site on the day that closure is certified. A clean closure is one in which all wastes and waste degradation products are removed or treated to the extent that 1) any contaminants left in the subsoils will not impact any environmental media in excess of specified limits and that 2) direct contact will not result in a threat to human health or the environment. Post-closure care and monitoring are not required for a clean-closed site. A dirty closure is one in which waste or waste degradation products remain at the site in excess of specified limits. Long term monitoring of the site is required for dirty closures, and the existence of the contaminated area must be noted on the property deed.

RCRA closure activities, as specified in 40 CFR 265.113(b)(1), must be completed within 180 days of the start of closure. The start of the closure period is tied to receipt of the last volume of waste or receipt of the approved closure plan, whichever is later. In order to extend the schedule beyond 180 days the applicant must demonstrate that the final closure activities will, of necessity, take longer than 180 days and all steps must be taken to prevent threats to human health and the environment.

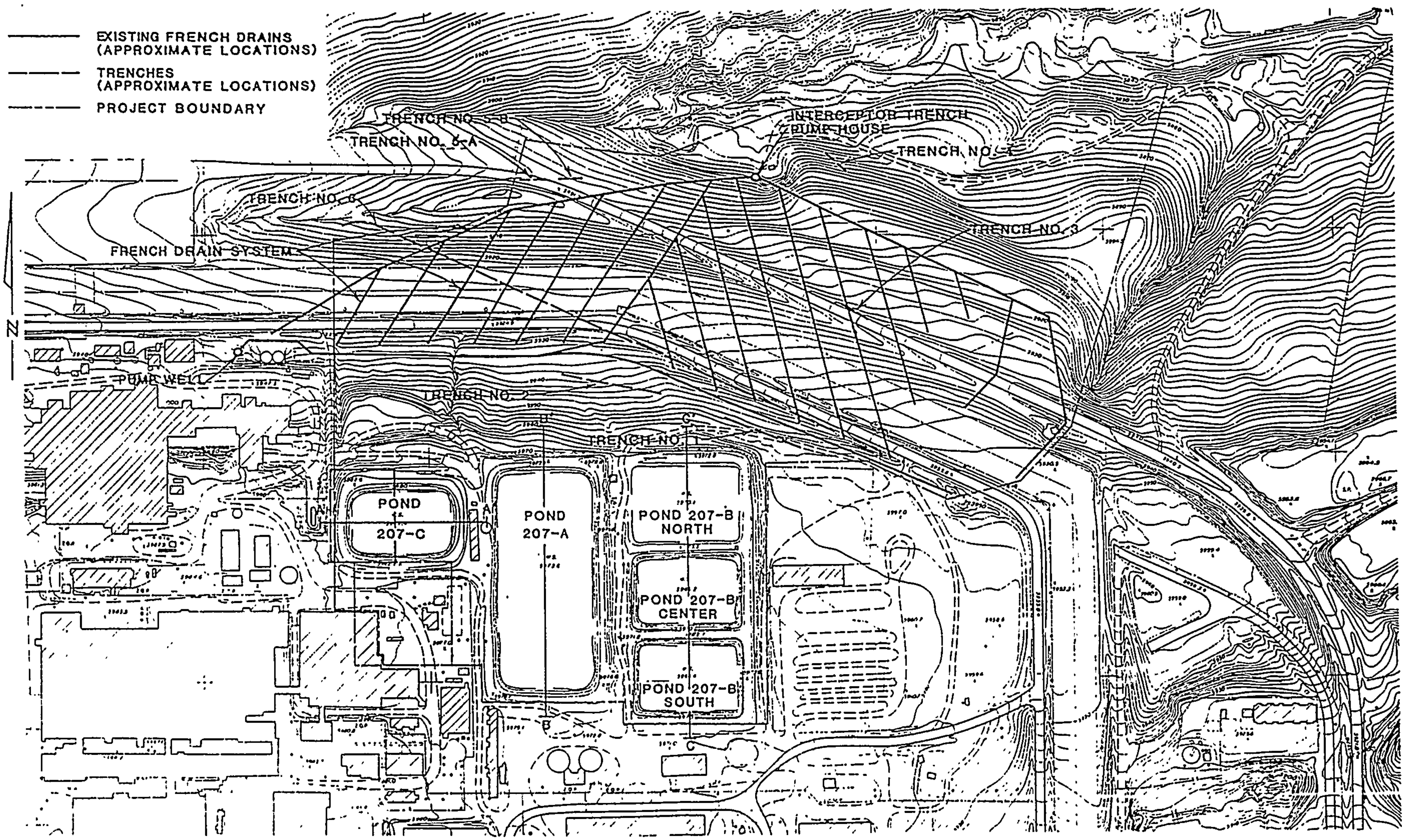
Solar Pond History

The original solar pond consisted of a clay-lined impoundment which was constructed in 1953. This unit was in regular service until 1956 when it was replaced by solar pond 207A, which was constructed of asphalt planking, approximately one-half inch thick. Solar ponds 207B-North, Center and South were placed into service in June 1960 (Figure 1). These ponds were also constructed of asphalt planking. These existing ponds were relined in 1960, 1961 and 1963. The relinings consisted of asphaltic concrete, asphalt tack coats and a catalytically blown asphalt seal coat. The last solar pond, 207C, was constructed and entered service in 1970 (Figure 1). Berm repairs on all ponds and relining on the 207B ponds took place at various times after 1970. These ponds routinely received waste until 1986, at which time routine receipt of waste ceased.

Six interceptor trenches and a french drain system were constructed on the hillside north of the solar ponds to prevent seepage and pond leakage from entering North Walnut Creek (Figure 1). The six interceptor trenches and two sumps were constructed north of the solar ponds in the 1970s. The french drain system was installed north of the solar ponds in the early 1980s, at which time use of the interceptor trenches and sumps ceased. Water collected in the french drain system is pumped back to solar pond 207B-North.

Closure Plan Summary

The anticipated closure activities for the solar ponds are described below. First, the sludges present in the ponds are removed, dewatered, and mixed with Portland cement. This material is allowed to harden and is commonly called Pondcrete. Pondcrete is a mixed waste and is being shipped off-site for disposal. Second, the liquids in the solar ponds are evaporated either through solar evaporation or forced evaporation in a process waste treatment building. During the pondcreting activities, site characterization studies are being conducted to identify routes of



ROCKY FLATS SOLAR EVAPORATION PONDS | LOCATION MAP | Fig. 1

contaminant migration in groundwater, contaminant concentrations in soils, and to help identify appropriate remedial actions. Removal of the pond liners, soil excavation, and construction of a cap over the area are planned remedial actions.

History of RCRA Activities

The issue of the authority of the Environmental Protection Agency (EPA) to regulate low-level mixed waste at the Rocky Flats Plant under the RCRA and CERCLA regulations was resolved at the Rocky Flats Plant on July 31, 1986 when the DOE, EPA and the Colorado Department of Health (CDH) signed a Compliance Agreement. This Compliance Agreement gave the regulatory authorities jurisdiction over hazardous and mixed low-level radioactive and hazardous wastes at the Rocky Flats Plant. One of the major projects identified in the Compliance Agreement was the closure of the solar ponds.

The original Solar Pond Closure Plan was submitted on August 29, 1986 (Rockwell, 1986). This closure plan has been updated or modified several times since the original submission. These revisions were in response to comments received from the regulatory agencies, or due to the need to more accurately reflect the technical requirements of closure. Numerous meetings with the regulatory authorities have been held to resolve closure issues for the solar ponds. Typical issues discussed at these meetings are the closure schedule, protection of human health and the environment, waste/site characterization, risk assessment and clean-up levels. The contents, schedule and approval of the closure plan is awaiting the outcome of an Inter-Agency Agreement that is currently being negotiated for the Rocky Flats Plant.

Closure Schedule

Characterization work at the Solar Ponds had started when the first closure plan was submitted in 1986, but the extent and magnitude of soil and water contamination in the solar ponds area was not yet delineated. Therefore, the schedule for closure could not be accurately predicted. The closure plan provided no details regarding soil and groundwater remediation, treatment of waste residues or capping activities. It was, however, stated that closure would take longer than 180 days since removal and solidification of sludge from the solar ponds required a number of years. No further details or justifications were given for extension of the closure schedule. The schedule identified data needs in a general way, but did not provide details regarding activities and related schedules to generate the required data.

Many of the comments received from CDH and EPA on the closure plans were directly related to the schedule. One major issue was the detail needed to support a greater than 180 day period to close the solar ponds. The revised closure plans submitted in response to comments have realistically anticipated the time activities necessary during the closure period. Assumptions and calculations have been given, along with supporting documentation. For instance, the limiting factor in closure of these ponds has been identified as the water balance around the ponds. Natural evaporation was inadequate to minimize the schedule for closure, so the forced evaporators associated with the process waste treatment system are being used to treat as much solar pond water as possible. This change represents removal of an additional 160,000 gallons per month compared to the average monthly evaporation rate of 367,000 gallons (Rockwell 1987).

The most recent version of the closure plan also provided details on all projects related to minimizing the time required for closure along with some information on the DOE funding process. This information was to demonstrate that all efforts were being taken to minimize the closure time period, and that major capital funding could not be immediately procured. Capital expenditure would be needed to construct an additional waste treatment system. This had been suggested by the regulators as a method to minimize the closure schedule.

In January 1989, the closure schedule was again modified so that actions and activities were not tied to dates. The closure schedule was instead tied to the activity that initiates the beginning of the closure period, receipt of an approved closure plan in this instance. The closure activities were scheduled in days from the beginning of the closure period. This change gives the RFP greater flexibility in completing closure since an approved closure plan has not yet been received. This, combined with difficulty in funding the closure actions, has resulted in delays to previously anticipated schedules. By tying implementation to approval of the plan rather than calendar dates there will be less need to constantly modify the closure schedule.

<u>Protection of Human Health and the Environment</u>

As required in 40 CFR 265.113(b)(2), activities related to protection of human health and the environment were described in the early versions of the closure plan. However, the activities were not specifically tied to protection of human health and the environment, and no interim activities were identified for protection of human health and the environment. These issues were discussed in meetings held in January 1988. The resulting closure plan went into considerable detail regarding protection of human health and the environment, including numerous interim actions to minimize the spread of any contamination (Rockwell 1988). Comments received on other closure plans at Rocky Flats indicate that actions described in a closure plan for protection of human health and the environment should be specific to the unit. It has been stated that general actions taken for protection of human health and the environment, such as general ambient air monitoring, do not meet the requirements of the RCRA closure regulations.

Waste/Site Characterization

To date, site characterization activities at the Solar Ponds have focused on two separate but related problems. The first problem has been the characterization of wastes currently or previously contained in the Solar Ponds. The second problem has been site characterization near the Solar Ponds.

Waste Characterization

Prior to the implementation of RCRA at the Rocky Flats Plant the analyses of solar pond wastes involved only a limited analyte list. More complete analyses were required to address RCRA concerns, so analyses of solar pond water and sludge for the full Hazardous Substance List (HSL) were done on the individual solar ponds. In general, contaminant levels in 207A and 207C were similar, as were the levels in the three 207B ponds, but the 207B ponds were generally two orders of magnitude less contaminated than 207A and C. Concentrations of nitrates in the ponds were found to be approximately 9,000 and 6,000 milligrams per liter (mg/l) in 207A and C, respectively, and approximately 400 mg/l in 207B-North. Tables 1 and 2 summarize the data for metals and radionuclides at the solar ponds. As can be seen from the data, nitrates and radionuclides are most indicative of solar pond wastes. HSL metal compounds are present at relatively low levels.

Site Characterization

Site characterization is directly related to the waste constituents treated, stored or disposed in the unit which caused the release of contamination; it is also related to the anticipated corrective actions necessary to remediate contamination. Site characterization activities near the solar ponds have been performed each year since 1986. Twenty-two groundwater monitoring wells were installed in the fall of 1986, five of these well installations involved soil sampling during installation. Soils were sampled from 16 boreholes in the fall of 1987, two of these boreholes were completed as wells, with two more wells also installed. Thirty-two new monitoring wells have been installed at the solar ponds this year (1989).

The regulators have developed very different interpretations of site characterization data compared to those developed by the RFP and its consultants. In general, the viewpoint of the Department

Table 1. Metal Concentrations in Waste

COMPOUND	POND 207-A LIQUID (ug/L)	POND 207-A SLUDGE (mg/kg)	POND 207-B NORTH LIQUID (ug/L)
Aluminum	2,310-2,640	11,000-11,900	ND[(a)]
Arsenic	150	ND	ND
Barium	ND	ND	ND-220
Beryllium	27-43	309-1,570	ND
Cadmium	70-150	1,110-10,500	ND
Calcium	ND	19,600-50,000	176,000-198,000
Chromium	13,700-16,700	1,010-19,700	ND
Cobalt	200-500	ND	ND
Copper	1,610-1,800	425-1,590	ND
Iron	1,500-8,000	3,590-6,900	ND
Lead	ND	65-455	ND
Magnesium	ND	6,110-21,000	66,400-72,600
Manganese	95-115	153-595	ND-15
Mercury	ND-0.2	7.5-25	ND
Nickel	1,900-2,000	124-1,320	ND-50
Potassium	13,200,000-14,300,000	50,000-65,300	56,100-62,700
Selenium	ND	ND	9
Silver	310-370	153-237	ND
Sodium	36,300,000-42,900,000	130,000-166,000	363,000-451,000
Tin	7,000-13,000	ND	ND
Vanadium	100-210	ND	ND
Zinc	620-780	227-595	ND-22
Phenols	13-35	ND-3.3	3-46

(a) ND indicates compound not detected above the detection limit.

Table 2. Radionuclide Concentrations in Waste

COMPOUND	POND 207-A LIQUID (pCi/L)	POND 207-A SLUDGE (pCi/g)	POND 207-B NORTH LIQUID (pCi/L)
Gross Alpha	46,000±4,000 to 80,000±6,000	4,700±200 to 14,000±1,000	74±58 to 120±50
Gross Beta	35,000±2,000 to 40,000±2,000	160±20 to 1,400±100	56±32 to 100±92
Plutonium-239	56±16 to 660±50	1,000±100 to 3,700±100	ND[(a)]
Americium-241	ND to 45±14	1,400±200 to 4,400±100	ND
Uranium-233+234	14,000±1,000 to 20,000±1,000	71±10 to 570±30	50±2 to 53±2
Uranium-238	21,000±1,000 to 28,000±1,000	130±10 480±30	31±1 to 33±1
Tritium	240±180 to 930±260	1,300±500[(b)] to 12,000±1,000	1,200±300 to 1,300±300

(a) ND indicates levels below the detection error limits.
(b) Units for tritium in sludge = pCi/l

of Health has been that contamination and the consequent threat to human health and the environment is significant. The RFP, in trying to best allocate its limited resources, felt that the presence of major problems should be verified prior to authorizing the expenditure of large sums of money.

The presence of VOC's in groundwater and soils in the vicinity of the Solar Ponds is an example of different interpretations of the data. The low levels of VOC's in the solar pond waste combined with the behavior of VOC's in the environment suggest that VOC's should only be present in the immediate vicinity of the solar ponds.

Traces of VOC's have been consistently identified in some groundwater samples near the solar ponds. Available data indicate that groundwater already contaminated with VOC's and other contaminants is flowing into the solar pond area from upgradient sources. Groundwater contamination present in upgradient solar pond monitoring wells, and other water sources in the area, supports this interpretation.

Detectable VOC concentrations have also been found in some wells downgradient from the solar ponds at a considerable distance. These detectable levels have not been found consistently; subsequent samples have often had non-detectable concentrations. In general, no pattern to these detectable concentrations has been identified. The RFP interpretation of this has been that if VOC's were not detected in subsequent analyses of groundwater from that well, then the presence of VOC's in the earlier sample was probably due to laboratory contamination. If the detection of VOC's was repeated, then the presence of VOC's was considered much more likely. To date, the majority of detectable VOC concentrations in downgradient wells appear to be due to laboratory or sampling contamination of the sample. A major field and laboratory quality assurance program has been put in place over the last year to resolve the issue.

Due to the presence of multiple sources of potential contamination, the source of the VOC contamination in the area is not necessarily the solar ponds. Plumes of contamination from more than one distinct source are a possibility at the RFP. The appropriate handling of coalescing plumes of contamination under RCRA closure is being addressed in the Inter-Agency Agreement. At this time, it appears that a comprehensive approach will be adopted that will integrate the remedial/corrective action requirements of both RCRA and CERCLA regulations.

Risk Assessment/Clean-up Levels

When RCRA site characterization activities began in 1986 it was expected that the RFP fenceline would be the point of exposure for members of the public and that a number of sites, such as the solar ponds, would not be clean-closed. The levels of contaminants permissible in the soils and groundwater near the solar ponds were to be calculated from acceptable levels at the fenceline. CDH deemed this approach inadequate to meet the needs of protection of human health and the environment. They maintain that institutional controls cannot be relied on for a long term period and that direct exposure to any contaminants remaining at the site is possible. The task of identifying soil and groundwater standards, or developing creditable numbers, capable of protecting human health and the environment from direct exposure and ingestion suggests the use of a risk assessment when more applicable guidance is not available. In the early part of 1989 the approach of risk-based clean-up levels for soils and groundwater was presented to CDH. This approach for determining action levels for soils has been conditionally approved by CDH, subject to the following conditions.

- The risk assessment approach must be governed by the cumulative and potential synergistic effects of all contaminants within the unit, it cannot rely on a single or a very few contaminants which, due to their intrinsic toxicity, drive the risk level.

- The risk assessment must assume that direct human contact through dermal exposure, inhalation or ingestion will not result in a threat to human health or the environment.

- The risk assessment must assume a point of exposure to hazardous wastes within the unit boundary for all potential routes of exposure, including groundwater ingestion. No attenuation of any hazardous waste constituent can be assumed to occur before the constituents reach the exposure point.

- The risk assessment approach may not be based on exposure control measures such as fencing, because future use of the property cannot be reliably controlled.
- If standards for exposure to some constituent do not exist, then the constituent must be removed to background levels, or sufficient data must be submitted for the CDH to determine the environmental and health effects of the constituent.

These requirements are extremely restrictive. Evaluation of synergistic effects may require the use of a biomonitoring method. This may represent one of the first applications of biomonitoring to RCRA activities. At the present time, a risk-based approach to closure is being negotiated as part of the Inter-Agency Agreement. A major goal of the Agreement is to achieve consistency between RCRA and CERCLA remedial actions at the Plant.

Summary

The following are the lessons learned at the Rocky Flats Plant regarding closure of mixed waste impoundments.

- Sufficient time for completion of a complete and technically detailed closure plan should be allowed.

- All actions leading up to certification of closure must be explicitly identified. A reasonable approach or estimate must be made of all actions that will, or may be, needed.

- The schedule for closure, especially when it exceeds 180 days, must be extremely detailed. This schedule should detail programs and actions that will be taken to minimize the time schedule for closure.

- Actions taken to protect human health and the environment from the unit must be detailed. It is preferable if these actions are specific to the regulated unit.

- Site characterization activities should be based upon a mutually acceptable approach to site remediation. Discussions should be held with the regulating authorities prior to the first submittal of the closure plan.

- Direct exposure and ingestion may be the required method for determination of site clean-up levels.

- Upgradient monitoring should be provided and additional upgradient wells added if contamination is found in that area. If the probable source of contamination is some other unit, additional work must be conducted to ensure that the source is truly some other area.

- A consistent regulatory interpretation of whether the unit being closed is one or several units (i.e., there are three adjacent solar ponds being closed under one closure plan) must be maintained if the unit is to achieve compliance with all RCRA requirements.

<u>REFERENCES</u>

Rockwell International, Solar Evaporation Ponds Closure Plan, Draft, August 29, 1986.

Rockwell International, Solar Evaporation Ponds Closure Plan, Revision 1, March 1, 1987.

Rockwell International, Solar Evaporation Ponds Closure Plan, Revision 2, July 1, 1988, Appendix to the Post-Closure Care Permit of October 7, 1988.

Remedial Actions: A Discussion of Technological, Regulatory and Construction Issues

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Introduction

The Oak Ridge Reservation consists of approximately 35,252 acres located in the Ridge and Valley Province of the Appalachian Mountains in Eastern Tennessee. Three Department of Energy facilities are located on the Reservation; the Y-12 Plant, the Oak Ridge Gaseous Diffusion Plant and the Oak Ridge National Laboratory. The plants have, over the years, disposed of low-level and mixed waste in various areas on the reservation principally with shallow land burial.

What follows is a discussion of some of the actions to remediate and close areas used for disposal of waste in the past. Current or planned activities for waste disposal and storage are also discussed. Closures completed to date have complied with Resource Conservation and Recovery Act Regulations.

The new approach for disposal and storage has adopted ideas that have been successfully used by the French to dispose of low level waste, as well as, improved on older shallow burial disposal techniques.

Tumulus

The Tumulus consists of an above grade storage/disposal unit for Solid Low Level Waste (SLLW). The Tumulus concept is currently used by France for low level waste disposal. The Tumulus may also accommodate high range SLLW and incorporate the shielding required to meet As-Low-As-Reasonably-Achievable (ALARA) standards. The Tumulus is a new concept with one Tumulus in place, a second in design and several more under study. Figure 1.0 shows a typical tumulus.

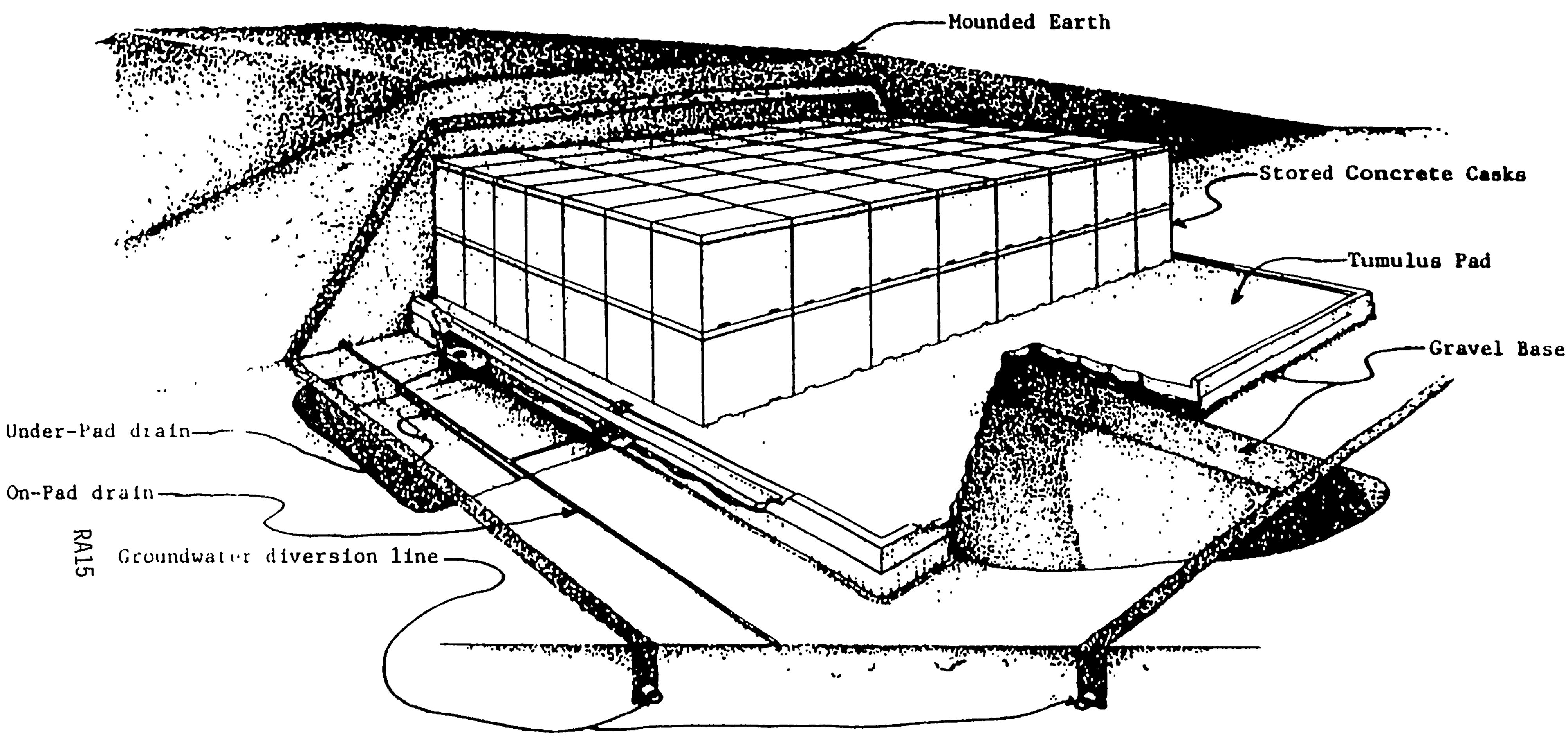
The "Tumulus" technology involves sealing prepackaged waste in concrete vaults and then providing them with a shallow burial. The waste will be packaged in either fifty-five gallon drums or large metal containers and have a radiation level of <2 rem/hr. The void between the containers will be grouted, and the containers will be placed on a curbed grade-level concrete pad, which when filled will be covered with a multi-layered soil cover approximately 7 feet thick. In addition to the tumulus pad, a drainage system will be included for the pad surface. Groundwater monitoring wells will also be provided around the Tumulus. The drain system will be tied to a monitoring system.

Prepared by the Oak Ridge Gaseous Diffusion Plant for the U.S. Department of Energy under Contract No. DE-AC05-84OR21400.

The first tumulus was constructed in Solid Waste Storage Area (SWSA) 6 in the early part of 1987 as part of the Low-Level Waste Disposal Development and Demonstration Program. The purpose of this demonstration was to develop experience and gain information which would help in evaluating the suitability of this technology for the management of solid low-level waste (SLLW) on the Oak Ridge Reservation (ORR). The Tumulus Disposal Demonstration consists of a steel reinforced concrete pad with associated drainage through two surface drains to a monitoring station where continuous flow measurements are recorded and proportional water samples are obtained. A leak detection system, consisting of sand, gravel, and a 30 mil flexible membrane liner, underlies the concrete pad and is attached to the sides of the concrete pad. A drain pipe below the pad was placed in the lower portion of the leak detection system and drains to a sump located in the monitoring station. The pad and liner system is underlain by a sand and gravel layer.

Currently over 120 vaults have been placed on the pad with no serious operational problems having been encountered. Monitoring of vault loading, grouting, and sealing operations and stacking of vaults on the pad have indicated that personnel exposures from these activities are extremely low (less than a few man-mrem/vault). Monitoring of the air, soil, and groundwater surrounding the pad has indicated that tumulus loading operations have not impacted the environment. Monitoring of the surface runoff from the pad and water collected from the liner below pad and gravel drainage base indicate that the zero release goal of the demonstration has thus far been achieved.

Based on the success of this demonstration, Oak Ridge National Laboratory (ORNL) has decided to use the tumulus technology for handling additional Class II category waste in the future. ORNL has already submitted to the Department of Energy (DOE) a Preliminary Proposal for constructing a Class II Tumulus in the southwest portion of SWSA 6. It will consist of six tumulus pads and is currently scheduled to accept ORNL's Class I and II waste during the period from October 1991 to September 1996, when permanent facilities designed to handle these wastes are scheduled to begin operation on the ORR. Class I waste is that waste with less than a 10 mrem dose at time of disposal and is suitable for disposal in a landfill similar to an industrial landfill. It generally is waste with low concentration and may be such things as mops and gloves. Class II waste has the same dose but is engineered for zero discharge in disposal units. Intruder protection is provided for the institutional control period. These dose limits are lower than 10CFR61 requirements.



TYPICAL TUMULUS

FIGURE 1.0

RA15

Landfill Closures

Various operations at the Y-12 Plant and ORNL involved landfill disposal of mixed waste. The landfill disposal operations at Y-12 have been closed under RCRA regulations while the operations at ORNL have been closed for an interim period and will be closed permanently within about two years. The operations at the two sites differed in construction and design because of this fundamental difference in purpose of the two projects. The landfills are referred to as Solid Waste Storage Areas (SWSA).

SWSA 6 Interim Corrective Measure at ORNL

The scope of the Interim Corrective Measure involved:

Placing a synthetic geomembrane cap over the 8 areas which contain RCRA wastes to minimize infiltration from surface water. The area to be covered comprises 10.4 acres.

Construction of berms and ditches to route and collect surface water runon and runoff to existing drainageways.

Upgrading the existing drainageways to accommodate the increased flows resulting from capping.

The construction of each cap included the removal of rocks and other sharp objects, application of a herbicide, and minor contouring of the cap areas before the 80 mil HDPE liner was placed. HDPE was chosen because it is not succeptible to degredation by the chemicals in the trenches. 80 mil was chosen because it would be less likely to be damaged by occasional foot traffic and deer. The cap areas vary from nearly flat to slopes of as much as 10%. The liner is held in place with anchor trenches around the perimeter of each capped area and anchor pillows placed at intervals across the cap. There are a significant number of penetrations through the liner primarily consisting of piezometers and monitoring wells which will be used to characterize the groundwater levels and conditions under the caps.

The hazardous chemicals of principal interest are believed to be lead, xylene, and toluene. Both low-activity and high-activity trenches have received waste containing lead, which was used for containerization and/or shielding of radioactive waste to facilitate safe handling during research and disposal. It is estimated that approximately 150,000 lb of lead have been buried in SWSA 6 since early 1980 (IT, 1986). The biological trenches contain the largest volume of xylene and toluene, which are components of scintillation fluids; however, at least two high-activity trenches (120 and 346) are also listed as containing scintillation fluids. Those trenches listed in Exhibit C.2 are known to have received scintillation vials, but other trenches and auger holes may also have been recipients of RCRA-regulated wastes. Since 1972, it is estimated that more than 12,000 gal of scintillation fluids have been disposed in SWSA 6.

Examination of the Waste Disposal Log indicates that as of May 1986, more than 200,000 Ci had been emplaced in SWSA 6. Major radionuclides include cobalt-60, tritium, strontium-90, cesium-137, europium-152, europium-154, europium-155, and uranium-235; it is estimated that these isotopes comprise about 80 percent of the total curies.

The solvent auger holes received a variety of chemical wastes before 1980, both radioactively contaminated and noncontaminated (IT, 1986). Wastes disposed there included oils, cleaning solutions, alcohols, paint thinners, kerosene, jet fuel, acids (HCl, HNO_3), sodium, and miscellaneous solvents and other chemicals. Containerization ranged from small bottles and cans up to 55-gal drums, and the exact volume of wastes disposed in the solvent holes in unknown. A vapor sample from Monitoring Well 650, which is located near the auger holes, detected a number of organic compounds that included trichlorofluoro-methane, dichloroethylene, methyl ethyl ketone, carbon tetrachloride, benzene, trichloroethylene (TCE), and toulene. The primary constituents were TCE and toluene. However of these compounds, only benzene and toluene were present in limited groundwater and trench leachate sampling.

Closure and Post Closure Activities (CAPCA) - Y-12

Twelve hazardous waste sites located at the Y-12 Plant in Oak Ridge, Tennessee are currently being closed in accordance with Federal Regulations. A project entitled CAPCA is coordinating the planning, management, design and construction of these site closures and support facilities.

In general, the sites are closed with the non-leachable wastes remaining in place in accordance with RCRA Regulations for landfills. Closure consists of structural stabilization of the waste as required and placement of a multi-layered cap to prevent intrusion of surface water into the waste. The solid waste landfills and the liquid and sludge waste impoundments are closed as landfills. The multi-layer caps consist of a 24" layer of compacted clay, a flexible membrane liner, a synthetic drainage layer, and an 18" soil layer for the support of vegetation. A typical cap cross-section is attached.

The CAPCA Project began in late 1987 and is scheduled for completion in 1990. The majority of the construction is anticipated to be this year. The following is a list of the specific sites included in the CAPCA Project.

SITE NAME	TYPE OF SITE	AREA (ACRES)	PROJ. STATUS % COMPLETE
West Borrow Area	Support	40.0	100% Const
East Borrow Area	Support	17.0	100% Const
Lake Reality	Support	2.5	98% Const

S-3 Ponds	Impoundment	5.1	98% Const
BC Burial Ground A	Landfill	17.9	98% Const
BC Burial Ground C	Landfill	7.3	30% Design
BC Burial Ground B&D	Landfill	7.6	Concept. Des.
Security Pits	Landfill	4.1	98% Const
Sediment Disp Basin	Landfill	5.0	60% Const
New Hope Pond	Impoundment	8.9	40% Const
Oil Landfarm	Landfill	12.7	30% Const
Haz Chem Disp Area	Landfill	3.5	30% Const
Burnyard/Boneyard	Landfill	11.1	CFC Design
Oil Retention Ponds	Impoundment	15.0	90% Design

The East and West Borrow Areas are sources of select clay fill material for capping the waste areas. These areas were prepared for use by the contractors closing the various waste areas by clearing the vegetation, providing sediment and runoff control, and constructing haul roads.

Lake Reality is a pond on the east end of Y-12 Plant which serves as a replacement for New Hope Pond. Lake Reality traps sediment from East Fork Poplar Creek which drains the Y-12 Plant.

The S-3 Ponds and New Hope Pond were sites which contained waste sludges and sediment. These sites were stabilized by placing limestone shot rock (6"-24" dia.) into the sludges to provide a structurally stable base. The sites then receive a multi-layer cap. The cap is shown in Figure 2.0.

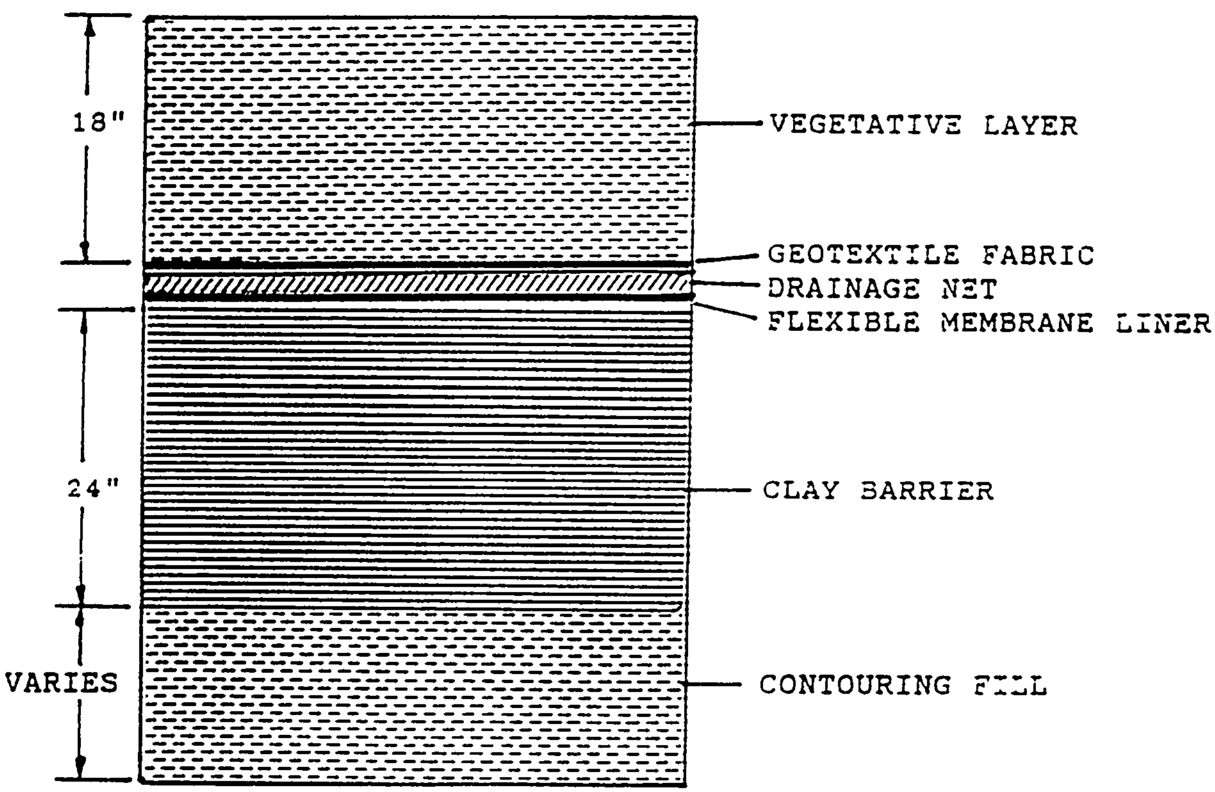
The Security Pits and Bear Creek Burial Ground A, B, C & D are sites underlain by old waste trenches. The Oil Landfarm, Hazardous Chemical Disposal Area, Burnyard/Boneyard, Sediment Disposal Area and Oil Retention Ponds are sites where wastes contaminated the surface or near surface soil. Both types of sites are treated as contaminated landfill areas and are covered with multi-layer caps.

Quarry Closure

Kerr Hollow Quarry is a rock quarry which operated in the 1940's as a rock and gravel quarry, but was abandoned in the late 1940's when the quarry filled with water. Subsequently, the quarry was used for the disposal of water reactive chemicals such as sodium. The quarry currently contains water and the containers in which the reactive wastes were placed in the quarry. Closure is required because unreacted wastes may still exist in the quarry. Closure consists of assuring that no unreacted materials remain in the quarry by breaching the containers underwater. This is currently planned to be accomplished by remote video inspection of the quarry and breaching of select containers. The containers will then be removed and disposed of as standard industrial waste.

Lessons Learned

Several contracting requirements because of OSHA & RCRA requirements should be implemented.



TYPICAL CROSS-SECTION OF CAP

GEOTEXTILE FABRIC: MIRAFI 140N OR EQUAL

DRAINAGE NET: NATIONAL SEAL PN 3000 OR EQUAL

MEMBRANE LINER: 30 MIL PVC LINER

COMPONENTS OF ENGINEERED CAP

FIGURE 1.[illegible]

Approval of acceptable training courses should be written into contract so that in-house review of programs is not required. This can be accomplished by stating the federal regulation that the training must adhere to and calling for a certified letter from the training institution saying they meet federal requirements per 29 CFR1910.120.

Weather has a significant impact on synthetic liner installation. The cooler weather is better for installation because the liner is in a contracted state. In hot weather extra liner is installed to compensate for contraction when the liner cools.

The installation of the liner should be by the same company that manufactures the liner to improve coordination, save time, and improve accountability for performance.

If the liner is not covered with an earthen cap and gas vents are needed, they should be designed to vent above the water runoff level.

The anchor trench design should call for liner to be doubled in the trench for a more secure anchor.

Regulatory Issues

The closures discussed are regulated by the Tennessee Department of Health and Environment and the Environmental Protection Agency. Closure plans were submitted for approval prior to start of construction. Upon completion of construction, certification of the closure is provided to TDHE via DOE that the closure is complete and complies with the approved closure plan. During the course of the closure, if field conditions require a revision to the design, in come cases if significant, the closure plan is revised.

Conclusion

The key ingredients to all these activities is early involvement of the regulatory agencies and a resolution of proposed closure and design, construction and economic restraints.

DOE HAZARDOUS WASTE REMEDIAL ACTIONS PROGRAM (HAZWRAP) WASTE TECHNOLOGY DEMONSTRATION PROGRAM

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One function of the Department of Energy (DOE) Hazardous Waste Remedial Actions Program (HAZWRAP) is to support the field demonstration of waste treatment technologies, both in-house and commercial, to determine the applicability of these technologies in remediating waste problems common to the DOE Defense Programs (DP) installations. A number of innovative technologies have the potential for dealing with DOE-DP Comprehensive Environmental Response, Compensation, and Liability Act-related and Resource Conservation and Recovery Act-related waste problems more economically and/or in a more socially acceptable manner than do current processes. It is the goal of HAZWRAP to critically review emerging technologies and to demonstrate those with the greatest potential for significant effect on the DOE-DP waste management program.

The Technology Demonstration (TD) Program is sponsored by the DOE Headquarters Office of Defense Waste and Transportation Management (ODWTM) through the Hazardous Waste and Remedial Actions Division (HWRAD). Funding is provided through two major management programs: the Hazardous Waste Compliance Technology Program and the Environmental Restoration Program.

A parallel function of HAZWRAP is to promote and expedite research and development (R&D) of selected new technology ideas, through the laboratory stages, for application in the elimination, minimization, destruction, stabilization, or delisting of hazardous and mixed wastes resulting from DOE-DP activities. The techniques are developed by DOE laboratories in cooperation with other governmental agencies and/or the private sector where applicable. The TD Program supports the field demonstration of these technologies when the R&D is completed. The R&D Program is funded by ODWTM through the Waste Research and Development Division and is managed by HAZWRAP.

The TD Program is managed by HWRAD and the HAZWRAP Program Manager. The HAZWRAP Support Contractor Office, staffed by Martin Marietta Energy Systems, Inc., personnel, supports the HAZWRAP Program Manager and HWRAD in their leadership roles. The program formally interfaces with key representatives of the eight field offices and their contractors, and frequent contact is made to establish and maintain program priorities and direction. These relationships are depicted in Fig. 1.

Prepared by the
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RA21
U.S. DEPARTMENT OF ENERGY
under contract DE-AC05-84OR21400

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                SECRETARY OF ENERGY
                         |
      ASSISTANT SECRETARY FOR DEFENSE PROGRAMS
                         |
 OFFICE OF DEFENSE WASTE AND TRANSPORTATION MANAGEMENT
                         |
    HAZARDOUS WASTE AND REMEDIAL ACTIONS DIVISION
                         |
HAZARDOUS WASTE REMEDIAL ACTIONS PROGRAM PROGRAM MANAGER
                         |
                         |--- Support Contractor Office
                         |     (TD Program Manager)
                         |
ALBUQUERQUE OPERATIONS ---|--- OAK RIDGE OPERATIONS
                         |
    CHICAGO OPERATIONS ---|--- RICHLAND OPERATIONS
                         |
      IDAHO OPERATIONS ---|--- SAN FRANCISCO OPERATIONS
                         |
     NEVADA OPERATIONS ---|--- SAVANNAH RIVER OPERATIONS
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Fig. 1. Organization structure for conduct of the Hazardous Waste Remedial Actions Program.

The TD Program began in FY 1986 when discussions were conducted with DOE Operations Offices concerning their particular waste treatment needs. In October 1986 a team of representatives from the eight field offices and Headquarters met to select candidate waste treatment demonstrations. Of the 18 candidate waste treatment problems presented, 3 were selected for demonstration.

In each of the following years the TD Program Manager convened a meeting of the designated Operations Office representatives to review the progress of each of the ongoing projects and to discuss new candidate projects. Each office was requested to provide information on new, high-priority candidate projects that were evaluated and ranked by the representatives based on criteria reviewed and revised as needed at each meeting. At the conclusion of each meeting, a ranked list of the new candidate projects was established. For projects with a high ranking, the TD Program Manager requested that the proposing site submit more detailed information, including costs, schedule, and technical detail. On the basis of this input, the TD Program Manager reviewed each new candidate project with consideration of cost, schedule, and the project's technical differences and compared it with other new candidate and ongoing projects. The results of the TD Program Manager's deliberations were then communicated to Headquarters as recommendations for funding. These recommendations often included a restructuring of the coming fiscal year budget to accommodate the rapidly evolving needs of DP waste management activities.

Following review and approval of the recommendations by Headquarters and the HAZWRAP Program Manager, the TD Program Manager established contact with the appropriate Operations Offices to develop detailed plans for the project. The sites were encouraged to include in the planning the exploration of private industry for new and innovative technological solutions. A common method for this search was the procurement request for proposal (RFP) process. The TD Program Manager closely followed the progress of each project, ensuring that plans were executed within cost and schedule, the technical intent of the project was maintained, and the transfer of the technology was completed.

In August 1987 a second meeting was convened to select more waste treatment problems for demonstration starting in FY 1988. In July 1988 a third meeting was held that combined the ranking of projects for the Compliance Technology Program and the Environmental Restoration Program for initiation in FY 1989. The TD Program has grown from 4 projects in FY 1987 to 20 projects in FY 1989.

These 20 ongoing technology demonstrations are in various project stages, ranging from recent initiation to nearing completion. These waste treatment technologies relate to the following general technology needs of DOE-DP:

Treatment/Disposal of Hazardous Mixed Wastes
Waste Minimization Methods
Standards/Methods for Site Remediation/Stabilization/Closure
Improved Burial Practices and Waste Forms
Pathways Analysis

Each of the ongoing technology demonstration projects is identified and a brief description of the technology is given in Table I. A more detailed description, including objective, status, and expected project duration, is included in Table II.

Table I. Summary of FY 1989 Technology Demonstration Projects

TREATMENT/DISPOSAL OF HAZARDOUS AND MIXED WASTE

- Supercritical Water Oxidation, Phase IV (ALO/LANL) - Demonstration of certain hydrocarbon oxidation reactions in supercritical water for management of hazardous chemical wastes.
- Gas Cylinder Disposal Plant Development, Phase IV (ALO/LANL) - Demonstration of a process for the safe disposal of the contents of unidentified or damaged gas cylinders.
- Treatment/Disposal of Reactive Metals, Phase IV (CHO/ANL) - Demonstration of a spray-burning process for converting reactive metal wastes to a glass product suitable for land disposal.
- Lead Decontamination (IDO/INEL) - Demonstration of a melt-refining system to decontaminate lead.
- Plasma Centrifuge Reactor (IDO/INEL) - Demonstration of use of high-temperature plasma centrifuge reactor to melt and process entire drums of organic-contaminated soils.
- Hexone Tanks (RLO/WHC) - Demonstration of technologies for treatment and disposal of hazardous organic liquids containing radioactive materials and stored in two deteriorating underground tanks.

WASTE MINIMIZATION METHODS

- Substitution for Chlorinated Solvent Degreasers (ORO/Y-12) - Large-scale demonstration of the substitution of aqueous solvents for chlorinated hydrocarbons currently used, including demonstration of recycling methods for spent aqueous solvents.
- Waste Acid Detoxification/Reclamation, Phase IV (RLO/PNL) - Demonstration of processes that reduce the volume, quantity, and toxicity of metal-bearing waste acids generated from metal-finishing operations.

STANDARDS/METHODS FOR SITE REMEDIATION/STABILIZATION/CLOSURE

- Trichloroethylene (TCE)-Contaminated Groundwater (ALO/KCP) - Demonstration of destruction of TCE contained in pumped groundwater by a hydrogen peroxide, ozone, ultraviolet (uv) light treatment system.
- Central Facilities Landfill-II (IDO/INEL) - Demonstration of technologies for nonintrusive locating and monitoring of buried hazardous wastes and for remediating localized hazardous waste contamination.
- Destruction of Volatile Organic Chemicals (VOCs) in Groundwater (ORO/ORNL) - Demonstration of several technologies for the destruction of VOCs contained in groundwater.
- Low-Level Waste Crib (116-B-6-1) (RLO/PNL) - Demonstration of in situ vitrification (ISV) technology to fix fission products and immobilize or destroy hazardous chemicals in soil at a mixed waste site.
- Gasoline Spill (SAN/LLNL) - Demonstration of vacuum venting technology for recovering and processing gasoline constituents from soil and groundwater.

Table I. (Continued)

STANDARDS/METHODS FOR SITE REMEDIATION/STABILIZATION/CLOSURE (Continued)

- Site 300 TCE Spill (SAN/LLNL) - Demonstration of vacuum venting for the removal of TCE from soil and perched groundwater.
- Groundwater Biological Treatment (RLO/PNL) - Demonstration of groundwater biodenitrification and carbon tetrachloride biodegradation using indigenous organisms.
- C&P Area Burning Rubble Pit (SRO/SRL) - Demonstration of bioreclamation of soil and groundwater contaminated with chlorinated hydrocarbons using indigenous bacteria enhanced by vegetation.

IMPROVED BURIAL PRACTICES AND WASTE FORMS

- Landfill Cap Verification (ALO/SNLA) - Field and laboratory studies to observe and simulate fluid movement beneath a landfill cap; results will be used to validate a model.
- Encapsulation Development - Phase IV (CHO/BNL) - Investigation of encapsulation materials for potential application to hazardous waste disposal.

PATHWAYS ANALYSIS

- In Situ Detection of Organics - Phase IV (SAN/LLNL) - Development of remote fiber spectroscopy system for detecting and monitoring selected hazardous organic compounds.
- Retardation Factors for VOCs (SAN/LLNL) - Demonstration of method for determining VOC distribution coefficients and retardation factors from soil and water samples collected from monitoring wells.

ALO = Albuquerque Operations Office
LANL = Los Alamos National Laboratory
CHO = Chicago Operations Office
ANL = Argonne National Laboratory
IDO = Idaho Operations Office
INEL = Idaho National Engineering Laboratory
RLO = Richland Operations Office
WHC = Westinghouse Hanford Company
ORO = Oak Ridge Operations Office
PNL = Pacific Northwest Laboratory
KCP = Kansas City Plant
ORNL = Oak Ridge National Laboratory
SAN = San Francisco Operations Office
LLNL = Lawrence Livermore National Laboratory
SRO = Savannah River Operations Office
SRL = Savannah River Laboratory
SNLA = Sandia National Laboratory - Albuquerque
BNL = Brookhaven National Laboratory

Table II. Description of ongoing Technology Demonstration Projects

PROJECT TITLE: SUPERCRITICAL WATER OXIDATION OF HAZARDOUS CHEMICAL WASTES (PHASE IV)

LOCATION: Los Alamos National Laboratory
Los Alamos, New Mexico

PROJECT OBJECTIVE: To demonstrate the feasibility of the supercritical water oxidation concept for the destruction of hydrocarbon and oxygenated wastes.

WASTE PROBLEM: Liquid wastes containing water, hydrocarbons, and oxygenated compounds are common to most DOE-DP facilities. Technology, in addition to incineration, for the destruction of the hazardous chemical contents of these liquid wastes is desired.

TECHNOLOGY: Above a certain temperature and pressure (647 K and 22.13 MPa), water becomes a fluid that is neither a liquid nor a gas but has some of the characteristics of both. In this state, the solvent properties of water reverse so that nonpolar, organic compounds become soluble and inorganic salts become insoluble. Under these conditions, oxidation of hazardous organic chemicals, such as chlorinated solvents and other hydrocarbons, takes place rapidly and completely. Carbon is converted to carbon dioxide, hydrogen is converted to water, and other components of the hazardous hydrocarbon are converted to an oxidized state. No oxides of nitrogen are generated, however. These properties of supercritical water will be utilized in a process tailored to the needs of DOE-DP facilities.

PROJECT INITIATION: 12/88 PROJECT COMPLETION: 9/91

PROJECT STATUS: This is a new project that will demonstrate a waste technology developed by a HAZWRAP R&D project. A demonstration reactor has been designed, and procurement of component parts is under way. Relevant regulatory requirements are being monitored, although no permits appear to be needed at this time. Contact is being maintained with several private companies that have interests in development of this technology.

Table II. (Continued)

PROJECT TITLE: DEVELOPMENT OF A GAS CYLINDER DISPOSAL PLANT (PHASE IV)

LOCATION: Los Alamos National Laboratory
Los Alamos, New Mexico

PROJECT OBJECTIVE: To demonstrate a system for safely disposing of gas cylinders that are damaged or leaking or whose contents are unknown.

WASTE PROBLEM: Most DOE facilities urgently need a practical method of handling and disposing of the contents of leaking or damaged gas cylinders or cylinders whose contents are unknown. Current safety considerations and environmental regulations have made the past practices of cylinder disposal unacceptable.

TECHNOLOGY: Technology exists within the commercial sector for the recontainerization of the contents of leaking or damaged cylinders or of the unknown contents of a cylinder. Contracts will be placed for the design and fabrication of a mobile system to handle one cylinder at a time. The system under consideration consists of a pressure vessel into which the problem gas cylinder is placed. The pressure vessel can be purged with an inert gas or evacuated with a vacuum pump. After the atmosphere of the pressure vessel has been prepared, a hole is drilled into the side of the problem cylinder with a hydraulically driven, remotely controlled drill located within the pressure vessel. Contents of the cylinder are released into the pressure vessel where the gas can be sampled and identified. Once identified, the gas can be repacked into a new cylinder.

PROJECT INITIATION: 12/88   PROJECT COMPLETION: 9/91

PROJECT STATUS: This is a new project that will demonstrate technology developed by a HAZWRAP R&D project. Commercial gas cylinder recontainerization, treatment, and disposing capabilities, both existing and under development, have been identified. Los Alamos is negotiating a contract for handling and disposal of these problem cylinders, which lend themselves to sampling and analysis and subsequent shipment to off-site treatment facilities. Existing recontainerization technology for unknown/unshippable cylinders has been determined to be available from two sources. Several issues related to procurement and testing of these technologies remain to be resolved.

Table II. (Continued)

PROJECT TITLE: TREATMENT/DISPOSAL OF REACTIVE METALS (PHASE IV)

LOCATION: Argonne National Laboratory
Argonne, Illinois

PROJECT OBJECTIVE: To demonstrate a spray-burning process for converting large quantities of reactive metal waste contaminated with radioactive materials into a glass product suitable for land disposal.

WASTE PROBLEM: Large quantities of waste sodium contaminated with radioactive isotopes of cesium, strontium, and sodium are stored at Idaho and at Hanford. It is estimated that approximately 530 tons is stored, and over 20 tons per year is produced at Hanford. Sodium is reactive with both water and oxygen and must be converted into other chemical forms before disposal.

TECHNOLOGY: The integrated glass formation system for disposal of reactive metal wastes will combine a spray-burn system for handling large quantities of reactive metal wastes, a glass-forming powder delivery system, and a cyclonic reactor to generate an appropriate glass product. The glass-forming powder delivery system and the cyclonic reactor, which were developed at Argonne, will be integrated with the spray-burn system available from a commercial vendor. The process will be demonstrated at the facility of a commercial vendor, who will be selected by the DOE procurement process. Successful completion of the demonstration at the vendor facility will be followed by an evaluation of the process at an appropriate waste sodium storage facility.

PROJECT INITIATION: 12/88 PROJECT COMPLETION: 9/91

PROJECT STATUS: This is a new project that will demonstrate technology developed by a HAZWRAP R&D project. Work progressed on the selection process for a subcontractor to perform the demonstration under the technical guidance of ANL. Intent to award a contract was published, and 20 commercial firms expressed interest in performing the demonstration. The Statement of Work and RFPs are being finalized and will be mailed to all potential bidders by July 1, 1989.

Table II (Continued)

PROJECT TITLE: RADIOACTIVE LEAD DECONTAMINATION DEMONSTRATION

LOCATION: Idaho National Engineering Laboratory
Idaho Falls, Idaho

PROJECT OBJECTIVE: To demonstrate melting/refining as a viable method for the decontamination of lead contaminated with radioactive material.

WASTE PROBLEM: Lead, in various forms, sizes, and shapes, has been used as shielding at virtually all DOE facilities dealing with radioactivity. This contaminated lead is subject to Environmental Protection Agency (EPA) regulations and cannot be disposed of through land burial. The only solution is to decontaminate the lead.

TECHNOLOGY: Bench-scale lead decontamination tests that involved beta/gamma surface contamination have been conducted at INEL with excellent results. This demonstration will use a 10-ton facility to melt/refine lead, in various forms and shapes, to reduce uranium contamination to levels that would permit release of lead for reuse or resale.

PROJECT INITIATION: 12/88 PROJECT COMPLETION: 6/90

PROJECT STATUS: This is a new demonstration project started in FY 1989. Necessary equipment and materials have been acquired for conducting small-scale refining tests in July 1989 on lead contaminated with both uranium and radioactive isotopes. Solidification tests will be conducted on the dross generated during these tests.

Table II (Continued)

PROJECT TITLE: PLASMA ARC FURNACE DEMONSTRATION

NOTE: This is a cooperative demonstration effort between the DOE HAZWRAP TD Program and the EPA Superfund Innovative Technology Evaluation (SITE) Program.

LOCATION: DOE Component Development Integration Facility (CDIF)
MSE, Inc.
Butte, Montana

PROJECT OBJECTIVE: To establish the efficacy of the Plasma Arc Furnace technology developed by Retech, Inc., Ukiah, California, to destroy the organic and immobilize the inorganic constituents of hazardous wastes. Phase 1 constitutes the SITE portion of the demonstration and will use soils from the Butte area that contain hazardous organic chemicals and tailings from the mining operations that contain various metals. Phase II constitutes the HAZWRAP portion and will utilize hazardous waste mixtures of interest to DOE.

TECHNOLOGY: This process destroys organic wastes and reduces the volume of inorganic wastes. Solid and liquid wastes are fed into a rotating reservoir within a centrifugal reactor. Wastes are indirectly heated by a plasma torch; the high temperatures achieved during this process volatilize liquid components of the waste and achieve high destruction efficiencies. Organic constituents are converted to carbon monoxide, hydrogen, and hydrochloric acid, and in some cases, to carbon dioxide and water. The volatilized components are captured and treated in a gas scrubber unit. The inorganic constituents of the waste (soils, metals, etc.) are converted to a vitrified mass.

PROJECT INITIATION: 10/88 PROJECT COMPLETION: 1/90

PROJECT STATUS: This is a new demonstration project started in FY 1989. Modifications at the CDIF to prepare a site for the plasma equipment are 70% complete. The Retech Plasma Centrifuge Reactor is scheduled for transport to Butte in mid-June. The EPA tests are scheduled to begin in September 1989.

Table II (Continued)

PROJECT TITLE: HEXONE TANK WASTE TREATMENT DEMONSTRATION

LOCATION: Hanford Reservation
Westinghouse Hanford Company
Richland, Washington

PROJECT OBJECTIVE: To demonstrate technology for the removal and disposal of organic solvents contaminated with radioactive material and contained in underground storage tanks (USTs).

WASTE PROBLEM: Two deteriorating USTs at the Hanford Reservation contain a total of 34,000 gal of a radioactively contaminated hazardous organic mixture, consisting of hexone, normal paraffin hydrocarbons, tributyl phosphate complexes, and water. To comply with both EPA and Nuclear Regulatory Commission regulations, this mixed waste must first be separated into two fractions that can be handled separately. Total radioactivity contained in the two tanks is estimated at 0.25 Ci of mixed fission products.

TECHNOLOGY: This remediation demonstration focuses on three technologies: (1) radioactive decontamination of the liquid through in situ steam stripping or distillation of the organics from the tanks, (2) destruction of the collected organics by incineration, and (3) solidification of the radioactive tars and residuals for subsequent disposal as solid radioactive mixed waste in a permitted area.

PROJECT INITIATION: 5/87   PROJECT COMPLETION: 12/90

PROJECT STATUS: Contents of both USTs have been sampled and analyzed. Pilot-scale tests to select the most efficient method for decontamination of the liquid were conducted; the process selected was distillation. Field-scale equipment has been designed, and fabrication is nearly complete. Five railroad tank cars have been acquired for temporary storage of the cleaned hexone before its incineration. Distillation activities are expected to begin in August 1989. The procurement process for hexone incineration services has started.

Table II (Continued)

PROJECT TITLE: CHLORINATED SOLVENT SUBSTITUTION AT THE Y-12 PLANT

LOCATION: Oak Ridge Y-12 Plant
Oak Ridge, Tennessee

PROJECT OBJECTIVE: To demonstrate the substitution of a nonhazardous degreasing process (using water and a detergent) for a process using a chlorinated solvent currently in use in maintenance operations.

WASTE PROBLEM: Some degreasing operations at the Y-12 Plant utilize a system that uses a chlorinated solvent (HydroSeal) plus freon in an ultrasonic bath. This solvent contains methylene chloride, which is an EPA-recognized carcinogen and which will also soon be covered under DOE Order 5480.10 (Carcinogen Control Program). Successful substitution will reduce chlorinated solvent disposal problems and also demonstrate compliance with waste minimization plans.

TECHNOLOGY: This demonstration will seek a process from the private sector that will replace the current process that uses a chlorinated solvent. Procurement, installation, and testing of the new process are major phases of the demonstration. This project will interface with the nationwide DOE-DP nuclear weapons complex chlorinated solvent substitution programs through established working committees.

PROJECT INITIATION: 12/88 PROJECT COMPLETION: 9/90

PROJECT STATUS: This is a new demonstration project started in FY 1989. Specifications and cost estimates are being prepared on the ultrasonic cleaning system that will be utilized in the demonstration. An outline was prepared and work begun on preparation of a report documenting work that has been conducted over the past several years at the Y-12 Plant on the replacement of chlorinated solvents. Involvement of project personnel with the DOE Chlorinated Hydrocarbon Solvents Coordinating Committee continues.

Table II (Continued)

PROJECT TITLE: WASTE ACID DETOXIFICATION AND RECLAMATION (PHASE IV)

LOCATION: Pacific Northwest Laboratory
Richland, Washington

PROJECT OBJECTIVE: To demonstrate processes that reduce the volume, quantity, and toxicity of metal-bearing waste acids generated from metal-finishing operations.

WASTE PROBLEM: Metal-finishing operations at DOE-DP facilities produce quantities of waste acids contaminated with radioactive materials. Detoxification and reclamation of these acids will produce an economic benefit in that the reclaimed acid can be recycled, and the amount of material for disposal is considerably reduced.

TECHNOLOGY: By using distillation, precipitation, and filtration processes, the following goals will be achieved: (1) principal metal ions such as Zr, Cu, and U will be removed from waste acid without reducing acid concentration; (2) the resulting rejuvenated acid will be recycled; (3) anions such as nitrates and fluorides as acid from wastes will be reclaimed by distillation with sulfuric acid; and (4) a residual sulfate waste with low concentrations of nitrates, heavy metals, and radionuclides will be produced.

PROJECT INITIATION: 12/88 PROJECT COMPLETION: 9/91

PROJECT STATUS: This is a new project that will demonstrate technology developed by a HAZWRAP R&D project. Precipitation and distillation were identified as the most feasible processes for reclaiming metals and recycling spent acids. Copper and zirconium were removed from actual spent acid streams with 85% recovery using oxalic acid and sodium fluoride, respectively. Vacuum distillation in a batch packed column demonstrated 80% recovery of acid and a 40% reduction in waste volume from a process stream containing uranium, nitric acid, and sulfuric acid. A 10 gal/h system has been designed, and construction will be completed this year. The system will test simulated spent acid streams from various DOE plants in FY 1990. The equipment will be transferred to an operating facility for on-site demonstration in FY 1991.

Table II (Continued)

PROJECT TITLE: TRICHLOROETHYLENE-CONTAMINATED GROUNDWATER TREATMENT DEMONSTRATION

LOCATION: DOE Kansas City Plant
Allied-Signal Aerospace Company
Kansas City, Missouri

PROJECT OBJECTIVE: To demonstrate the destruction of chlorinated hydrocarbons contained in pumped groundwater by liquid-phase treatment with hydrogen peroxide, ozone, and uv radiation.

WASTE PROBLEM: This demonstration is being conducted on TCE-contaminated groundwater located below a tank farm at the DOE Kansas City Plant. The top of the water table lies 10 to 15 ft below the ground surface, and the zone extends downward to a depth of about 35 ft. TCE concentrations in the pumped groundwater reach several parts per million.

TECHNOLOGY: Groundwater is extracted through water recovery wells and is passed through a hydrogen peroxide, ozone, uv treatment system. The cleaned water is being discharged to the city sanitary sewer system.

PROJECT INITIATION: 5/88 PROJECT COMPLETION: 9/90

PROJECT STATUS: The treatment unit has been operational for approximately 12 months. To date, approximately 1.5 million gal of groundwater has been successfully treated. The uv/ozone treatment unit has been producing effluent water that meets all permitted discharge standards. Problems have been encountered, however, with iron and manganese oxidizing within the system and clogging the sparger tubes and coating the uv lamp sheaths. The manufacturer is currently working on the system and making modifications to increase the treatment efficiency and the ozone generation capability.

Table II (Continued)

PROJECT TITLE: CENTRAL FACILITIES LANDFILL-II REMEDIATION DEMONSTRATION

LOCATION: Idaho National Engineering Laboratory
Idaho Falls, Idaho

PROJECT OBJECTIVE: To demonstrate technology for the nonintrusive locating and monitoring of buried hazardous wastes and to investigate technology for the remediation of localized hazardous waste contamination.

WASTE PROBLEM: The Central Facilities Area (CFA) Landfill-II received various hazardous wastes over the period of operation from 1951 to 1982. The types of waste received include waste solvents contained in drums. The quantities of EPA hazardous waste are fairly well known, but the burial locations are not.

TECHNOLOGY: The objective of this project is to find new methods to identify and control localized contaminated areas rather than to remediate the entire landfill. The project includes three phases: (1) obtain site characterization information, (2) obtain and demonstrate technology for nonintrusive locating and monitoring of localized waste sites, and (3) obtain and demonstrate innovative localized remediation technology. Technology will be sought from the private sector through RFPs.

PROJECT INITIATION: 5/87 PROJECT COMPLETION: 9/90

PROJECT STATUS: The hydrogeological characterization of the site was completed. Six shallow monitoring wells were drilled and instrumented. Drilling problems were encountered in the two deep wells in the form of a heaving sand layer at 628 ft below land surface; completion of these wells was delayed. The RFP to private industry for technology applicable to this project was issued in December 1988 and the contract issued in June 1989. The survey technologies to be used include a variety of geophysical methods combined with a localized soil gas survey. The geophysical methods include magnetometry, electromagnetometry (EM), transient electromagnetometry (TEM), ground-penetrating radar (GPR), and complex resistivity. In addition, a field test of the Ultrasonic Ranging and Data System (USRADS) combined with a magnetometer and an EM31 terrain conductivity meter will be conducted in June 1989 by ORNL. These studies will concentrate on the feasibility and applicability of the various methods to the hydrogeological setting of INEL.

Table II (Continued)

PROJECT TITLE: DESTRUCTION OF VOLATILE ORGANIC CHEMICALS IN GROUNDWATER

LOCATION: Oak Ridge National Laboratory
Oak Ridge, Tennessee

PROJECT OBJECTIVE: To demonstrate several of the most promising treatment methodologies available from the private sector for the removal or destruction of VOCs in groundwater.

WASTE PROBLEM: The presence of trace quantities of VOCs in groundwater at DOE facilities is a common and pervasive problem.

TECHNOLOGY: This project consists of the off-site demonstration, on a pilot scale, of several of the most promising treatment methodologies available from the private sector for the removal or destruction of VOCs in groundwaters from the Oak Ridge Reservation. Results should facilitate the comparison of the performance, capability, and costs of the selected methodologies.

PROJECT INITIATION: 12/88 PROJECT COMPLETION: 9/90

PROJECT STATUS: This is a new demonstration project started in FY 1989. A request for expressions of interest was issued to the private sector; responses were requested by the end of June 1989. A draft Statement of Work was prepared and is under review.

Table II (Continued)

PROJECT TITLE: LOW-LEVEL WASTE CRIB (116-B-6-1) REMEDIATION DEMONSTRATION

LOCATION: Pacific Northwest Laboratory
Richland, Washington

PROJECT OBJECTIVE: To demonstrate the most appropriate technology to "fix" fission products and immobilize or destroy hazardous chemicals in the soil at a mixed hazardous waste site.

WASTE PROBLEM: This low-level waste crib (116-B-6-1) received radioactive wastes from equipment decontamination from 1951 to 1968. In addition to fission products, this crib also contains sodium dichromate, sodium oxalate, and sodium sulfomate. The crib is approximately 14 by 18 ft.

TECHNOLOGY: Based upon preliminary site characterization information, the ISV process appears suitable for treatment and stabilization of this site. The ISV technology involves conversion of contaminated soil into a durable glass and crystalline waste form through melting by joule heating. An electric current is passed between electrodes placed in the soil, creating temperatures sufficient to melt the soil (about 1700°C) and to produce, upon cooling, a vitreous mass of relatively high strength and chemical integrity. The project will include (1) a remedial investigation to locate, identify, and quantify the contaminants present in the crib; (2) verification that the ISV technology is applicable to remediate the site; and (3) a demonstration of the ISV technology at the site.

PROJECT INITIATION: 2/88 PROJECT COMPLETION: 9/91

PROJECT STATUS: A GPR survey was performed to provide a more accurate determination of the location and depth of the crib and surrounding underground structures. Following this survey, boreholes were drilled into and adjacent to the crib to obtain soil samples for chemical and radionuclide characterization. Preliminary data indicate that the major part of the contamination is located just below the crib (at about 14 ft) and decreases to background at a depth of about 25 ft. An engineering scale ISV test was performed to verify that ISV is capable of vitrifying the contaminants, soil, and wooden timbers expected at the crib site; the results confirmed that ISV technology is applicable. Initial preparations are under way at the site, and the ISV system will be moved onsite by late summer.

Table II (Continued)

PROJECT TITLE: GASOLINE SPILL REMEDIATION DEMONSTRATION

LOCATION: Lawrence Livermore National Laboratory
Livermore, California

PROJECT OBJECTIVE: To demonstrate innovative in situ processing technology to remove and process organics (gasoline) from affected soil and groundwater for restoration of the quality of water in the affected water-bearing zones.

WASTE PROBLEM: This demonstration is being conducted on a reasonably well-defined spill of leaded gasoline that leaked from a UST over a period of several months in 1978 to 1979. Gasoline constituents penetrated to a depth of about 130 ft and expanded over a diameter of about 120 ft. Concentrations of the constituents of gasoline in the soil range from a few parts per billion to 80,000 ppb, depending upon depth. Concentrations in the groundwater are in the several-parts-per-billion range.

TECHNOLOGY: The demonstration will include mobilization and removal of gasoline constituents from soil, both water-saturated and water-unsaturated, to depths of 150 ft by use of an induced venting process. This process involves application of a partial vacuum created by a vacuum blower system connected to a venting well. The gas flow containing gasoline vapors, air, and water coming from the venting well will be processed through air strippers, with the organic vapors vented through a thermal oxidizer. To treat the water-saturated zones, the water table will be depressed by use of dewatering pumps at the base of the venting well. Induced venting will operate concurrently with the dewatering operation.

PROJECT INITIATION: 4/87 PROJECT COMPLETION: 9/90

PROJECT STATUS: A multiply completed extraction well was installed, and each of the five individually screened intervals in the unsaturated zone was tested for fuel hydrocarbon concentrations. A vacuum extraction system with thermal oxidizer was put into operation, with monitoring of vapor concentrations at the wellhead and after the oxidizer. Calculations based upon flow rates and hydrocarbon concentrations indicate that about 3300 gal of fuel has been removed through May 1989. This has been accomplished over an accumulated operation time of 1140 hours. These operations demonstrated the effectiveness of vacuum extraction for removing fuel hydrocarbons from the unsaturated zone. Hydrocarbon concentrations in the uppermost zone (20 to 25 ft) declined significantly (from >2600 ppm to <50 ppm). Deeper zones have not shown significant decreases. Consequently, extractions in the recent months have been focused on zones 2 through 5.

Table II (Continued)

PROJECT TITLE: SITE 300 TRICHLOROETHYLENE SPILL REMEDIATION DEMONSTRATION

LOCATION: Lawrence Livermore National Laboratory
Livermore, California

PROJECT OBJECTIVE: To demonstrate the technique of induced vacuum venting for the removal of TCE from soil and perched groundwater.

WASTE PROBLEM: This demonstration is to be conducted on TCE leakage from a process system line that has contaminated a soil interval about 14 ft thick and about 25 ft below the surface. The lateral extent of the contamination covers an area about 300 ft in diameter. The lower portion of the contaminated soil lies in a perched water zone.

TECHNOLOGY: This project will demonstrate a process involving induced venting by applying vacuum to a series of wells completed and screened in the affected soil interval. The induced gas flow through the soil, created by the partial vacuum maintained on the well bore, will cause the trapped TCE to volatilize and move toward the well bore in an areal sweep process. Entrained TCE in the effluent air stream from the wells will be disposed of through surface-mounted processing equipment. The soil will be dewatered to near the bottom of the contaminated soil interval to expose the soil to the venting process.

PROJECT INITIATION: 5/88 PROJECT COMPLETION: 9/90

PROJECT STATUS: Two pilot remediation systems were constructed and installed at the Building 834 Complex. The systems consist of a dual-tank air sparging unit for extraction and treatment of groundwater and an induced vacuum unit for extraction and discharge of TCE vapors from the unsaturated zone. The first system was installed near the southern, downgradient end of the TCE plume. In 6.5 months of operation, about 20,000 gal of water was extracted. TCE concentrations in the extracted water have declined from 19 ppm (by weight) to about 0.2 ppm. TCE concentrations in the extracted vapors have declined from about 6 ppm (by volume) to about 2 ppm. The second system is installed near the center of the 834 Complex in the vicinity of the TCE leaks, where TCE concentrations in water range up to 400 ppm (by weight). About 4300 gal of water containing about 10 pounds of TCE has been extracted. Extracted vapors contain up to 730 ppm (by volume); about 500 pounds of TCE has been removed. Thus far, the project demonstrated that air sparging and induced vacuum extraction are effective methods to remove TCE from groundwater and from sparingly permeable soil and rock.

Table II (Continued)

PROJECT TITLE: GROUNDWATER BIOLOGICAL TREATMENT DEMONSTRATION

LOCATION: Pacific Northwest Laboratory
Richland, Washington

PROJECT OBJECTIVE: To demonstrate a biological process for the destruction of nitrates and organic contaminants in groundwater.

WASTE PROBLEM: Liquid wastes have been generated over the 40 years of Hanford site operations. Some of these liquid wastes that were discharged to the soil contained radioactive and hazardous chemicals as well as nitrates. Groundwater from the U1/U2 crib area contains nitrate in excess of 400 ppm and up to 600 ppb of carbon tetrachloride. This groundwater also contains uranium and other heavy metals.

TECHNOLOGY: This project will demonstrate technology to destroy nitrates and specific organic contaminants in groundwater using facultative anaerobic microorganisms. Laboratory tests have been conducted using microorganisms capable of simultaneous destruction of both nitrates and carbon tetrachloride. Tests will be conducted using a pilot-scale bioreactor system, developed in FY 1988 for another project, first on simulated groundwater and then on actual groundwater at the U1/U2 crib area.

PROJECT INITIATION: 12/88 PROJECT COMPLETION: 3/91

PROJECT STATUS: This is a new technology demonstration project started in FY 1989. Initial tests with simulated groundwater (nonradioactive) are partially complete. Tests are being performed with a pilot-scale bioreactor system consisting of a bioreactor, clarifier, feed tanks, and associated control and monitoring equipment. Denitrification tests were completed in April 1989, and the results demonstrated that the system could be operated at feed rates exceeding design while producing an effluent nitrate concentration below drinking water standards. Carbon tetrachloride destruction tests were initiated in May 1989. These tests using simulated groundwater will continue through FY 1989; tests with groundwater from the U1/U2 crib site will begin in FY 1990.

Table II (Continued)

PROJECT TITLE: C&P AREA BURNING RUBBLE PIT BIORECLAMATION PROJECT

LOCATION: Savannah River Site
Aiken, South Carolina

PROJECT OBJECTIVE: To develop and implement an environmental project for demonstrating/evaluating the potential of in situ bioreclamation for cleanup of shallow subsurface contamination and bioreactor bioreclamation of deep subsurface contamination resulting from disposal of chlorinated hydrocarbons in an unlined waste disposal facility.

WASTE PROBLEM: Disposal of liquid chemical wastes in the past consisted of discharge and/or burning in small, shallow, unlined basins. Over the period from 1956 to 1974, burning rubble pits at the Savannah River Plant were used in this manner. The soil (at a depth of 1.5 ft) has detectable amounts of perchloroethylene (PCE) and TCE at levels of 44.8 and 5.5 micrograms per gram of soil, respectively; the groundwater contains these same contaminants at much lower levels.

TECHNOLOGY: The first subtask is a demonstration of in situ bioreclamation of contaminated soil using microorganisms enhanced by vegetation. Indigenous bacteria have been isolated that aerobically degrade chlorinated alkenes and alkanes to carbon dioxide, hydrochloric acid, and water. These microorganisms will be selectively enhanced in subsurface soils by planting and cultivating certain types of vegetation. The second subtask is a demonstration of bioreclamation of contaminated groundwater using a bioreactor containing indigenous bacteria.

PROJECT INITIATION: 2/88 PROJECT COMPLETION: 9/91

PROJECT STATUS: Soil samples and plants were taken from the site to set up laboratory vegetation microcosm studies. The soil samples were characterized for particle size distribution, nutrient content, and cation exchange capacity. Rhizosphere and edaphosphere soils were collected so that microbial degradation of PCE could be evaluated. Live plants from the site were transferred to greenhouses for study. Laboratory studies are continuing with a new series of bioreactor tests.

Table II (Continued)

PROJECT TITLE: LANDFILL CAP VERIFICATION DEMONSTRATION

LOCATION: Sandia National Laboratories
Albuquerque, New Mexico

PROJECT OBJECTIVE: To investigate the performance of an impermeable composite-cap closure of a chemical waste landfill in the mitigation of contaminant migration in the vadose zone resulting from water infiltration.

WASTE PROBLEM: This demonstration is to be conducted on an unlined landfill used for shallow burial of a variety of wastes. This landfill will be capped for closure with funds from other sources in FY 1990. The landfill is situated in unsaturated alluvium (primarily sand and gravel) about 500 ft above the water table. Hazardous wastes contained at this site include mineral acids, oxidizing and reducing agents, organic compounds, metals, inorganic salts, and chromic acid in concentrations up to several hundred parts per million in near-surface soil. This landfill was in operation from 1962 until 1980.

TECHNOLOGY: The demonstration consists of a field test of the effectiveness of the cap method by direct measurement of water infiltration adjacent to and beneath the cap. Measurements include moisture content, soil moisture tension, and permeability. Complementary laboratory measurements include soil moisture retention and moisture flow experiments.

PROJECT INITIATION: 12/88   PROJECT COMPLETION: 9/90

PROJECT STATUS: This is a new demonstration project started in FY 1989. Primary activities were the collection of all available data on the landfill site and the development of new data on surface sediments and geological features. A laboratory permeameter was constructed and tested for the determination of saturated hydraulic conductivity on samples collected at the site. Neutron probes for in situ moisture determination were acquired, and field testing is under way. Construction of tensiometers and thermocouple psychrometers for in situ determination of capillary pressure head is under way. A location adjacent to the landfill was established as a site for development, field testing, and calibration of instruments.

Table II (Continued)

PROJECT TITLE: ENCAPSULATION DEVELOPMENT - PHASE IV

LOCATION: Brookhaven National Laboratory
Upton, Long Island, New York

PROGRAM OBJECTIVE: To demonstrate the application of encapsulation materials and technology developed in the HAZWRAP R&D Program for the treatment of selected hazardous chemical wastes.

WASTE PROBLEM: Many of the DOE-DP plants and laboratories produce hazardous chemical and mixed waste streams. Disposal of these stored wastes is a problem common to the DOE-DP complex.

TECHNOLOGY: Specific wastes, such as incinerator ash, sludges, and toxic metals, have been selected as potential candidates for application of new or improved encapsulation materials that are not currently being used for the encapsulation of radioactive and/or hazardous waste materials. These encapsulation materials include polyethylene, sulfur cement, and polyester-styrene.

PROJECT INITIATION: 1/89 PROJECT COMPLETION: 9/92

PROJECT STATUS: This is a new project started in FY 1989 to demonstrate technology developed in the HAZWRAP R&D Program. The feasibility of using polyethylene as a solidification agent for nitrate salt wastes has been demonstrated on a bench-scale. High volumetric efficiencies (70 wt%) were obtained using a single screw-type extruder at 120^{o} C. The EPA Extraction Procedure test indicated that the nitrate release from this encapsulated form was an order of magnitude lower than the regulatory limit for drinking water standards. Confirmatory work is currently under way using actual nitrate salt waste from the DOE Rocky Flats Plant. Planning for the demonstration activity is under way.

Table II (Continued)

PROJECT TITLE: IN SITU DETECTION OF ORGANICS - PHASE IV

LOCATION: Lawrence Livermore National Laboratory
Livermore, California

PROJECT OBJECTIVE: To demonstrate the application of a fiber-optic-based system for monitoring contaminant species in groundwater. Development of optrodes (optical chemical sensors) chemistries for detecting TCE and chloroform was carried out in the HAZWRAP R&D Program.

WASTE PROBLEM: The problem of monitoring groundwater at multiple in situ locations for selected hazardous organic compounds with remote instrumentation exists at most DOE-DP sites.

TECHNOLOGY: Optical chemical sensors have been developed that are compatible with optical fiber spectrometers. Optrodes have been developed that are selective for TCE in the presence of chloroform. The instrumental system will be demonstrated under field conditions with actual waste streams and in underground water locations.

PROJECT INITIATION: 1/89 PROJECT COMPLETION: 9/92

PROJECT STATUS: This is a new project started in FY 1989 to demonstrate technology developed in the HAZWRAP R&D Program. Much of the work has involved planning the project, obtaining and modifying equipment for field use, and calibrating optrodes. Several cabled optrodes have been fabricated and are ready for field application. Most of the low-level (below 1 ppm) calibrations are completed, and higher level (above 1 ppm) calibrations have been started.

Table II (Continued)

PROJECT TITLE: FIELD-BASED MEASUREMENT OF RETARDATION FACTORS

LOCATION: Lawrence Livermore National Laboratory
Livermore, California

PROJECT OBJECTIVE: To demonstrate field-based measurement techniques for determining the distribution of solutes between solid and liquid phases in a heterogeneous geological setting. Methods will be developed to incorporate the spatial variability of the field-measured distribution into predictive modeling of the rate of plum movement, extent of site contamination, and the effectiveness of remedial processes.

WASTE PROBLEM: There is a need for improved models for use in predicting plume movement/distribution in geologic formations.

TECHNOLOGY: Analytical data will be derived from the numerous monitoring and extraction wells being installed at LLNL. These data will be used to improve the accuracy of the retardation factors currently used in various models used to predict movement of contaminants in underground geologic formations.

PROJECT INITIATION: 1/89 PROJECT COMPLETION: 9/90

PROJECT STATUS: This is a new technology demonstration project started in FY 1989. An algorithm was developed to calculate the field-based retardation factors. Sensitivity analyses were done involving parameters such as bulk soil density, skeletal density, and distribution coefficient to quantitatively establish the degree of accuracy needed in individual parameters to ensure desired accuracy in the final retardation factors. Comparison of solid structure determinations were performed on LLNL soils to evaluate such methods as wet weight/dry weight analyses, mercury porosimetry, dry gas pycnometry, and fluid volume displacement. Comparisons of VOC extraction techniques used during EPA Method 8010/8020 analysis have begun to identify methods that yield the best estimate of total VOCs in well core samples. Procedures were examined to improve field and laboratory handling of saturated core samples to minimize loss of VOCs.

DEPARTMENT OF ENERGY SUPPORT TO OTHER FEDERAL AGENCIES:

EXPERIENCES WITH THE INSTALLATION RESTORATION PROGRAM

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ABSTRACT

The Hazardous Waste Remedial Actions Program (HAZWRAP), in addition to its role as the focus for hazardous waste management for the Department of Energy Defense Programs, also provides technical support to other federal agencies. HAZWRAP currently manages over 130 projects in support of the Department of Defense (DOD) Installation Restoration Program (IRP). The IRP is DOD's program for identifying past disposal sites and for mitigating hazards to public health and the environment. This paper relates the history of this involvement, lessons learned during the relationship, and initiatives that are being implemented to facilitate response to regulatory requirements.

INTRODUCTION

Through interagency agreements with various components of the Department of Defense (DOD), the Department of Energy (DOE) Oak Ridge Operations Office is providing technical resources for the characterization of and remedial planning for hazardous waste sites at military bases throughout the United States. The DOE assists the DOD in implementation of its Installation Restoration Program (IRP), by which DOD meets the requirements of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), the Superfund Amendments and Reauthorization Act of 1986 (SARA), and other relevant statutes. The support is provided through the Hazardous Waste Remedial Actions Program (HAZWRAP) support contractor, Martin Marietta Energy Systems, Inc. (Energy Systems).

Energy Systems subcontracts with environmental services firms to complete the projects. Energy Systems provides subcontract management and technical oversight for the tasks. The types of projects conducted by HAZWRAP cover the full range of steps outlined in the National Contingency Plan (NCP) of CERCLA regulations - Preliminary Assessment (PA), Site Inspection (SI), Remedial Investigation/Feasibility Study (RI/FS), and Remedial Design (RD) - except for actual implementation of Remedial Actions.

Prepared by the HAZWRAP Support Contractor Office, operated by Martin Marietta Energy Systems, Inc., for the U.S. Department of Energy under DE-AC05-84OR21400.

HAZWRAP is currently conducting about 130 projects at 100 military bases for several sponsors. A breakdown of the types of projects is given in Table 1. Very few of these projects include sites containing radioactive wastes. Since a large portion of DOE wastes are either radioactive or mixed (radioactive and chemical), a direct extrapolation from the IRP to DOE environmental restoration efforts may not be possible. However, there are a number of similarities between the situations facing the two agencies, and elements of the DOD experience can be of benefit to DOE. For example, both agencies maintain large facilities and have been the sole tenants for 30 to 40 years; thus there is no controversy as to the ownership of the wastes. Many of the facilities are listed on the National Priorities List (NPL) but include sites that range from the seriously threatening to those that pose little threat to health and the environment.

Table 1. Installation Restoration projects assigned to HAZWRAP.

Project description	In progress	Complete
Preliminary Assessments	5	22
Preliminary Assessments/ Site Inspections	2	0
Site Inspections	22	9
Remedial Investigations	9	1
Remedial Investigations/ Feasibility Studies	69	2
Feasibility Studies	0	0
Remedial Designs	2	1
Remedial Actions	2	1
Other Projects	19	11
Totals	130	42

This paper discusses some issues that have arisen during HAZWRAP's involvement with the DOD and that may have common application to remediation of low-level waste problems.

INTEGRATION OF NEPA AND CERCLA

The National Environmental Policy Act of 1969 (NEPA) requires that environmental considerations be a part of the decision-making process when significant amounts of federal dollars are being expended. Procedural requirements include assessment of environmental consequences of proposed actions, weighing of environmental impacts with other considerations, and public participation in decisions regarding selection among alternative actions. Implementation of these procedures can result in the preparation of either Environmental Assessment or Environmental Impact Statement documents with provision for regulatory and public comment.

CERCLA also requires evaluation of environmental impacts of remedial alternatives, along with engineering assessments of cost, schedule, and technical considerations in the RI/FS. Regulatory and public involvement is a clearly stipulated part of this process. However, EPA provides no definitive guidelines that stipulate that fulfilling CERCLA requirements satisfies an agencies' requirements to comply with NEPA.

The DOD's policy regarding the integration of NEPA and CERCLA recognizes that NEPA applies to actions taken under the IRP and that DOD cannot assume that IRP documents are the functional equivalent of NEPA documents. However, since it is not the purpose of NEPA to foster the generation of paperwork, DOD policy states that feasibility studies can be conducted in a manner that simultaneously ensures that the single FS report meets the requirements of NEPA and CERCLA. If this option is chosen, it is essential that all meetings with regulators and the public, as well as the FS report itself, make clear that the FS process is intended to meet both regulatory requirements.

FOCUSED FEASIBILITY STUDIES

One objective of the National Contingency Plan of CERCLA is to facilitate cost recovery from responsible parties. To accomplish this, sites must be characterized, and cost-effective alternatives must be selected. The RI/FS in these cases must be detailed and completed to reduce potential litigation. At federal facilities, ownership of the wastes is generally not in question, and the cognizant agency has assumed responsibility for cleanup. For some types of waste sites, remedial alternatives are few and have often been well demonstrated. It is therefore superfluous to conduct a full FS to select a remedial action. It is necessary, however, for the federal decision maker to document the selection process and to record the rationale upon which the selection was made. An FS can be conducted to consider a narrow list of criteria and to set options that have been proven to be applicable to the specific waste type. Sound engineering judgement must be used to decide whether this approach is justified on a case-by-case basis. If appropriate, such a "focused" FS can be completed in less time and for a lower cost than a full FS. Nonetheless, in certain situations defensible decisions can be made and effective remediations can be implemented sooner.

DECISION DOCUMENTS

Under the NCP, a Record of Decision (ROD) document is the process by which the course of action for NPL sites was selected and concurrence reached among concerned parties. For non-NPL sites, it is no less important to formalize the decision-making process and to obtain agreement with regulatory agencies. The ROD is often an unsatisfactory vehicle for non-NPL sites because the scope and cost are not needed for these lesser sites. Beginning in 1986, HAZWRAP, in coordination with the Air Force, initiated development of a Decision Document (DD) to record decisions at a non-NPL site at an Air Force Base in Florida. This document became the model for an Air Force policy letter issued in January 1988. The DD is used whenever a significant event needs to be made part of the administrative record. Among the events that call for documentation are decisions to (1) take no further action, (2) select a remedial alternative, (3) implement an immediate removal, and (4) implement long-term monitoring.

HAZWRAP has completed DDs for nearly 50 sites at multiple installations across the country and is preparing many more. The DDs are limited in scope and are not intended to be stand-alone documents. Rather they summarize previously published data and reference the reports in which detailed information is to be found. A suggested format for the DD is given in Table 2.

As can be seen from the table, the DD is a simple document. Typically the DD consists of from 10 to 15 pages. The Introduction merely states the objectives of the DD. The Background section provides summary information on past waste disposal activities and site characterization efforts, an assessment of the types of wastes found, and a description of potential pathways and receptors with a brief assessment of risks. Section 3 of the DD lists potential remedial measures, the criteria against which the measures were evaluated, and the rationale for selection of the preferred alternative. The selection is reaffirmed in the Conclusions section below to which signatures of the cognizant federal agency and the concurring regulatory agencies are affixed.

The Air Force has been successful in removing many sites from further consideration using the DD. The DOE may be able to use a similar mechanism to reduce the number of sites it must continue to track and fund.

Table 2. Format for a Decision Document

1. Introduction

2. Background
    2.1 Site Description
    2.2 Chemical Characteristics
    2.3 Migration Pathways and Receptors
    2.4 Risk Assessment

3. Control Measures
    3.1 Identification of Control Measures
    3.2 Evaluation of Control Measures
    3.3 Selection of Control Measures

4. Conclusions

5. References

    Signatures - Cognizant Agency and Regulatory Agency

MULTIDISCIPLINARY REVIEW

Although HAZWRAP has employed highly qualified environmental services firms to carry out IRP projects, we have found it necessary to institute multidisciplinary technical and management review of contracted work to ensure consistency, cost-effectiveness, and technical adequacy. To this end, HAZWRAP has assembled a staff that includes geologists, chemists, environmental scientists, engineers, and specialists for risk assessment and quality assurance that are available as needed to support projects. The benefits of this review are many. First, contractors may not be sensitive to policies regarding response to regulatory requirements which can vary among sponsors. Review from the policy perspective ensures consistency of approach in fulfilling these requirements.

In our experience, contractors usually take a conservative approach to the design of remedial investigations that can result in high cost. Often such investigations produce data in excess of what is needed to make sound judgements regarding selection of alternatives. In other cases, inadequate provisions are made for data collection. Review of project plans for data objectives and supporting rationale for the RI can focus the approach more directly to obtain the necessary information at a reduced cost. Review of the plans for technical content, including details of field procedures and quality control requirements, helps to ensure that the data collected will be of sufficient quality to defend selection of the preferred alternatives.

Included in the review of contractor performance should be periodic field audits and surveillances to monitor the implementation of project plans. Our experience reveals that contractors often ignore approved sampling plans, especially procedures for equipment decontamination and sample preservation. Likewise, deviation from plans in the field is generally poorly documented. Audits identify deficiencies and recommend resolutions for preventing repeated violations.

Validation of analytical data and review of conclusions presented in reports also need review from management and technical viewpoints. Recommendations for actions may be highly dependent upon funding and schedule information that may not be available to the contractors.

SUMMARY

In 4 years of support to DOD's CERCLA program, HAZWRAP has gained experience that can be of use to DOE in management and restoration of low-level waste problems. Exchange of lessons learned between the two federal agencies is an effective use of funds and expertise in efforts to solve national environmental problems. This paper has given examples of policy implementation and technical approaches that may benefit low-level waste programs.

PROGRAM OPTIMIZATION SYSTEM*

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1. OVERVIEW

The Program Optimization System (POS) constitutes a structured approach intended to help the Department of Energy (DOE) decide how to make the most effective use of funds for cleaning up hazardous waste sites at national defense nuclear facilities. It is being used in developing the budget for the Environmental Restoration (ER) Remedial Actions (RA) Program directed by DOE's Hazardous Waste and Remedial Actions Division. The current ER budget is $350 million, and the long-term cost of the ER Program is estimated in the tens of billions of dollars. POS provides a quantitative measure of value of possible ER field office budget levels, and shows how any total budget can be allocated among facilities to optimize that value. It is intended to ensure that the allocation of ER funds among facilities and regions of the country is technically defensible and even-handed, and perceived to be so by the affected parties and their elected representatives who must approve the annual budgets for the Program.

2. BACKGROUND

For more than 40 years DOE and predecessor agencies have operated a vast complex to produce nuclear weapons and materials for national defense. This complex, managed by seven DOE field offices, includes 17 facilities in 13 states and seven Environmental Protection Agency (EPA) regions. Historical operations at these facilities have left a legacy of hundreds, and perhaps thousands, of sites contaminated with radioactive and hazardous chemical wastes. These sites must be examined and considered for remedial actions under the Resource Conservation and Recovery Act and the Comprehensive Environmental Response, Compensation, and Liability Act.

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Congress recently gave added impetus to DOE cleanup activities by establishing a specific ER element in the DOE budget. Projected resource requirements for the ER Program are tens of billions of dollars over several decades. All sites cannot be studied and cleaned up immediately, even if the budget were unlimited - which it is not. DOE is, therefore, faced with the challenge of reconciling the priorities and limitations of a national program with the desires of states, EPA regions, and communities to obtain fast, effective action at their individual sites. Recognizing the need for a systematic, rational approach to environmental restoration, Congress directed DOE DP to establish a priority system so that available ER RA funds would be applied "to achieve the greatest benefits to health, safety, and protection of the environment from further damages." POS is DOE DP's response to that directive.

3. MAIN FEATURES

POS has several noteworthy features. First, it uses a proven formal analytical procedure that requires key technical and value judgments to be both explicit and quantitative. It is based on a well-accepted technique, developed and documented over the past 40 years, for dealing with problems that involve many competing objectives. [This technique, formally known as multiattribute utility analysis, is a systematic method for the application of expert judgment to complex decisions. It has been used by DOE in characterizing and ranking potential candidate sites for high-level radioactive waste repositories.] DOE believes a more informal approach, in which key judgments remain implicit and, therefore, not subject to scrutiny, would not be sufficient in view of the need for a process that is seen by the affected parties as technically sound and fair.

Second, POS focuses on the total ER RA Program at each facility, instead of on the individual tasks that make up those programs. For example, the Richland Operations Office (RL) has close to 1,000 release sites in their ER Program. POS allocates funds to the RL ER Program, and RL, in turn, prioritizes the funds among their release sites or tasks. Other priority systems rank individual tasks in order of preference and then drop off the lowest ranked projects that exceed the available budget. In contrast, POS evaluates the entire set of projects proposed for a particular facility as a whole. This allows DOE Headquarters (HQ) to deal with only a relatively small number of alternative programs for each facility instead of a much larger number of individual tasks. In addition, it allows consideration by each field office of interdependencies among tasks and of partial funding of tasks, thereby avoiding the "all-or-nothing" decisions about tasks normally produced by task ranking systems.

Third, POS balances the perspectives of DOE HQ and the field offices. DOE views ER RA as a national program with national priorities, but HQ lacks detailed knowledge about specific sites and local concerns. The field offices have hands-on knowledge of sites, communities local concerns, states, and EPA regions, but also, quite understandably, they have a somewhat parochial perspective. To balance the two different views, POS involves a sharp division of labor and responsibility:

- o HQ establishes rules for the system and makes value judgments concerning objectives of the program and their relative importance.

- o Field offices develop proposed ER RA programs and provide technical judgments about their anticipated effectiveness. These proposals then undergo a quality assurance process designed to avoid intentional or unintentional biases.

4. STEPS IN APPLICATION OF THE PROGRAM OPTIMIZATION SYSTEM

In developing POS, DOE HQ identified important criteria for the ER RA Program, developed quantitative scales for measuring achievement of those objectives, and determined their relative importance. POS, in turn, considers health and safety issues, regulatory responsiveness, public concerns, impact on the DOE defense mission, and costs. Health and safety for private citizens living in the area receives the greatest weight. Other objectives may be added later.

To apply POS to a particular budget year, field offices propose complete ER RA programs for each of their facilities, assuming up to five possible funding levels for those facilities. (See Table 1.) Each field office then scores its alternative programs against the quantitative scales for each objective developed by HQ. These scores are reviewed and, if necessary, revised at a workshop involving representatives from all field offices and DOE HQ. Strong peer review is part of the workshop.

After much discussion and possible revisions from the peer review comments, final scores are then combined using explicit value judgments made by HQ to develop an overall measure of value for each program at each facility. Finally, a POS computer program is used to determine the allocation of the total ER RA budget among the field offices and facilities that would produce the greatest net gain.

4.1 Identification of Objectives

As a basis for comparing different programs, POS requires identification of the objectives the programs are to achieve, and numerical scales or "yardsticks" for measuring the degree of achievement. The ER RA Program criteria used in POS were selected by HQ based on judgments about (a) the importance of the objectives and (b) the ability of ER program activities to make a significant difference with regard to those objectives. It is important to recognize that a high level of concern about a particular objective does not by itself justify its use in a budgeting system. Unless funds can be effectively used to help achieve that objective, it is irrelevant to the budget process.

Table 1. List of DOE DP facilities scored in the FY 1991 POS application

Field Office	Facility/Installation
Albuquerque	Kansas City Plant Los Alamos* Mound Facility Pantex Plant Pinellas Plant Rocky Flats Plant Sandia - Albuquerque** Sandia - Livermore **
Idaho	Idaho National Engineering Laboratory*
Nevada	Nevada Operations Office
Oak Ridge	Fernald Feed Materials Production Center Oak Ridge Gaseous Diffusion Plant Oak Ridge National Laboratory* Y-12 Plant
Richland	Richland Operations Office
San Francisco	Lawrence Livermore*
Savannah River	Savannah River Plant

* National Laboratory
** National Laboratories

4.1.1 Health and Safety

Not surprisingly, health and safety is the first objective of the program. The challenge for POS is how to estimate risks and potential reductions resulting from ER RA activities, given that for many sites there is very limited information about what type and level of contamination and danger is there and how much of a real risk it presents.

POS allows several alternative bases for health and safety scores. If available, results of a detailed site-specific risk analysis are used. In the absence of a detailed risk analysis, the favored basis for health and safety scores is the Health Potential Index (HPI) developed for the Environmental, Safety and Health (EH) survey of DOE DP facilities conducted by the Assistant Secretary for Environment, Safety, and Health. This survey produced a ranking of sites in terms of their potential risk. The results of this ranking can not be used directly in POS because the ranking deals with individual sites at each facility rather than with the entire ER RA Program for the facility. Also, it does not consider the potential for reducing risks through ER RA activities. The survey focuses on the magnitude of potential problems, while POS focuses on the effectiveness of possible solutions. However, the survey's HPI scores for sites at each facility are used in POS to estimate an overall health and safety score for the whole facility in cases that no ER RA activities can improve. HPI in these cases provides a basis for scoring the "no-action" option. POS uses this option to measure the effectiveness of alternative programs. This provides a direct link between POS and the EH survey. Estimates of how alternative programs can reduce those HPI scores are then made by the field offices based on their best technical judgment.

Other available risk estimates can be used to justify health and safety scores if necessary or appropriate. For example, scores from the Hazard Ranking System (HRS) developed by EPA might be used instead. A part of the health and safety scale corresponding to levels 3 and 4 on a 1-to-5 scale is shown in Table 2. We anticipate that as the ER RA Program progresses, judgments can be based to an increasing extent on detailed risk analyses for specific sites and proposed remedial actions.

4.1.2 Regulatory Responsiveness

The ER RA Program is governed by a complicated set of regulatory requirements involving federal and state laws, and multiparty agreements between DOE, EPA, and affected states developed under those laws. There are many explicit schedules for action, with deadlines (hammer dates) established in law or in enforceable agreements. The deadlines relate to actions ranging in importance from procedural requirements such as production of documents to substantive matters such as progress on specific remedial actions. All of these requirements must be considered in deciding where to spend available funds.

DOE policy is to comply with all applicable laws and regulations. If funds were unlimited and there were no technical limits to what could be accomplished in any given year, full responsiveness to all regulatory requirements would be a prerequisite for any proposed ER RA Program. However, it appears that in at least some cases it may not be technically feasible to meet all regulatory requirements regardless of how much money is spent. Furthermore, in the real world of large estimated future costs of ER RA activities and serious federal budget constraints, it is possible that appropriations may not be adequate to allow full responsiveness to every regulatory requirement, no matter how minute. In that event DOE will have to make some extremely tough

Table 2. Performance measure scale for health and safety risk.

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3 = The public health and safety risks occurring under the program funding level are MODERATE. Thus, either the health and safety risks attributable to the sites are inherently only moderate, or they are reduced to moderate levels as a result of the activities included in the program. The conclusion that the risks are moderate is substantiated by calculations using data and/or models.

- If models are used to substantiate the conclusion that risks are moderate, then it must be the case that when the models are applied using inputs consistent with the conditions and scenarios that might reasonably exist under the program, the results indicate current and future impacts to public health (attributable to the sites) that are about the average of what are typically computed.

- Suppose the aggregate HPI score for all sites associated with the facility was calculated using appropriate inputs. The result would have to be around 60 to add credibility to the judgment that risks are moderate.

- If an HRS score was computed for the facility using appropriate inputs, the result would be around 40.

- If such calculations were to be made, the individual risk to the most highly exposed member of the public would be less than 10^{-4}. Also, if calculated, the total expected annual health effects (computed by weighting estimated health effects under alternative scenarios by the probabilities of the scenarios) would be around 0.1.

- Alternatively, the conclusion of moderate risk might be justified if it can be convincingly argued that there are low-probability scenarios producing significant public health impacts, or, if the probability of such scenarios is moderate, then the only significant health effects that would occur would take place in the distant future.

4 = The public health and safety risks occurring under the program funding level are HIGH. Thus, either the health and safety risks attributable to the sites are inherently high and the program activities do not significantly reduce these risks, or the activities are only capable of reducing the risks to levels that are still high. The judgment that the risks are high is substantiated by calculations using data and/or models.

- If models are used to substantiate the conclusion that risks are high, then it must be the case that when models are applied using inputs consistent with the conditions and scenarios that might reasonably exist under the program, the results indicate current and future impacts to public health (attributable to the sites) that are higher than those that are typically computed.

- Suppose the aggregate HPI score for all sites associated with the facility was calculated using appropriate inputs. The result would have to be around 70 or greater to add credibility to the judgment that risks are high.

- If an HRS score was computed for the facility using appropriate inputs, the result would be around 60.

- If such calculations were to be made, the individual risk to the most highly exposed member of the public would be less than 10^{-3}. Also, if calculated, the total expected annual health effects (computed by weighting estimated health effects under alternative scenarios by the probabilities of the scenarios) would be equal to or greater than 1.

- Alternatively, the conclusion of moderate risk might be justified if it can be convincingly argued that there are likely scenarios that generate public health impacts and/or low-probability scenarios with great consequences.

Source: A Program Optimization System For Aiding Defense Programs Evnironmental Restoration Decisions - An Application to FY 1991 Budgeting, May 1989.

decisions about priorities among regulatory requirements, and between regulatory requirements and other important objectives such as health and safety considerations.

POS includes a specific regulatory responsiveness scale to help DOE determine whether full responsiveness is achievable at all, and to make the difficult trade-offs among objectives if funding limits the ability to respond to all regulatory requirements. The scale is a tentative estimate of the level of responsiveness that would occur if the budget level in question is received in the target year and if there is no change in projected funding in the preceding years. The regulatory responsiveness scale provides an "early warning" indicator that a proposed funding level for a field office, or for the ER RA Program as a whole, might not ensure full responsiveness to all applicable laws, regulations, and agreements. The scale also shows whether additional funding would make a difference.

4.1.3 Public Concern

It is an understatement to say that the public is concerned about cleanup of DOE sites. It is this concern that most directly affects the public's elected representatives, and it must be taken into account in budget decisions. Other things being equal, we want to allay concerns and anxieties to the maximum extent possible. One would hope that an emphasis on health and safety would do this. But public concern, technical assessments of real health and safety risks, and regulatory requirements are not always in complete alignment. As a result, an independent measure was developed to allow balancing of public concerns with other objectives when they are competing rather than complementary.

4.1.4 National Security

Threat to DOE's national DP mission is another consideration in POS. Obviously, successful achievement of DOE's national security mission is very important. If failure to perform any particular ER RA action would lead to a direct and immediate threat to a significant part of that mission, POS will allocate funds to it. Unlike other objectives which allow varying degrees of achievement, this is a constraint that will always be satisfied if at all possible. However, in POS an appeal to the threat-to-mission argument is an extreme measure that must be justified to HQ. It cannot be made lightly. It can be compared to an appeal to the Supreme Court.

4.1.5 Cost

Obviously, DOE wants to achieve the most results for the least cost. POS takes an innovative approach to cost that ensures that the full costs of alternatives, not just the budget year costs, are taken into consideration. This is done by subtracting from the value of a program an estimate of future program costs beyond the budget year in question. These future costs are divided into two categories: (1) remaining costs to complete ongoing remedial actions, and (2) changes in cost of future activities. The first category, remaining costs, reflects the "mortgage" associated with beginning a multiyear activity. Because POS allows the full value of an action to be credited in the year the action is started, it is appropriate to set against that value the full costs required to complete the action - not just the costs in the first year. Remaining costs are subtracted from the value of the project, so that if two projects have the same positive effects and the same initial Fiscal Year (FY) costs, the one with lower remaining costs will have the higher net gain and, therefore, be recommended for higher priority for funding.

The second category, changes in costs of future activities, reflects another important consideration. It is a measure of urgency that allows POS to give extra emphasis to problems that become more expensive to solve the longer action is delayed. An example is a site with a contaminant plume that is spreading. If reduced program funding delays cleanups and thereby increases the ultimate cleanup costs, an estimate of the cost increase caused by the delay is subtracted from the program value associated with the funding level causing the delay. This reduces the net gain of that funding level. The effect is to favor additional FY expenditures that reduce future costs.

4.2 Specification of Relative Importance of Criteria

Once criteria and yardsticks are defined, HQ makes judgments about relative importance. This is often seen as a difficult and controversial step, but such value judgments are unavoidable in any difficult decision. POS requires they be made explicitly and quantitatively so that they can be subject to review. Two kinds of value judgments are made. The first concerns the relative value of improvements at the high and low ends of the measurement scales for each objective. This corrects for the possibility that the steps in a scale might not all have the same value. The second concerns the "weight" to be given to each objective. In POS, health and safety is given by far the heaviest weight, followed by regulatory responsiveness and then public concern. The weights can easily be changed to test whether the particular value judgments they reflect make a significant difference in POS results, and to assess the implications of different judgments.

4.3 Field Offices Use of Program Optimization System

Field offices provide the technical judgments required to make POS work. The first step is to develop alternative programs for each facility for up to five possible funding levels ranging from zero funding (the "no action" option, included as a baseline reference only), to a maximum case representing the field office's own estimate of the highest funding that could be used productively at the facility. [Because of the large disparity in size of ER RA programs among the 17 facilities, not all facilities define programs for five budget levels. Some of the lowest-cost facilities (Kansas City, Mound, Pinellas, and Sandia-Livermore) score only three programs: zero-level or "null," target, and maximum programs. All others include a minimum program representing the minimum budget level that can produce some benefit. Only facilities for which the cost difference between the minimum and target programs, or between the target and maximum programs, exceed $10 million are asked to score additional programs for a "decremented" budget about halfway between the minimum and target levels, or an "enhanced" budget about halfway between the target and maximum levels.]

The focus on total programs rather than individual projects is an innovative and valuable part of POS. In the first place, by allowing HQ to deal with 17 programs (one for each facility) rather than hundreds or thousands of separate projects, it makes the whole process more manageable. In addition, it gives the field offices great latitude to determine the best mix of tasks for each funding level, taking into account interactions among tasks as well as the concerns and interests of the local community, state, and EPA region. It allows the field office to consider partial funding of tasks (e.g., through schedule stretch-outs) rather than the "all or nothing" choices commonly involved in project ranking systems.

These advantages come at a cost. Developing several complete programs requires considerable effort from the field offices. In addition, it means that program values are calculated only for a small number of specified budget levels for each facility. POS does not deal with funding levels at a facility that lie between the specified levels that were evaluated. Because some of the increments between funding levels are very large at the larger facilities, the appropriate budget level for the facility may lie in-between. For this reason, for any total ER RA budget level, POS only finds an "optimal" allocation among the facilities that is in the right "ballpark." Additional discussions between HQ and the field office, and judgments by HQ, are required to determine a final allocation. Thus, POS does not prescribe a single right answer. It aids DOE's budget decisions, but does not make them.

4.4 Field Offices Score Programs Against Objectives

Once programs have been defined for each facility and alternative funding level, field office personnel score each program in terms of how well it performs on each of the objective scales defined by HQ. This is obviously a critical step in using POS, and it has an obvious potential problem: while the field offices have the technical expertise and best available site-specific knowledge needed to do the scoring, they also have a vested interest in seeing the results lead to a higher allocation for their facilities. Furthermore, with scoring done by seven different groups, there is always the possibility of an unintentional bias resulting from different interpretations of the scales.

To minimize these potential problems, the process includes several protections. First, HQ developed a scoring manual and conducted training sessions for field office personnel using expert consultants. Consultants were also provided as necessary to help individual field offices in their scoring process.

Second, each field office must defend its scores to the other field offices and HQ in a peer review workshop. The goal of the workshop is to reach a consensus about the scores or any appropriate revisions. (See Fig. 1.) Disagreements must be reconciled by vote. The experience so far shows that there are few disagreements that cannot be resolved through consensus.

4.5 Computation of Optimal Allocations

Once the programs have been scored and the scores reviewed and approved by the workshop, a computer program (technically multiattribute utilities) is used to convert the raw scores into net values for each alternative program for each facility, using the value judgments discussed above. Then, for each possible budget level, the computer finds both the highest attainable net value and the allocation among the facilities (the combination of funding levels for the facilities) that produces that value. (See Fig. 2.) A computer is needed because there are billions of possible combinations of funding levels for the 17 facilities. The number that must be considered is reduced by using three rules to eliminate some allocations: (1) no facility is allowed to have zero funding, (2) no facility is allowed to have a serious threat to the national defense mission, and (3) inequitable allocations are not considered unless they produce a significantly higher value than more equitable alternatives. More than a billion combinations remain, of which only several hundred are optimal. This suggests that it is unlikely that anyone could guess the best allocation available for any total budget level. It takes about 5 minutes on a personal computer to find the optimal allocations.

The computer produces a curve showing the maximum total value that can be achieved for each total budget level, and the allocation of that budget among the 17 facilities needed to produce that total value. The total curve can be used to help determine appropriate levels for appropriations requests, and the allocation helps determine the division among the field offices.

To see how sensitive the results are to the scores and the value judgments, the model is rerun a number of times to determine the effect of different assumptions. This analysis has shown that the results of POS are relatively stable. Small changes in scores, costs, or weights produce small and predictable changes in POS results. This has enhanced confidence that POS produces useful insights for funding decisions.

5. FUTURE IMPROVEMENTS

Development of POS involved simplifications to keep it manageable. For example, POS excludes some factors (such as environmental impact) that might be considered important. It does not deal directly with uncertainties in the cost and effectiveness of

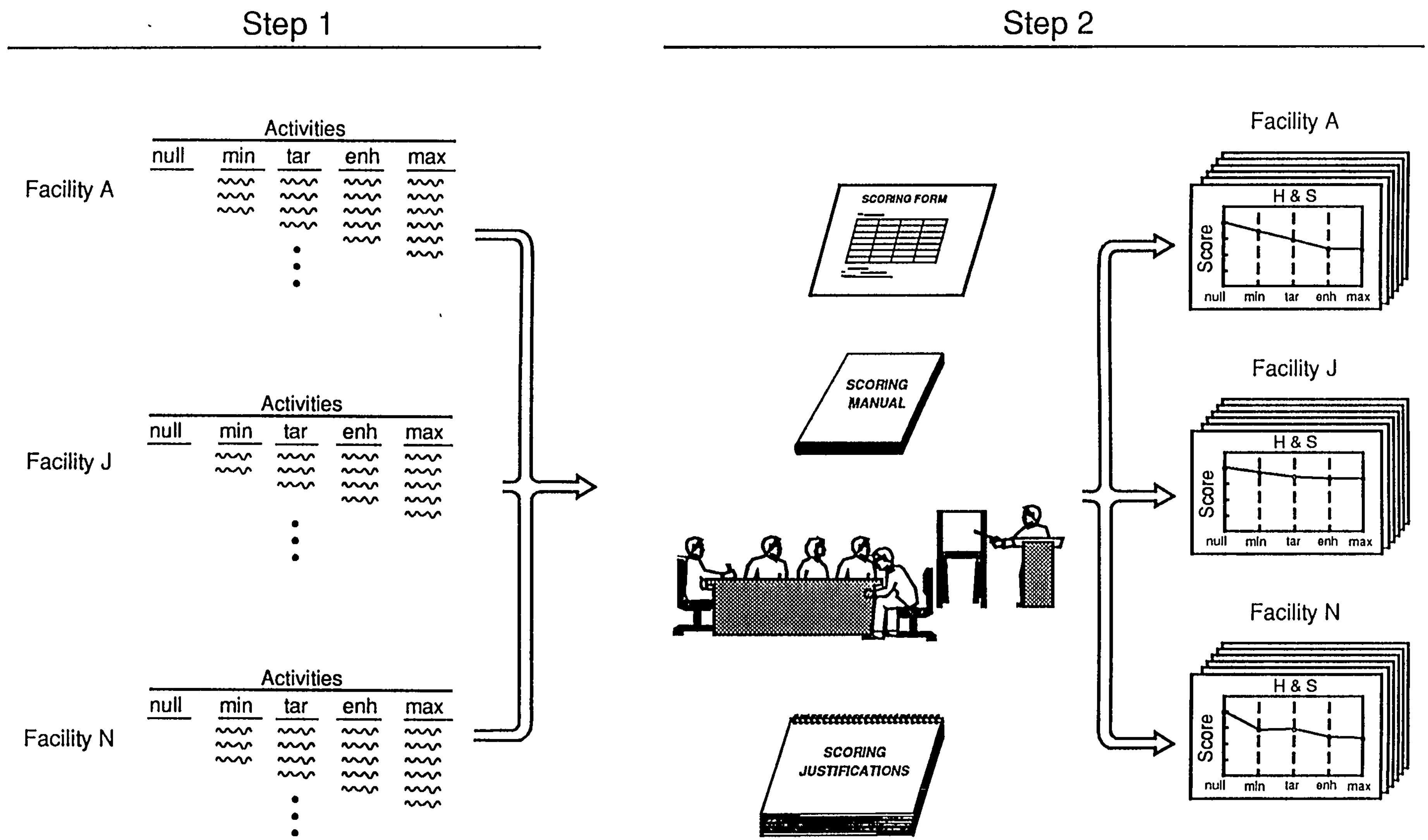

Fig. 1. Steps in the application of POS. Step 1, field offices define programs; Step 2, field offices score programs. (Null=baseline, min=minimum, tar=target, enh=enhanced, max=maximum.)

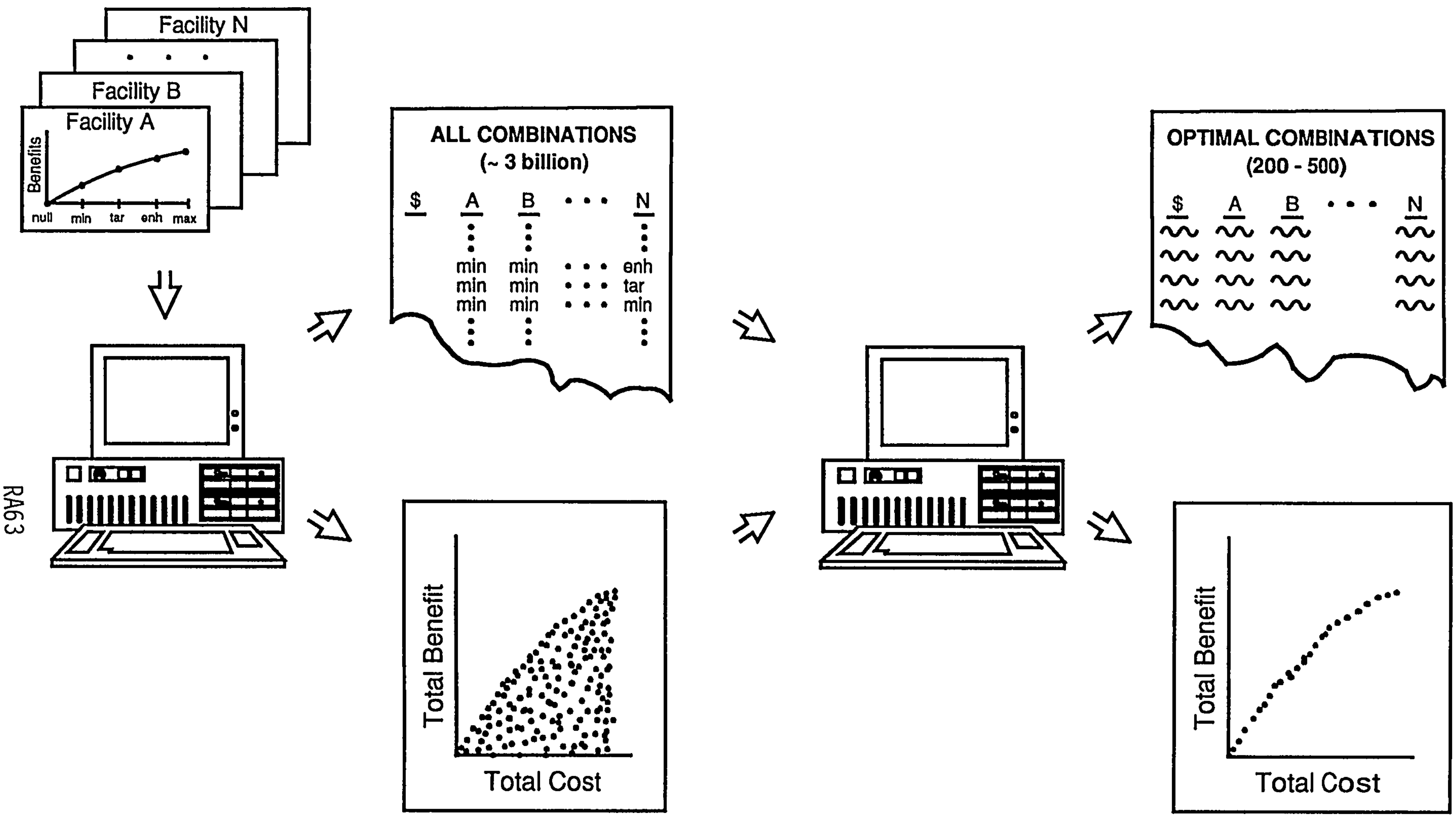

Fig. 2. Steps in the application of POS. Step 4, a computer finds funding combinations that give greatest benefit.

RA63

proposed programs. Work is under way to enhance the capabilities of POS in these areas.

One important area in which improvements are expected is that of the risk estimates required for scoring on the health and safety scale in POS. As mentioned above, POS gives the heaviest weight to health and safety improvements. It is likely that any priority system would do so. As a result, if the output of the priority system is to be credible to the affected parties, then the risk estimates that produce those outputs must also be credible.

It is difficult to make credible risk estimates at this time for several reasons. First, for many sites the available data are severely limited. In these cases the inputs required for detailed site-specific risk assessments will not be available until site characterization has been completed.

Second, there is no uniform approach to making risk estimates that is used by all the DOE field offices. This raises the possibility that the risk estimates made for some facilities might be consistently higher or lower than those for others because of differences in underlying assumptions or risk assessment techniques.

To minimize the potential for such unintended biases in the risk inputs to POS, DOE plans to establish a working group involving representatives from the Hazardous Waste Remedial Actions Program Support Contractor Office and Oak Ridge, Sandia, and Argonne National Laboratories to develop a consistent approach to risk assessment for all the field offices in ER RA activities. This group will address both the question of how to make risk estimates with very limited data, and the question of how to perform the site-specific risk analyses required for Remedial Investigations and Feasibilities Studies in a consistent way.

DOE also plans to invite the principal affected parties to participate in this effort as part of a broader plan for their involvement in development of an overall priority system for DOE waste management activities. Because it is important that these parties have confidence that the resulting approach to risk assessment is as sound and unbiased as possible given the current state of the art, it is appropriate that they have an opportunity to be involved in its development.

6. CONCLUSION

POS provides a logical, defensible, auditable, and flexible system for aiding budget decisions. By clearly identifying the criteria to be applied uniformly and consistently in evaluating programs, POS promotes development of ER RA programs that achieve DOE objectives for the ER RA budget. It also allows the field offices great flexibility in the design of programs to deal with the unique conditions at each facility, and it gives them an incentive to plan the most cost-effective mix of activities for each possible budget level.

At the same time, POS has limitations. It is more complicated than the traditional budget process. Yet it is still a simplification of a complex reality. As discussed above, improvements to POS are now under development. Yet even with further refinements to POS, additional judgment will be required to take into account those site-specific considerations that cannot be captured in a model, and to assess funding levels for facilities that lie between the limited number evaluated in POS.

On balance, DOE believes that POS provides a valuable information base for supporting budget requests and for evaluating the impacts of budget changes. We are applying it again in the FY 1991 budget process, and are considering further refinements to the system that could remove some of its present limitations. We believe that POS represents an important step forward in increasing the real and perceived soundness and fairness of the ER RA budget process, and that it is fully responsive to the congressional directive to develop a priority system that will ensure that ER RA funds are put to the best use.

PRODUCT ACCEPTANCE OF A CERTIFIED CLASS C LOW LEVEL WASTE FORM AT THE WEST VALLEY DEMONSTRATION PROJECT

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ABSTRACT

The Department of Energy, is charged with the solidification of high-level liquid waste (HLW) remaining from nuclear fuel reprocessing activities, which were conducted at West Valley, New York between 1966 and 1972. One important aspect of the West Valley Demonstration Project's fully integrated waste program is the treatment and conditioning of low-level wastes which result from processing liquid high-level waste. The treatment takes place in the project's Integrated Radwaste Treatment System which removes Cesium-137 from the liquid or supernatant phase of the HLW by utilizing an ion exchange technique. The resulting decontaminated and conditioned liquid waste stream is solidified into a Class C low-level cement waste form that meets the waste form criteria specified in NRC 10 CFR 61. The waste matrix is placed in 71-gallon square drums, remotely handled and stored on site until determination of final disposition. This paper discusses the programs in place at West Valley to ensure production of an acceptable cement-based product. Topics include the short and long term test programs to predict product storage and disposal performance, description of the Process Control Plan utilized to control and maintain cement waste form product specifications and finally discuss the operational performance characteristics of the Integrated Radwaste Treatment System. Operational data and product statistics are provided.

WORK PERFORMED UNDER CONTRACT DE-AC07-81-NE 44139

INTRODUCTION

Background

In 1987 and 1988, the Integrated Radwaste Treatment System (IRTS) was installed and placed in operation at West Valley. This system was designed to remove Cesium-137 from the 600,000 gallons of High Level Waste remaining in tank 8D-2 as a result of a former fuel reprocessing operation. Ion exchange using zeolite clay was chosen as the best technique for Cesium-137 removal. Decontamination effluents from this 600,000 gallons of High Level Waste or supernatant are solidified with Portland cement and admixtures to establish a certifiable Class "C" Low Level Waste form that meets the waste form acceptance criteria specified in NRC 10CFR61. Prior to the start of the actual cementation process, a waste recipe and waste form were developed, along with a Process Control Plan. This documentation was submitted to the Nuclear Regulatory Commission (NRC), Division of Low Level Waste Management, which consulted with the project on the applicability of the waste form meeting 10CFR61 criteria.

Figure 1 shows an overview of the IRTS which consists of four major subsystems. These subsystems are:

- Supernatant Treatment System (STS)
- Liquid Waste Treatment System (LWTS)
- Cement Solidification System (CSS)
- Drum Cell (DC)

The low level portion of the IRTS quite simply involves a process where supernatant (high level waste) is treated by ion exchange to remove Cesium 137, evaporated to remove excess water, and blended with cement and admixtures in a high shear mixer to form a homogenous waste form which is poured into 71-gallon square drums for on-site storage. The startup and operation of these systems were presented at the 1988 DOE Low-Level Waste Management Conference in a paper entitled "Status of the West Valley Demonstration Project Low Level Waste Treatment System Start-up".

Since startup of the system in June 1988, 10 campaigns have been completed and approximately 4,000 drums of cemented waste were made representing about 30 percent of the original supernatant inventory. Assurance of continued in-process product acceptability as well as verification of long term waste form performance will be demonstrated. Verification of continued product acceptance is controlled by the:

A. Process Control Plan
B. Short Term Test Program
C. Long Term Test Program

This paper will discuss the scope and implementation of the controls in place at West Valley to assure continued product acceptability.

A. THE PROCESS CONTROL PLAN (PCP)

The Project's Process Contol Plan (PCP), is the key element for verification of continued acceptance of solidified cement product. This plan includes the following major elements:

1. Presolidification Test Samples
2. The Data Acquisition System
3. In-Process Drum Inspection
4. 10CFR61 Radionuclide Verification

1. PRESOLIDIFICATION TEST SAMPLES

As part of the NRC 1983 Branch Technical Position (BTP) on low level waste forms, assurance of product acceptability must be established for each 5,000 gallon batch of processed waste. Included in the PCP is a requirement to sample decontaminated supernatant based on 5,000 gallon lots and verify its acceptability. Waste is analyzed in the Project Analytical Laboratory to assure it falls within the 37-41 weight percent Total Dissolved Solid recipe envelope and meets the criteria for the allowable amount of Cs-137. Samples from each 5,000 gallon lot are mixed with appropriate ratios of cement, sodium silicate, calcium nitrate and an anti-foam agent. The mixture is then poured into molds to form 2" cube specimens. The samples are representative of the actual product to be produced by the IRTS process. Penetration resistance testing is conducted after 24 hours and compression testing after 7 days as the final gauge to product performance. This procedure verifies that the chemistry of the IRTS processing is correct and that the cement recipe, if followed, will yield a qualified product.

Included in Figure 2 are the compressive strength results of the first 24 cubes produced at West Valley. Initially, the test was designed as a go, no-go verification to assure that solidified cement product would exceed the NRC requirement of 60 psi. It was not designed to provide qualified results but rather a verification result.

After numerous discussions with the NRC, this criteria was changed and it was determined that the highest compressive strength values achievable were warranted. A review of the Figure 2 data shows that the average compressive strength now approaches 900 psi for the 2" cubes. Note that this is a significant improvement over our earlier testing which is attributable to improvements in performing the compressive strength test and uniformity of test conditions. Procurement of a new compressive test device with a larger range, plus formalizing our program and procedures also contributed to reduced data scatter. Some of the specific sources of error contributing to data scatter included:

° Sample preparation
  - Weighing errors
  - Mixing time, speed, etc.
  - Variation in techniques

° Curing
  - Duration
  - Oven temperatures
  - Sealed bag versus unsealed bag

° Crush Test
  - Variation in rate of pressure applied
  - Parallelism of cube planes
  - Sample damage while removing from molds

2. DATA ACQUISITION SYSTEM

The Data Acquisition System (DAS), an IBM Industrial AT microcomputer system, is used to verify and document the processing of each mixer batch into the product drums in accordance with the Process Control Plan. The DAS accepts signals from the mixer load cells, the dry cement metering system, drum dose rate counter and bar code reader. Input to the DAS continues during actual processing such that in-process weight changes can be monitored and tracked for each drum. Evolving from the DAS is a computer printout of pertinent essential variables necessary to document product acceptance.

The Data Acquisition System also is used to insure that each mixer batch is within acceptable recipe limits, as determined by the previously qualified recipe parameters for min/max waste weight and min/max water to cement ratio. If any one of these parameters is outside the acceptable limits for the mixer batch, the DAS will alarm and alert the operator. At this point, manual corrections for such conditions as low waste weight or high water-to-cement ratio may be made, while maintaining automatic control. This assures that each mixer batch and each waste drum conforms with the qualified recipe. Final drum weight is calculated and recorded by the DAS as the sum of the recipe constituents. Several drums from each process run are removed and individually weighed to verify the continued accuracy of the DAS.

A real time display and printout of all major process steps and alarm conditions is generated using the DAS. In addition, the DAS maintains files for all drums made during the course of production. An on-line display exists to allow instant display of drum/mixer weights, water-to-cement ratios, overpacks and dose rates of any drum monitored by the DAS. A weekly activity file is maintained on disk in order to identify drums made during an operational period. These formatted drum records may be copied to diskette during nonoperational periods and placed in spreadsheet form for further off-line analysis. This information will form the permanent record by drum serial number for each product container produced at West Valley.

Included in Figure 3 are the essential variable control points tracked and recorded by the DAS. Note that backup data is manually taken as part of the West Valley Standard Operating Program and serves to accommodate potential computer related upsets or lost data.

3. IN-PROCESS DRUM INSPECTION

In addition to the presolidification sample verification described in Section 1, full-scale verification of solidified waste drums is also performed. One drum per each process tank of approximately 5,000 gallons of waste is selected at random to verify that the drum meets or exceeds NRC acceptance criteria specified in 10CFR61.55 for drum fill, free water presence and penetration resistance as it relates to waste hardness. The drum is placed in a test fixture after curing for 72 hours, rotated 100° from vertical and let stand for 24 hours (see Figure 4), whereupon it is inspected for free water presence, drum fill and hardness. All in-process drums inspected to date which number 30 since startup, were found to exceed the 85 percent fill requirement, contained no free water and had penetration resistance in excess of 700 psi.

4. 10CFR61 RADIONUCLIDE ANALYSIS

Each 5,000 gallon batch of concentrated supernatant is sampled and analyzed for radionuclide concentration to verify the waste form will meet the 10CFR61 criteria for a Class "C" Low Level Waste. All waste drums produced to date were found to meet radionuclide concentrations for the "sum of fractions" rule for radionuclide concentrations identified in Tables 1 and 2 of 10CFR61.55 for a Class "C" waste. Average values, the "sum of the fractions" for short and long lived radionuclides are 3.9 E^{-01} and 5.1 E^{-05} respectively.

B. SHORT TERM TESTING OF CEMENT WASTE FORM

The intent of the Short Term Testing of cement waste form is to assure that waste produced under actual production conditions continues to show homogeneity of the product and that correlation between product qualification tests and actual system product testing remains consistent. Specifically, this plan was intended to evaluate compressive strength, Cs-137 homogeneity, radionuclide distribution and leachability.

Two drums of actual product were cured for approximately 60 days and core bored to remove representative sections from the top, middle and bottom of each drum. Compressive strength tests performed on the two drums are reported in Table I and range from 752 to 880 psi.

Leach testing per ANSI 16.1 was performed on 10 actual core samples with each sample having a Leach Index for Cs-137 greater than the NRC acceptance criteria of 6.0. It should be noted that compressive strength tests after leach testing were also performed as part of the Short Term Test Plan and resulted in an average value of 650 psi.

Finally, one of the drums was analyzed for waste homogeneity using samples from the top, middle and bottom of the drum. The average Cs-137 value for the three sections were found to be equivalent to each other within one standard deviation which indicates that the drum contents were homogeneous. Results of the Cs-137 homogeneity test are shown in Table II.

The Short Term Test Program served as an excellent verification of the waste form qualification program in that actual product met or exceeded the NRC acceptance criteria defined in 10CFR61 for compressive strength, leachability index and waste homogeneity.

TABLE I

COMPRESSIVE TEST RESULTS - WVNS SHORT AND LONG TERM TEST PROGRAMS

° Short-Term Testing - 2 Month Cure

	Compressive Strength (PSI)
Drum SN 72949	752
Drum SN 71004	880
Drum SN 71004 (After Leach Testing)	693

° Long-Term Testing - 8 Month Cure

	Compressive Strength (PSI)
Drum SN 72791	1,249
Drum SN 72842	952

TABLE II

Homogeneity Testing on Drum 71004

DRUM SECTION	AVERAGE CONCENTRATION Cs-137 uCi/g	ONE STANDARD DEVIATION
Top	7.56 E-03	7.7 E-04
Middle	8.15 E-03	1.3 E-03
Bottom	7.60 E-03	3.2 E-04

C. LONG TERM TESTING OF CEMENT WASTE FORM

A Long Term Test Plan was developed to provide assurance that cemented waste from the IRTS continues to meet or exceed the NRC acceptance criteria while in extended storage at West Valley. Twenty (20) drums of waste were selected from the same production lot and set aside in a stack within the West Valley drum storage facility. These drums are stored in the same configuration and temperature controlled environment as all drums in the Drum Cell. The objective of the test program is to establish a trend of compressive strength over 6-8 month intervals for five years so that a waste performance assessment can be made using actual test data.

After an initial cure period of approximately 8 months, cores were obtained from two drums and subjected to compressive strength testing. Results are shown in Table I and average values range from 952 to 1,249 PSI and as expected are markedly superior to the 2-month test results. It should be noted that several extra cores were obtained and set aside for future inspection for degradation such as cracking and spalling as a result of aging.

Long term testing involves the destructive evaluation of one drum every six months from the lot of twenty for the next five years. Primarily, only compressive strength evaluation and core inspection will be performed. Ten drums will remain in storage in the RTS Drum Cell for possible future evaluation and testing.

The combination of the PCP in conjunction with the Short and Long Term Test Plans provide a comprehensive inspection and evaluation program to assure our waste form meets NRC acceptance criteria and continues to perform above NRC standards while in extended storage. It is anticipated that a data base will evolve over the next five years at West Valley that can be used as an industrial standard for performance acceptance of cemented radioactive waste. The Project at this time is the only organization that is physically performing destructive evaluations of actual product drums over extended periods of time so that the test data generated will be the first of its kind.

IRTS OPERATIONAL PERFORMANCE CHARACTERISTICS

At the end of ten campaigns, West Valley had successfully processed approximately 30 percent of the decontaminated high level waste through the IRTS. A campaign involves maximizing the loading of Cesium-137 on the zeolite in the lead ion exchange column in STS prior to discharging the column to a storage tank. This spent zeolite will ultimately be used as feedstock in the melter vitrification program where it will be mixed with borosilicate glass formers and poured into stainless steel canisters for ultimate disposal at a HLW repository.

Included as Table III is a summary of the key processing parameters through the first ten campaigns including volumes processed and drums produced. As of August 1, 1989, West Valley has produced 4,136 drums of certifiable Class "C" Low Level Waste at an acceptance rate of greater than 99.9 percent.

TABLE III

KEY PROCESSING PARAMETERS THROUGH 10 CAMPAIGNS OF IRTS OPERATIONS

° SUPERNATANT TREATMENT SYSTEM	
- Volume from 8D-2 (HLW Tank)	216,000 Gallons
- Volume Transferred (Including Dillution)	509,000 Gallons
° LIQUID WASTE TREATMENT SYSTEM	
- Concentrates at 37-41 (Weight Percent Salt)	165,000 Gallons
- Distillates Discharged to WVNS Water Treatment System	344,000 Gallons
° CEMENT SOLIDIFICATION SYSTEM and DRUM CELL	
- 71-Gallon Containers	4,136

Table IV provides a comparison of the actual processing parameters versus system design. In every instance, the system meets or exceeds the design. Of particular interest is the actual average Decontamination Factor (DF) of 49,000 as compared to a design value of 1000. The excellent performance of the ion exchange columns in the STS will maximize Cesium-137 loading in the glass high level waste form and minimize the amount remaining in the low level waste form. A completion date of May 1991 is projected for the completion of the decontamination and solidification of all the High Level Liquid Supernatant Waste at West Valley.

TABLE IV

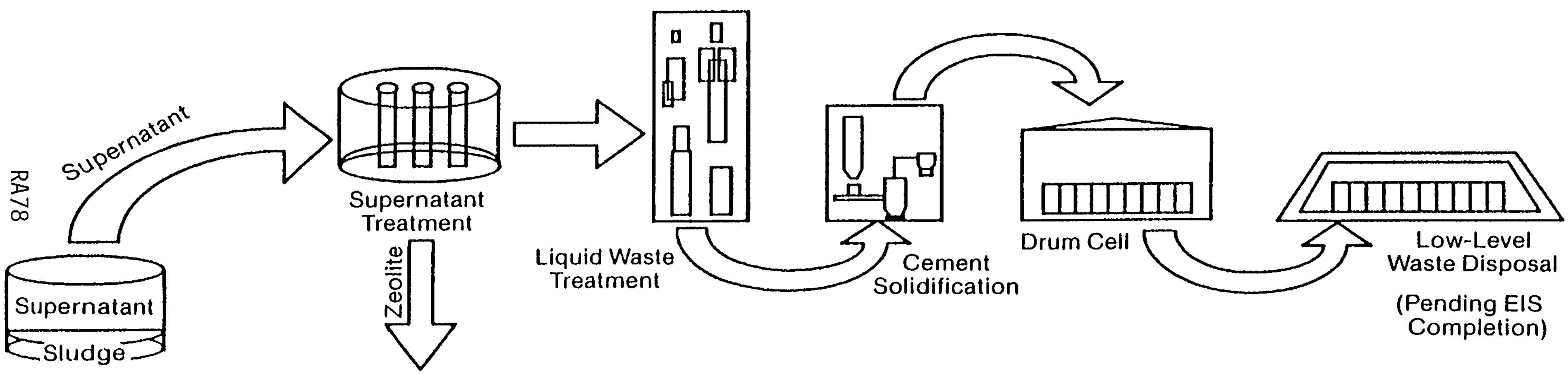
COMPARISON OF ACTUAL PROCESSING PARAMETERS VERSUS DESIGN CRITERIA

	CAMPAIGN NOS. 1-10	DESIGN
° SUPERNATANT TREATMENT SYSTEM		
- Decontamination Factor	49,000	1,000
° LIQUID WASTE TREATMENT SYSTEM		
- Cs-137 Min.-Max. (uCi/mL)	0.02 - .635	50 Max.
- Total Solids (w/o)	37.6 - 40.8	37 - 41
° CEMENT SOLIDIFICATION SYSTEM		
- Drum Acceptance (%)	99.94	98
- Drum Dose Rate (mR/Hr.)	Range 5 - 90	700 Maximum

CONCLUSION

The results of the first ten IRTS campaigns were highly successful as greater than 99.9 percent of the drums produced were judged to be acceptable. Controls inherent in the Process Control Plan (PCP) greatly enhance West Valley's ability to continue to produce acceptable drums. Product verification acceptance measured by the cube compressive tests, radiochemical sample analysis, in-process drum inspection program, and Short and Long Term Test Programs provide excellent assurance that cemented decontaminated supernatant meets all applicable NRC acceptance criteria. Verification prior to solidification during in-process operation and while in extended storage is crucial to the overall waste management program at West Valley to ensure continued acceptable cement product in the CSS.

INTEGRATED RADWASTE TREATMENT SYSTEM



Supernatant liquid is treated through ion-exchange media to remove cesium, which is then concentrated in the Liquid Waste Treatment System, processed into cement in the Cement Solidification System and stored in the Drum Cell. A decision on final disposal is pending completion of the Environmental Impact Statement (EIS).

Figure 1

CSS PRODUCT COMPRESSIVE STRENGTH SETS NEW INDUSTRY STANDARDS

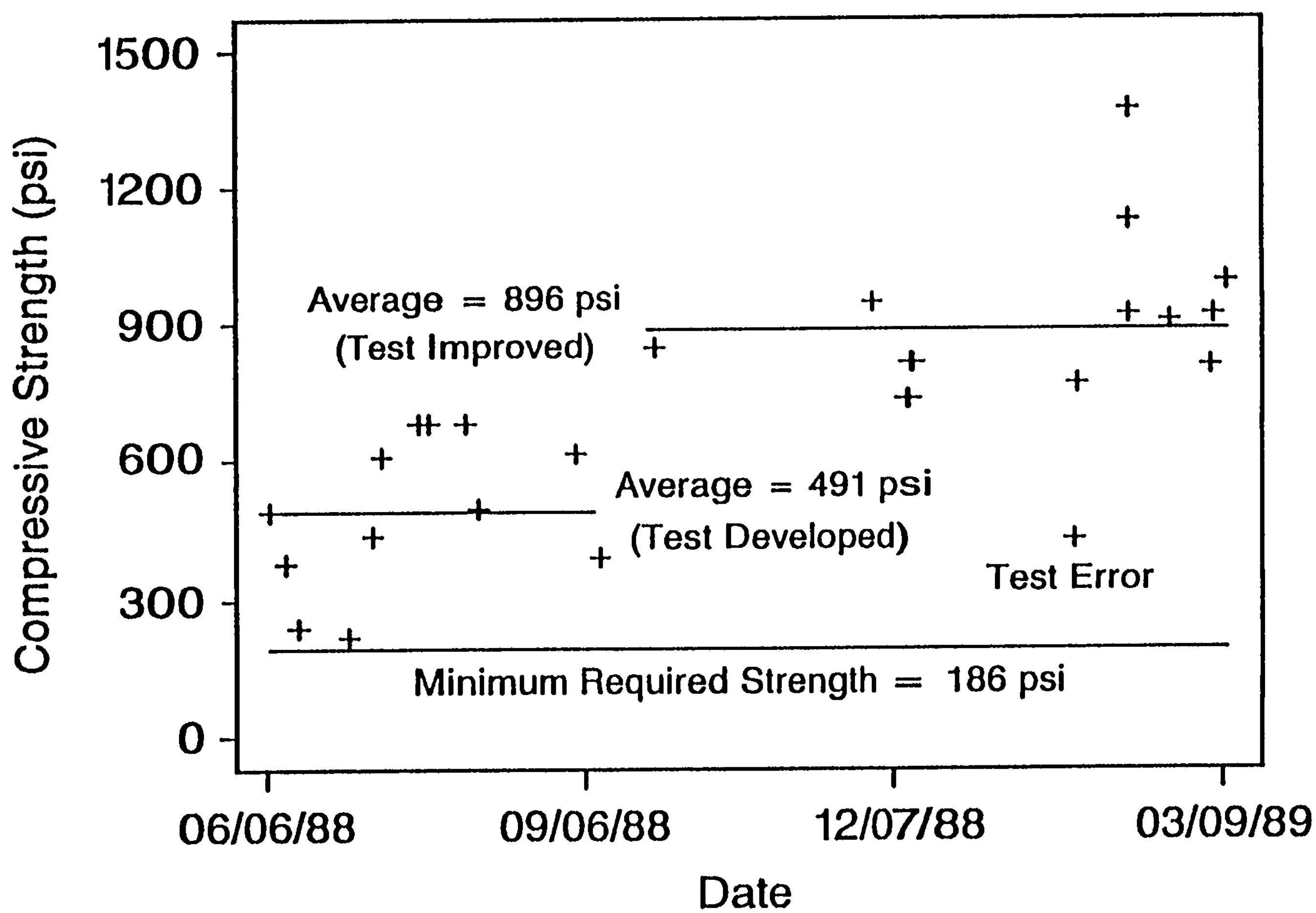


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Figure 2

ESSENTIAL VARIABLE CONTROL POINTS

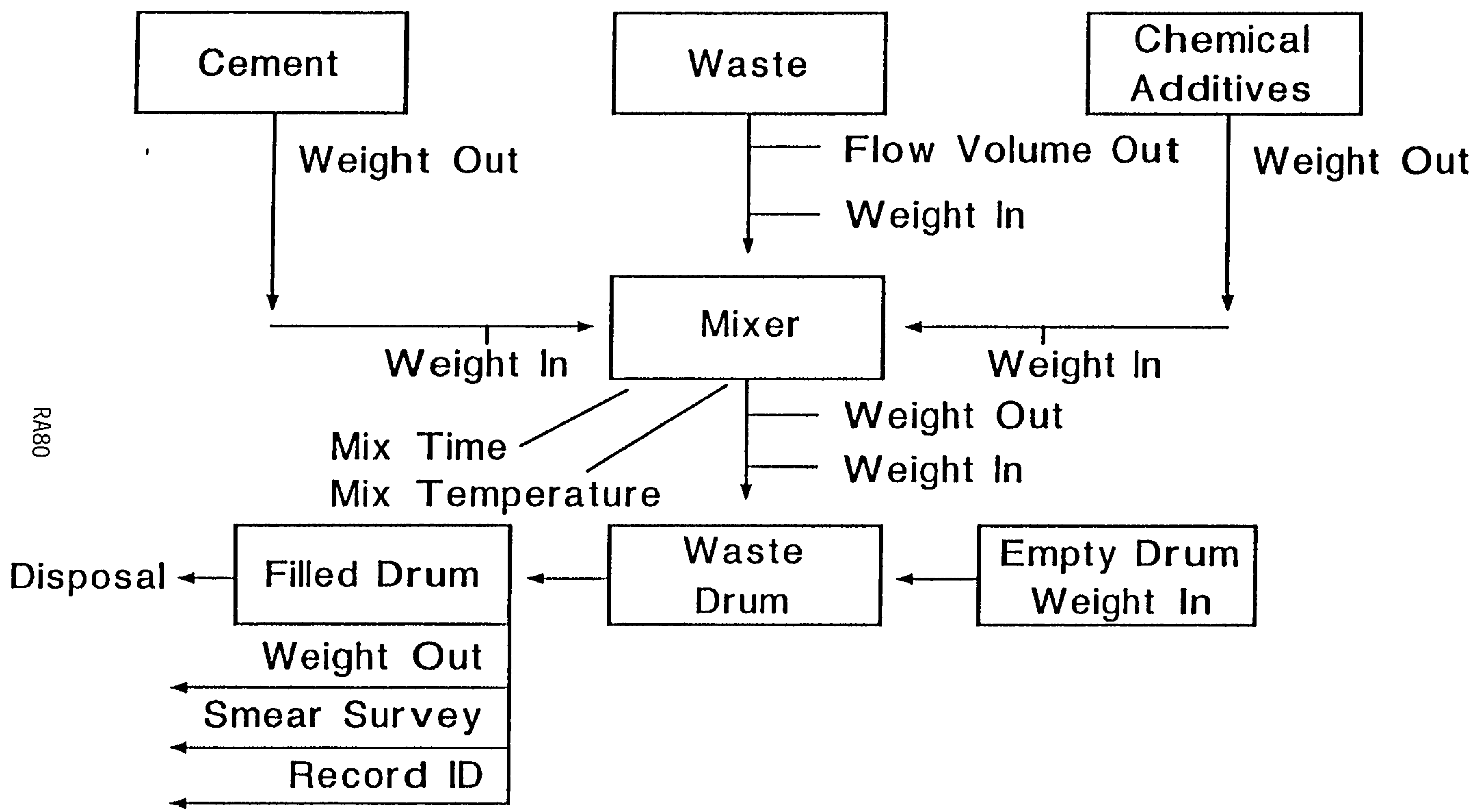

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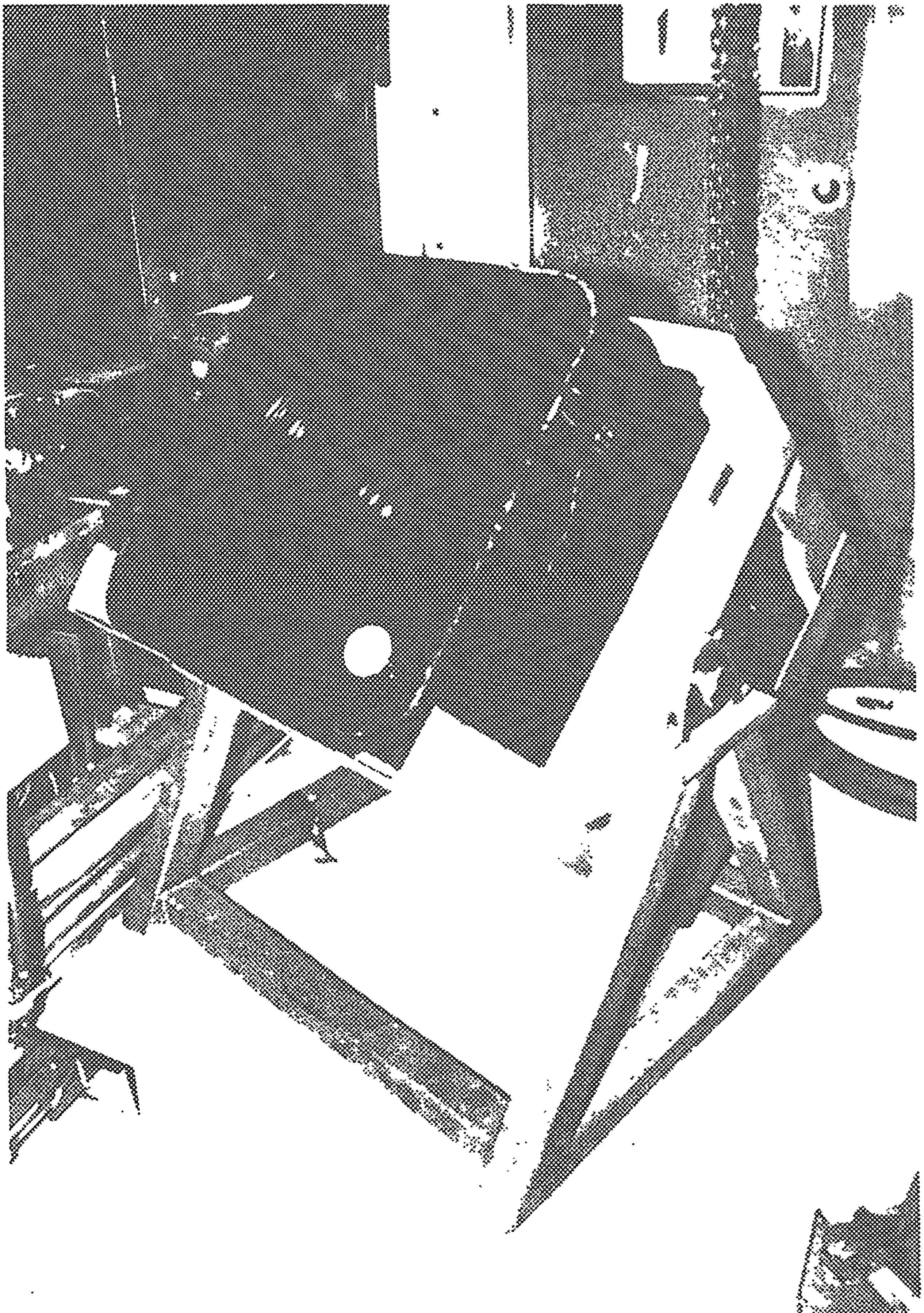
Figure 3

RA80



In-Process Inspection Actual Product Drum

FIGURE 4

SOIL GAS SURVEYING AT LOW-LEVEL RADIOACTIVE WASTE SITES[a]

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ABSTRACT

Soil gas sampling is a useful screening technique for determining whether volatile organic compounds are present at low-level radioactive waste burial sites. The technique was used at several DOE sites during the DOE Environmental Survey to determine the presence and extent of volatile organic compound contamination. The advantages of the soil gas sampling are that near real time data can be obtained, no excavation is required, safety concerns are relatively minor, costs are relatively low, and large amounts of data can be obtained rapidly on the contaminants that may pose the greatest threat to groundwater resources. The disadvantages are that the data are difficult to interpret and relate to soil concentrations and environmental standards. This paper discusses the experiences of INEL sampling and analysis personnel, the advantages and disadvantages of the technique, and makes recommendations for improving the sampling and analytical procedures.

INTRODUCTION

One major problem at low level radioactive waste sites is determining what wastes are present in old trenches and pits. Records are usually incomplete, especially for hazardous constituents. However, some assessment must be made as to what contaminants are present to estimate current hazards and determine whether detailed site characterization, and possibly remedial action, may be needed.

The Idaho National Engineering Laboratory's sampling and analysis teams were faced with the problem of determining whether hazardous constituents were present in waste burial sites at DOE facilities. These teams, supporting the DOE Environmental Survey, were initially asked to obtain representative samples of waste and analyze them for organic compounds (volatiles, semivolatiles and pesticides/PCBs), and metals. Because of the heterogeneity of waste sites it is impractical to collect a set of representative samples. Low-level radioactive waste sites may contain almost anything including rags, paper, heavy equipment, hoods, contaminated construction debris, drums, lead bricks, etc. Even if it were possible to obtain representative samples, the costs and hazards associated with the effort would be extremely high. To provide the Survey with some useful data, several approaches were considered. Sampling of soil or perched groundwater beneath the waste site would provide information on what constituents had migrated from the site, and the sampling of ground water both up and down gradient from the site would provide data on contaminants which had reached the aquifer. Sampling in these cases would be costly and involve drilling through the waste or diagonal drilling. Installation of wells meeting RCRA specifications is also costly and time consuming. Neither approach answers the original question of what hazardous materials exist in the waste. The approach

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a. Work performed under the auspices of the U.S. Department of Energy, DOE Contract No. DE-AC07-76ID01570.

finally used was sampling soil gas which permits identification of volatile organic compounds associated with the waste. VOCs, as shown in Tables 1 and 2, are of special interest at waste burial sites because of their great mobility and threat to ground water. They account for 15 of the top 25 most frequently reported substances at Superfund sites (1). VOCs also account for 13 of the 15 most frequently detected contaminants in ground water from 358 hazardous waste disposal sites (2).

This paper reviews the potential uses of soil gas sampling for VOCs at low-level radioactive waste sites, available sampling and analytical methods, INEL case studies from the Environmental Survey and the Radioactive Waste Management Complex at the INEL, and discusses attributes and limitations of the technique.

POTENTIAL SAMPLING OBJECTIVES

Soil gas sampling may prove useful for a variety of sampling situations. Several site characterization objectives where soil gas should be considered at low-level radioactive waste disposal sites are:

1. determine the presence or absence of VOCs,
2. determine the distribution of VOCs in the subsurface environment,
3. determine the extent of ground water plumes containing VOCs,
4. determine the optimum location for new ground water monitoring wells, or
5. determine the emission rates of various VOCs,

Soil gas sampling has been used effectively in all of the above situations at RCRA and CERCLA sites and should be just as effective at DOE sites with similar problems. However, soil gas sampling is not a panacea, but it should be regarded as another sampling tool to achieve an objective. Before a soil gas sampling study is planned and implemented, the attributes and limitations of the general techniques and sampling and analytical procedures should be understood.

The following section briefly discusses the available sampling and analytical techniques as abstracted from "Soil Gas Sensing for Detection and Mapping of Volatile Organics" (3) and supplemented with other references.

SOIL GAS SAMPLING AND ANALYTICAL APPROACHES

Four basic soil gas sampling procedures have been used: head space, probes, flux chambers and sorbent samplers. Most of the procedures were developed originally for oil and gas exploration but have been modified in recent years for hazardous waste investigations. Although many procedures have been developed, none have been standardized or approved by EPA. In some cases, there are little data to support the use of the procedures, and the limitations are often poorly understood or documented. However, some commercial firms routinely offer soil gas sampling services using proprietary devices or sophisticated onsite analytical laboratories.

Table 1. Most frequently reported substances at 546 sites on the National Priorities List (1).

Rank	Substances	Percent of Sites
1	Trichloroethylene (V)*	33
2	Lead	30
3	Toluene (V)	28
4	Benzene (V)	26
5	Polychlorinated biphenyls (PCBs)	22
6	Chloroform (V)	20
7	Tetrachloroethylene (V)	16
8	Phenol	15
9	Arsenic and compounds	15
10	Cadmium and compounds	15
11	Chromium and compounds	15
12	1,1,1-Trichloroethane (V)	14
13	Zinc and compounds	14
14	Ethylbenzene (V)	13
15	Xylene (V)	13
16	Methylene chloride (V)	12
17	Trans-1,2-Dichloroethylene (V)	11
18	Mercury	10
19	Copper and compounds	9
20	Cyanides (soluble salts)	8
21	Vinyl chloride (V)	8
22	1,2-Dichloroethane (V)	8
23	Chlorobenzene (V)	8
24	1,1-Dichloroethane (V)	8
25	Carbon tetrachloride (V)	8

Table 2. Ranking of groundwater contaminants based on frequency of detection at 358 hazardous waste disposal sites (2).

Contaminant	Detection Frequency
Trichloroethene (V)*	51.3
Tetrachloroethene (V)	36.0
1,2-trans Dichloroethene (V)	29.1
Chloroform (V)	28.4
1,1-Dichloroethene (V)	25.2
Methylene chloride (V)	19.2
1,1,1-Trichloroethane (V)	18.9
1,1-Dichloroethane (V)	17.9
1,2-Dichloroethane (V)	14.2
Phenol (A)	13.6
Acetone (V)	12.4
Toluene (V)	11.6
bis-(2-ethylhexyl) phthalate (B)	11.5
Benzene (V)	11.2
Vinyl chloride (V)	8.7

* V = Volatile
A = Acid Extractable
B = Base/Neutral

Head Space Sampling

Head space sampling can be done in two ways -- from existing subsurface structures, such as dry wells, or on collected soil cores. Head space analysis can be used as a very preliminary tool to obtain reasonable data for designing possible future studies. For subsurface structures, ambient air sampling techniques for VOCs (4) are applied to air in a subsurface structure.

The Environmental Survey used such procedures at the Hanford Site and Sandia National Laboratories. At Hanford, there was a question whether solvents had been disposed of in cribs. Cribs are similar to large septic systems where wastewater is discharged underground to the soil column. Some of the cribs had vents so a sorbent tube containing Tenax and charcoal was lowered into the vent at the end of a hose connected to a personal dosimeter pump used to draw air through the trap. At Sandia, dry wells adjacent to several lagoons were sampled in the same manner. One caution is particularly appropriate. Cribs and dry wells breath with changes in atmospheric pressure. Sampling should only take place when air is being discharged from the ground or in a sealed and equilibrated system. If sampling in an open system is done when atmospheric pressure is increasing, the results may be false negatives.

Headspace measurements of soil cores are easily made by placing a soil sample, preferably a core, in a sealed container and allowing absorbed and free organics to equilibrate with the head space. The air above the soil is then sampled and analyzed for volatiles. More sophisticated procedures have been used in which a core is sealed in a tube with minimal head space -- an air sample is withdrawn through a port using a syringe, and the gas is analyzed by gas chromatography (GC).

Soil Probe Sampling

Many types of probes exist which can generally be divided into large and small volume types. Typically, both types of probes are driven into the soil using a hammer or hydraulic system, although in some cases open holes are augered and sampled. The small volume probes have been recommended over large volume probes because smaller purge volumes are required and a more representative sample can be collected. Sensitivity will improve with increased sampling depth, even when the source of contamination is below a reasonable depth for inserting a probe. Also, low volume probes that are only vented at the tip should prove more sensitive than open hole techniques. An example of the probe used by Kerfoot et al. (5) and the DOE Environmental Survey is shown in Figure 1. During the Survey, difficulties were encountered in driving the probe to a depth of 4 ft through the coarse rocky soils at Hanford. One disadvantage of this probe is the relatively high cost of the custom machining to fabricate the probes.

A commonly used probe, which is much less expensive, requires only an open pipe with a disposable tip to seal the end during driving. After reaching the desired depth, the probe is withdrawn slightly, exposing the inlet.

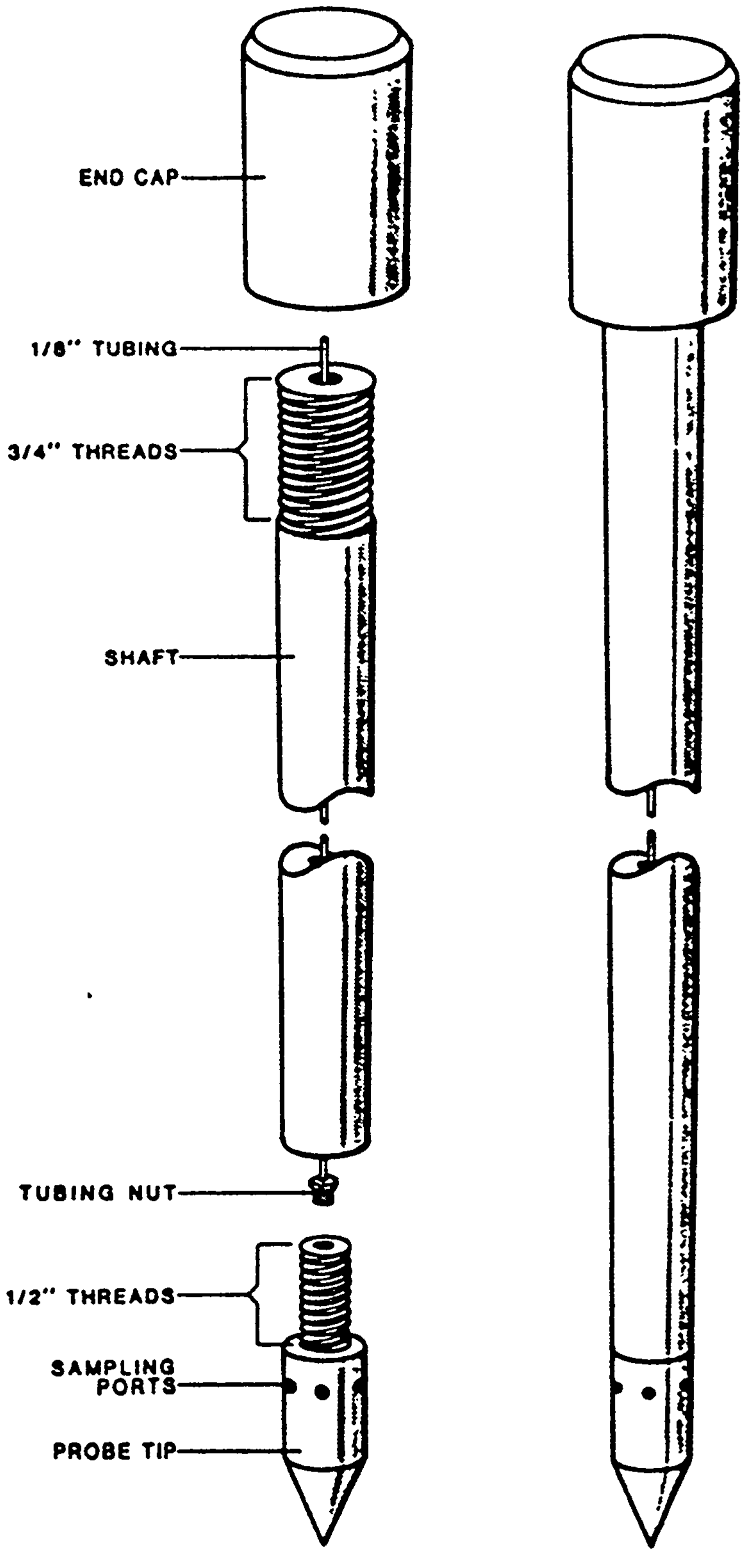

Figure 1. Sampling probe design (5).

Soil probes are usually used for shallow sampling, although hydraulic equipment and auguring to considerable depth, followed by probe insertion, has been demonstrated. The probes are of limited utility in rocky and clayey soils and their vent holes frequently become plugged. When large samples or purge volumes are used, the possibility of dilution with ambient air from the surface exists.

Surface Flux Chambers Sampling

Flux chambers are used to determine emission rates of volatile species from the soil surface. They operate by flushing clean sweep gas through a chamber placed on the soil surface (Figure 2). To obtain a representative measurement, it is necessary to keep the concentration of the volatile organics at a minimum in the chamber. The use of a sweep gas is effective for this purpose, but it also dilutes the exit air. Therefore, sample concentration techniques or sensitive instrumentation are required.

Sorbent Sampling

Passive sorbent sampling of soil gas typically involves burying a sorbent, such as charcoal or Tenax, for an extended period followed by retrieval and analysis. Kerfoot and Mayer (7) used a commercially available personal dosimeter to investigate a ground water contamination problem. The dosimeter was mounted in an inverted paint can (Figure 3) which was buried for two weeks. Although good data were obtained for the species of interest, the charcoal dosimeter is not suited to analysis by GC/mass spectrometry due to the extracting solvent.

Petrex Corporation has developed a system using a ferromagnetic wire, coated with activated charcoal, which is buried in a glass tube for several weeks (Figure 4)(8,9). The sampler is later retrieved, heated in a vacuum chamber, and analyzed by Curie-point mass spectrometry.

Sorbents are also used with active samplers to concentrate contaminants and improve chemical stability. This becomes more important with increasing time between collection and analysis. Tenax tubes and Tenax/charcoal combination tubes have been used, and Supelco markets their Carbotrap tubes for sampling VOCs.

Analytical Techniques

Analytical techniques for determining soil gas VOCs range from relatively simple portable volatile organic analyzers to laboratory GC/mass spectrometers and everything in between. It is beyond the scope of this paper to more than mention a few of the techniques.

Portable continuous analyzers, such as Photovac's TIP and HNU's PI 101, have been used to analyze head space in subsurface structures, contained soil, and bore holes. Both instruments are sensitive to less than 1 ppm of benzene but they provide no qualitative data. They also are designed to operate at flow rates of about 250 mL/min, but at these rates a relatively large sample is required.

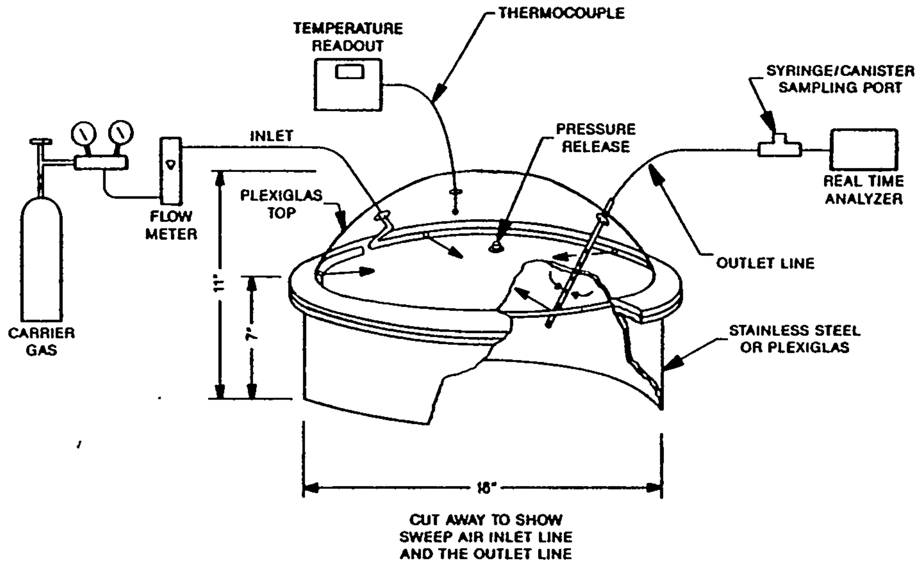

Figure 2. A cutaway diagram of the emission isolation flux chamber and support equipment (6).

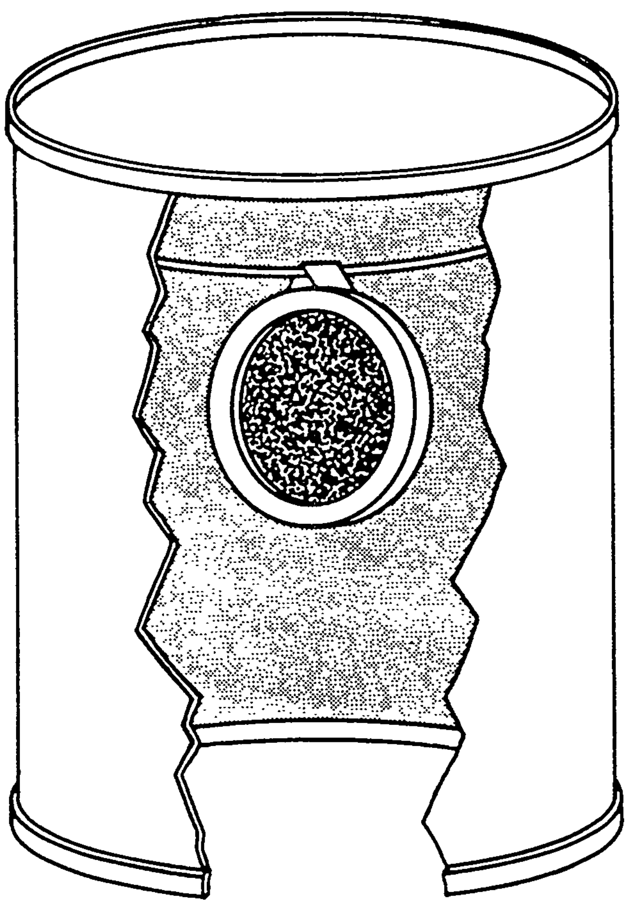

Figure 3. Cutaway view of a sorbent sampler assembly (7).

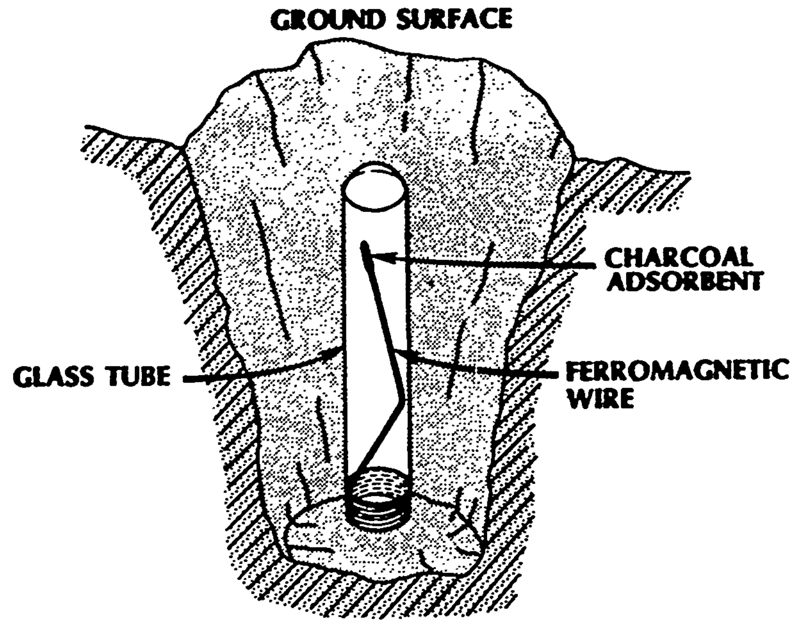

Figure 4. Schematic diagram of the Petrex static collector used for trapping volatile organic compounds (8).

Simple GCs may provide similar data but can also provide some indication of the number of organics possibly present and, by using appropriate standards, an indication as to identity. More sophisticated GCs with dual columns and/or multiple detectors provide much better quantitative and qualitative data. Various detectors, including photo and flame ionization, electron capture, and mass selective detectors, are used to analyze soil gas. Each detector has its attributes and limitations. One possibly significant limitation of flame ionization detectors operated in survey mode is their sensitivity to methane. High concentrations of methane are frequently present in landfills and would obscure the presence of other VOCs.

Sample Containment

Samples of soil gas may be contained in Teflon or Tedlar bags, metal canisters, syringes, on sorbents, etc. With gas bags and canisters, the samples may be analyzed in the field, at a mobile laboratory, or at an offsite laboratory. Typically an aliquot is withdrawn from the container and injected into a GC. Direct sampling with a syringe is common with portable GCs and mobile laboratories where analyses will be conducted after short holding times (minutes). When sorbents are used, a thermal or chemical extraction step is involved which usually requires a mobile or offsite laboratory.

Plastic bags and canisters contain a large sample which allows multiple analyses of various volumes to optimize GC conditions and sample volume. Syringe sampling may require collection of another sample but since such samples are usually analyzed in the field, this is not a significant problem. Thermal desorption of Tenax or charcoal at an offsite laboratory does not offer the same possibilities. Typically, only one analysis is available from these traps which makes instrument conditions and the sample volume much more critical. These limitations can be reduced if the source is reasonably well known, multiple samples are collected as a contingency, or field screening instruments are used to survey the site.

SOIL GAS AND VAPOR SAMPLING AT THE HANFORD SITE

During the summer and fall of 1987, soil gas and vapor surveys were conducted at radioactive liquid and solid waste disposal sites at Hanford as part of the DOE Environmental Survey efforts. The requests for sampling and analysis were developed by the DOE Survey Team after careful consideration of the needs of the Hanford site for identifying both actual and potential environmental problems. The team based their requests on detailed and lengthy considerations of the local environmental characteristics, historical environmental monitoring data, and an understanding of the production and research and development operations performed at the site over the last 40 years. The sites sampled can be categorized into inactive solid radioactive waste, radioactive low-level waste, and radioactive liquid waste disposal areas.

Eight inactive solid radioactive waste disposal sites were sampled. These sites are known to have received radioactively contaminated waste, and there are some data on metallic wastes being disposed; however, little is known about potentially hazardous organic waste materials that may have also been disposed of in these areas. These sites were constructed without liners or other groundwater protection. In some cases, liquid waste disposal sites are located nearby which may enhance the potential for contaminants to migrate from the fill area. The inactive solid radioactive waste disposal sites are typically hundreds of feet long, tens to hundreds of feet wide, 20 to 40 feet deep, and generally contain numerous smaller trenches, pits, spline silos, pipe facilities, and/or caissons. The types of materials disposed at these sites include: radioactive soft wastes, reactor components, hardware and metallic wastes, and industrial and construction wastes.

Five radioactive low-level waste disposal areas (landfills) were sampled. These sites are still considered active and do not have liners or impermeable caps. They have similar dimensions to the inactive solid waste sites. It is likely hazardous materials were mixed in with wastes because of the variety of wastes disposed, including reactor core barrels, TRU contaminated soils, drums of non-combustible TRU contaminated waste, and industrial and construction waste.

Eleven radioactive liquid waste disposal areas, consisting of ponds, ditches, and cribs, were sampled. Liquid wastes at the Hanford Site have been discharged to the ground or into land-based disposal units for over 40 years with little or no treatment before their discharge. These waste streams are from reactor stream condensate and cooling water, process condensate, process waste, and tank and scavenged waste and are contaminated with low-level mixed fission products and transuranic radionuclides as well as various organic and inorganic chemicals. Very little analytical work has been performed to date to determine the chemical constituents of the waste streams.

The purpose of the sampling effort was to determine whether organic contaminants are present in selected disposal sites using volatile organics as an indicator of such contamination. Indications of organic contaminants in a disposal site would provide supporting documentation for additional studies.

Sample Design

Because of the large surface areas of the solid waste disposal areas, the desire not to disturb the integrity of the wastes already placed in the units, and the necessity for reducing the exposure to sampling personnel, a minimal number of soil gas samples were taken at selected sites to provide an indication of the VOCs present at the disposal areas. Sites were selected at each disposal area based on volume and type of wastes received and the likelihood of finding residual chemical contamination if it was present in the area. It was assumed that the areas of the waste sites with the highest contamination levels could be predicted based on previous operating experience. Generally, 3 to 6 soil gas samples were collected from each disposal area. If there was insufficient evidence for biasing the exact location for sampling, samples were spaced equidistant down the center of the site.

For purposes of selecting liquid waste disposal sites for sampling, they were grouped into five general categories based on the nature of the waste constituents: steam condensate and cooling water, process condensate, miscellaneous, process waste, and tank and scavenged waste. Seventeen of the inactive waste sites were selected from those general categories for sampling. The sites were chosen for sampling based on the volume and kinds of waste received and the likelihood of residual chemical contamination. Sampling activities associated with many of the liquid waste sites had the potential for releasing radionuclides to the environment and, in many cases, the direct radiation fields were high. To minimize disturbance to the waste site and to reduce the exposure time for field personnel, vapor samples were collected from existing vent pipes. From 1 to 3 vapor samples were collected at each site depending on availability of vents.

Sampling Procedures

Vapor (subsurface headspace) and soil gas samples were collected using a sample train consisting of a low flow personnel air sampling pump, Tygon tubing, and borosilicate collection tubes which were compatible with the laboratory GC/MS and which contained Tenax-GC and charcoal adsorbents. The personnel pump was calibrated to draw air through the collection tubes at a specific flow. The sampling train was removed after a predetermined volume of air had been sampled.

Soil gas samples were collected using a 5/8-in. od. carbon steel probe driven to a depth of 2 to 4 ft through the backfill or soil cap at the solid waste disposal sites. The probe consisted of a drive head or tip with air vents, support shaft, and a stainless steel tube extending from the drive tip to the end of the support shaft. The lower end of the pipe was later modified and fitted with a removable metal cap to prevent clogging of the air vents. Once driven to the desired depth, the cap was then displaced using a steel rod inserted through the pipe. The sample collection tube of the sampling train was attached to the end of the probe tube and air was drawn through the system (Figure 1).

Vapor sampling at radioactive liquid waste disposal sites involved sampling in-place vent pipes (Figure 5). One day before sampling, the vent pipe was sealed with aluminum foil. The following day, the collection tube connected to the personnel air pump with Tygon tubing was lowered into the vent pump through a small hole in the foil. The pump was run until a specific volume of air was sampled.

Analytical Procedures

Volatile organics in soil gas samples were determined using a volatile organic sampling train (VOST) methodology. This method is detailed in SW-846, Method 5040 (10), and was modified to follow the 10/86 Contract Laboratory Program (CLP) Volatile Organic Statement of Work QA/QC objectives and reporting requirements. This protocol was used for the determination of low level volatile organic compounds in environmental soil gas samples with a targeted detection limit of 0.1 ug/m^3 (lower detection limits are possible under some conditions). The Tenax/charcoal collection tubes used to trap volatile organic compounds were analyzed by thermal desorption/purge and trap sample introduction to a gas chromatograph-mass spectrometer (GC/MS). This protocol allowed both quantitative and qualitative analysis of 34 target compounds and for identification and semi-quantitation of non-target compounds known as tentatively identified compounds (TIC).

Quality Control/Quality Assurance

Tenax/charcoal, used as the sorptive material for trapping volatile organics, is very effective and is therefore easily subject to contamination from sources other than the sampling location. In addition, there is a concern for cross-contamination because of contamination of sampling probes between sampling sites.

Sampling probes were decontaminated after each sample using an ethanol wash and hexane rinse. The probes were then wrapped in aluminum foil and stored in a clean area. Before use, the probes were checked with an organic vapor analyzer. If volatiles were detected, the probe was returned for decontamination and another probe was used. To check for cross-contamination in the sampling train, several batches of blank samples were collected by pulling air through decontaminated probes. The samples were then sent to the lab for analyses. No evidence of cross-contamination was seen from analysis of the results. In addition, all shipments of collection tubes included a trip blank to check for contamination of tubes during shipping and handling.

The Tenax/charcoal adsorbent tubes were prepared in batches at Oak Ridge National Lab (ORNL). Some tubes were sent to Hanford to collect soil gas/vapor samples and some were reserved at ORNL to be spiked with target compound calibration standards or for use as method blanks. Because the tubes are excellent adsorbents, all of the method blanks were found to

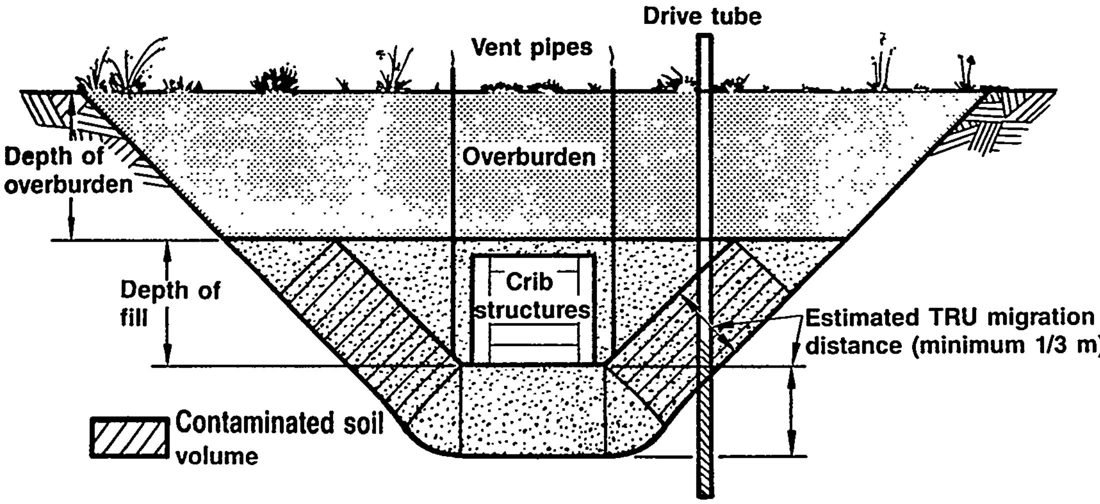

Figure 5. Crib cross section.

contain a number of VOCs. Table 3 summarizes the compounds detected in the 21 method blank tubes from batches of tubes sent to Hanford. The method blanks were found to contain 21 of the 34 target VOCs and 6 TICs. These data were used to interpret the Hanford sample results. When compounds were present in blanks and samples at comparable levels, the compounds were not attributed to the samples. Hexane, used to decontaminate field equipment, was detected in many of the samples and blanks; therefore, hexanes and hexane related hydrocarbons were not attributed to the samples. Siloxane and freon related contaminants were detected in many of the samples and blanks and were attributed to column degradation and laboratory contamination, respectively.

Soil gas collection tubes were stored at 4°C from the time of sample collection until analysis. The EPA recommended holding time for soil gas tubes is 2 to 6 weeks. Extended holding times for tubes may adversely affect the data because of loss of some of the more VOCs; however, it is possible that the tubes would continue to trap organics encountered during storage. Either scenario is undesirable so efforts were made to keep the holding times down to a minimum.

Results

Four groups of volatile organics were identified consistently in both soil gas and vapor samples from active and inactive solid waste and liquid waste disposal sites at Hanford. Those groups were carbon disulfide, chlorinated hydrocarbons, ketones, and aromatic hydrocarbons. Vinyl acetate was commonly identified in samples from solid waste disposal sites but was not detected in the samples from the liquid waste sites. Samples from the liquid waste sites, except for carbon tetrachloride (1700 ug/m^3), showed consistently lower concentrations of volatile organics (0.008 to 40 ug/m^3) than samples from either the active (0.01 to 9000 ug/m^3) or inactive (0.02 to 2500 ug/m^3) solid waste

Table 3. Summary of results for 21 Tenax/charcoal adsorbent tube method blanks

Compound Name	Quantity Detected			Frequency of Detection	
	Range (ng)	Mean (ng)	Std. Dev. (ng)	Number	Percent
Target Compounds					
Acetone	14-120	57	36	9	43
Benzene	1-10	5	3.3	6	29
Bromodichloromethane	0.6-10	3	4.6	4	19
2-Butanone	8-120	58	36	11	52
Carbon disulfide	5	5	N/A	1	5
Carbon tetrachloride	7-20	12	7.2	3	14
Chloroform	7-32	19	8.8	11	52
Chloromethane	13-59	36	33	2	10
Ethylbenzene	3	3	N/A	1	5
2-Hexanone	2-20	10	4.9	9	43
Methylene Chloride	3-89	21	20	17	81
4-Methyl-2-pentanone	3-70	26	22	8	38
Styrene	4-8	6	2.8	2	10
1,1,1-Trichloroethane	1-7	3	2.1	7	33
1,1,2-Trichloroethane	7	7	N/A	1	5
Trichloroethene	1-10	3	3.8	5	24
Tetrachloroethene	3-5	4	1.2	3	14
Toluene	0.9-1200	202	489	6	29
Vinyl acetate	8	8	N/A	1	5
Xylene	1-4	2	1.5	3	14
Tentatively Identified Compounds					
Hexanes	30-8700	2200	4325	4	19
Hydrocarbons (misc. RT)	20-230	125	148	2	10
Freon	111	111	N/A	1	5
Freon 113	9-53	27	22	5	24
Methyl styrene	8	8	N/A	1	5
Trichlorofluoromethane	6-77	30	30	5	24

N/A - Not Applicable, a standard deviation can not be calculated from one number.

sites. Subsurface soil samples collected from the liquid waste sites also contained very few organic contaminants, although several samples contained 1,1,1-trichloroethane (TCA) and polyaromatic hydrocarbons at concentrations of 19 to 48 ug/m^3.

Eighty of eighty-four samples from both solid and liquid waste disposal sites contained at least one volatile organic compound attributed to the sample and not to contamination caused by shipping, handling, or lab procedures. Analysis of shipping blanks revealed contamination levels consistent with those levels found in lab analytical blanks; therefore, introduction of contaminants during shipping and handling was not considered a problem during this study. Of the volatile organics identified in soil gas and vapor samples, carbon disulfide, TCA, trichloroethene, carbon tetrachloride, chloroform, toluene, and benzene were identified in the majority of samples at sufficient levels to conclude that they are prevalent at disposal sites at Hanford. Vinyl acetate appears to be prevalent only at solid waste disposal sites.

The results of six field replicate samples which were collected one foot away from the original sample location were evaluated to assess the representativeness and precision of the field sampling techniques. Most of the data indicated very good agreement between the concentrations and types of contaminants detected. Other data did not support this conclusion. The data did suggest, however, that there may be a correlation between increased sample volume and improved representativeness and precision of the data obtained.

Conclusions

Effective use of soil gas sampling data requires that the qualitative and quantitative limitations of the technique be thoroughly understood and supported by a rigorous QA/QC program. In contrast to classical CLP type analyses which are conducted on water or soil matrices, soil gas determinations are performed on a sample of Tenax/charcoal sorbent media. From a qualitative perspective, low level hits on soil gas samples are more difficult to assign to the presence of field contamination because the tubes prepared for field use will often contain low levels of a variable number of volatile organic compounds. Therefore, the low level hits may be a result of blank contamination even though they did not show up on the blank run with that particular batch. These low levels would require confirmatory sampling to conclusively demonstrate their presence in the field. However, higher levels of volatile organics can be attributable to field contaminants because they are higher than those observed in blank Tenax samples. Qualitative identification of contaminants in soil gas analysis utilizes the same GC/MS techniques used for CLP identification. As a result of this mass spectral interpretation, chemical identification of the contaminants is done with a very high degree of confidence.

Although the limitations and qualifications of the soil gas and vapor data indicate that the data are highly suspect, particularly at low levels, the data met the purpose of the study, which was to determine if volatile organic compounds were present at disposal sites, identify them, and do it with minimum safety risks to sampling personnel. However, for subsequent studies of this nature, vacuum canisters were substituted for sorbent tubes. The use of the canisters will allow a large volume to be collected, will reduce the number of samples that were lost because of breakage, will reduce the chance of swamping the instrumentation because of high levels, and will reduce the problem of contaminated collection media.

SOIL GAS SURVEY AT THE IDAHO NATIONAL ENGINEERING LABORATORY

In the fall of 1987, a soil gas survey was conducted at the Radioactive Waste Management Complex (RWMC) at the Idaho National Engineering Laboratory (INEL). The purpose of the survey was to determine the sources and relative concentrations of selected chlorinated volatile organic compounds in the vadose zone. The soil gas survey performed at the RWMC was conducted in response to a number of occurrences which suggested the possible presence of VOCs buried within the RWMC. These occurrences were: 1) detection of VOCs in the ground water beneath the RWMC, 2) organic vapors in wells being drilled within the RWMC, and 3) recently uncovered information on the shipment of organic substances to the INEL from the Rocky Flats Plant near Denver, CO.

Numerous wells have been drilled at the RWMC for the purpose of collecting samples of sediments for analysis of radionuclides. No previous reports had been made of the detection of VOCs. In September 1987, however, VOCs were detected in a well when a temporary casing was raised a few inches exposing a sedimentary interbed at a depth of 110 ft below the land surface. At that time the field crew reported a strong organic odor emanating from the casing at land surface. On the following day, organic vapors were also noted during drilling operations at a second borehole within the RWMC. The vapors were first noted when the 110 ft interbed was encountered. These field observations were verified by collection of gas samples from the boreholes of the two wells and laboratory analysis of the samples for volatile organic compounds. Based on these findings, an effort was made to evaluate the RWMC waste inventory.

Visits to the Rocky Flats Plant in Colorado and review of waste management records revealed that significant quantities of organic wastes had been shipped to the INEL. The estimated volume of organic wastes buried in the RWMC is 88,400 gal. Of this total, approximately 24,400 gal are carbon tetrachloride. The remaining volume consists of approximately 39,000 gal of Texaco Regal Oil used in machinery processes and 25,000 gal of miscellaneous organic solvents. Receipt of organic wastes from Rocky Flats did not begin until August 1966. During 1967-1968, the backlog of organic waste (primarily lathe coolant) generated between 1953 and 1966 was shipped to the INEL for disposal. The organic wastes were believed to have been buried in Pits 5, 6, 9, and 10 (Figure 6).

The organic wastes received from the Rocky Flats Plant consist of liquid organic wastes mixed with calcium silicate to form a paste-like material. Prior to 1971 or 1972, this mixture was wrapped in plastic bags and placed in 55-gal drums. Since 1972, 90-mil rigid polyethylene drum liners have been used inside the 55-gal drums.

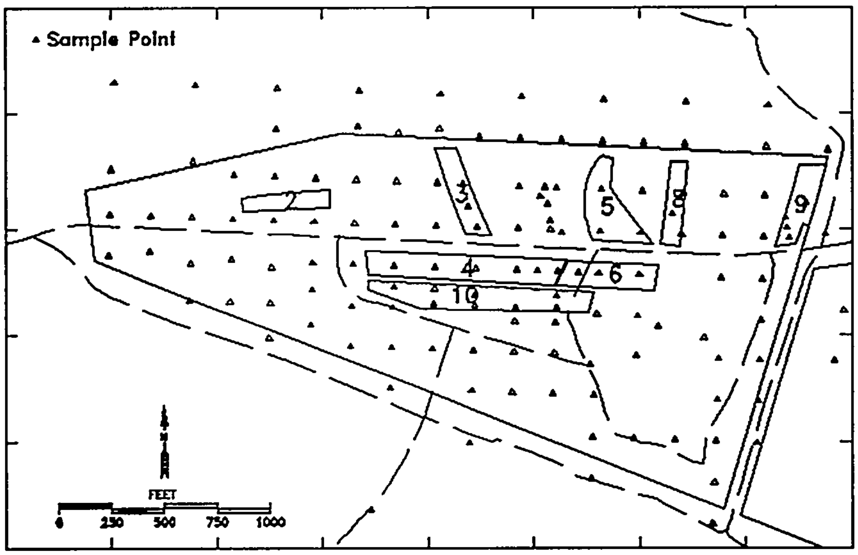

Figure 6. Locations of sampling points for soil gas survey and pits within the RWMC.

Sample Design

To assure uniform coverage of the RWMC, a grid with 200 ft spacing in north-south and east-west directions was defined. The grid generally extended one row beyond the fence. In addition to the grid locations, 63 supplemental locations were sampled to better define areas where high VOCs were detected. A total of 153 points were sampled (Figure 6).

Sampling Procedures

Soil gas was extracted by installing a 5/8-in. od. carbon steel pipe into a 1/2-in. hole drilled approximately 30 in. into the ground using a hand-held electric drill. The lower end of the pipe was fitted with a metal cap to prevent clogging, and the pipe driven into the hole with a sliding hammer. The cap was then displaced using a steel rod inserted through the pipe. A battery operated pump was attached to the top of the probe using a stainless steel quick-connect coupler and surgical rubber tubing. From 3 to 10 pipe volumes were then pumped from the probe. An organic vapor analyzer (Century 128 OVA or HNU PI 101) was used to monitor the discharge from the sampling pump. Gas concentrations in the discharge stream stabilized very quickly. The gas sample was collected from just inside the stainless steel quick-connect by inserting a glass syringe through the surgical tubing. The syringe was then sealed and transported to the field analytical laboratory.

Analytical Procedures

Analysis of soil gas samples was performed in a field laboratory set up in a trailer immediately to the north of the RWMC. Analyses were performed with an HNU Model 321 field GC. The GC was equipped with two silica capillary columns and electron capture and photoionization detectors. Standard mixtures of VOCs were prepared by serial dilution of pure chlorinated and aromatic compounds in dodecane or hexane. Soil gas samples were directly injected into the GC for analysis and the response compared to those of VOC standards. The detection limit varied from 0.01 to 1 ug/L depending on the VOC.

Quality Control/Quality Assurance

A major concern of quality control is to assure that there is no carry-over of compounds between samples due to contamination of sampling probes, the sampling train, or syringes. All syringes were cleaned with hexane and then heated in an oven at 100°C for 10 to 15 minutes between uses. After cleaning, the syringe was tested by pulling ambient air into the syringe and injecting into the GC. If volatile organic compounds were detected by the GC, the syringe was cleaned again. To check for possible cross contamination in the sampling train, blank samples were collected by pulling air through a probe before installing it in the ground. This sample was then analyzed with the GC. Twenty four such samples were collected at the RWMC and showed that, at most, barely detectable quantities of volatiles were carried over between samples.

Results

Four organic compounds were consistently identified by the survey, TCA, carbon tetrachloride (CBT), trichloroethylene (TCE), and tetrachloroethylene (PCE). In most chromatograms, the elution of chloroform was obscured by large concentrations of TCA and CBT. Therefore, no chloroform results are reported from the survey. The numbers generated by the survey give an accurate indication of the relative amounts of VOCs in soil gas at the RWMC. They do not, however, provide a rigorous quantitative analysis of all the organic compounds.

CBT, TCE, and PCE showed very similar spatial distribution. Of these three, CBT is the most prevalent, and PCE the least prevalent. These compounds seem to be coming mainly from the southern end of Pit 9, the northern end of Pit 5, the eastern end of Pit 4, and the western end of Pit 10 (Figure 7). Maximum concentrations of CBT in excess of 1000 ug/L were measured over Pits 4 and 9. A lesser area of contamination by these three compounds occurs to the north of the road running through the RWMC and is associated with Pit 2. Whether this is a source area, or just an area where organic vapors accumulate, is not clear. Only CBT appears to show movement of plumes away from the pits. There is a concentration of CBT under the drainage ditch along the north boundary of the RWMC, and there may be a plume moving to the southwest.

TCA showed a behavior different from the other three VOCs (Figure 8). The highest concentrations of TCA were found in the southern end of Pit 5, the middle of Pit 3, and in a trench near the southeast corner of the RWMC. High concentrations of TCA were also found associated with Pits 2 and 4. The area of Pit 4 highest in TCA does not correspond to the area highest in CBT, however.

Samples were also collected from three deep wells instrumented with gas sampling ports at various depths. Higher concentrations occurred at shallow depths and maximum concentrations generally occurred at depths near 100 ft (80 to 150 ft). Concentrations dropped off at depths greater than about 170 ft, but detectable concentrations were measured in all samples. The deepest sample was collected at 355 ft.

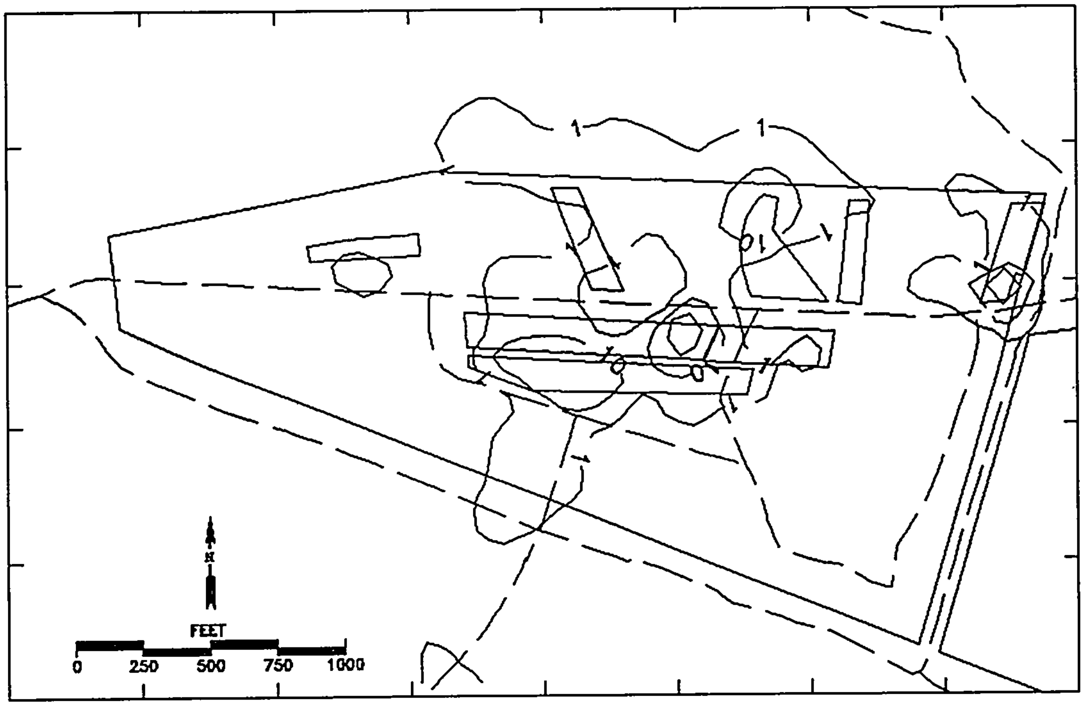

Figure 7. Isopleths of carbon tetrachloride in soil gas at the RWMC, December, 1987, (ug/L).

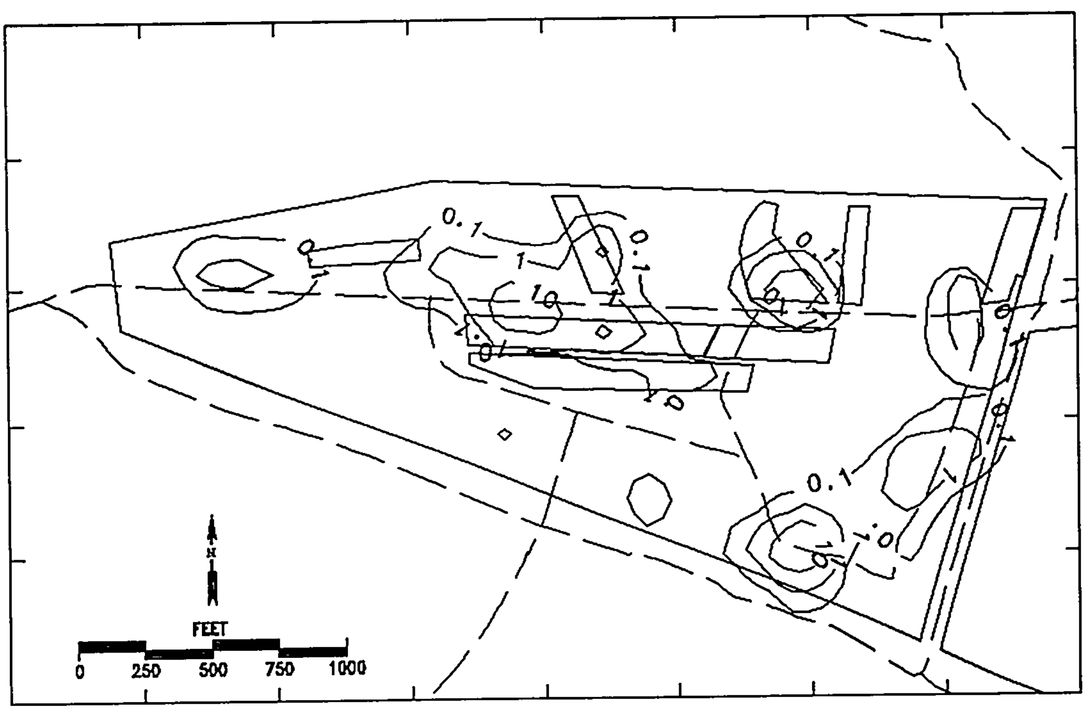

Figure 8. Isopleths of 1,1,1-trichloroethane in soil gas at the RWMC, December, 1987, (ug/L).

Conclusions

The soil gas survey conducted at the RWMC clearly identified the pits which are the source of the organic vapors in the subsurface. These pits contain waste shipped from the Rocky Flats Plant near Denver, CO. The chlorinated solvents are migrating from the pits, and seem to be concentrating in or above a sedimentary interbed at a depth of 110 ft below land surface. The information derived from the soil gas survey will be used to identify areas of the RWMC which would be preferred targets for remedial actions and installation of monitoring devices.

INTERPRETATION OF SOIL GAS DATA

Although soil gas sampling is often used as an exploratory technique to guide further sampling, it is essential to have a quality assurance/quality control program that is adequate to determine whether the data are suitable for the intended use. Enough quality control data must be available to determine whether variations in concentrations are real or just random errors. Calibration of instruments, documented sampling and analytical procedures, trained personnel, blanks, trip blanks, standards, duplicate samples, co-located samples, etc. go a long way toward achieving quality goals. The initial data evaluation should be to determine the quality of the data and whether it meets quality goals. If the data do not meet goals, this should not mean automatic rejection of the data but that the data are of less utility than intended.

Frequently soil gas data are used to develop concentration isopleths. Since the sampling and analytical techniques permit collection of many samples on a grid pattern, the use of kriging and other geostatistical procedures is logical. However, knowledge of subsurface geology is critical to avoid misinterpretation. The ideal situation is when the geological substrate is homogeneous from ground surface to the contaminant source. Such conditions seldom exist, however, and discontinuous geologic strata, low and high permeability zones, impermeable surface layers such as pavement, etc. all affect results (11). A competent geologist should be consulted during data interpretation. Obviously geologic and possibly hydrologic data must be available or collected for proper data interpretation.

SUMMARY

Soil gas sampling can be a useful technique at both hazardous and radioactive mixed waste sites for achieving a variety of objectives. It offers the advantages of providing large amounts of data in a short period at low cost. Since excavation is not required, sampling hazards are also greatly reduced. For effective use of the technique, knowledge and skill are required to design the sampling effort, select sampling and analytical techniques and interpret the data.

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