RCRA FACILITY INVESTIGATION ACTIVITIES AT THE SANDIA NATIONAL LABORATORIES MIXED WASTE LANDFILL*

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ABSTRACT

The Mixed Waste Landfill (MWL) is an inactive landfill located on 1.6 acres (0.65 ha) in the north-central portion of Technical Area 3 at Sandia National Laboratories (SNL) in Albuquerque, New Mexico. The landfill accepted mixed hazardous and radioactive wastes, including low-level radioactive wastes and fission products, liquid wastes, tritium-contaminated equipment, and contaminated oils and other liquids in drums with dirt, plaster of Paris, and concrete, from 1959 through 1962 and radioactive wastes from 1962 through 1988. No waste has been accepted for disposal since 1988.

The MWL consists of two disposal areas: the classified area and the unclassified area. The unclassified area is the larger of the two areas, and is 432 feet by 200 feet (132 by 61 meters). Wastes were disposed into a series of seven unlined trenches, each approximately 180 feet (55 meters) long by up to 60 feet (18 meters) wide and about 25 feet (8 meters) deep. The classified area lies immediately adjacent to the unclassified area, measures 216 feet by 100 feet (66 by 31 meters). The classified area contains 40 known disposal pits and small trenches, most of which are located in the southern half of the area. The pits are unlined, circular or square in map view, and measure approximately 10 feet (3 meters) across by 25 feet (8 meters) deep.

Starting in 1989, a network of four ground water monitor wells were installed, and 18 soil borings were drilled as part of a Phase I RCRA Facility Investigation (RFI). The results of this phase of the investigation indicate that there is no ground water contamination beneath the site, and that tritium is the only contaminant in the soil zone immediately beneath the landfill. Tritium was found at low levels in the soil to a maximum depth of about 80 to 110 feet (25 to 34 meters). Ground water occurs at about 450 feet (140 meters) below land surface.

A Phase II RFI will be conducted during late 1992 and early 1993 to provide additional characterization information. Phase II of the RFI work is designed to produce data adequate to support selection of an appropriate response action. The work is to include: determination of the contaminant source term using surface geophysical and other methods; in-situ determination of the hydraulic characteristics of the unsaturated zone to support unsaturated zone flow and transport modeling; environmental tracers to quantify the rate of water and contaminant movement; and the determination of contaminant release mechanisms and exposure pathways in support of a probabilistic risk assessment. In addition, a methodology is being employed to quantitatively define the adequacy of the monitor well network. In-situ testing is scheduled to begin within the next several weeks.

INTRODUCTION

The Mixed Waste Landfill (MWL) at Sandia National Laboratories (SNL) in Albuquerque, New Mexico is a disposal facility that was used from 1959 to 1988 for the disposal of low-level radioactive and mixed wastes. A RCRA Facility Assessment (RFA) was performed in 1987 for the entire SNL installation pursuant to the requirements of Section 3004 (u) of RCRA. The MWL was identified through this RFA as a composite of nine separate solid waste management units (SWMUs).

In 1989, SNL conducted Phase I of a RCRA Facility Investigation at the MWL in order to determine the existence of contamination beneath the landfill and to assess the release potential of contamination (1). Evidence that tritium was migrating from the landfill was discovered through this work, however, no other contaminants were conclusively identified as having been released. The results of the work conducted during the Phase 1 RFI indicated that further work during a second phase of the RFI was required to further characterize the nature and extent of contamination at the MWL, and to determine the release and transport mechanisms of the contaminants. Additional work is currently being conducted according to the "Compliance Activities Work Plan" submitted on August 26, 1991. The Compliance Activities are work activities designed to address several issues related to Applicable and/or Relevant and Appropriate Requirements (ARARs), including the determination of the direction and rate of ground water flow, and the adequacy of the monitor well network. This facility has also been selected as an test site for the demonstration of new or emerging technologies by

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DOE's Office of Technology Development, and is entitled the Mixed Waste Landfill Integrated Demonstration.

REGULATORY FRAMEWORK

The MWL, being a mixed waste facility, has numerous regulatory drivers and DOE Orders to comply under. The site does not rate a ranking on the National Priorities List (NPL), and therefore is not specifically under a CERCLA/SARA (i.e., Superfund) regulatory driver. The site is being considered under the RCRA HSWA Part B permit which will be issued to SNL later this year. Therefore the main regulatory driver for this site is the RCRA 3004u Corrective Action rules. The regulatory process will be one in which characterization, or assessment, activities are carried out in order to define the extent of a contaminant release, and to provide the necessary information to evaluate risk and the potential remedial alternatives for the site. This step is called the RCRA Facility Investigation. Next, will be a Corrective Measures Study (CMS), whereby the remedial alternatives will be evaluated, and a recommendation made for final disposition of the site.

In addition to the RCRA Corrective Action process, DOE Order 5820.2A on Radioactive Waste Management also applies. Like RCRA, this Order also requires characterization of the site, monitoring, performance assessment, and closure. Many of these requirements are redundant with respect to the RCRA Corrective Action process, and therefore the RCRA driver will take precedence. However, the DOE Order necessitates air and subsidence monitoring, and this will be done outside the framework of the RCRA process. In addition, there are several other DOE Orders that deal with radioactive materials and constituents, which the RCRA regulations do not deal with explicitly. The framework becomes complicated with two federal agencies having oversight on different types of waste, namely hazardous versus radioactive wastes.

In addition to the RCRA Corrective Action driver and the DOE Orders, other regulations may fall into the category of Applicable and/or Relevant and Appropriate Requirements (ARARs). As required by DOE order 5400.4, the Environmental Restoration (ER) program approach is designed to meet RCRA requirements and to be "not inconsistent with" the Comprehensive Environmental Response and Liability Act (CERCLA) and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), 40 CFR part 300, as amended by 55 FR 8666 (March 8, 1990). Even though a regulatory requirement may not be directly applicable, it may be considered relevant, and therefore must be addressed. The closure criteria under RCRA's 3008(h) requirements do not appear to be directly applicable, but are considered relevant. So, too, are the monitor well network requirements in RCRA.

FACILITY SETTING

SNL is located (Fig. 1) on approximately 2,800 acres [1,133 ha] approximately 6.5 miles [10 km] east of downtown Albuquerque, New Mexico (1990 population 400,000), in Bernalillo County, entirely within the boundaries of Kirtland Air Force Base (KAFB) and portions of the Cibola National Forest. KAFB property is bounded to the north by the City of Albuquerque, to the west by State of New Mexico land, to the south by reservation land of Isleta Pueblo, and to the east by U.S. Forest Service land within the Cibola National Forest.

The climate of this region is typical of high-altitude, dry, continental climates; semi-arid, with an average annual precipitation of approximately 8 inches [20.3 cm]. Most of the precipitation occurs as intense, short-lived, thunderstorms during the late summer and early fall (2). The average monthly precipitation is less than 0.5 inches [1.27 cm] in the winter and 1.5 inches [3.81 cm] in the summer. Owing to a high evaporation rate and the low annual precipitation, the average annual net infiltration rate is presently estimated to be less than 1 inch [2.54 cm] (3). Wind speed is usually the greatest during the late winter and early spring, when much blowing dust and sand occurs as a result of a combination of contributory causes, including low vegetation density, wind speed, and low soil moisture.

SNL is located on the eastern edge of the Albuquerque-Belen basin in central New Mexico (4). The basin is bounded by the Nacimiento Uplift and Jemez Caldera to the north, the Socorro Channel to the south, the Puerco Plateau to the west (2), and the Manzano and Manzanita Mountains to the east. The Rio Grande flows north to south through the center of the basin, dividing the basin into an eastern half and a western half. The western half is called the West, or Cejas, Mesa; the eastern half is called the East Mesa. SNL lies on the eastern boundary of the East Mesa, on a broad, pediment which slopes 3 to 4% west toward the Rio Grande.

MWL SITE INFORMATION

The Mixed Waste Landfill (MWL) is an inactive landfill located on 1.6 acres (0.65 ha) in the north-central portion of Technical Area 3 at Sandia National Laboratories (SNL) in Albuquerque, New Mexico. The landfill accepted mixed hazardous and radioactive wastes, including low-level radioactive wastes and fission products, liquid wastes, tritium-contaminated equipment, and contaminated oils and other liquids in drums with dirt, plaster of Paris, and concrete, from 1959 through 1962 and radioactive and mixed wastes from 1962 through 1988. In 1967, approximately 270,000 gallons of coolant wastewater from the Sandia Engineering Reactor Facility was disposed of in Trench D which may have already contained waste. Approximately 1 curie (ci) of total radioactivity, mainly short-lived radionuclides, was discharged into the trench during this episode. No waste has been accepted for disposal since 1988.

The MWL consists of two disposal areas: the classified area and the unclassified area. The unclassified area is the larger of the two areas, and is 432 feet by 200 feet (132 by 61 meters). Wastes were disposed into a series of seven unlined trenches, each approximately 180 feet (55 meters) long by up to 60 feet (18 meters) wide and about 25 feet (8 meters) deep. The classified area lies immediately adjacent to the unclassified area, measures 216 feet by 100 feet (66 by 31 meters). The classified area contains 40 known disposal pits and small trenches, most of which are located in the southern half of the area. The pits are unlined, circular or square in map view, and measure approximately 10 feet (3 meters) across by 25 feet (8 meters) deep.

MONITOR WELL NETWORK

Three groundwater monitoring wells were installed at the MWL in 1989 and developed in 1990 to supplement one installed in 1988. These monitor wells were installed in a one-upgradient, three-downgradient pattern, based on

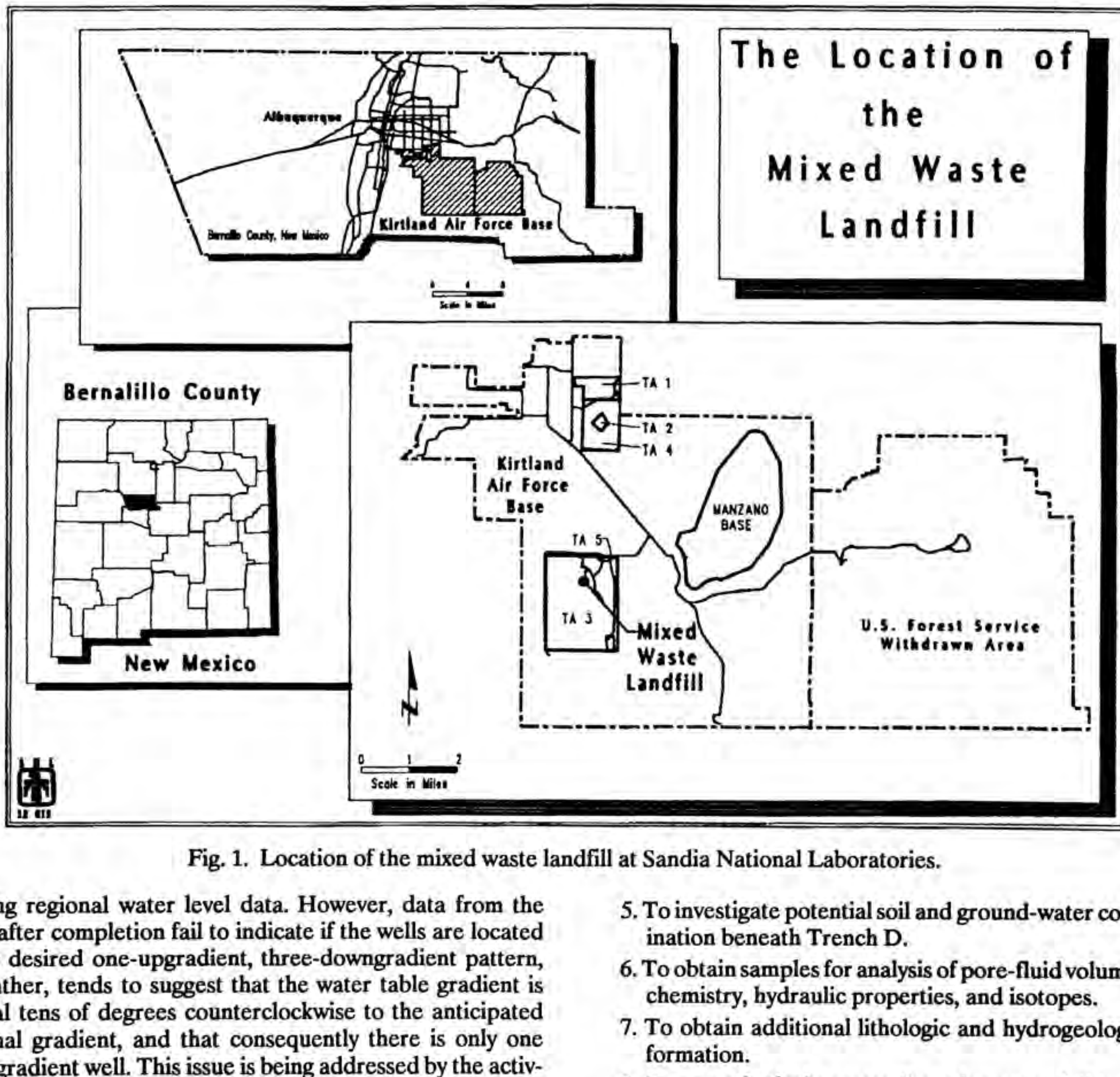


Fig. 1. Location of the mixed waste landfill at Sandia National Laboratories.

existing regional water level data. However, data from the wells after completion fail to indicate if the wells are located in the desired one-upgradient, three-downgradient pattern, but rather, tends to suggest that the water table gradient is several tens of degrees counterclockwise to the anticipated regional gradient, and that consequently there is only one downgradient well. This issue is being addressed by the activities conducted in accordance with the Compliance Activities Work Plan. No contaminants were detected in the unsaturated zone sediments during drilling of the monitor well boreholes or in the produced water during development. A total of five rounds of groundwater sampling have been conducted since September 1990. No contaminants were found in any of the monitor wells during any of these sampling events. Depth to groundwater is approximately 450 feet (140 meters).

The Compliance Activities Work Plan is intended mainly to address the adequacy of the monitor well network. Specific goals of this work include:

1. To install an additional monitor well (or wells, if necessary)
2. To obtain additional information regarding the groundwater gradient directly beneath the MWL.
3. To determine whether there is a ground-water mound beneath Trench D.
4. To collect data on the horizontal and (approximate) vertical saturated permeabilities of the aquifer strata beneath the MWL.
5. To investigate potential soil and ground-water contamination beneath Trench D.
6. To obtain samples for analysis of pore-fluid volume and chemistry, hydraulic properties, and isotopes.
7. To obtain additional lithologic and hydrogeologic information.
8. To quantitatively assess the adequacy of the entire monitor well network.

An assessment of the monitor well network performance will be done using Performance Assessment (PA) methodology. PA methodology is an approach by which a physical system can be evaluated against a set of performance criteria. For assessment of the monitor well network, steps in the approach are:

1. Establish performance criteria.
2. Formulate conceptual models of the physical system.
3. Select, or identify, major pathways and transport processes within the framework of the conceptual model.
4. Collect available site characterization data, specified in the form of probability density functions (pdfs).
5. Select analytical or numerical methods to calculate or simulate flow and transport.
6. Using Latin Hypercube Sampling (LHS) and Monte-Carlo techniques, generate many realizations of predicted contaminant plume intersections at the water table and transport in the saturated zone.

7. Evaluate the placement of the monitor wells with respect to the probability distribution of contaminant plume intersections and transport paths to determine whether the performance criteria are met.
8. If the criteria are not met, then an optimization method will be utilized, together with the Monte Carlo results, to define the optimal placement of well(s) in order for the criteria to be met.

In general, there exists a certain amount of uncertainty in the input data and parameters (i.e., what is known about the physical system), and therefore the results of a performance assessment also have associated uncertainty. The performance criterion for this PA is proposed to be the 80% probability of detecting a possible contaminant plume. For example, if 1,000 realizations of possible plumes are simulated, and 800 of the realized plumes intersect at least one monitoring well, then there exists an 80% probability that a contaminant plume would be detected (Fig. 2). Parsons and Davis (5) provide a more detailed discussion of the methodology. The proposed probability of detection, 80%, is consistent with EPA's statistical criteria for sampling/detecting a contaminant release in soils. Additional monitor wells may need to be installed if the results of the well network assessment indicate that the present monitor well network is not capable of detecting the contaminant plume with the desired confidence level. This methodology puts a quantitative endpoint on the elusive question "When are enough wells enough?"!

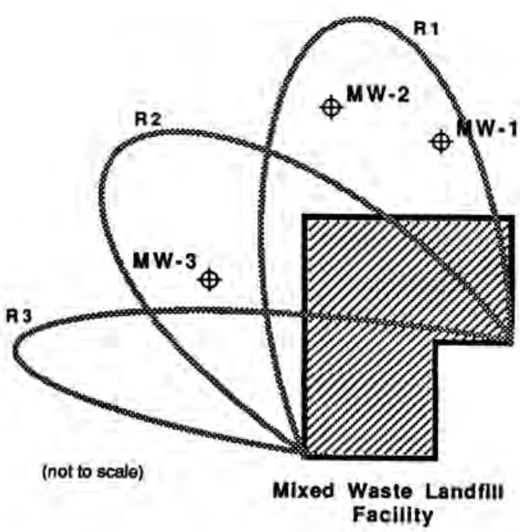
The methodology just described has been transcribed by SNL into a public domain computer code with:

- User friendly, mouse driven, graphical user interface (GUI)
- Unix/X Windows system on a Sun hardware platform
- Interfaces to the Geographical Information System GRASS
- Process models that are not 'locked in', they are user defined
- Currently undergoing beta testing

Phase 1 RFI

The goals and objectives of Phase 1 of the RFI have been successfully accomplished. Evaluation of the Phase 1 findings indicates that additional source, contaminant release, and environmental characterization needs to be completed in order to better define the source term, distribution of potential contamination, and the subsurface hydrogeologic characteristics beneath the MWL. The most important Phase 1 results included in the summary, conclusions, and recommendations in the RFI Phase 1 report include:

- The site lithology is typical for alluvial-fluvial depositional environments, consisting predominantly of coarse to fine sands and silts. Two *distinct* very-coarse units were identified under the northern portion of the landfill: one northeast-southwest trending gravel and cobble unit was identified between 50 and 75 feet (15 and 23 meters), another more aerially extensive and thicker gravel and cobble unit was observed to occur from about 95 feet to 130 feet (29 and 40 meters) across the entire site.
- Caliche is present as coatings, thin veinlets, and layers throughout much of the upper 150 feet (46 meters) or more of the profile.
- Results of analyses for inorganic and organic contaminants from soil samples did not reveal the presence of any target compounds above action levels.
- The results of radiological analyses for alpha and beta emitters, gamma radiation spectometry, uranium, and plutonium were within background limits.
- Radioanalytical results for tritium from the same samples show significant tritium contamination in the soil within the upper 30 feet (9 meters), with



Wells	Hits 1	2	3	Plume Detected
Realization 1	1	1	0	1
2	0	0	1	1
3	0	0	0	0
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
1000	.	.	.	.
Total Detected				950

$$\text{Probability of Detection} = \frac{950}{1000} = 95\%$$

Fig. 2. Monitor well network methodology for multiple plume realizations to estimate probability of detection.

concentrations above background levels extending down to 110 feet (34 meters).

- Results of air-pathway monitoring show that airborne tritium concentrations are less than or equal to background levels.
- Additional characterization work is recommended in order to better define the source term and existing soil contamination, to assess the potential for further migration of contaminants away from the landfill, and to provide sufficient information upon which further corrective action may be based.

PHASE 2 RFI

The Phase 2 RFI Work Plan contains the rationale and procedures necessary to produce data adequate to support the selection of one of the following actions at the MWL:

- No Further Action (NFA);
- Interim Measures (IM); or
- Corrective Measures Study (CMS);

Phase 2 characterization is to include identification of the type and concentration of hazardous substances released, information on the rate, direction, and extent of potential and observed contaminant migration, and to provide suitable characterization information to support the selection, design, and completion of one of the above alternatives.

The decisions on whether an NFA , IM, or a CMS is required will be based on an analysis of all available information obtained prior to, and during, the RFI, and will include a thorough review of all analytical results for the sampled media along with an assessment of risk to human health and the environment resulting from each of the above responses. Because tritium has been identified as a migratory contaminant at the MWL, a full probabilistic risk assessment (RA) is necessary to determine if the observed concentrations present an acceptable risk level for each of the response scenarios. If the concentration of any target substance is observed to exceed specified action levels and exposure pathways exists which may threaten human health and the environment, further action (IM or CMS) will be required. If results of all analyzed samples are below the established action levels, and there are no apparent risks, the site will be categorized for NFA under the RCRA CA process.

In order to accomplish these objectives, the following activities are proposed for the Phase II RFI:

1. determination of the nature and extent of the contaminant source,
2. determination of the nature and extent of contamination within the soil and ground water,
3. determination of the environmental setting at the MWL, with respect to contaminant transport mechanisms.

The activities proposed in this work will utilize extensively the Data Quality Objectives (DQOs) concepts, as well as the Observational Method (sometimes referred to as Streamlined Approach) guidelines in order to collect defensible data and to make cost and time effective decisions in the course of this investigation. The resulting general approach included in this work plan includes the following components:

1. Contaminant Source Characterization:
   - surface geophysical surveys to define trench and pit boundaries and locations of buried wastes, along with continuation of an ongoing literature search and compilation to identify all available records, reports, interviews, and other information about the buried waste types, volumes, and characteristics.
2. Contaminant Release Characterization
   - walkover radiation survey of the surface at the MWL, including a gamma-spectometry survey,
   - air sampling at the ground surface within, and adjacent to, the MWL,
   - subsurface soil gas survey for tritiated water vapor and volatile compounds in the soil,
   - subsurface soil sampling, including samples for radiological and chemical analyses, and samples for laboratory determination of soil hydrologic/hydraulic properties,
   - ground water samples
3. Environmental Characterization:
   - in-situ testing to determine soil hydrologic/hydraulic properties,
   - laboratory analysis of core samples for soil hydrologic/hydraulic, physical/geotechnical, and chemical properties.
   - the use of environmental tracers (3) to quantify the rate of water and contaminant movement (e.g., bomb-pulse chlorine-36 and tritium, stable isotopes such as deuterium and oxygen-18)

The data collected during this investigation will be used to complete an assessment of the risk hazards to human health and the environment arising from contamination associated with the MWL.

PROBABILISTIC RISK ASSESSMENT

As with the performance assessment methodology described above to define the monitor well network adequacy, a risk assessment must also take into account the uncertainties in the input data and parameters to evaluate the impact of these uncertainties on the outcome. In other words, uncertainty in the physical system should translate into uncertainty in risk. In order to account for these uncertainties explicitly a probabilistic risk assessment methodology is being undertaken. The basic components of this methodology are as follows:

- Define conceptual model
- Define source term
- Define potential pathways/receptors
- Choose process models
- Define pdf's for key parameters
- Use LHS to optimize combinations of values from the input pdf's
- Run multiple simulations (Monte Carlo)
- Analyze output pdf for performance measure (e.g., uncertainty in dose/risk estimate)

Realizing the importance of quantifying uncertainty, to the extent possible, will enable a more rational approach to defining the risk associated with a waste site, whether ecological or health based. Basically, by using a probabilistic approach to risk assessment, then a probability may be assigned to the risk estimate. Deterministic, or single run, risk assessments are not defensible. The uncertainties are not quantified in a deterministic approach, and therefore assumptions made for input data and parameters may or may not be conservative for the performance measure.

SNL is currently developing methodologies which would utilize probabilistic risk assessment and statistical techniques to define how many samples to collect, and where to collect the samples, during characterization activities. This approach is directly tied to the DQO process. In addition, based on risk assessment, the residual concentrations of hazardous and/or radioactive constituents in the soil may be quantitatively determined. This will help answer the question "How clean is clean?" because the cleanup levels will be risk driven. The risk assessment methodology, the statistical sampling methodology, and the risk driven cleanup level approach, are all slated to be part of the Decision Support System (DSS) model described above. The DSS will provide a user-friendly platform upon which decisions can be made related to "How many wells are enough?", "How many samples are enough?", and "How clean is clean?". The DSS provides an easy to use graphically oriented tool, such that the user does not have to get caught up in the complex mathematical and bookkeeping tasks inherent in conventional modeling approaches.

SUMMARY

The Mixed Waste Landfill facility at Sandia National Laboratories is undergoing a number of assessment activities. A Phase 1 RCRA Facility Investigation has determined that tritium is the contaminant of concern at the site. It has migrated to depths of 80 to 110 feet (24 to 34 meters) below the landfill, and is probably outgassing from the landfill surface. The depth to groundwater at the site is 450 feet (140 meters). The monitor well network at the site has not detected any contaminants to date. The monitor well network's adequacy is suspect. A methodology has been devised to quantitatively assess the adequacy of the network. This method relies on probabilistic performance assessment techniques, using Latin Hypercube Sampling and Monte Carlo simulation methods. If the network is deemed unsatisfactory, an optimization method is employed to define the optimal locations for additional well(s) based on the Monte Carlo output of all possible plume realizations. A Phase 2 RFI will begin this year to supplement the information gathered in the Phase 1 RFI. Additional characterization of the site is necessary in order to evaluate potential contaminant pathways, receptors, health risk, and the potential remedial measures. The health risk assessment will be accomplished probabilistically also. The uncertainty in the physical system is quantitatively accounted for when utilizing a probabilistic approach, thereby translating this uncertainty into a probability of risk. This probabilistic approach is more defensible than a deterministic one.

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