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Revision 0

SUMMARY OF RWMC INVESTIGATIONS REPORT

R. J. Bargelt
C. A. Dicke
J. M. Hubbell
M. Paarmann
D. Ryan (SAIC)
R. W. Smith
T. R. Wood

Published January 1992

Idaho National Engineering Laboratory
EG&G Idaho, Inc.
Idaho Falls, Idaho 83415

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SUMMARY OF RWMC

INVESTIGATIONS REPORT

EGG-WM-9708

Reviewed by:

J. P. Shea

J. P. Shea
ERP Independent Review Committee

Nov 13, 1991
Date

D. J. Claflin

D. J. Claflin
Patent Clearance

11/22/91
Date

Approved by:

W. H. Sullivan

W. H. Sullivan, Manager
WAG-7

11/20/91
Date

FOREWORD

The summary of investigations at the Radioactive Waste Management Complex was initiated according to requirements described in the Resource Conservation and Recovery Act (RCRA) Facility Investigation Work Plan completed in December 1988 as per the RCRA Consent Order and Compliance Agreement (COCA). In November 1989, due to detection of three contaminant release sites, the Idaho National Engineering Laboratory (INEL) National Priorities Listing (NPL) Notice was published in the Federal Register. Activities pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) commenced in accordance with the National Contingency Plan (NCP). These activities include the completion of a Federal Facilitization Agreement Consent Order (the Notice of Intent to Execute the Federal Facility Agreement and Consent Order was signed July 22, 1991 by representatives of the State of Idaho, U.S. Environmental Protection Agency, and U.S. Department of Energy).

As described in the Federal Facility Agreement Action Plan, the Radioactive Waste Management Complex (RWMC) is now divided into fourteen operable units for investigation and remediation. With this approach of individual operable unit study, this document serves as a resource base for existing knowledge of the nature and extent of contamination and site characteristics that affect contaminant migration at the RWMC.

ABSTRACT

The Radioactive Waste Management Complex was established in 1952 for disposal of solid radioactive waste generated by U.S. Department of Energy operations at the Idaho National Engineering Laboratory, and other U.S. Department of Energy sites. This summary of investigations presents a preliminary conceptual site model, based on an evaluation of data through August 1990, and describes the environmental phenomena that impact the movement of contaminants through the RWMC. Summary investigations were developed for each transport medium including the geologic setting, fluid flow in the vadose and groundwater zones, pore-water and groundwater geochemistry, terrestrial ecology, and atmospheric setting.

CONTENTS

FIGURES

FIGURES (continued)

FIGURES (continued)

FIGURES (continued)

TABLES

TABLES (continued)

TABLES (continued)

1.1 INTRODUCTION

The Resource Conservation and Recovery Act Facility Investigation (RFI) Work Plan for the Radioactive Waste Management Complex (RWMC), Idaho National Engineering Laboratory (INEL), was completed in December 1988. The document outlined the investigation of site contaminant characterization of nonradioactive hazardous constituents at the Subsurface Disposal Area (SDA). The investigation was to be documented in an RFI Report to the U.S. Environmental Protection Agency (EPA). However, in November 1989, due to the detection of three contaminant release sites, the INEL was placed on the National Priorities List (NPL). Given the potential for the investigation at the SDA to be subject to Comprehensive Environmental Response, Compensation Liability Act (CERCLA) requirements, site characterization of radioactive constituents would be incorporated into the RFI work. EPA agreed to delay the deliverable of an RFI Report, and the work in progress was divided into two separate reports: 1) the RWMC Investigation Report EGG-WM-9707 (summarizing data collected through August 1990, and 2) the summary of RWMC investigation Report EGG-WM-9708 (evaluating site physical characteristics, and the native and extent of contamination).

Under CERCLA, the U.S. Department of Energy (DOE) as the managing agency at the INEL, is required to enter into a Federal Facility Agreement to coordinate assessment and remediation activities. The Notice of Intent to execute the INEL Federal Facility Agreement and Consent Order (FFA) was signed July 22, 1991 by the State of Idaho, EPA, and DOE. The FFA integrates CERCLA response obligations with RCRA and Hazardous Waste Management Act corrective action obligations. All environmental restoration activities are also conducted to meet location, contaminant, and action--specific requirements imposed by statues and regulations.

In the FFA, the INEL is divided into ten waste area groups (WAGs) for management purposes. WAGs are further divided into operable units (OUs) that group potential or confirmed release sites, and identify similar contamination problems. Descriptions of WAGs and corresponding OUs can be found in the *INEL*

Environmental Restoration and Waste Management Site-Specific Plan for Fiscal Year 1992. Further information on INEL OU studies is presented in the *INEL Action Plan for Implementation of the Federal Facility Agreement and Consent Order*, which identifies and describes the CERCLA process "tracks" including No Action, Preliminary Scoping (Track 1 and Track 2), Interim Action, and Remedial Investigation/Feasibility Study Scoping.

Within the CERCLA process, this preliminary conceptual model will serve as reference of the nature and extent of contamination, and contaminant transport at the RWMC, in operable unit studies.

1.1 PURPOSE

This report provides a status of the present knowledge and understanding of the RWMC site and processes affecting contaminant movement from the RWMC. In addition to serving as a basis for planning future site characterization activities for the RWMC, this report will be a technical source document for the baseline risk assessment studies and for ongoing remedial technology development projects (e.g., vapor vacuum extraction and in situ vitrification). This report presents the following information:

- Description of the waste source characteristics

- Interpretation of historical and recent data on the geologic, hydrologic, geochemical, biotic, and atmospheric characteristics

- Interpretation of the existing data regarding their significance to potential contaminant movement

- Identification of key issues regarding the present understanding of the physical, chemical, and biological transport processes

- Recommendations for future site characterization.

1.1.1 Overview

One of the main objectives of the Idaho National Engineering Laboratory (INEL) Environmental Restoration Program (ERP) is to determine the need for any environmental restoration of the Radioactive Waste Management Complex (RWMC) site in a timely manner. By the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), in-depth evaluations will be made of the alternatives for final disposition of the mixed wastes at the RWMC. Some of the basic alternatives are (a) in-place stabilization of the waste (e.g., in situ vitrification and protective barriers); (b) in situ remediation (e.g., vapor vacuum extraction and bioremediation); and (c) retrieval (i.e., removal, minimization, packaging, and transport to a repository). For each of these basic alternatives, there is a broad spectrum of options composed of current and emerging remedial technologies.

Health-based risk assessments that address present and future risks to workers and the public will play a key role in determining the need for any remediation. These same assessments will be used to screen, select, and design remedial alternatives for individual operable units if required (i.e., cleanup action for a designated portion of the waste site). Exposure scenarios will be evaluated by modelling the fate and transport of contaminants through air, surface water, groundwater, soil, and biota. To reliably model the relationships between the waste sources, transport processes, and the receptors, a specialized data base will be compiled through site characterization activities.

Because of the diverse nature and high cost of site characterization activities, there is a need to carefully guide the data collection process and ensure that the specific data needs for risk assessments are met. A conceptual modelling approach has been adopted as a tool for maintaining a focused site characterization activity for the RWMC. This approach is consistent with the guidance for the CERCLA and Resource Conservation and Recovery Act (RCRA) Remedial Investigation/Feasibility Study (RI/FS) process (EPA, 1988 and 1989). An iterative process (see Figure 1-1) is envisioned for conceptual model development, risk assessment, and remedial alternative selection/design. As indicated in the figure, the appropriate degree of characterization will be determined on the basis of level of confidence in compliance with regulatory requirements.

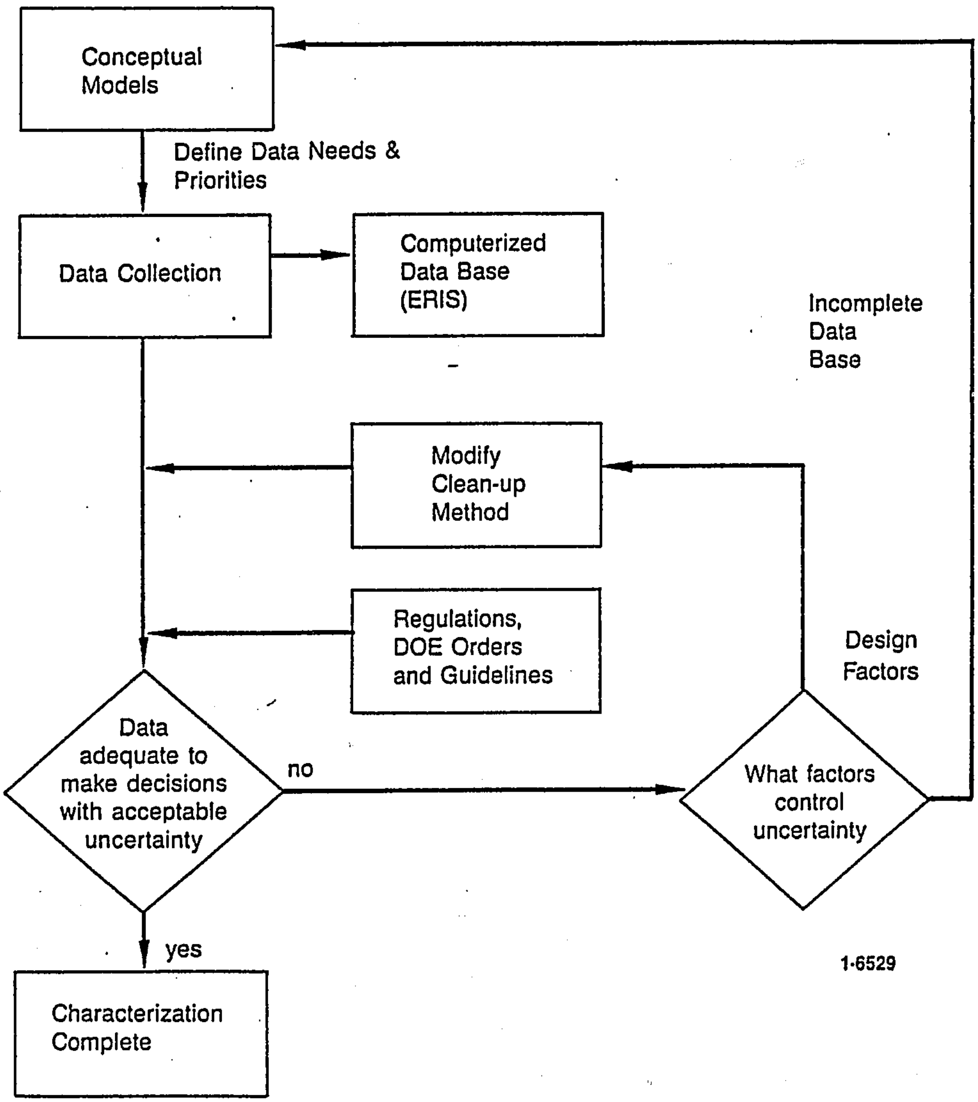

Figure 1-1. Iterative Process through which adequate Site Characterization will be determined.

2. RWMC CONCEPTUAL MODEL SUMMARY

This conceptual model has been developed to describe the movement of water and contaminants from the RWMC based on an evaluation of the existing data. The sections of this report discuss in detail the current conceptual understanding of the environmental phenomena that impact the movement of contaminants from the RWMC. This section presents a brief description of the processes that are important for contaminant migration; it also serves as a summary of what is known about the hydrogeologic, meteorological, and geochemical systems at RWMC.

The conceptual model of the RWMC (Figure 2-1) depicts the relationship between primary sources of contaminants and receptors. Contaminants can travel by several pathways to reach receptors, as shown through the description of the sources of contaminants and contaminant release mechanisms, contaminant transport times, contaminant pathways, exposure routes and receptors, and demography and land use.

2.1 CONTAMINANT SOURCES AND RELEASE MECHANISMS

Contaminants are released from stored waste (primary sources) to surficial sediments (secondary sources), to vadose zone basalts, interbeds, and to perched water (tertiary sources). Contaminants are released from the primary, secondary, or tertiary sources to various pathways by volatile emission or infiltration/leaching.

A generalized processed-based source term model for the RWMC has been developed using the following assumptions:

- The waste is emplaced in trenches and pits. The waste may initially not be enclosed or may be enclosed in steel drums or boxes. Also, free liquid was disposed in the acid pit.

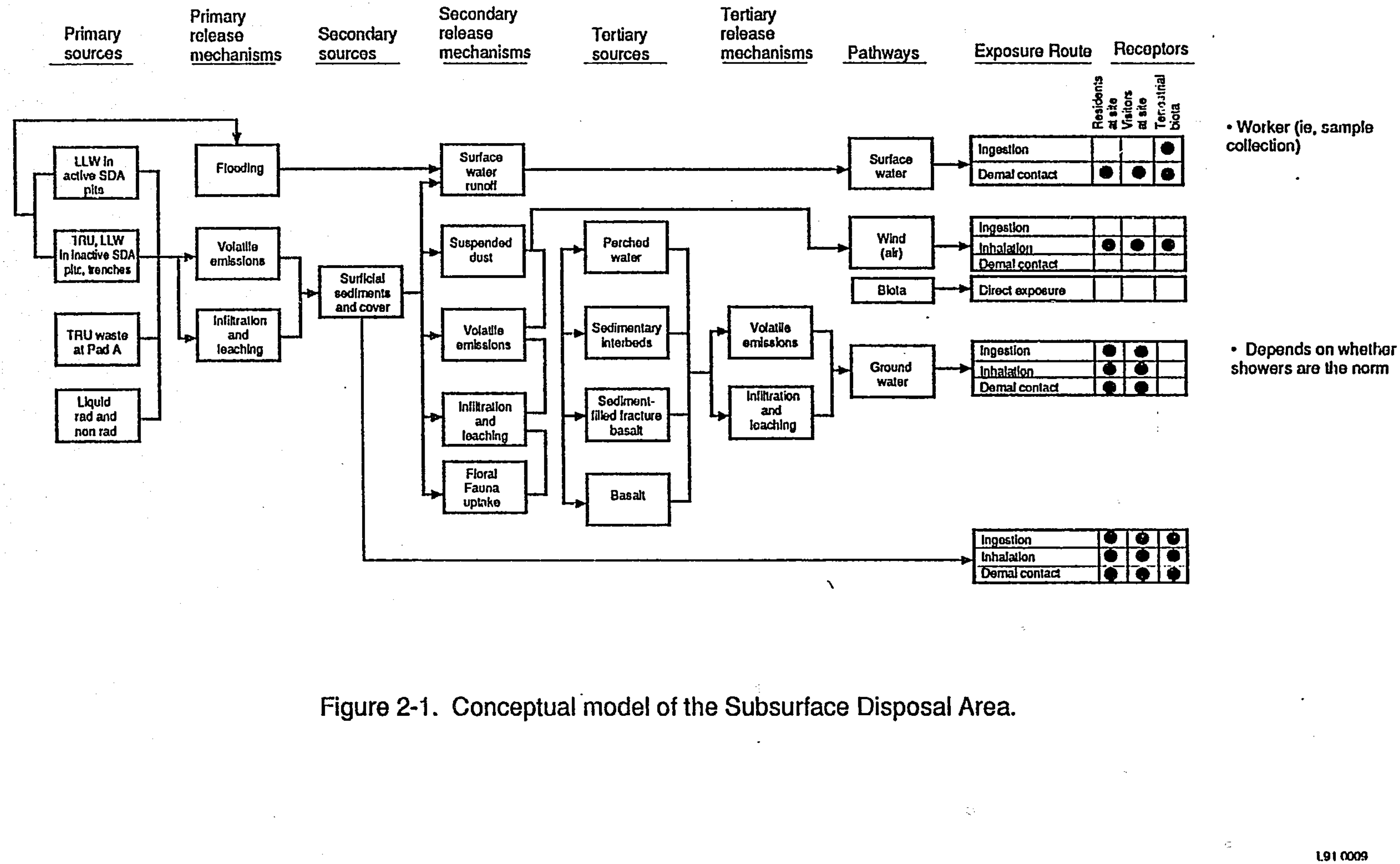

Figure 2-1. Conceptual model of the Subsurface Disposal Area.

- Over time the containers fail and the material is available for leaching.

- Water passing through the waste pits leaches out contaminants. This leaching may be slowed by adsorption on the waste materials or backfill and by solubility limitations.

- The radionuclides may be absorbed in the soil layer below the waste, delaying release and providing additional time for radioactive decay.

- The sediment/basalt or the air/landsurface interfaces are defined as boundaries for release of contaminants from the source.

2.1.1 Primary Sources

Primary sources of contamination at the RWMC include the waste disposal at the Subsurface Disposal Area (SDA): low-level waste (LLW) in active pits, transuranic (TRU) waste, TRU mixed waste, LLW mixed waste and hazardous waste buried in pits and trenches, and TRU waste at Pad A. Additionally, liquid wastes namely, radioactive and nonradioactive laboratory solvents and acids were disposed and/or poured into selected pits at the SDA. Hazardous and radioactive wastes have been disposed in the SDA since 1952.

Past disposal practices have resulted in early failure of a significant number of drums and other containers with the release of contaminants. Before 1969, these drums and containers were randomly dumped into the disposal areas. Since 1969, the disposal practices were changed to stacking of the containers in the minimization of environmental impacts.

2.1.1.1 Primary Release Mechanisms. Contaminant sources and release mechanisms of radionuclide and hazardous contaminants at the SDA are summarized in Figures 2-2 and 2-3. Movement of contaminants from the SDA may occur by three primary release mechanisms: (1) aqueous

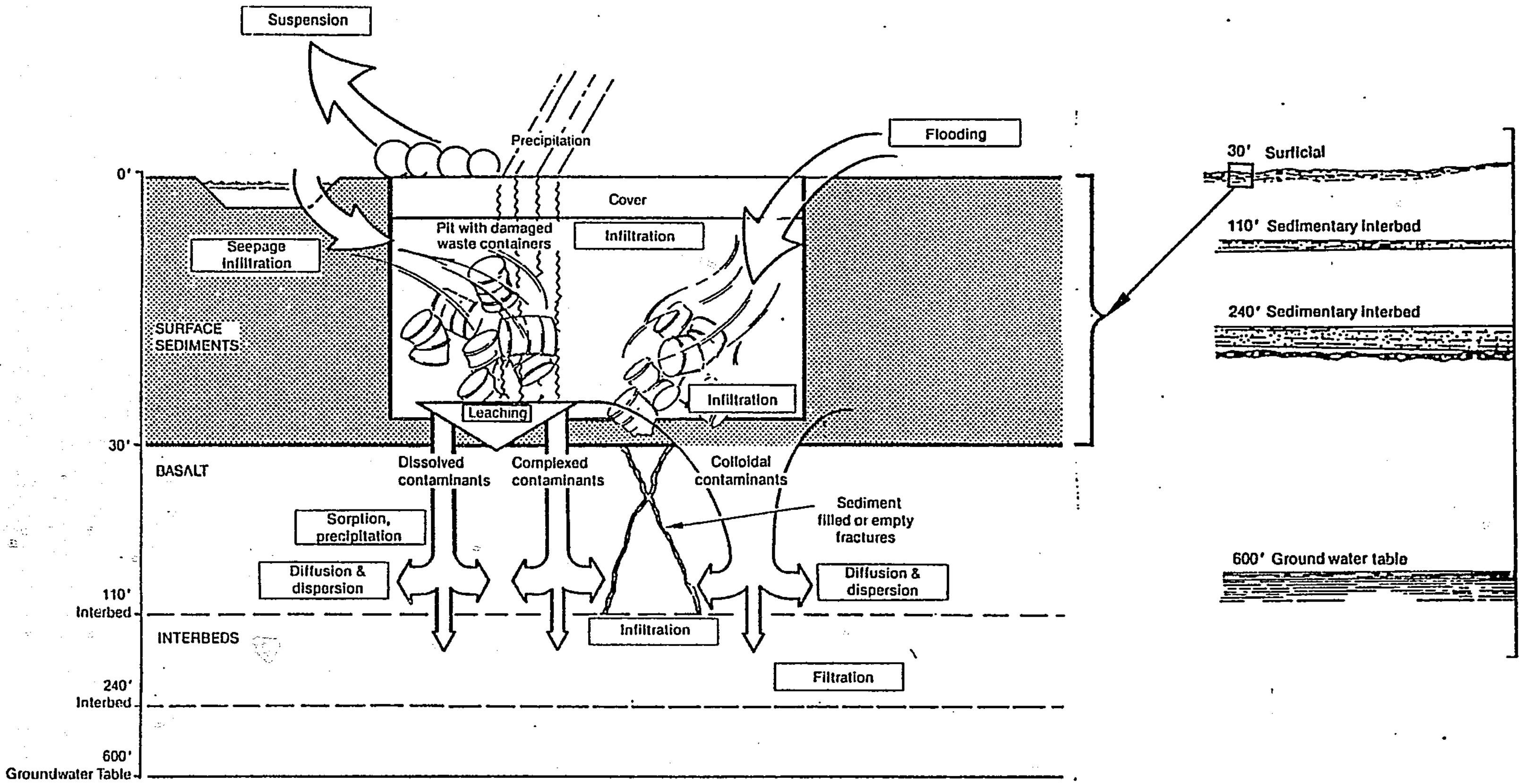

Figure 2-2. Conceptual model of radionuclide and hazardous contaminant migration at the SDA.

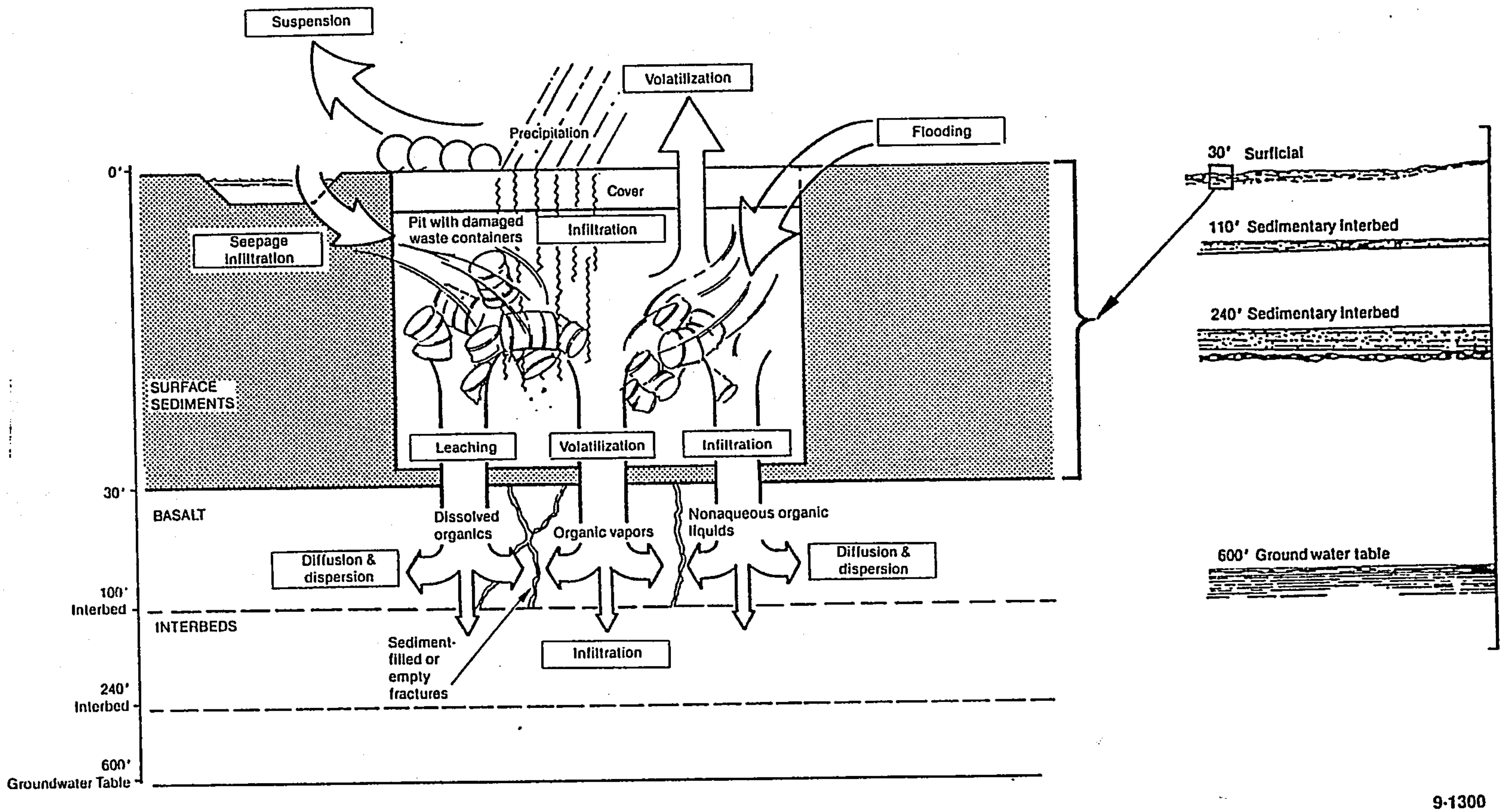

Figure 2-3. Conceptual model of volatile organic chemical containment migration at the SDA.

phase transport during flooding, (2) gaseous phase transport of volatile emissions, and (3) infiltration and leaching from the waste pits through the vadose zone.

2.1.1.2 Flooding--The SDA was flooded in 1962, 1969, and 1982 because of local basin runoff. These flooding events were the consequence of rapid snowmelt combined with heavy rains and warm winds, which resulted in runoff water from surrounding areas entering the SDA. During these events, various open pits and trenches which store hazardous and radioactive waste were flooded. Flooding of the SDA accelerates the release of contaminants by increasing the direct exposure to water. Contaminants may then be released to surface water systems or to the vadose zone/groundwater system due to increased infiltration rates.

2.1.1.3 Volatile Emissions--Volatile emission from organic compounds is another primary release mechanism (Figure 2-3). The sources of these organic compounds are predominantly drums of chlorinated solvents, (i.e., carbon tetrachloride mixed with machine oil and solidified with a commercial absorbent). Because of the loss of the integrity of many containers due to crushing and corrosion, organic vapors have escaped and have been migrating through the vadose zone, downward toward the underlying aquifer or upward towards the atmosphere.

The transport of volatile organic compounds through the unsaturated zone is a complex process. The disposed contaminants may exist in three phases: aqueous (or dissolved) phase, a nonaqueous (or oily) phase, and a vapor phase. Because of the volatile nature of the organics, there is rapid partitioning between the aqueous, nonaqueous, and vapor phases.

In the surficial sediments, transport of organic vapors is dominated by the processes of molecular diffusion and density-driven flow. These processes dominate during low moisture conditions in the soil and account for the venting of the vapors to the atmosphere. During conditions of high soil moisture, such as flooding, the processes of dissolution and liquid transport dommate. As a result, water flow through the unsaturated zone mostly affects the rate and direction of the organic vapor transport.

The interconnected porosity and permeability of the basalt and sediments are major factors controlling the direction of vapor transport because the vapor will preferentially follow fractures and porous intraflow structures. Sedimentary interbeds act as barriers (pore space is mostly filled with water) to organic vapor movement.

The nonaqueous phase organics are expected to be the least mobile components of the organics because of the property of high viscosity. The nonaqueous phase component consists of machine oil. This oil that was in the 55-gal drums is assumed to remain in the near vicinity of these containers. Any significant movement of the nonaqueous phase could occur by only immiscible displacement. Past flooding events may have induced some degree of immiscible displacement of the nonaqueous phase organics.

If future flooding and deep infiltration of water were excluded, migration of aqueous and nonaqueous phases should be very slow. Migration of vapor phase organics is expected to continue as long as waste sources exist in the pits.

2.1.2.3 Infiltration and Leaching. Infiltration and leaching of contaminants are identified through primary, secondary and tertiary release mechanisms. Geochemical processes significant to this primary release mechanism (infiltration and leaching) are speciation, dissolution and precipitation, and sorption.

Initial leaching of disposed waste will occur by dissolution processes. The rate and extent of dissolution of the waste will be affected by the speciation of radionuclides and other contaminants in soil waters. The potential to form intrinsic or true colloids is greatest during dissolution of disposed waste, and contaminants can sorb onto natural colloids to form pseudo colloids.

2.1.2 Secondary Sources

Secondary contaminant sources result from the release of contaminants from flooding, volatile emissions, or infiltration and leaching of primary sources. Surficial sediments around and beneath the pits and solid cover over inactive pits and trenches are secondary sources that release contaminants (see Figure 2-1).

2.1.2.1 Secondary Release Mechanisms. Release of contamination from the surficial sediments can occur from surface water runoff from the SDA cover areas, wind suspension of contaminants, volatile emissions, infiltration and leaching, and flora and fauna uptake.

2.2.1.1 Surface Water—Surface water is considered a major mechanism for the release of contaminents only during refevent flood events. Secondary release mechanisms move contaminants directly into the surface water and air pathways from the surficial sediments (see Figure 2-3).

Migration of contaminants (via., surface water) has been observed only during flooding events. The possibility of surface migration to or from the SDA is controlled by the perimeter drainage channel. Local runoff within the SDA flows to a sample/discharge outlet on the east end of the SDA. These flood control measures have proven successful in diverting local basin runoff greatly reducing the risk of flooding.

2.2.1.2 Wind Suspension of Contaminants—Contaminated particulates may be found at both the surface and the subsurface soil layers. Wind suspension of these contaminates is caused by the following factors: (a) breaching of above-ground containers, (b) contaminated subsurface soils exposed during retrieval operations, (c) flooding events that transport contaminants from the subsurface to the surface soils, (d) fine particulate contaminants that percolate to surface layers similar to gaseous emissions, (e) wind blown particulates transported into RWMC from other INEL operating areas, and (f) biotic pathways.

Generally these release mechanisms are not considered a major threat of contamination. Operating procedures, safeguards, and preventive construction have minimized wind suspension of contaminants. Examples of activities that reduce wind suspension of contaminants include containment of spills and of retrieval operations, construction of dikes and ditches for the control of runoff, and the design of the SDA cover in the minization of both biotic disturbance and gaseous emissions.

2.2.1.3 Volatile Emissions—Breaching of the waste containers buried in the subsurface soils of SDA has allowed the escape of both gaseous- and liquid- phase contaminants to the pathways. The gasses may migrate or diffuse upward through the soil column, to the air-soil surface interface, and eventually to the atmosphere. The volatile fraction of liquid contaminants will evaporate and undergo the same diffusion process. This process may serve as the major mechanism for long-term releases of volatile organic contaminants from the buried waste containers in the SDA to the air pathway.

Because of current management practices, surface spills or leaks of gaseous or liquid volatile contaminants are not frequent occurrences at the RWMC, and therefore are not a significant contributor to short-term atmospheric pollutant levels.

2.2.1.4 Infiltration and Leaching—The passage of contaminated soil waters through surficial sediments and cover could result in the loss of contaminants from the water to the sediments by sorption and colloid filtration. Although sorption retards the movement of contaminants in the soil water and groundwater, sorption could result in the formation of a secondary source of contaminants in the surficial sediments. The secondary source is also subject to release by the leaching processes.

Dissolution may not be an important process for secondary sources because the contaminants may occur as predominately sorbed to clay or carbonate and oxide surfaces. In addition, the concentrations of contaminants may be low such that they could preclude any formation of true colloids. However, speciation continues to be an important process because of the dependence of surface properties on solution composition and the potential for complexation and pseudocolloid formation.

2.2.1.5 Flora and Fauna Uptake—Contaminants can enter plants by uptake from soil, deposition from air, or sorption from water. Contaminants in soil may pass through the root to be incorporated into plant tissues, or they may adhere to the surfaces of the plant where they may be absorbed.

Fauna uptake from contaminated plants to herbivores occurs through the food chain. Herbivores also ingest contaminants associated with soils or sediments. In dusty environments, particulate contaminants can be inhaled by the animals in close proximity to the RWMC. Small mammals live in the SDA, and many of these animals burrow into the cover and in the soil adjacent to the buried waste.

2.1.3 Tertiary Sources

Tertiary sources of contamination are perched water, sedimentary interbeds, sediment-filled fractures, and the basalt underlying the surficial sediment. The formation of tertiary sources are analogous to the formation of secondary sources (Figure 2-1). The volatile emissions, infiltration, and leaching of surficial sediments contribute to the formation of these contaminants.

Some perched water zones have been contaminated by deposition from primary and secondary sources. Because small perched water zones have been detected just above the sedimentary interbeds. Evidence suggests that during high recharge events the water movement in the perched zones may be lateral as well as vertical. Contaminant levels in perched water zones have been relatively high and may represent the presence of significant tertiary sources.

Because of high clay content in the sedimentary interbeds, sediment-filled fractures, high cation exchange capacity, and filtration of colloids, the interbeds have the potential to be a significant tertiary source.

Sedimentary zones are generally assumed to control the movement and adsorptive chemistry of subsurface contaminant waste solutions and colloids.

Basalt that has become contaminated by surface/runoff water leaching or infiltrating the waste is also a tertiary source because contaminants may flow through open fractures within the basalt or through the interconnecting vesicles, with capillary flow that may occur in closed fractures and joints. Lateral movement and perched water will occur at the sediment/basalt interface because of this contrast in hydraulic properties.

2.1.3.1 Tertiary Release Mechanisms. Release mechanisms for tertiary sources include volatile emissions and infiltration and leaching (Figures 2-1 and 2-3). Releases from tertiary sources are at lower concentrations than from the primary sources, but the releases may be significant because they are close to the Snake River Plain Aquifer.

2.1.3.1.1 Volatile Emissions—Volatile emissions are identified with primary, secondary, and tertiary release mechanisms. The processes of volatilization and condensation are the geochemical contributions to the volatile emissions mechanism. In response to temperature quadrants, volatile wastes migrate away from the primary, secondary, or tertiary source by gaseous diffusion.

2.1.3.1.2 Infiltration and Leaching—Tertiary release mechanisms of infiltration and leaching are analogous to the processes of primary and secondary sources. The concentrations of the contaminants are less, but the contamination is more dispersed. Examples at RWMC are the contaminants found in the perched water, sedimentary interbeds, sediment filled fractures, and basalt units.

2.2 Contaminant Transport Times

Scoping calculations for the travel time of water in the vadose zone to the aquifer beneath the SDA indicate that under variably saturated conditions, the movement of water may take as long as 560 years (NAS, 1990). This travel time is sensitive to the infiltration rate. Calculations for the NAS study show that at very high infiltration rates the travel time may be approximately 210 years. However, the assumptions for these calculations did not take into account past flooding events that undoubtedly shorten overall transit time. A simulation study conducted to evaluate the migration of radionuclides from waste storage facilities at the Idaho Chemical Processing Plant (ICPP) (Thomas et al., 1986), which is about 8 mi northeast of the SDA, provides another estimate of contaminant migration time through the unsaturated zone. The unsaturated zone at ICPP is very similar to the unsaturated zone below the SDA. One of the scenarios considered in Thomas et al. (1986) was the gradual leaching of radionuclides by rainfall and no retardation by soils. A transit time through the unsaturated zone (approximately 470 ft at the ICPP) was estimated to be approximately 100 years.

Evidence from percolation ponds at the ICPP (Thomas et al., 1986) and the Test Reactor Area (TRA) (Robertson, 1977), and modeling studies at the SDA (NAS, 1990) suggest that transport times under saturated conditions are much faster than under variably saturated conditions. Robertson (1977) calculated a flow rate of approximately 2 ft/day in the saturated sediments below the waste ponds at TRA. This is consistent with observations of the movement of radionuclides from the ponds. At a flow rate of 2 ft/day, it would require 290 days for flood waters to reach the aquifer under saturated conditions at the SDA. This velocity is valid only for situations where water is present on the surface long enough for the entire unsaturated zone to come to equilibrium with the applied moisture. As such, it represents the minimum travel time for flow through the unsaturated zone.

The studies conducted at the SDA and other INEL facilities indicate that under normal (natural dry) conditions the travel times for water through the vadose zone to the aquifer will occur in the hundreds of years. Under flooded conditions the travel time through the vadose zone will occur in the hundreds of days.

2.3 CONTAMINANT PATHWAYS

Pathways are the routes contaminants will travel from their sources to eventually expose humans or biota. The major pathways identified at the RWMC are surface water, the atmosphere, and groundwater.

2.3.1 Surface Water

Potentially, surface water could provide a pathway from the SDA. The outlet of internal drainage system of the SDA opens to the perimeter channel, which in turn leads to the Big Lost River drainage. Water infrequently flows in this perimeter channel because of the low annual precipitation and the high rate of evapotranspiration. Warm rains on snow have caused the SDA to flood on three occasions. However, precautionary measures such as the Big Lost River Diversion, the runon/runoff perimeter dikes and canals at RWMC, and the continued recontouring of the SDA cover have reduced the risk of surface water as a major pathway. In any event, the surface water becomes part of the groundwater.

2.3.2 Atmosphere

The atmosphere is recognized as a potential exposure pathway for the migration of contaminants. Unlike other environmental media, the air pathway is characterized by short migration times, relatively large exposure areas, and the inability to mitigate the consequences of a release after the contaminant enters the atmosphere. It also acts as both a source and sink for air contaminants. Upward movement of volatile contaminants by gaseous diffusion results in releases to the atmosphere.

2.3.3 Groundwater

Continued infiltration and leaching may ultimately result in the transport of contaminants to the aquifer and the groundwater pathway. Once contaminants reach the Snake River Plain Aquifer, they may migrate in a down-gradient direction. Groundwater flow near the RWMC is complicated because of recharge to the aquifer from the spreading areas, which will be discussed later, that cause changes in groundwater flow direction.

Additionally, water supply pumping at the RWMC production well may induce a local gradient in the water table beneath the RWMC. Contaminants have been detected in the production well at levels below drinking water standards, indicating that the groundwater pathway can provide a way for contaminants to reach human receptors. Other than the RWMC production well, the next down-gradient groundwater receptors are stock wells located to the southwest of the SDA off the INEL.

Volatilization of chlorinated organic solvents from tertiary sources may result in contamination of groundwater, providing a groundwater pathway for exposure.

2.4 EXPOSURE ROUTES AND RECEPTORS

Receptors can be humans and terrestrial and aquatic biota that may be exposed to contaminants (via., the identified pathways). The potential receptors at the RWMC can be employees of the INEL, visitors at the INEL, and terrestrial biota that inhabit the INEL or use the INEL in their migration route. Receptors may be exposed to contaminants by ingestion, inhalation, dermal contact, or direct exposure (i.e., photoionizing radiation exposure).

Human receptors can be divided into two groups based on the time spent at the site. The employees of the RWMC/SDA site who work 40 hours/week can experience a variety of scenarios including exposure from RWMC production well water (drinking/showering), flooding of the area, and accidental releases of material during routine operations. It is assumed that special visitors who usually spend less than 8 hours/day at the site would not be exposed to scenarios of routine operations and/or any unusual occurrences at the RWMC/SDA site.

Terrestrial biota can be the desert mammals and birds, migratory waterfowl, reptiles and amphibians, and terrestrial plants and grasses. Aquatic biota can be the fish, amphibians, aquatic plants, and algae.

The interactions of receptors with the pathways is given in the a matrix in Figure 2-1.

2.5 DEMOGRAPHY AND LAND USE

2.5.1 Population at the INEL

The INEL is a large area of southeastern Idaho that contains portions of six counties: Jefferson, Madison, Bonneville, Butte, Bingham, and Bannock. Population growth since the 1980 census (the 1990 census not available) has varied for these six counties. The 1980 county population, projected 1989 county population, population density by county, and the percent change for the six primary counties and other counties within an 50-mi radius of the INEL are shown in Table 2-1. Generally, many counties experienced either a rapid increase or decrease in population after the mid-1980s.

In fiscal year 1989, the INEL employed an average of 10,378 persons with 7610 working at site facilities and the remainder at facilities located in Idaho Falls. Approximately 99 of the site employees work at the RWMC daily with shift work covering a 24-hour period 4 days per week. These personnel support ongoing operations at the SDA, Transuranic Storage Area (TSA), and Stored Waste Examination Pilot Plant.

The greatest visitor traffic near the RWMC is found at the Experimental Breeder Reactor No. 1 (EBR-I), which is located 2 mi to the northeast of the

SDA. EBR-I is a museum open to visitors during the summer months with approximately 10,578 visitors annually (1987). The main access to the INEL is U.S. Route 20, which traverses across the INEL from southeast to northwest. Vehicle access to EBR-I and the RWMC is by a paved road off U.S. 20 and is 2.5 mi long.

2.5.2 Surrounding Populations

In 1985, a computer code was developed by the Radiological and Environmental Sciences Laboratory of the U.S. Department of Energy Idaho Operations Office (DOE-ID) for population projections surrounding the INEL. The baseline location population was determined by using 1980 census data and 7.5-minute United States Geological Survey (USGS) quadrangle maps. Dwellings were located on the topographical maps and assigned an average of 3 residents per unit based on the 1980 census household size for southeast Idaho. A population estimate was entered for each 1 m^2 section. Exact city and town populations were entered in the appropriate sections. The estimate was then adjusted to match census division totals. The number of persons per section was entered into a data base file. Population is therefore assumed to be uniform across each section. The code reads the file by geographic coordinates and calculates the population within 22.5-degree radiating sectors, which are divided into 10-mi increments for a total of 80 sections (Figure 2-4).

Results of this computer code formed the baseline for population projections for the INEL. The total population figure for each individual section was updated. Population projection by county for 1989 was obtained from the Idaho Department of Employment, Bureau of Research and Analysis.

There are no permanent residents at the INEL (Hull, 1989). Sectors 10 through 12, in Figure 2-4, show there may be as many as 33 people living downgradient (defined as the southwest direction of regional groundwater flow) of the RWMC. All these people live more than 30 mi from the RWMC.

Table 2-1. County population surrounding the INEL[a]

County	miles^2	1980 Population	1989 Projected Population	Population per mi^2	% Change
Bannock	1,112	65,421	71,374	64.2	9.1
Bingham	2,096	36,489	40,333	19.2	10.5
Bonneville	1,840	65,980	74,645	40.6	13.1
Butte	2,236	3,342	3,182	1.4	-4.8
Jefferson	1,093	15,304	17,505	16.0	14.4
Madison	468	19,480	23,493	50.2	20.6
		Other counties within 50-mi radius			
Blaine	NA[b]	9,841	13,774	NA	36.1
Clark	NA[b]	798	715	NA	-10.4
Custer	NA[b]	3,385	5,194	NA	53.4
Lemhi	NA[b]	7,460	7,374	NA	-1.2
Power	NA[b]	6,844	6,858	NA	0.8

a. Source: Hull, 1989.
b. Not applicable.

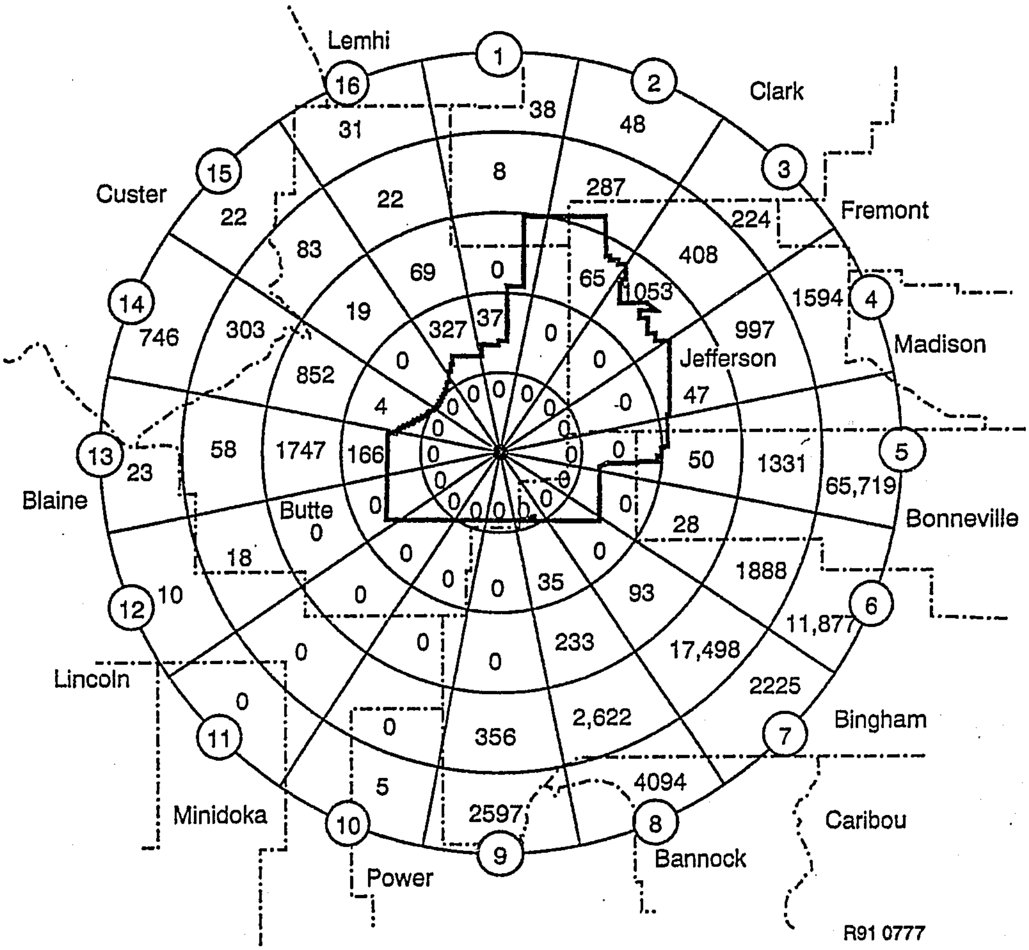

Figure 2-4. Population distribution around INEL.

The RWMC is in Butte County, which includes the majority of the western portion of the INEL. The total Butte County population is 3342. Arco is the largest town in Butte County with 1241 residents. The county population density is 1.4 persons/mi^2.

The closest towns to the RWMC are Butte City (population 93) and Atomic City (population 141). Butte City is approximately 12 mi to the northwest, and Atomic City is approximately 12 mi to the southeast of the RWMC. Neither town is located downgradient of the RWMC.

2.5.3 Surrounding Land Use

The INEL is committed to energy research and development and was designated a National Environmental Research Park in 1975. Approximately 95% of the 890 mi^2 area is withdrawn from the public domain. A series of Public Land Orders dating to 1946 has established the present uses of the INEL. Lands originally under the control of the Bureau of Land Management (BLM) were withdrawn from the public domain under three principal Public Land Orders. Six other Public Land Orders pertaining to INEL lands have been issued. These orders primarily concern the managerial transfer responsibilities (Bowman et al., 1984).

Land in Sectors 10 through 12, downgradient of the RWMC (Figure 2-4), is predominantly controlled by the Federal Government (DOE and the BLM) and the State of Idaho. Only about 4% of the land is private (Bowman et al., 1984).

Approximately 330,000 acres of the INEL are open to grazing by cattle or sheep. Figure 2-5 presents a map of grazing areas relative to the RWMC/SDA.

These areas at the INEL are mutually agreed to by the DOE and the Department of the Interior. Grazing permits are administered through the BLM. Grazing is prohibited within 2 mi of any nuclear facility, and livestock populations are controlled. No dairy cows are allowed in the area (Bowman et al., 1984).

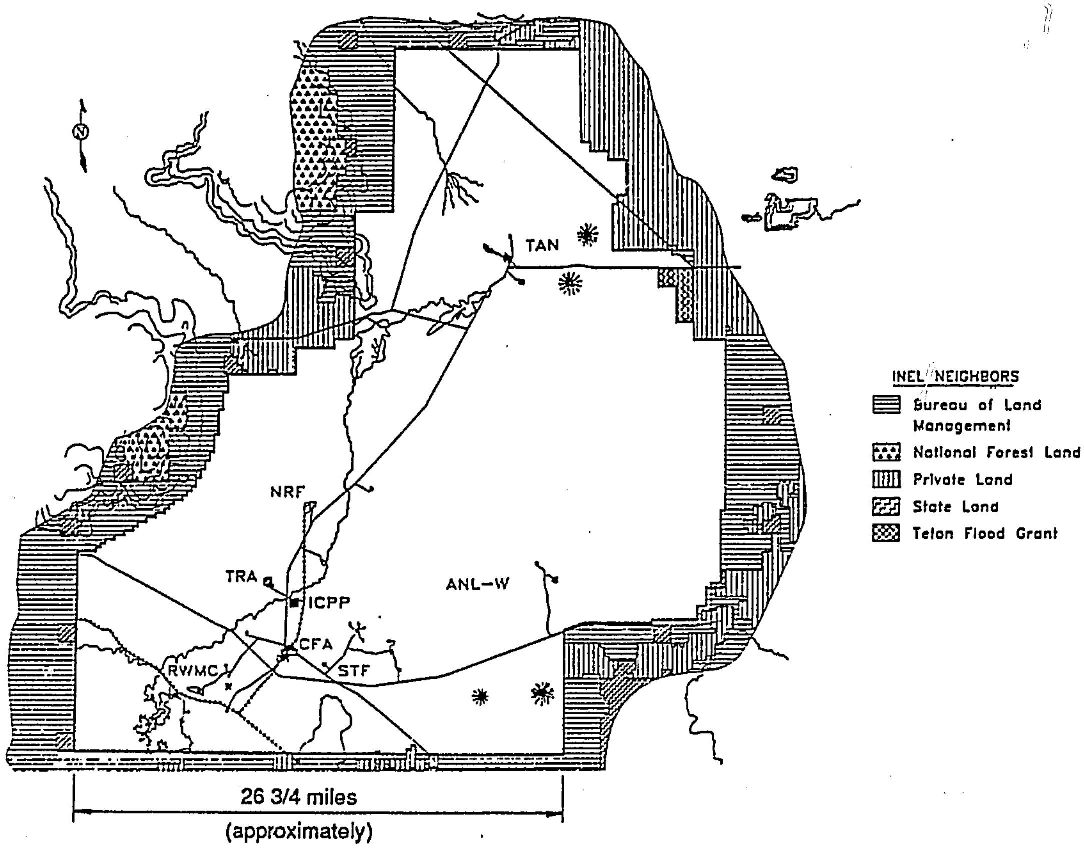

Figure 2-5. Land ownership surrounding the INEL.

Crops grown in Sectors 10 through 12 within 50 mi of the INEL include alfalfa, hay, and grains (Bowman et al., 1984). The approximately 22,000 animals in these sectors, include cattle, beef cows, and sheep (Bowman et al., 1984).

3. GEOLOGY

Water and contaminant movement under migration scenarios are strongly influenced by the geological surface/subsurface media. To evaluate the migration of contaminants from the RWMC, an accurate model for the geology must be developed. The most sophisticated flow or behavioral model will yield inaccurate results unless a reasonable model of the geologic system is available. This section of the report provides a review of the RWMC conceptual geological model.

3.1 GEOLOGICAL MODELING GOALS

What is the specific intent of this modeling effort?

The purpose of developing this geological model is to draw conclusions and make interpretations based on existing data, not to summarize or review all of the existing data.

What factors are considered in geological modeling, and what specifically has been considered for modeling at the RWMC?

The features generally considered in geological modeling are

- Development of the regional geologic setting including tectonics, structure, and stratigraphy
- Identification and characterization of relevant units
- Identification of a relevant time frame
- Characterization and correlation of geologic units
- Identification of relevant processes

- Interpretation of geology for areas without detailed knowledge of geology.

The geologic model for the RWMC area requires a comprehensive understanding of all geologic features and processes that may affect the movement of contaminants and natural fluids. The present state of knowledge is based on surface geologic relationships, drill hole information, results of geophysical studies, results of laboratory determinations of physical properties in core and surface samples, geochemical characteristics, and volcano-tectonic relationships.

<u>What is the importance of the geologic model?</u>

This model is important to understand how contaminants may move through the vadose and groundwater zones beneath the RWMC. Although recent studies have developed important quantitative petrophysical information, the present understanding is mostly qualitative. Quantitative data on the geology at the RWMC can then be used in performance assessment models.

3.2. Geology of the RWMC Site

<u>What is the regional geological setting of the INEL?</u>

The RWMC is located on the Eastern Snake River Plain (ESRP), a low-lying region of basalt lava flows, surrounded by high mountains of the Basin and Range province (Figure 3-1). The Snake River Plain and the surrounding mountains developed during the past 17 million years. This time has been characterized by ongoing extension of the earth's crust and mountain building. During this same time period the westward continental drift of the North America Plate over a mantle hot spot (Yellowstone Plume) has formed the ESRP. The hot spot theory explains the volcanic pattern of the Snake River Plain-Yellowstone region (Morgan, 1972; Leeman, 1982; Malde, 1990 in press).

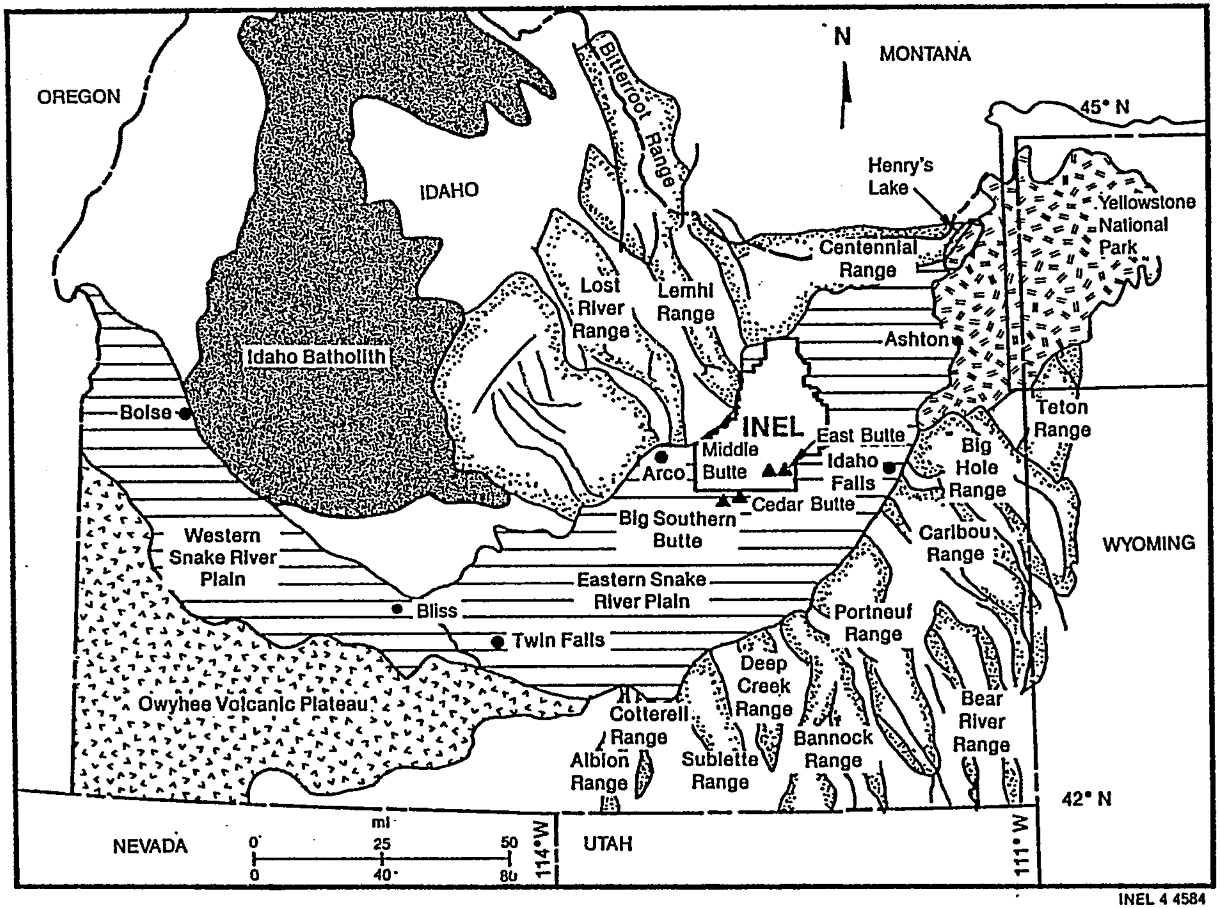

Figure 3-1. Physiographic features of the INEL area.

characterized by ongoing extension of the earth's crust and mountain building. During this same time period the westward continental drift of the North America Plate over a mantle hot spot (Yellowstone Plume) has formed the ESRP. The hot spot theory explains the volcanic pattern of the Snake River Plain-Yellowstone region (Morgan, 1972; Leeman, 1982; Malde, 1990 in press). Early rhyolitic volcanism and crustal extension has been dated at about 17 million years ago in southwestern Idaho, and this activity becomes progressively younger toward the east (Yellowstone) (Armstrong et al., 1975; Rodgers and others, 1990 in press). The present geothermal activity and explosive volcanism of the Yellowstone area during the past 2 million years (Iyer et al., 1980; Christiansen, 1984), as well as regional heat-flow patterns (Blackwell, 1989) and seismicity (Stickney and Bartholomew, 1987; Anders et al., 1989) indicate that the plume now lies under the Yellowstone Plateau. A major implication of the plume hypothesis is that the hot spot has passed the INEL and future explosive silicic volcanism is unlikely to occur in the INEL area.

The ESRP is a bimodal volcanic province consisting of silicic volcanic activity followed by basaltic lava flow. It is a 60 mi wide basin extending 200 mi from near Twin Falls, Idaho, to the Island Park Caldera, north of Ashton, Idaho. Silicic volcanic activity has migrated from the west to the northeast, culminating in the Yellowstone Caldera, which erupted as recently as 600,000 years ago. Silicic volcanism on the plain was followed by basaltic lavas that extruded primarily from vents along northwest-trending rift zones. The volcanic material is dominated by rhyolite ash flow tuffs and lava flows (>8,200 ft in thickness), overlain by 2,000-3,000 ft of basalt and interbedded sediments.

Near the INEL, the early silicic volcanism occurred between approximately 6.5 and 4.3 million years ago with explosive and voluminous eruptions of silicic tuffs, accompanied by the formation of large volcanic calderas (Morgan et al., 1984). Eruptions and landforms of the Yellowstone-Island Park region are a more youthful analog of early eastern Snake River Plain volcanism.

During the past 4 million years, subsequent outpourings of basalt have covered the early volcanic centers, producing the present-day, low-lying lava beds of the ESRP. Basalts on the ESRP erupted mainly from northwest-trending volcanic rift zones, marked by belts of elongated shield volcanoes and small pyroclastic cones, fissure-fed lava flows, and noneruptive fissures or small-displacement faults. Deposition of sedimentary interbeds occurred during quiescent periods between eruptive events.

Late-stage emplacement of viscous rhyolite lava occurred at three locations on the ESRP near the INEL, forming the rhyolite domes of Big Southern Butte (300,000 years ago) and East Butte (600,000 years ago). Middle Butte is a block of several-million-year-old basalt lava flows, inferred to have been forced upward by a rhyolite dome that failed to reach the surface.

The ESRP is bounded on the north and west by Cenozoic fault-block mountains of the Lost River, Lemhi, and Beaverhead Ranges (Figure 3-1). These ranges are composed of Paleozoic limestones, dolomites, and shales. The fault-block ranges trend northwest-southeast, and the volcanic rifts that parallel the ranges are believed to be surface expressions of extensions of the range-front faults.

What is the geology of the INEL?

The basalt lava flows at the RWMC and throughout the INEL are thought to have been formed by plains-style volcanism, as shown in Figure 3-2 (Greeley, 1982). This style is intermediate between flood basalt volcanism of the Columbia Plateau, and basaltic shield volcanism of the Hawaiian Islands. The very low shield volcanoes, with slopes of about one degree dip, form in an overlapping manner; this overlapping and coalescing of flows form the low relief surface of the ESRP. Tube-fed lava flows travel long distances, and minor fissure-fed flows help to fill in low areas between shields, producing subdued topography.

Interpretation of INEL and ESRP subsurface geology obtained from drill hole information suggests the concept of plains volcanism be modified in two

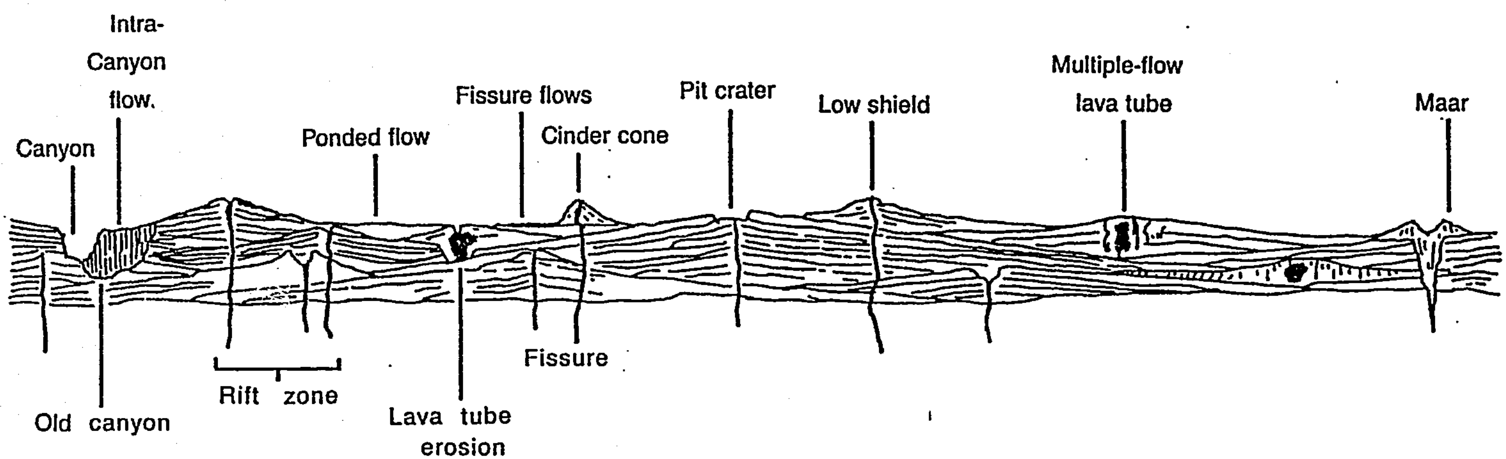

Figure 3-2. Schematic cross section showing the salient features of a "plains" basalt region, typified by the Snake River Plain (not to scale).

ways. First, volcanic vents are not randomly distributed over the plain, but they are more or less restricted to volcanic rift zones (Figure 3-3). Most vents in the INEL region of the ESRP are located in one of the rift zones, the Hell's Half Acre, and the Arco Rift Zone. The rift zones are characterized by fissuring and minor faulting resulting from emplacement of dikes feeding the vents (Smith et al., 1989a, 1989b). Because volcanic eruptions occur in rift zones more commonly than elsewhere, the rift zones persist as ridges of increased relief. Second, deposition of sediments is a major contributor to maintaining low topographic relief by filling in low-lying areas between shields and rift zones. These sediments are of several types: loess, alluvial silts, sands, gravels, and lacustrine clays and silts. Sediments on the INEL were deposited from (a) the Big Lost River and other streams that enter the plain from the intermountain valleys to the north, (b) the waxing and waning of Lake Terreton during the last few million years, and (c) loess deposition.

Figure 3-4 shows the proposed volcanic-sedimentological model for the INEL area. The complex intercalation of basalt lava flows from vents in rift zones with sedimentary material between rift zones is apparent.

The RWMC is located near the southwestern margin of the inter-rift basin near the Arco Rift and the Axial Rift Zones. The RWMC has received lava flows from both rift zones, alluvial sediments from the Big Lost River, and loess deposits from sources to the southwest. The volcanism is episodic, depicted by flows emplaced over a short period of time (a few centuries to a few thousand years). Little interflow of sedimentary accumulation occurs between flows. Other volcanic episodes are separated by long periods of time (tens to hundreds of thousands of years), during which sedimentary interbeds accumulate between flows (i.e., the sedimentary interbeds) (Kuntz et al., 1986; Champion et al., 1988).

<u>What is the stratigraphy at the INEL?</u>

Basalt flows near the INEL erupted from rift zones that cross the Snake River Plain and generally trend northwest-southeast. These rifts are defined

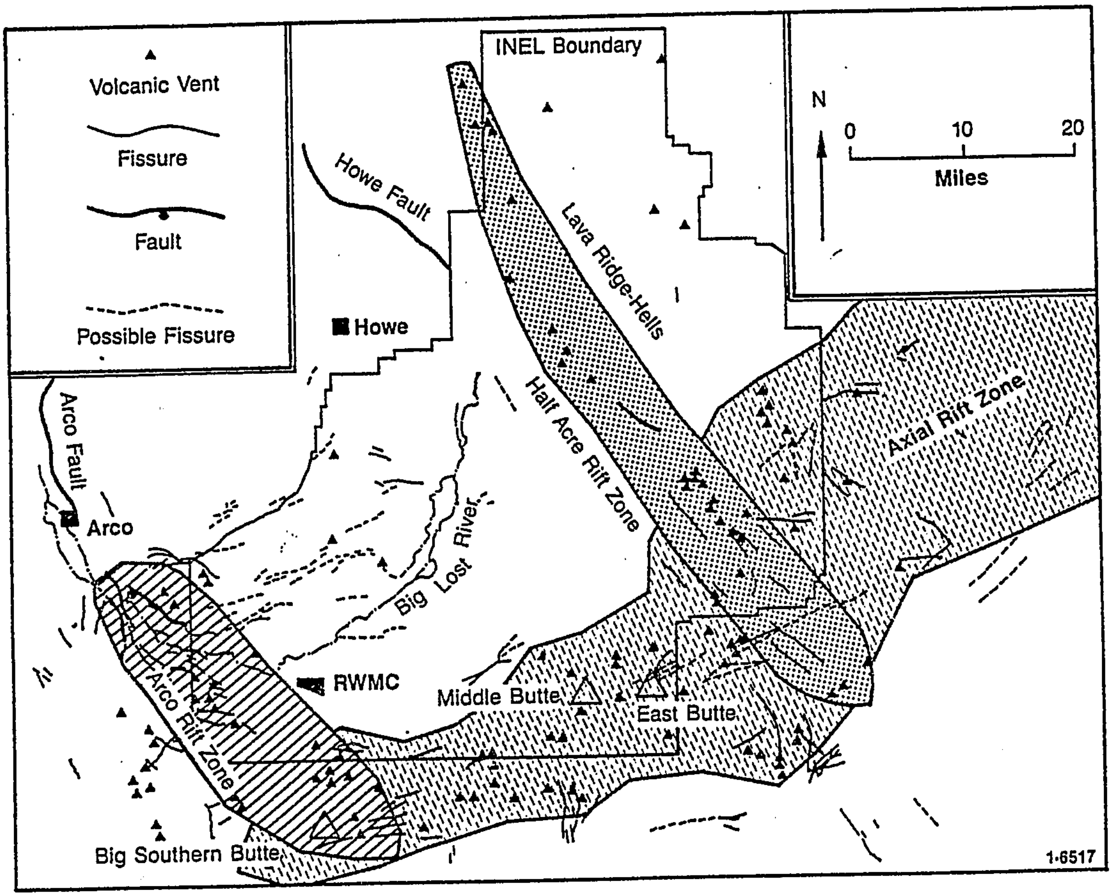

Figure 3-3. Volcanic rift zones near the INEL.

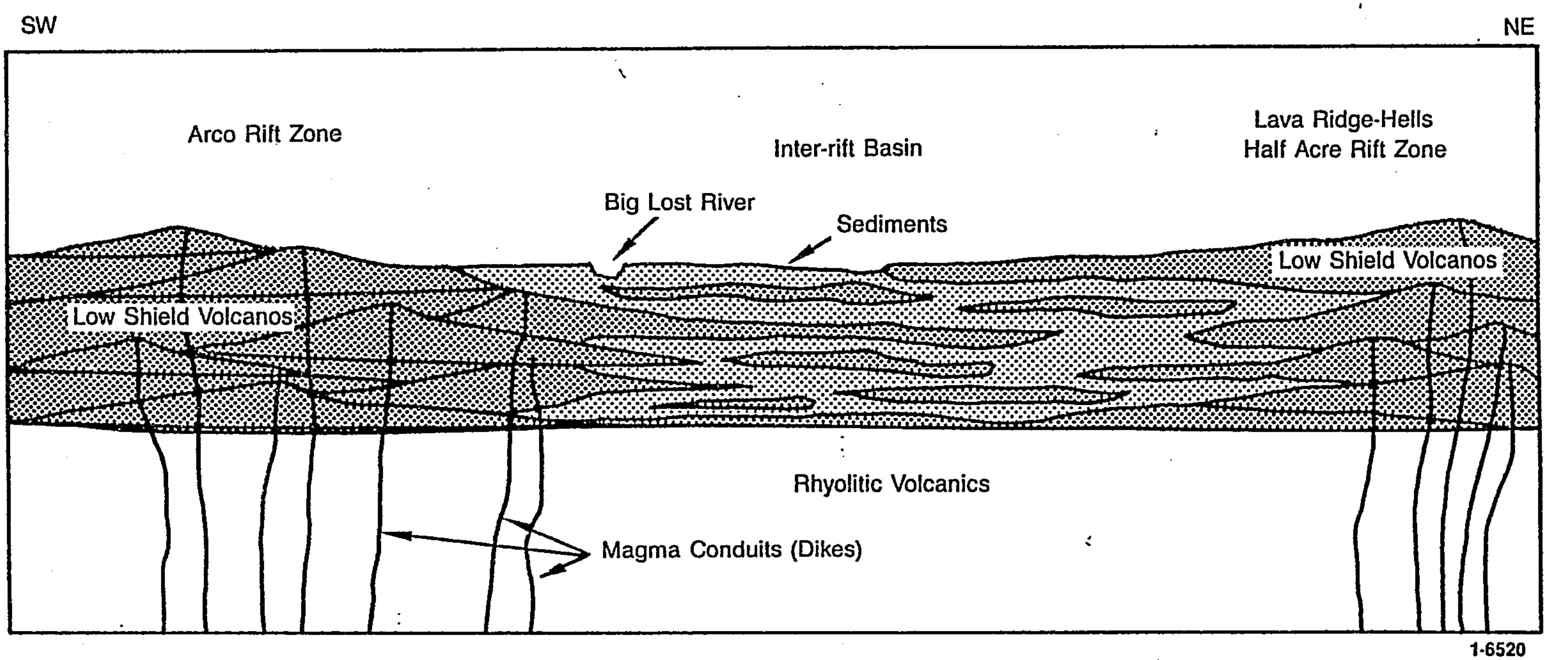

Figure 3-4. Schematic diagram of modified "plains-style" volcanism (RWMC lies south of this cross section near Arco Rift Zone)(not to scale).

by the linear arrangement of vents, fissures, and grabens (Kuntz and Dalrymple, 1979). Dating of basalt flows on the INEL gives eruption dates of 12,000 to 400,000 years ago. The Hell's Half Acre flow, immediately adjacent to the INEL Site boundary, is dated at 4,100 years. The youngest basalt flows on the Snake River Plain occur along the Great Rift (Craters of the Moon National Monument) and are dated at 2,100 years old.

Much of the land surface is composed of Pleistocene and Neocene basalt flows. The western portion of the INEL Site is the flood plain of the Big Lost River. Alluvial sediments of Quaternary age occur in a band that extends across the site from the southwest to the northeast. The alluvial deposits extend into lacustrine deposits in the northern portion of the INEL Site where the Big Lost River enters a series of playa lakes. Paleozoic sedimentary rocks are exposed in a very small area of the INEL Site along the northwest boundary. A number of silicic and basalt cinder cones occur on the INEL Site near the southern boundary.

Basalt flows at the INEL Site characteristically occur as layers of pahoehoe lava a few feet to a few tens of feet in thickness. The basalt flows are interlayered with unconsolidated sediments, cinders, and breccia. Considerable variation in texture occurs within individual basalt flows. In general, the base of a basalt flow is glassy to fine-grained and minutely vesicular. The mid-portions of the flow are typically coarser grained with fewer vesicles than the top or bottom of the flow. The upper portions of the flow are fine-grained and highly fractured with many vesicles. The massive interiors of basalt flows are generally jointed, with vertical joints in a hexagonal pattern formed during cooling. Basalt flows that were exposed at the surface often have vesicles and fractures filled with fine-grained sediments and secondary calcite.

During quiescent periods between volcanic eruptions, sediments were deposited on the surface of basalt flows. These sedimentary deposits display a wide range of grain size distributions depending on the mode of deposition (i.e., aeolian, lacustrine, or fluvial); the source rock; and length of transport. Because of the very irregular topography of the basalt flows, isolated depressions are common where sedimentary material has accumulated. Thus, localized interbeds of sedimentary material occur in the stratigraphic sequence beneath the RWMC. A number of extensive noncontinuous sedimentary interbeds are identified. These extensive interbeds would have formed during extended quiescent periods.

<u>What is the extent of the subsurface well control at the RWMC?</u>

From June 1971 to September 1988, 45 wells (Figure 3-5) with a composite length of 13,880 ft were drilled to evaluate the geologic, geohydrologic, and geochemical characteristics of the unsaturated zone and aquifer (Anderson and Lewis, 1989).

Well logs, water levels, and water chemistry data are available in files at the INEL office of the USGS, and much of this data has been published in USGS reports. Geological and geophysical logs from these wells and the RWMC production well have been used to characterize the stratigraphy at the RWMC.

<u>What is the site-specific geologic setting at RWMC?</u>

The RWMC is located on a relatively thin layer of eolian, lacustrine, and alluvial sediments deposited by the Big Lost River (See Figure 3-6). These sediments are composed of silt, sand, clay, and gravel and range in thickness from 2 to 24 ft (Anderson and Lewis, 1989). Underlying the surface sediments is a complex sequence of interlayered basalt flows and discontinuous sedimentary interbeds.

Basalt flows at the RWMC are characteristic of basalts of the ESRP. Based on the work by Anderson and Lewis (1989), the average flow thickness for 22 flows identified beneath the RWMC is about 30 to 40 ft and ranges from 10 to 120 ft. The basalt flows are interlayered with unconsolidated sediments, cinders, and breccia. Tentative correlations with eruptive vents on the southwestern INEL indicate that lava flows beneath the RWMC may have been issued from vents along the Arco rift zone (Smith et al., 1989) and the axial volcanic zone. (Figure 3-3).

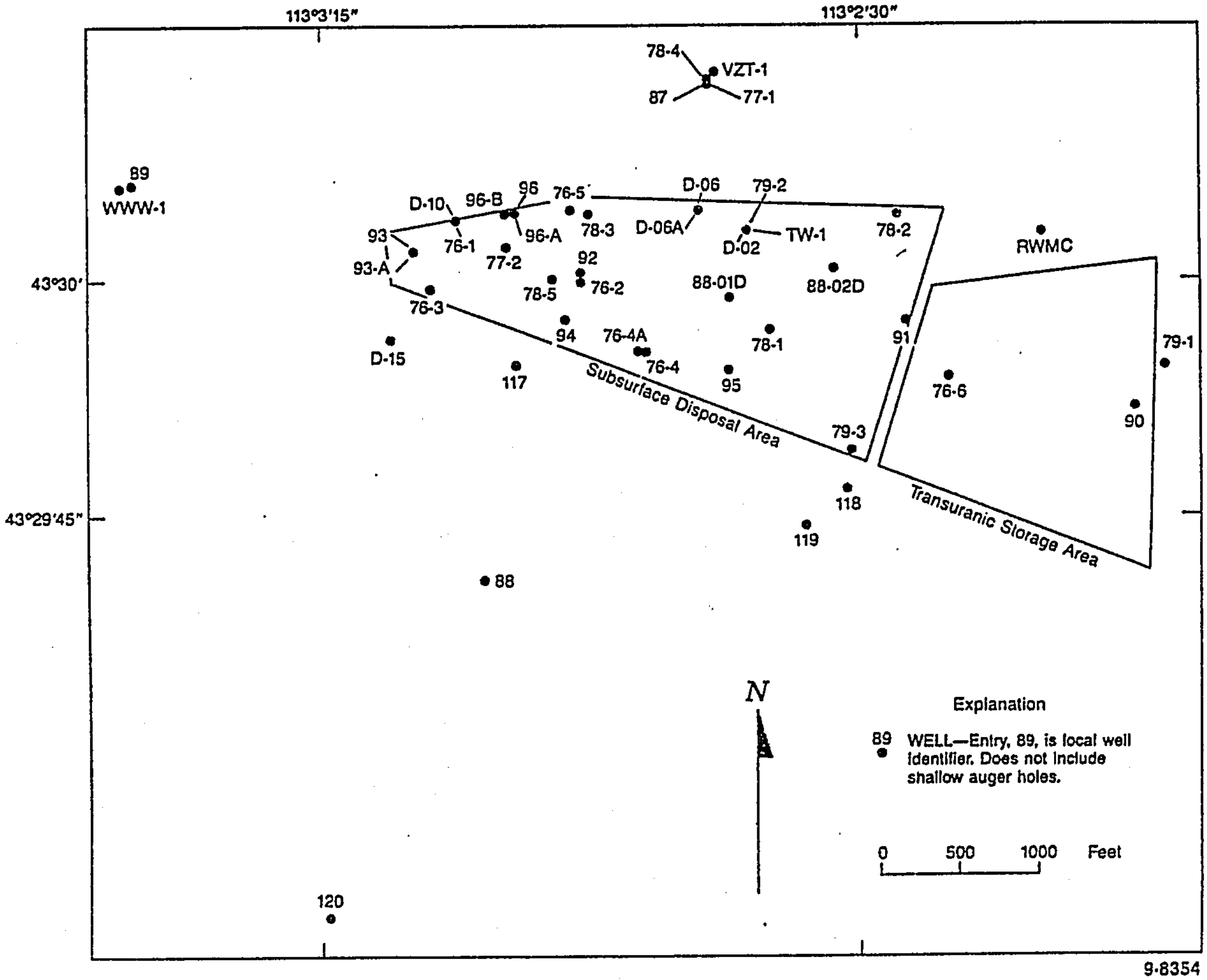

Figure 3-5. Location of wells in the RWMC area (Anderson and Lewis, 1989)

Anderson and Lewis (1989) correlates the stratigraphy at the RWMC based on 45 wells including 8 aquifer wells. Using geophysical well logs, well cuttings, cores, K-Ar (potassium-argon) ages, and geomagnetic properties, the USGS report shows cross sections, maps, and tables of the stratigraphy for the RWMC. In earlier work, Barraclough et al. (1976), four basalt series were identified based on natural gamma log differences. Basalt flow groups identified by Kuntz et al. (1980) and Anderson and Lewis (1989) are similar to the basalt series correlated by Barraclough et al. (1976). Twenty-two individual lava flows are noted, forming 10 basalt lava-flow groups. Flow groups are separated by seven major sedimentary interbeds ranging in age from less than 100,000 to 600,000 years old. One cross section from the USGS report by Anderson and Lewis (1989) is included in this report. Figure 3-6 shows the general stratigraphy of the RWMC. The cross section suggests that the sedimentary units are relatively continuous in the vicinity of the RWMC, and folding and/or faulting are not apparent.

The stratigraphic units A through I are defined based on flow group nomenclature established by Kuntz et al. (1980). The nomenclature was based on the study of 600 ft of core from Well 77-1, near Well 86, and four other shallow wells. Kuntz et al. (1980) defined flow groups as one or more petrographically similar flows or flow units extruded from the same vent or magma source from a single eruption or multiple eruptions during a relatively short time interval. Generally, successive flow groups are separated by sedimentary interbeds. The interpretation by Kuntz et al. (1980) and Anderson and Lewis (1989) suggests the flow groups represent eruptions from the same source vent or flows erupted from several source vents that tapped the same magma source. This interpretation was based on variations in natural gamma activity between groups but consistent for flows within a group. Paleomagnetic and K-Ar age dating was also used to establish this interpretation. Based largely on K-Ar ages and the presence of sedimentary interbeds between flow groups, Kuntz et al. (1980) considered the eruptive events to be episodic with many thousands of years between eruptive events. Sedimentary interbeds are considered to represent quiescent periods between volcanic episodes, when the top-most lava flow was covered by accumulations of eolian and alluvial sediments. An alternative depositional history might

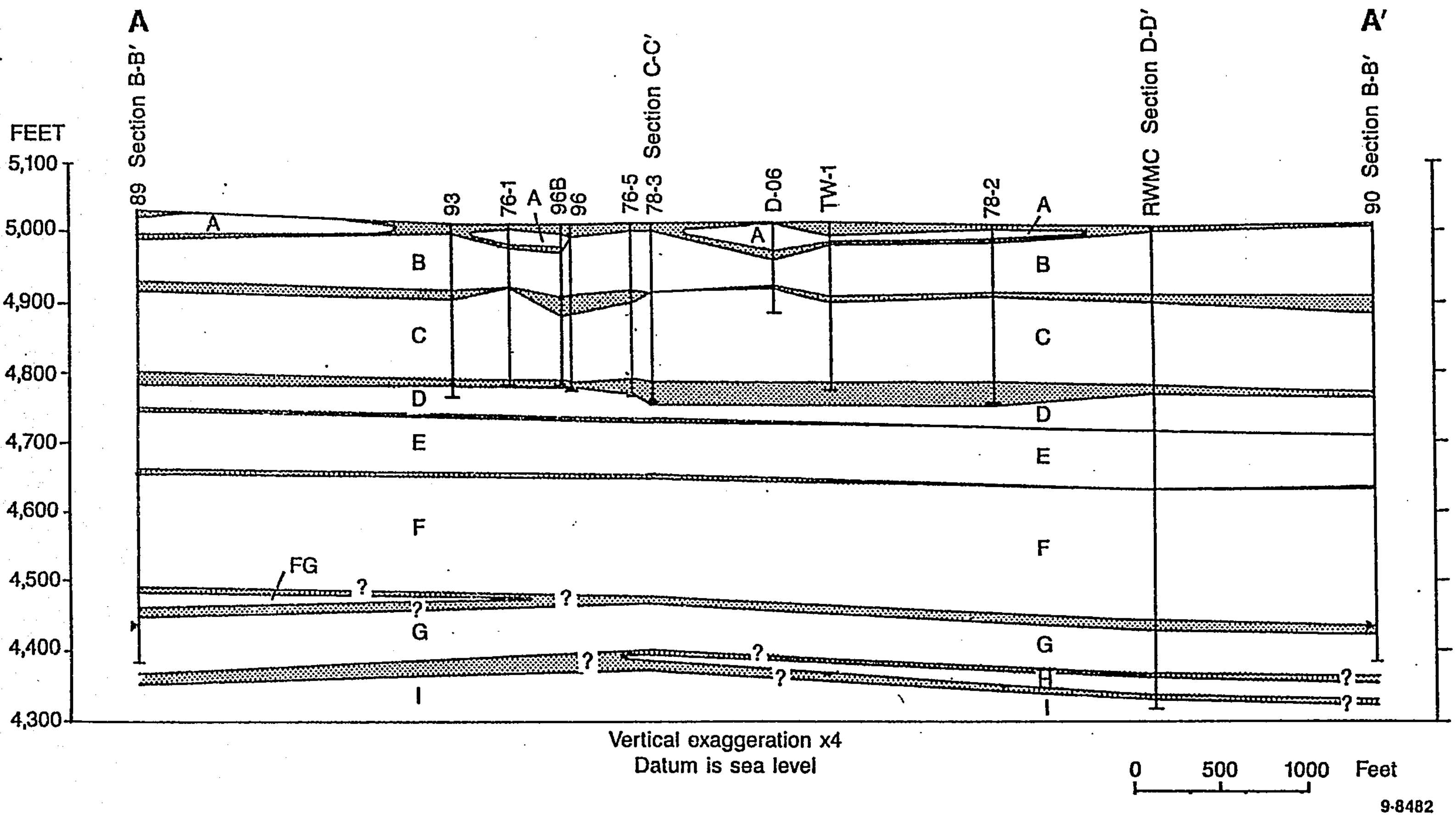

Figure 3-6. Geologic section A-A' at the Radioactive Waste Management Complex, from Anderson and Lewis, 1989.

Explanation

B — BASALT — Basalt-flow group composed of one or more related flows. Letter, B, indicates sequence of group from top to bottom of section. Locally includes cinders and thin layers of sediment

CLAY, SILT, SAND, AND GRAVEL — Major sedimentary interbed between volcanic flow groups. Locally includes cinders and basalt rubble

GEOLOGIC CONTACT — Queried where uncertain

89 — WELL — Entry, 89, is local well identifier. Arrow indicates water level in aquifer in June, 1988. Water level in well RWMC not measured

Location of Section

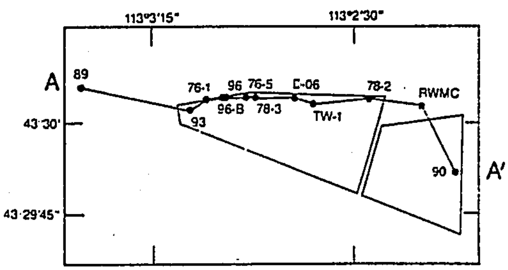

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Figure 3-6. (Continued)

have occurred when lava flows dammed local drainages, and floods may have deposited alluvial and lacustrine sediments during periods as short as a few months.

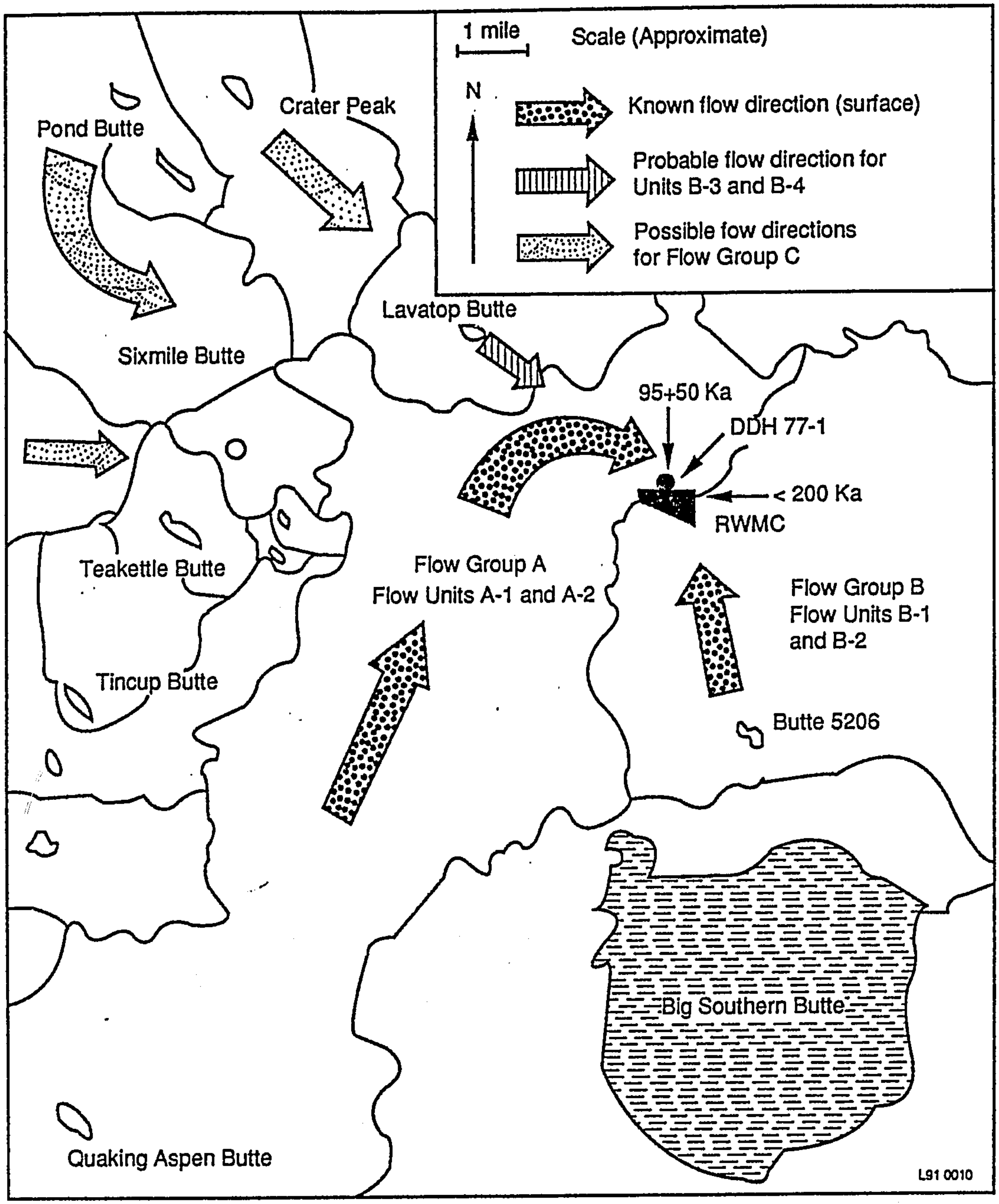
<u>Where are the source vents and what are the flow directions for lava flows at the RWMC?</u>

Near-surface basalt lava flows at the RWMC erupted from several volcanic vents in the southwest part of the INEL Site. Most of the lava flows are younger than 500,000 years (Champion et al., 1988) and were erupted from vents in the Arco Rift Zone.

Drill Hole 77-1, located on the north side of the RWMC, penetrated several different lava flows above the water table. The topmost flow, Flow Group A (Flow Units A-1 and A-2), is about 100,000 years old and flowed many miles from its source vent at Quaking Aspen Butte to the southwest of the RWMC. The overall direction of the flow is northwest; however, the flow direction curved toward the south and southeast in the local area of the RWMC (Figure 3-7).

The first two lava flows of Flow Group B (Flow Units B-1 and B-2) in Well 77-1 are also exposed in the SDA burial pit. These flows came from Butte 5206, just north of Big Southern Butte (Figure 3-7). Their flow direction at the RWMC is almost due north. They have been dated by the K-Ar method at less than 200,000 years old (Champion et al., 1981).

At greater depths it is more difficult to identify the source vents for basalt flow units. The source of Flow Units B-3 and B-4 is most likely Lavatop Butte (Figure 3-7). Lava flows below the Flow Group B could have been erupted from numerous vents in the RWMC area. The most likely vents are Crater Peak, Pond Butte, and Sixmile Butte. These are all large vents with lava flows that could have traveled many miles.



Figue 3-7. Inferred Source vents and flow directions for lava flows at the RWMC.

What are the important geologic processes that may affect the RWMC area?

Faulting and associated earthquakes are likely to continue in the mountains surrounding the ESRP, as evidenced by historical seismic events such as the 1983 Borah Peak, Idaho, (Stein and Bucknam, 1985) and the 1959 Hebgen Lake, Montana, earthquakes. The possibility of future volcanism is suggested by the fact that approximately 10% of the ESRP is covered with Holocene lava flows that are approximately 15,000 to 2,000 years old (Kuntz et al., 1986). Erosion and deposition of sediments by flooding of surface waters is of concern because the channel of the Big Lost River lies 2 mi northwest of the RWMC, and both historical and Quaternary flooding have occurred in that drainage. However, the INEL Diversion System and dikes protect the RWMC from flooding from the Big Lost River.

3.3 GEOMETRY

What are the controlling factors that determined the geometry of the subsurface units at the RWMC?

The deposition of sediments and basalts at the RWMC has been controlled by local topographic relief. The wind deposits sediments as a blanket over the entire area with thicker deposits in low lying areas and areas of lower wind velocities. Sheet flow of the water provides transportation from topographic highs to lows. The result is sediments deposited by wind or water are found occupying the topographically lower portions of the surface, with basalt highs protruding above the sediment layer.

The bulk of the sediments in the RWMC area are probably deposited by streams, either as fluvial/alluvial channel and overbank deposits or in local impondments resulting from lava flow damming or local tectonism.

The basalt flows are also dependent on topography for flow direction, as source areas present in area reduce the field gradients. The lava flow geometric complexity is increased by the fingering caused as the material cools as well as the pulsing of the output flow rate. A more comprehensive discussion of the geometric complexity of the plains type lava flows can be found in Knutson et al. (1990) and references contained therein. Discussions of sedimentary processes can be found in Reineck and Singh (1980).

What is an idealized basalt lava flow at the RWMC?

Basalt lava is subjected to varying processes and mechanisms as it travels away from its source area. Therefore, the resulting lava flows exhibit varying characteristics with distance from the source. The proximal volcanic facies of a basalt lava flow is a zone of thin lava, cavernous flows (termed shelly pahoehoe) with interlayered vent facies pyroclastics and agglutinate. The thin lava grades outward into thicker flows with upper and lower crusts; upper and lower vesicular zones; and columnar-jointed, massive interiors. The distal segments of a lava flow consist of numerous terminations of lava flows and irregularly-shaped lobes or fingers that extend outward from the main body of the flow. The intermediate and the distal segments contain deflated areas from which lava has flowed to lower areas, causing the upper crust to collapse into irregular depressions. Fissures develop around the deflated areas and near the terminus of the flow. Figure 3-8 shows an idealized section of a basalt lava flow.

In the RWMC area, none of the lava flows observed at the surface or at depth in drill core exhibits proximal facies characteristics. From surface observations (Knutson et al., 1990) the two uppermost lava flows represent distal facies. It is likely that deeper flows at the RWMC are also distal or intermediate facies because the area is just outside the rift zones and within the inter-rift basin.

What is the characteristic geometry of the basalt flows?

The characteristic geometry of the basalts is one of flat-topped steep-edged finger-like basalt ridges with intervening depressions. The flow ridges or lobes tend to flow along and fill low lying areas in the surface that are covered.

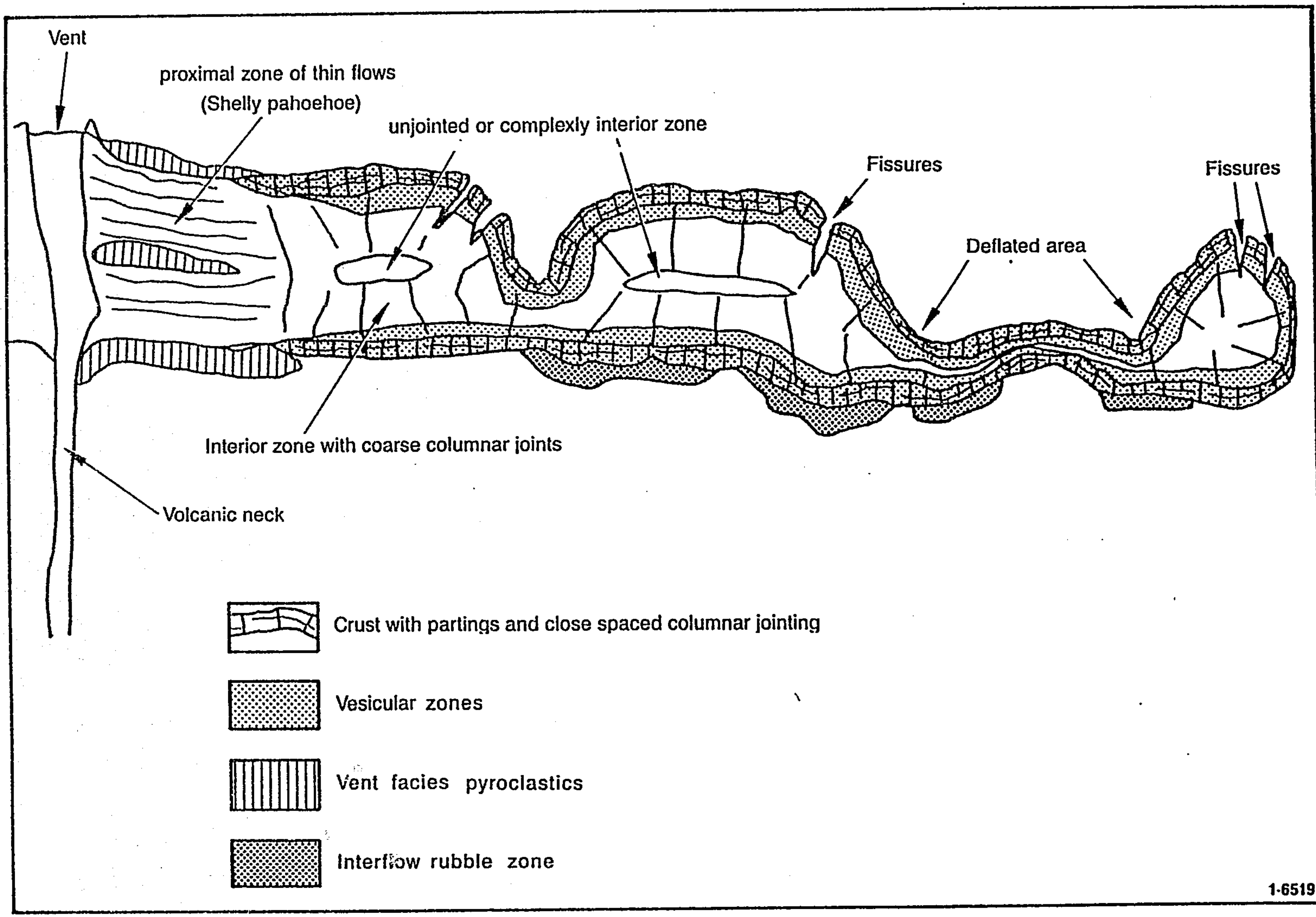


Figure 3-8 Idealized section of a basalt lava flow on the ESRP (Not to Scale).

Knutson et al. (1990) provides a quantitative estimate of the variation in structural and textural characteristics within flows. Knutson et al. (1990) defined four elements or vertical dimensions within flows as (1) top vesicular zone, (2) a central zone, (3) a bottom vesicular zone, and (4) substrate (Table 3-1). On the average, the thickest single element is the central massive zone, followed closely by the top vesicular zone. The bottom central vesicular zones comprise smaller amounts of the median flow thickness. The vesicular zones (top, central, and bottom) are considered to be the most permeable interval because of the large number of fractures (caused by rapid cooling of the basalts) and open areas in these zones. This assessment is based on field observations of the zones, air injection tests by the USGS, and common well completion practices where production zones are selected across fractured vesicular zones.

<u>What is the characteristic geometry of the sedimentary layers?</u>

The surficial sediments and interbeds generally have gently undulating upper surfaces and rather complex and variable lower surfaces. The interbeds are thick where sediments filled low lying areas in the topographically irregular underlying basalt surface and are thin or nonexistent where the basalt forms highs.

Table 3-1. Thicknesses of individual flow elements[a]

Flow Element	Median Thickness (ft)	Range (ft)	Number of Measurements
Top vesicular zone	6	1-28	114
Central zone	7.5	1-44	114
Bottom vesicular zone	1.5	1-6	114
Complete flow	15	1-56	119
Special Cases			
Intermediate vesicular zone	3	0-8	8
Collapse/rubble zone/substratum	4	0-12	13

a. Source: Knutson et al. (1989).

The interbed correlations presented in Figure 3-6 are extrapolated between wells and do not represent the actual discontinuity or continuity of these units. Studies of the shallower interbeds, where more stratigraphic well control and outcrop exposures are available, indicate that sedimentary interbeds are discontinuous.

Figure 3-9 is a thickness map that illustrates the variable thickness of the Flow Group B-C or the 110-ft interbed near the RWMC. It is better defined than the deeper interbeds because more wells penetrate the 110-ft interbed. B-C was not encountered in four wells; this is indicated with a bold contour line in Figure 3-9. Where wells are near the holes, the interbed have thicknesses of over 20 ft. For instance, Well 76-2 did not encounter Flow Group B-C; however, Well 78-5, which is about 200 ft to the west of Well 76-2, encountered 25 ft of sediment, and Well 92, about 50 ft to the north of Well 76-2 encountered 5 ft of sediment (Anderson and Lewis, 1989). It is likely that holes may exist in deeper interbeds.

Although the intent of the study by Knutson et al. (1989) was to describe the basalts in detail, much information about the configuration of the sedimentary interbeds can be inferred from the results. Sediments deposited on the flow surfaces filled the low areas between flows and inversely reflect the geometry of the underlying flows. In other words, sediments initially filled long linear lows and approached the median thickness of a typical flow (15 ft) before covering all of the basalt. Additional relief between the flow tops and the bottom of the sedimentary interbeds are commonly associated with collapse features in the lava and create low spots in the topographic surface. Therefore, interbeds with local thicknesses in excess of 25 ft might not completely cover the tops of the basalt flows. This is supported by mapping in Anderson and Lewis (1989) presented in Figure 3-9.

Interbeds with a thickness of 5 to 10 ft are probably discontinuous and contain numerous holes and thin spots.

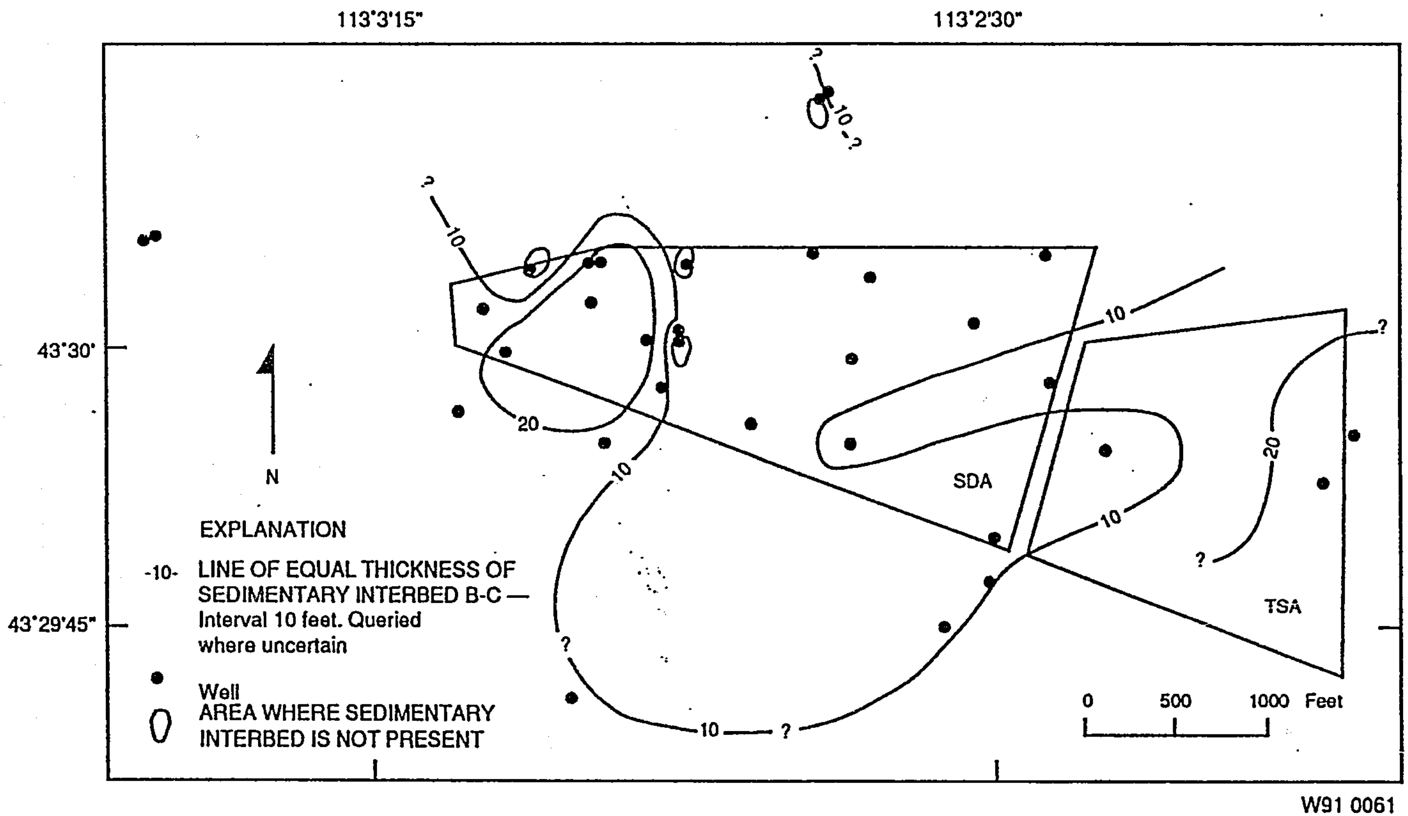


Figure 3-9. Thickness of sedimentary interbed B-C at the Radioactive Waste Management Complex (source: Anderson and Lewis, 1989).

What are the compositions of the sedimentary interbeds beneath the RWMC?

The Flow Group A-B 30-ft interbed consists of reddish brown to dark brown silty clay. The reddish-brown color results from oxidation of iron-rich minerals. Organic-rich paleosols were encountered in several wells. In addition, baked clays occur in this interbed, overlain by a cinder zone in one well (Rightmire and Lewis, 1987). The top of the Flow Group B-C 110-ft interbed contains a dark brown, organic-rich soil horizon. Basalt pebbles with iron oxide filled vesicles occur in this interbed. Some of the pebbles are coated with a calcium carbonate crust, and small aggregates of opaline silica are contained in the calcium carbonate crust (Rightmire and Lewis, 1987). The Flow Group C-D 240-ft interbed is typical of a stream deposit with clays, silts, sands, and gravels. Fluvial gravels make up over 50% of the interbed (Rightmire and Lewis, 1987). The interbed material is uniformly oxidized throughout its thickness. At the time this interbed was deposited, the SDA area may have been the flood plain of the Big Lost River (Rightmire and Lewis, 1987). Few sedimentary samples have been recovered from the deeper interbeds.

3.4 PETROPHYSICAL AND HYDROLOGIC PROPERTIES

What is the origin of the data set used to provide rock properties for this model?

During 1989 and 1990, the core from 25 wells were logged and petrophysical and hydrological properties were measured. Porosity, permeability, density, and water saturation data were collected from selected cores (Knutson et al., 1990).

What are the characteristics of the data set?

Petrophysical data were initially presented as continuous distribution characteristics of the flow elements within each flow. Four flow elements were used based on vesicularity (Knutson et al., 1990).

Subsequently, data were viewed to determine the vesicular or nonvesicular properties of the sample. It was later determined that vesicularity of the basalt is not the controlling factor for permeability for statistical distributions.

Porosity

Figure 3-10 presents distribution plots of the porosity values for the four elements. The respective median porosities for the upper, central, and intermediate vesicular and lower elements or zones for the flow groups are Flow Group A--20, 10, (no intervesicular zone), and 22%; Flow Group B--22, 10.5, 22, and 21.5%; and Flow Group C--22, 12, 22.5, and 21.5%. The top vesicular and central element median values for Flow Group D are 21 and 16.5% and for Flow Group E are 24 and 11% (only one data point was acquired in each bottom vesicular zone of Flow Groups D and E). The median porosity values for all samples are 22, 11, 22.5, and 21.5%.

The vadose zone basalt porosity can be generalized based on data collected to date. At least 75% of the time the porosity for the nonvesicular elements is less than 15%, and the porosity for the vesicular elements is greater than 15%. Clearly, porosity is controlled by the fraction of vesicles present. Thus, the vesicular and nonvesicular elements can be separated on the basis of porosity.

Permeability

Figure 3-11 presents distribution plots of the permeability values (log scale) for the elements. The respective median permeabilities for the upper, central, and intermediate vesicular and lower elements for the flow groups are Flow Group A--16, 22, (no intervesicular zone), and 8 mD; Flow Group B--6.5, 8, 1, and 4.5 mD; and Flow Group C--3.5, 9, 5, and 4 mD. The top vesicular and central element median values for Flow Group D are 5.5 and 5.5 mD and for Flow Group E are 10 and 4 mD (only one data

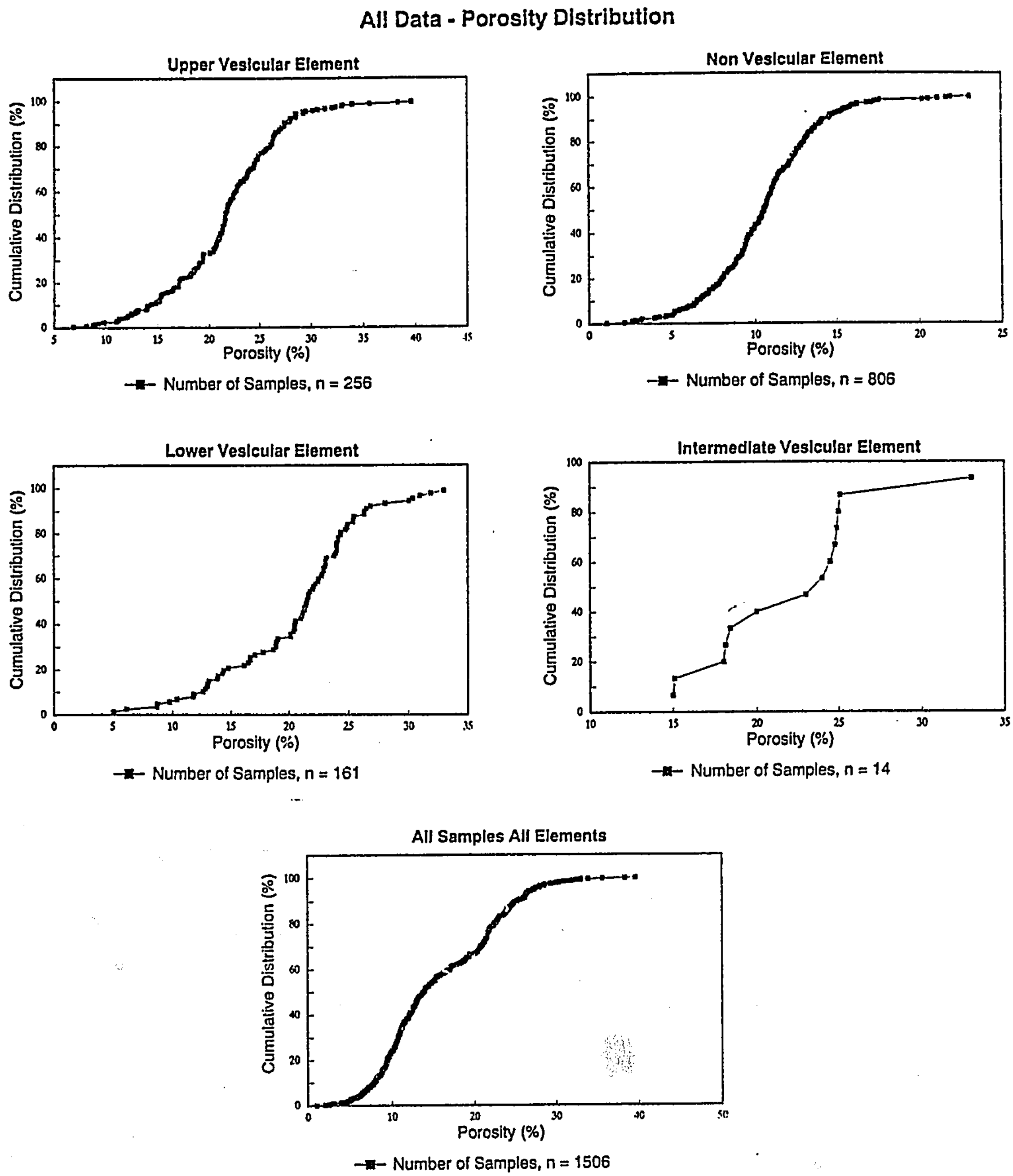


Figure 3-10. Porosity Distribution curves for complete data set.

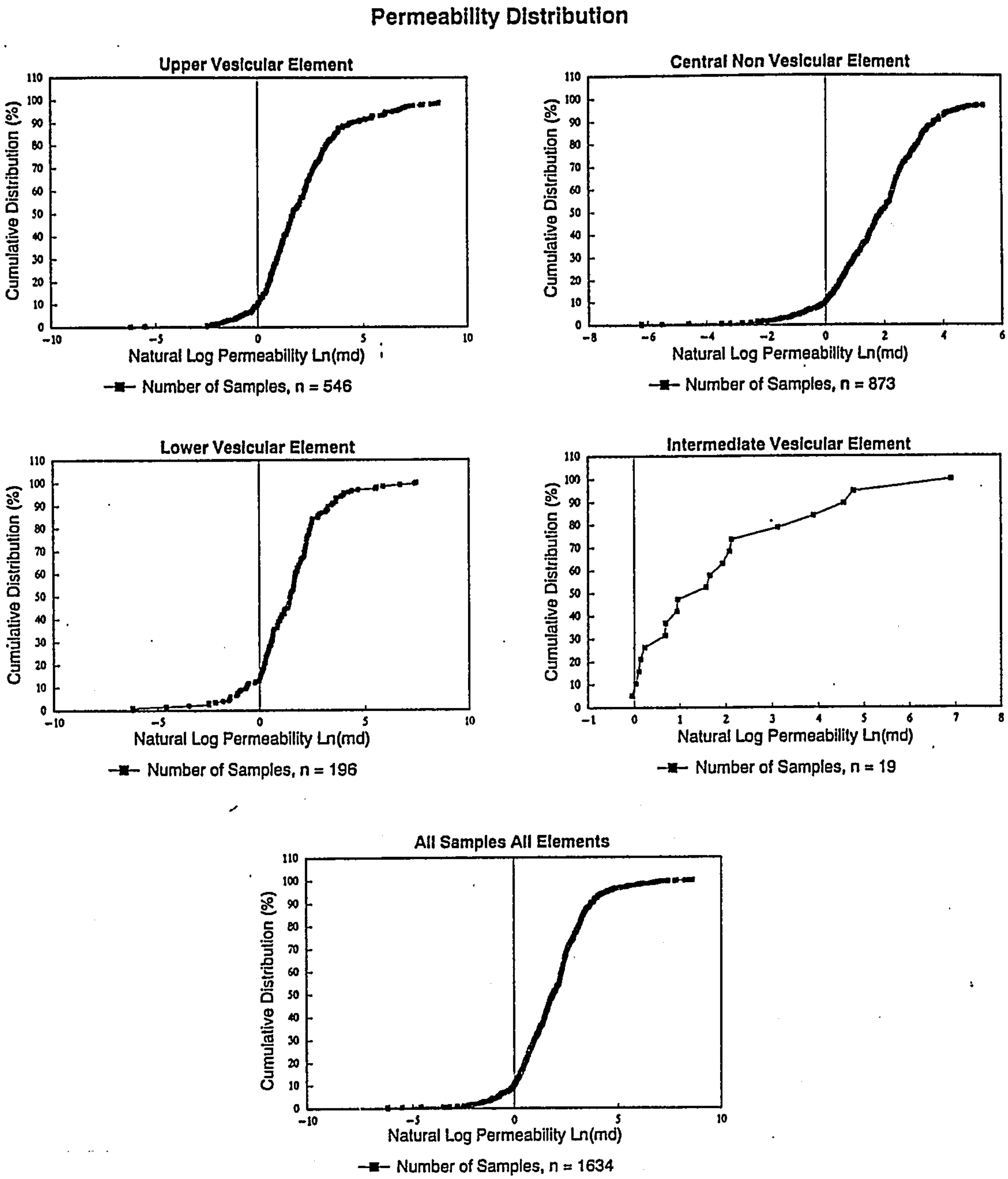


Figure 3-11. Permeability distribution curves for all samples.

point was acquired in each bottom vesicular zone of Flow Group D and E). The median values for all samples are 5, 9, 5, and 4 mD. Locally, the highest maximum permeabilities occur in the vesicular elements in samples where there is good local connection between the vesicles. Statistically, the median permeability of the vesicular elements is less than that of the central nonvesicular element. Analysis of the permeability data suggests that higher permeabilities are fracture dependent.

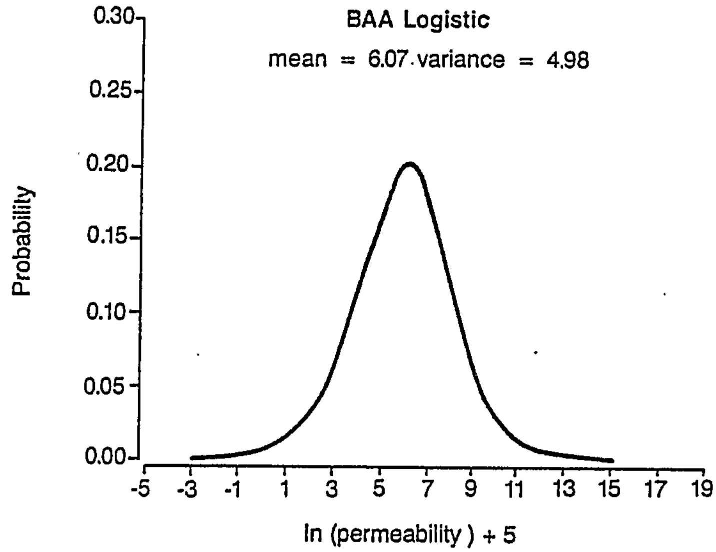
The average permeability for the vadose zone, based on well tests, is in the range of a few darcys (Sisson and Ellis, 1990). Based on the current well, core, and outcrop data, the basalt intervals average around 10 D while the sediments average 0.1 D (Sisson and Ellis, 1990; Knutson et al., 1990). The fractures, fissures, and rubble zones are filled with the finer components from the sediments, where they are directly overlain by sediments.

Density

Figures 3-12 and 3-13 are distribution plots of the grain density and bulk density of the four elements.

The median grain density for all the samples was 190.50 lbm/ft^3. However, when the data were evaluated by element (i.e., vesicularity), there was a small, median density difference between the top vesicular, nonvesicular, and bottom vesicular material. In general, the upper vesicular, nonvesicular and bottom vesicular elements have median grain densities of 190.00, 190.87, and 190.50 lbm/ft^3.

The bulk density distributions are similar to the porosity distribution, with upper vesicular, nonvesicular and lower vesicular median bulk densities of 149.38, 170.63, and 149.38 lbm/ft^3. The median bulk densities of all samples is 164.38 lbm/ft^3. In general, at least 90% of the time the vesicular element bulk densities are less than 163.13 lbm/ft^3, and the nonvesicular element bulk densities are greater than 181.88 lbm/ft^3.



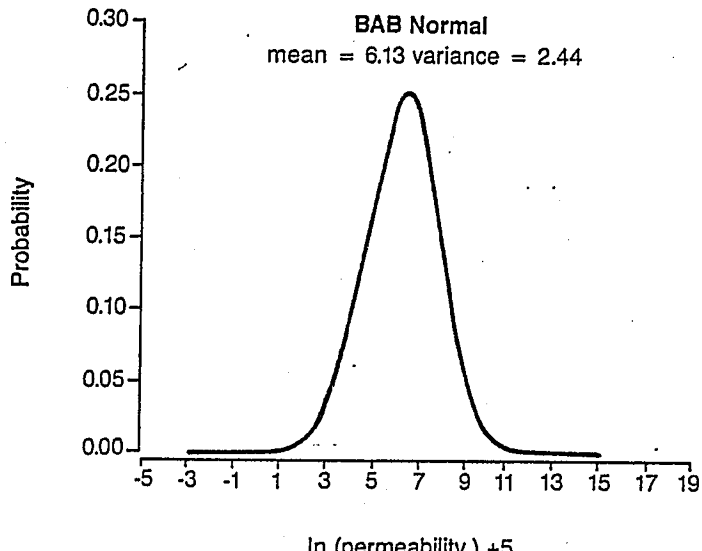
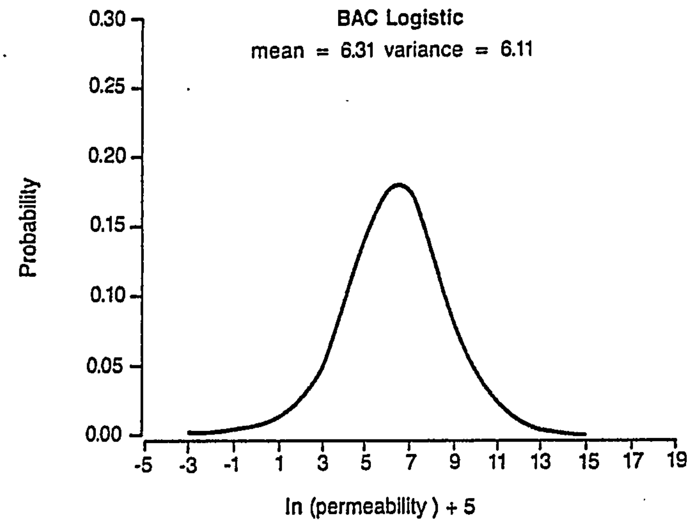


Figure 3-12. Permeability distribution curves for Flow Group A (BAA) and Flow Group B (BAB).



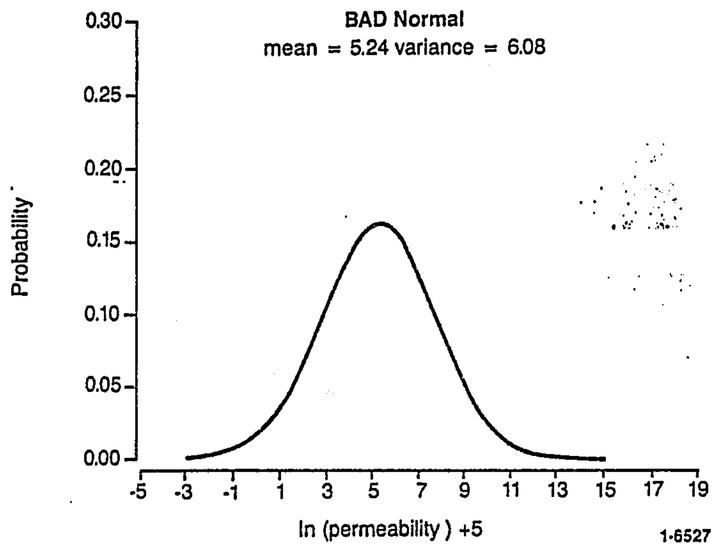


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Figure 3-13. Permeability distribution curves for Flow Group C (BAC) from just below the flow group Flow Group B-C interbed to approximately 195 ft and Flow Group C from 195 ft to the Flow Group C-D sedimentary interbed.

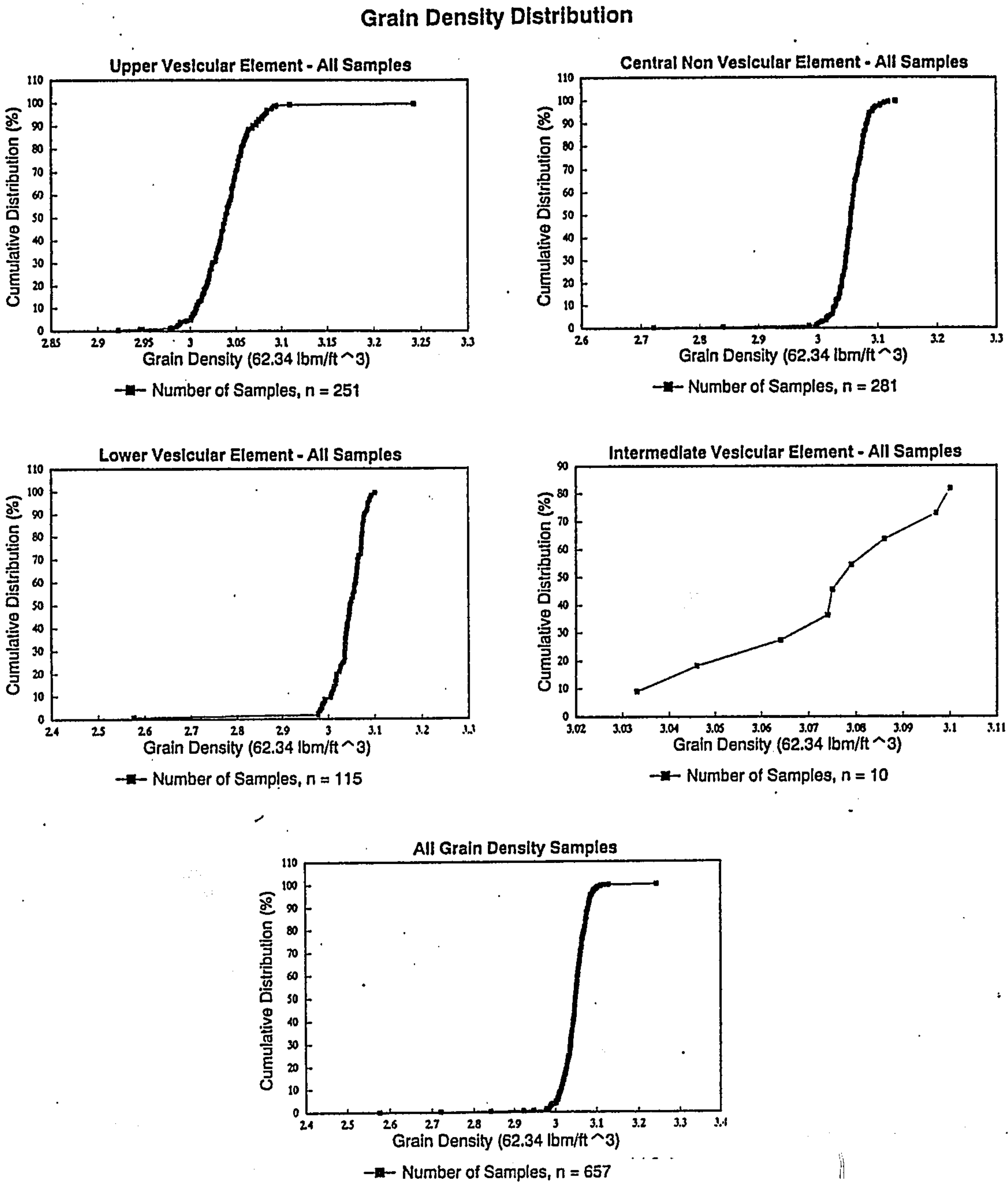

Figure 3-14. Grain density distribution curves for all samples.

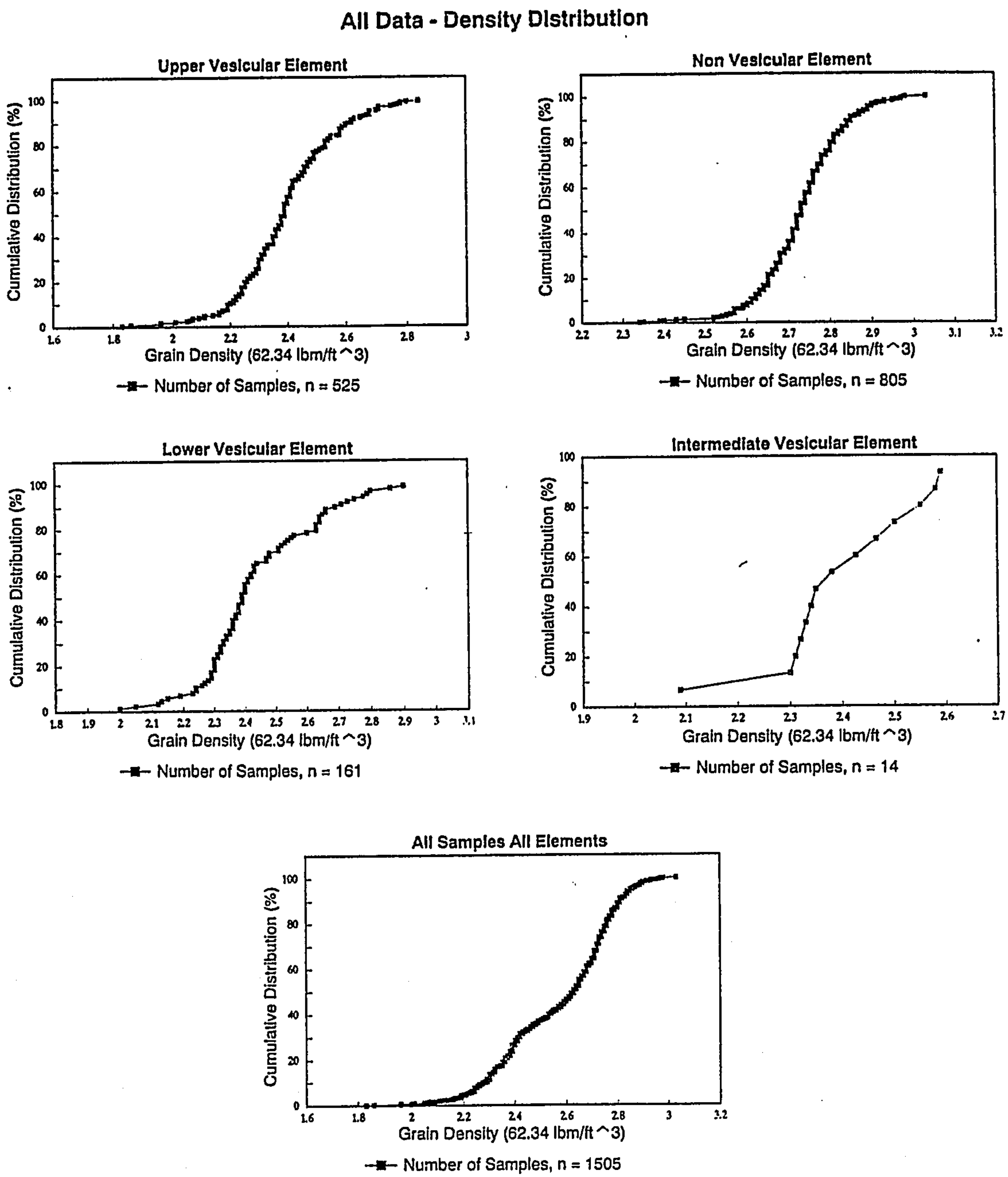

Figure 3-15. Bulk density distribution curves for all samples.

Equilibrium Water Saturation

Water saturation data were collected on 44 basalt samples (i.e., 0.98 in. diameter, 1.1 in.–long plugs) by maintaining systematically higher or lower vapor pressures around the samples and recording the quantity of wateradsorbed or desorbed in each case. [This method yields a wetting (adsorption) and drying (desorption) curve for each sample for 0% relative humidity to 100% saturation and back down to 0.] The basalt plugs range in porosity from 6.5 to 43%, in permeability from 0 to 4824 mD, and in pore volume from 3.04×10^{-5} to 2.00×10^{-4} ft^3.

In all cases, little water was adsorbed by the samples at relative humidities less than 99.9%. At the expected relative humidity within the vadose zone under the RWMC, the range in percent saturation among the 44 basalt plugs was 0.07 to 1.76% vol. saturation for a 25% vol. vapor pressure and 0.10 to 2.08% vol. saturation for a 30% vapor pressure. At complete saturation, the percent of pores filled rarely approached 100%. The percent saturation ranged from 47.3 to 93.5, and the median value was 72.1% of porosity. Total saturation was not attained because the large size surface vesicles drained and some interior non effective porosity was present.

Does the data set available represent the field scale properties?

Limitations are inherent in the physical properties data because of the size of the sample set. This same caveat is true for all measurements that use core or plug porosity, permeability, and density. Because core is retrieved from only the most competent portion of the formation, the more transmissive features (i.e., rubble piles, lava tubes, partially collapsed areas, and intensely fractured zones) are not represented by core that was recovered. These important features were evaluated using more sophisticated logging techniques and equipment.

Tests were made on five fractures that exist in the central massive portion of a flow in Box Canyon. In all cases, in situ fracture permeabilities are a function of closure pressure, silt/clay filling, extent of precipitated filling, wall rugosity, and aperture. The resulting permeabilities for the five fractures range from 1 to 153 D. These fracture permeabilities are orders of magnitude higher than the permeabilities of the rock matrix (e.g., compared with the values in Figure 3-6).

Fractures are considered a contaminant pathway, and the permeabilities are considerably higher than the matrix values. Fractures occur in significant numbers within the basalt flows under the INEL Site. Field studies show the bottom vesicular median fracture frequency is one every 0.75 to 1.5 ft, the central element median joint frequency is one every 3.2 ft, and the upper vesicular median joint frequency is one every 3 ft.

Lava tubes, collapsed lava tubes, and deep fissures also may occur within the flow. These essentially two-dimensional features have very high transmissivity and can extend for hundreds of feet. However, the occurrence of these features is rare (Geostatistics have been produced and are accessible).

3.5 Geologic Processes

<u>What geologic processes are of particular concern?</u>

- Volcanism with associated ground deformation and seismicity
- Tectonic seismicity and associated ground deformation
- Subsidence (or uplift) and associated ground deformation

- Changing climatological conditions could affect potentials for flood, drought, and snowfall

- Erosion or deposition by wind and water.

<u>What concerns are associated with volcanism, ground deformation, and seismicity?</u>

Radiometric age determinations on cores from lava flows at RWMC (Drill Hole 77-1) indicate that the RWMC area has been inundated by lava flows with an average recurrence of 94,000 ± 45,000 years for the last 600,000 years. The youngest lava flow at the site is 95,000 years old (Kuntz et al., 1978). The most recent flow traveled almost 12 mi to reach the RWMC from a vent (Quaking Aspen Butte) to the southwest. The probability of a future lava flow reaching the RWMC is very low and depends upon the vent location, the ground slope direction between the vent and RWMC, and the output rate of lava from the vent.

<u>What are the concerns associated with ground deformation resulting from tectonic seismicity?</u>

Ground shaking and ground deformation because of earthquakes associated with tectonism are a concern for the RWMC. Although the ESRP is characterized by relative aseismicity, the surrounding Basin-and-Range province contains active northwest-trending normal faults that have formed in response to northeast-southwest directed extension. The Basin-and-Range faults, which lie closest to the RWMC, are the Arco segment of the Lost River fault (Figure 3-3), which lies about 15.5 mi northwest of the RWMC, and the Howe segment of the Lemhi fault, which lies about 21.7 mi north of the RWMC. These two fault segments may be capable of generating earthquakes as large as the magnitude 7.3 Borah Peak earthquake of 1983 (Smith et al., 1989). Ground motions at the RWMC from such an earthquake would be significant and could damage buildings, protective covers, diversion dams, drill holes, grout curtains, and waste containers. Surface deformation that could occur because of such ground shaking includes local subsidence of saturated, uncompacted fill material.

<u>What adverse effects might be anticipated from subsidence and its associated ground deformation?</u>

The ESRP is an accumulation basin that collects sediments from the surrounding mountain ranges and basalt lava flows from local volcanic vents. This is a result of the plain subsiding after passage of the Yellowstone mantle plume beneath the crust. Since that time, the INEL area has subsided from an elevation similar to that of the Yellowstone Plateau at a rate of about 0.002 to 0.04 in./year. The surface, estimated at an elevation of about 8000 ft 4.3 million years ago, is now at an elevation of about 2,000 ft and buried by about 3,000 ft of basalt lava flows and sediments. Two lines of evidence suggest that the subsidence is continuing today:

1. Erosion of the ESRP is only minimal, affecting only the upper slopes of young volcanic vents and localized stream channels where subsidence may have slowed (e.g., the Box Canyon of the Big Lost River--the canyon cutting may be due to a decreased subsidence rate or slight uplift in the Arco Rift Zone area because of magmatic dike injection and volcanism)

2. Subsurface correlation of lava flows in the INEL area shows that the subsidence rate over the past 200,000 years has been as high as it was for the past 4.3 million years.[a]

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a. S. R. Anderson, 1990, personal communication

Given subsidence rates of 0.002 to 0.04 in./year, the RWMC area could subside as much as 27 to 33 ft over the next 10,000 years. This subsidence could cause burial of the area in alluvial sediments, windblown silt, or basalt lava flows. Local differential subsidence rates could cause fissuring and ground deformation that would affect container integrity and strength of isolation structures (e.g., dams, walls, and impermeable covers).

3.6 FEDERAL FACILITY AGREEMENT OPERABLE UNIT STUDY

As water and contaminant migration are strongly influenced by geological surface/subsurface materials, information presented in Section 3 will be used for further study of Operable Unit 7-07 Vadose Zone. This operable unit is described as the subsurface region (beginning at the surface) beneath the RWMC down to the top of the Snake River Plain aquifer. The objective of this study is to determine sources, releases, and potentially unacceptable risk from any radionuclides and heavy metal contamination in the vadose zone beneath the RWMC. A Preliminary Scoping Track 2 study will commence in FY92 to conduct field investigation and laboratory analysis sufficient to make a decision to recommend no further action, or proceed with interim action, or R1/FS Scoping. Data needs will be addressed in this Track 2 study.

4. HYDROLOGIC MODEL

4.1 Characterization Goals

The hydrogeology of the INEL Site has been studied by the USGS for over 40 years, and groundwater studies specific to the SDA have been conducted since 1971-1972 when four monitoring wells were drilled to the water table near the SDA. Studies of the vadose zone have been performed since the 1960s. Numerous studies by DOE contractors and consultants have added to the general body of knowledge at the SDA. This section of the report summarizes and interprets the research papers, reports, and other documents that focus on water pathways for contaminant migration from the SDA. This section of the report does not present new studies or research, but rather it incorporates all completed studies into one comprehensive document. Based on shortfalls and incomplete areas of understanding, proposals will be made to fill gaps to reduce the level of uncertainty associated with the data on hand.

What is a hydrologic model?

A hydrologic model focuses on the movement of water both on the surface and beneath the ground. Tnis includes movement of water on the surface, in the variably saturated zone above the water table (vadose zone), and in the saturated zone beneath the water table. Movement of water may potentially serve as a pathway for contaminants to migrate from the SDA. Defining water movement ranges from difficult in the vadose zone, to less difficult in the aquifer, to easiest at land surface. The SDA is unique in several aspects with respect to water movement including a thick vadose zone, a fractured discontinuous geologic media, low precipitation interspersed with high runoff and recharge events, and large manmade surface diversion areas.

What are the goals of the hydrologic model?

The goals of the hydrologic model are to present a concise summary of the hydrologic conditions at the SDA that addresses specific questions and to provide references to support the conclusions presented.

What are the hydrologic characterization goals?

The objective of the hydrologic characterization at the SDA is to describe and understand the surface, vadose zone, and groundwater pathways for performing risk assessments and evaluating potential remedial alternatives. The hydrologic characterization must be adequate to reduce the uncertainty to an acceptable level and fulfill the aforementioned objective, while at the same time limiting costs and meeting regulatory deadlines.

How is the hydrologic model organized?

Section 4.2 presents information on surface water at the RWMC, including key factors that affect contaminant migration through the vadose zone. Major topics in this section include the influence of infiltration, spacial distribution of recharge, and potential flooding at the SDA. Section 4.3 describes water movement through the vadose zone, rates of water and contaminant movement, and estimated travel times for transport through the vadose zone. Section 4.4 discusses groundwater flow paths in the Snake River Plain Aquifer beneath the RWMC, factors that affect movement of water in the aquifer, rates of travel, and estimated arrival times at the INEL Site boundary. Section 4.5 presents a summary of hydrologic characterization needs required to improve the conceptual understanding of contaminant transport through the vadose and groundwater zones.

4.2 SURFACE WATER

Surface water features near the SDA consist of the Big Lost River, 2 mi to the north; the INEL diversion area, 1 mi to the west; local basin surface runoff from the surrounding slopes of the SDA; and precipitation falling directly on the SDA. Potential for contamination and exposure resulting from direct contact and ingestion of surface water is discussed in this section. Also, the potential for deep percolation (recharge) of water to groundwater transport of contamination is reviewed.

What is the surface water hydrology of the Big Lost River drainage basin?

The SDA lies within the Big Lost River drainage basin. This drainage terminates in the northwest part of the INEL Site (Figure 4-1). The Big Lost River is an important source of irrigation water for agricultural areas west and northwest of the INEL Site. Streamflows are often depleted before reaching the INEL Site by irrigation diversions and infiltration losses along the river. However, in times of heavy runoff, the river flows to its terminus in the Big Lost River Sinks at the northwest corner of the INEL Site. During these high flow years, the Big Lost River is an important source of recharge to the Snake River Plain Aquifer (see Section 4.4).

The main stem of the Big Lost River is formed by the confluence of its East Fork and North Fork about 22 mi northwest of Mackay Dam, which impound the river flows approximately 4 mi northwest of Mackay. A significant portion of the streamflow is controlled by the dam, which stores runoff for irrigation.

The Big Lost River flows southeast from Mackay Dam down the Big Lost River Valley, past Arco, and onto the Snake River Plain. During high flows the river may flow onto the southwest portion of the INEL Site. Here, the river flows northward across the INEL Site in a shallow, gravel-filled channel, or it is diverted to the INEL diversion area. Two 6-ft diameter corrugated metal pipes allow for passage of less than 900 ft^3/s of water through the dam downstream into the main channel (Lamke, 1969). The main channel branches into several channels 18 mi northeast of the INEL diversion dam, forming four shallow playas, referred to as the Big Lost River Sinks.

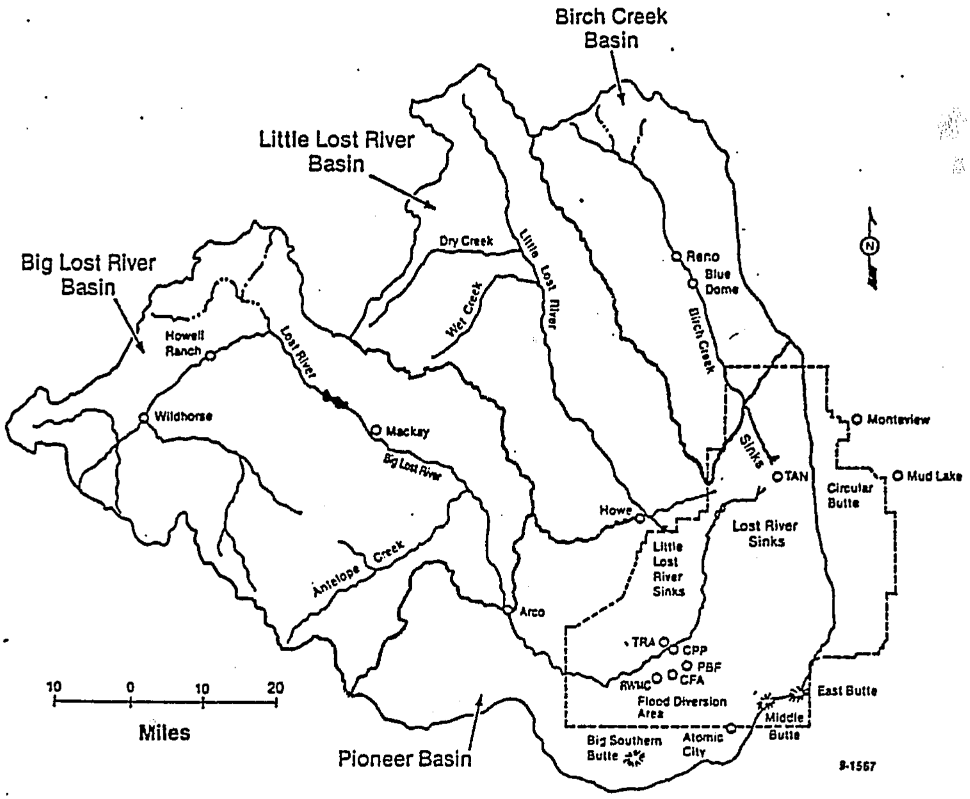

Figure 4-1. Big Lost River drainage basin.

What is the INEL diversion system?

The INEL diversion area was constructed in 1958 to divert high runoff flows from the INEL Site facilities. The diversion system consists of a diversion dam, diversion channel, two 6-ft diameter gated culverts, three dikes, four spreading areas, and two interconnecting channels (See Figure 4-2). Flow in the diversion channel is uncontrolled at discharges that exceed the capacity of the culverts. The diversion channel is capable of carrying 7200 ft^3/s of water from the Big Lost River into the spreading areas. Two low swales located southwest of the main channel will carry an additional 2100 ft^3/s for a combined diversion capacity of 9300 ft^3/s of water (Bennett, 1986).

Spreading Area B, with a top dike elevation of 5053 ft, is less than 1 mi west of the SDA and has an average elevation of 5000 ft.

Does the Big Lost River or a failure of Dike 2 at Spreading Area B have potential for flooding the SDA?

The Big Lost River, 2 mi north of the SDA, is at an elevation 30 to 40 ft higher than the SDA. The Big Lost River flows northeast, away from the SDA, to its termination in the playas. A detailed flood-routing analysis of a hypothetical failure of Mackay Dam resulting from hydrologic and seismic failures shows the RWMC would not be inundated by this severe flooding (Koslow and Van Haaften, 1986). Big Lost River flows have not entered the SDA during its operation, which began in 1952. However, there is evidence of alluvial deposits in the SDA, possibly deposited during the Pleistocene period. It is uncertain if these deposits are actual Big Lost River deposits or alluvial fan deposits from the surrounding mountains. Two eroded notches or wind gaps (one of which has been filled with earth material) in a basalt ridge west of the RWMC also suggest past surface water flows. There is evidence of glacial outburst flooding of the Big Lost River during the Pleistocene period (Rathburn, 1988). Climatic conditions were much better during the Pleistocene period.

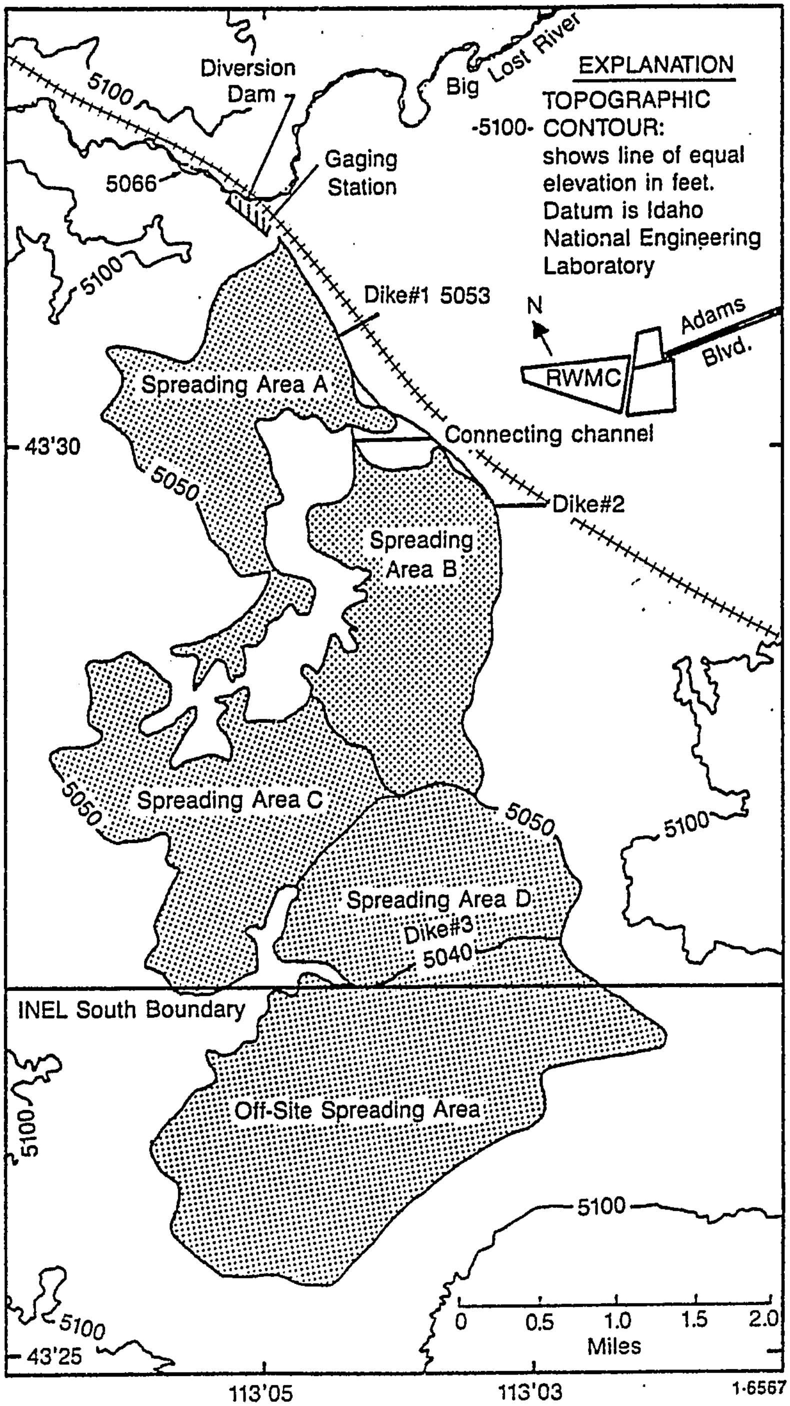

Figure 4-2. INEL diversion area.

The elevation of the SDA and an access road on the west side of the SDA provide a direct route for floodwaters should a failure of Dike 2 occur when water is stored in Spreading Area B. The floodwaters released from this hypothetical failure would require high velocities and flood stages to actually overtop or breach the existing peripheral dike to allow floodwaters to enter the SDA. Historically, the spreading areas have seldom contained water. A recent study shows it is unlikely that spreading Area B poses a flood threat to the SDA (Martineau, 1990).

Is the topography at the SDA conducive to flooding?

The SDA is situated in a natural topographic depression at an average elevation of 5000 ft. This natural depression holds precipitation falling upon it and collects additional runoff water from the surrounding slopes. The SDA has been flooded at least three times in 1962, 1969, and 1982 by local basin runoff. These flooding events were the consequence of rapid snowmelt combined with heavy rains and warm winds, resulting in runoff water from surrounding areas entering the SDA.

What were the effects of the 1962, 1969, and 1982 floods?

In February 1962, approximately 1.81 in. of rain fell on 8 in. of snow in 3 days. The top foot or so of undisturbed ground was frozen, resulting in an estimated 30 acre-ft of runoff entering the SDA (Karlsson, 1977). Pits 2 and 3 and Trenches 24 and 25, all of which were open to receive additional waste, became ponded with the runoff (Figure 4-3).

Water samples from monitoring wells immediately adjacent to trenches indicated no significant migration of radionuclides through the soil as a result of the flooded conditions (Karlsson, 1977). In response to this local flooding, dikes were constructed around the perimeter of the SDA to prevent local runoff from entering the SDA.

In January 1969, rainfall and snowmelt, amounting to about 1.7 in. of water, resulted in an estimated 20 acre-ft of local basin runoff ponding in

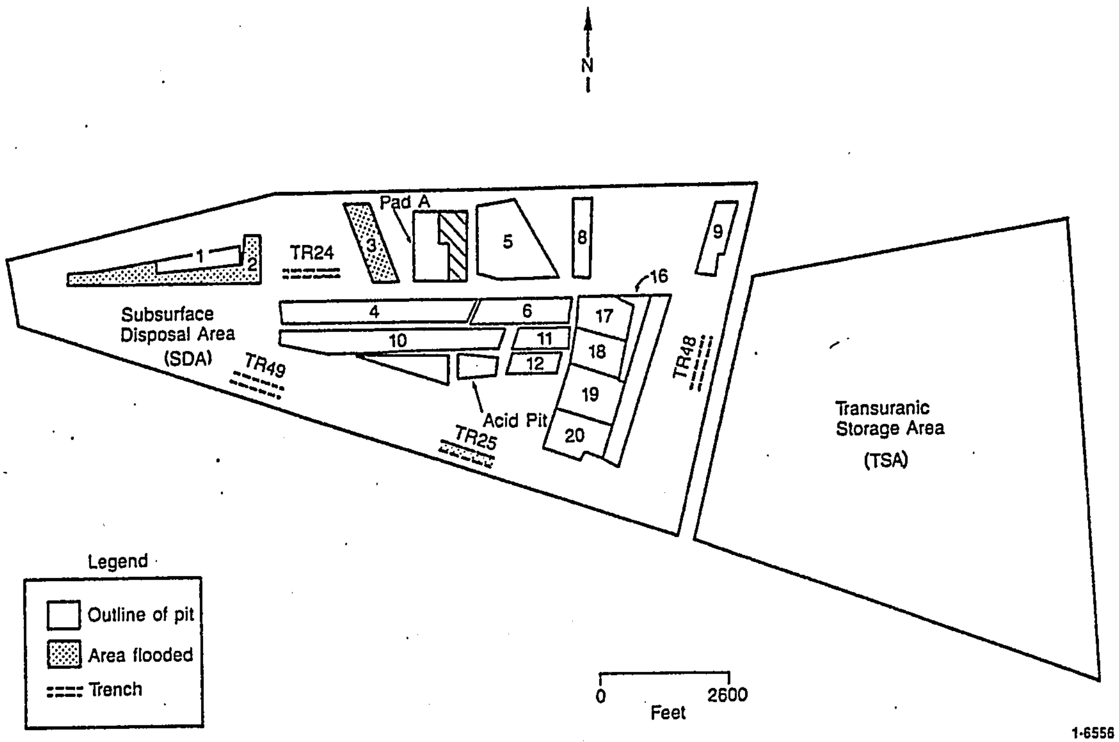

Figure 4-3. Areas flooded during the 1962 flood.

the SDA (Karlsson, 1977). Large snowdrifts in the perimeter dike blocked the drainage flow path, resulting in runoff from the local basin to overflow the dike and enter the SDA. Pit 10 and Trenches 48 and 49, which were open to receive additional waste, became ponded (Figure 4-4). Pit 9, which was partly open, also became ponded. After this flood, the dike around the SDA was raised and the perimeter drainage ditch was enlarged. The ditch was enlarged to permit heavy equipment to remove snowdrifts.

In 1971, the SDA was graded to provide drainage channels for surface water runoff. An outlet pipe with a flap valve was placed through the dike in the northeast corner of the SDA to allow surface water to flow out and to prevent local basin surface runoff from entering the SDA.

On February 17, 1982, warm winds, heavy rains, and snowmelt from the local basin surrounding the SDA resulted in an accumulation of water in the southeast corner of the SDA, causing a rupture of the perimeter dike.

This rupture resulted in floodwaters entering Pits 16, 17, and 18 (Figure 4-5). About 8.3 acre-ft of runoff water entered the SDA and ponded in Pit 16. Again, snow and ice blocking the drainage channel resulted in a rupture of the perimeter dike.

In response to the 1982 SDA local basin runoff flooding, two studies were conducted to determine the magnitude of a local basin flood, because of natural precipitation events, with a recurrence interval of 25 and 100 years (Koslow, 1982; Truitt, 1984). These studies provided the framework for upgrading flood control measures at the SDA.

Final improvements to the perimeter dike at the SDA were completed in 1988. These improvements consisted of raising the dike as much as 3 ft, widening the dike, and adding riprap. Recontouring work within the SDA added

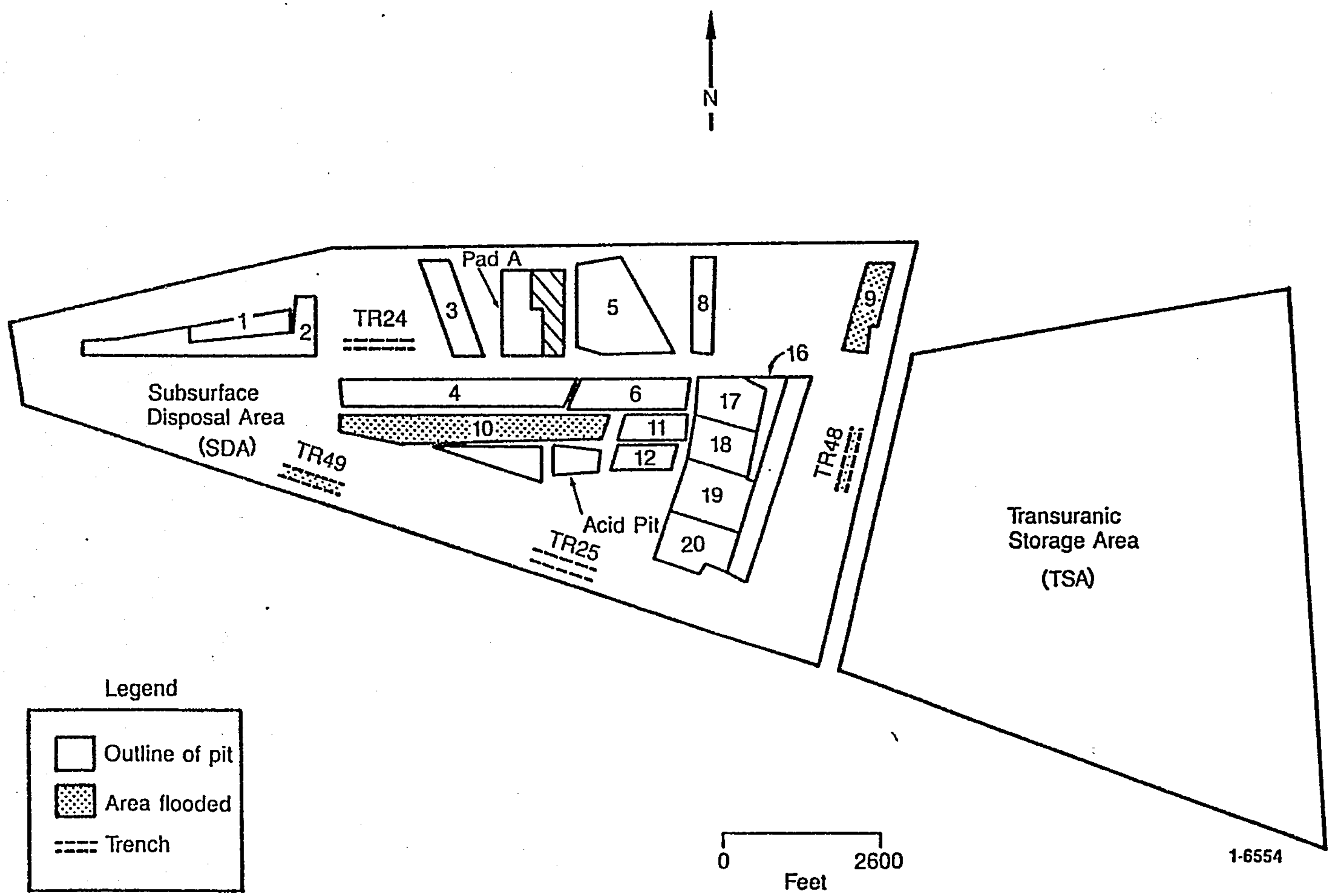

Figure 4-4. Areas flooded during the 1969 flood.

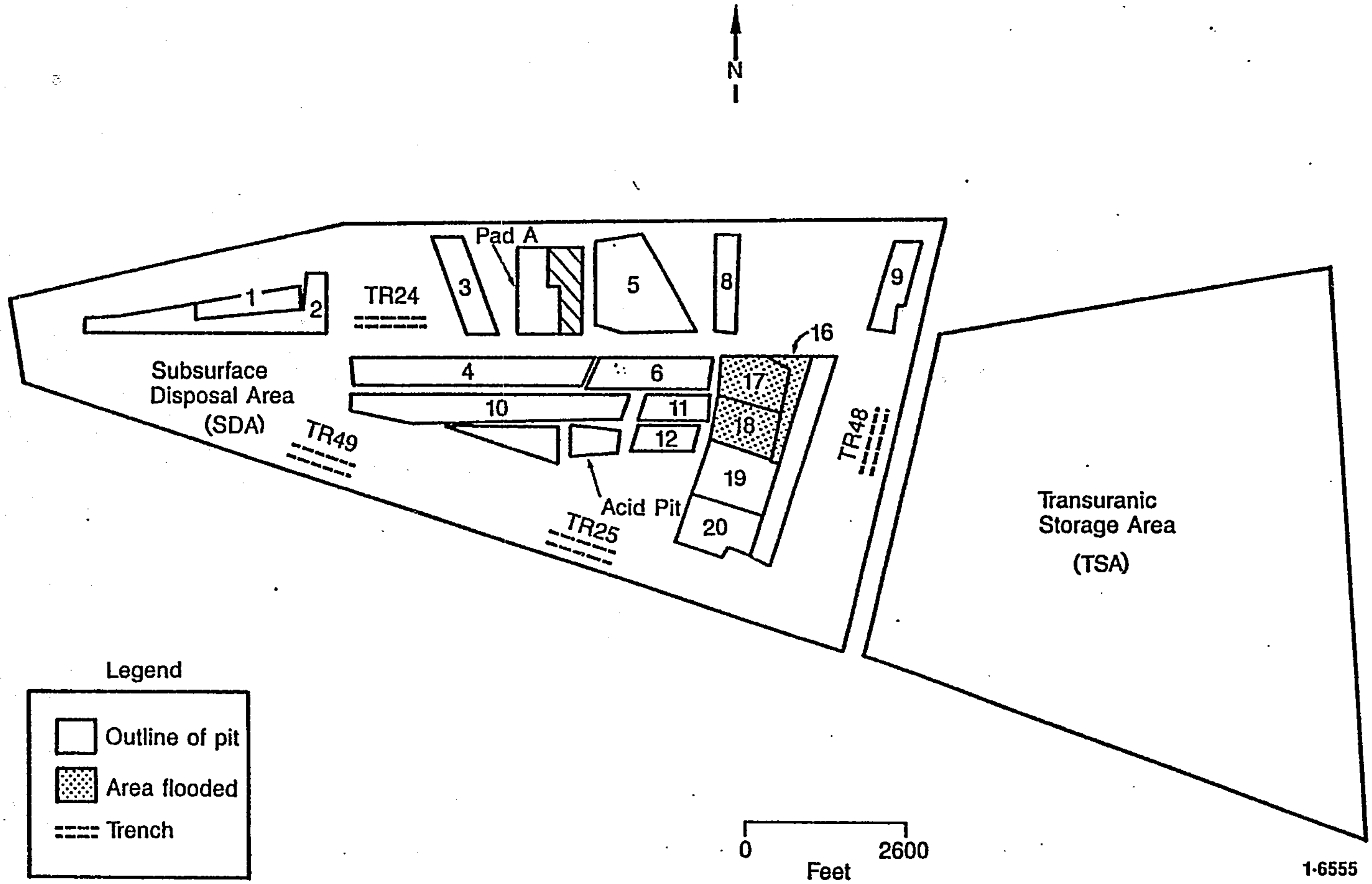

Figure 4-5. Areas flooded during the 1982 flood.

approximately 138,000 yd^3 of fill to eliminate surface ponding and provide sufficient flow to the drainage ditch.[1]

A study was conducted in 1988 to evaluate the existing SDA soil cover and drainage system to reduce water infiltration into the SDA.[2] The study concluded that no new drainage improvements were recommended for the near term, with the suggestion that this decision be reviewed on a yearly basis as new information on infiltration at the SDA is compiled.

Can runoff flood the SDA?

Localized runoff from the surrounding slopes is prevented from entering the SDA by the perimeter drainage channel and dike surrounding the SDA (Figure 4-6). A design cross section of the dike and perimeter drainage channel is shown in Figure 4-7. The present elevation of the top of this dike is about 5015 ft, which ranges from 2 to 15 ft above areas within the SDA. A dike within the SDA, with a top elevation ranging from 5013 to 5015 ft, has been constructed around the active pit in the southwestern part of the SDA. Both dikes are protected from erosion by coarse riprap.

Local runoff from within the SDA flows to a sampling/discharge outlet on the east end of the SDA. The outlet consists of a sump pump capable of pumping 250 gpm, a catch basin that collects waters exceeding the pumping rate, and valved culverts that prevent outside waters from entering the SDA. This outlet directs waters to the RWMC drainage channel, then to a drainage basin that drains to the Big Lost River (Figure 4-6). Surface runoff from the SDA and surrounding slopes infiltrates the soils and/or evaporates before reaching the Big Lost River. Implementing these flood control measures has

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[1]A. C. M. Barnes, 1988, Evaluation of Cover on Drainage Improvements for Interim Stabilization of the SDA at the INEL RWMC, EG&G Idaho, Inc., EDF-BWP-SC-03.

[2]IBID, Barnes.

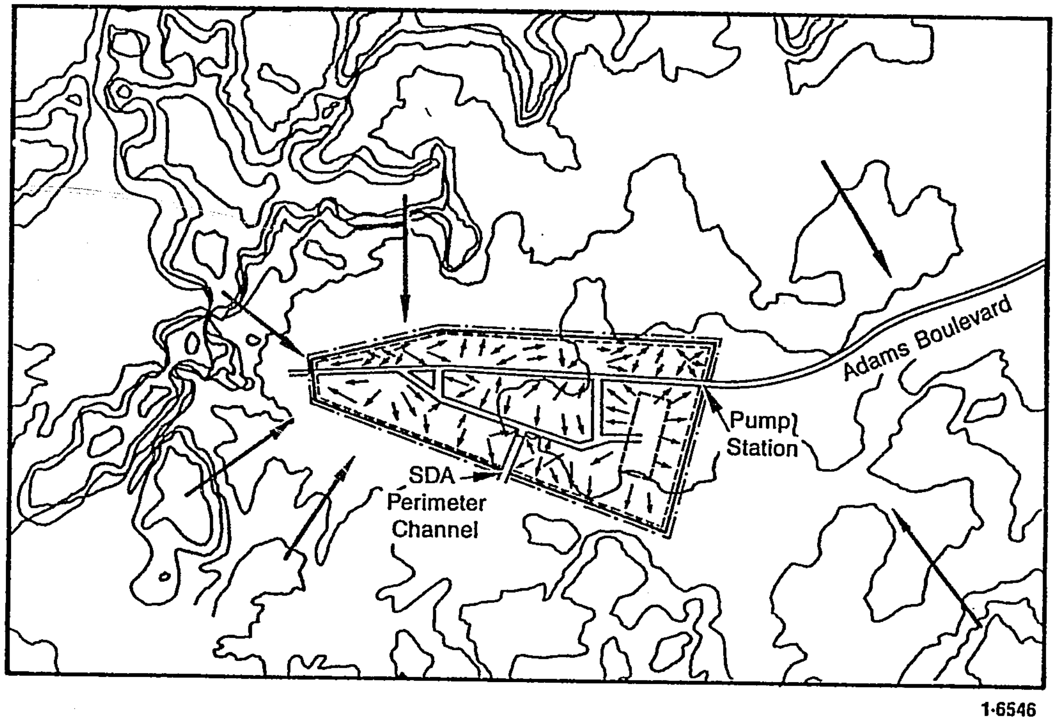
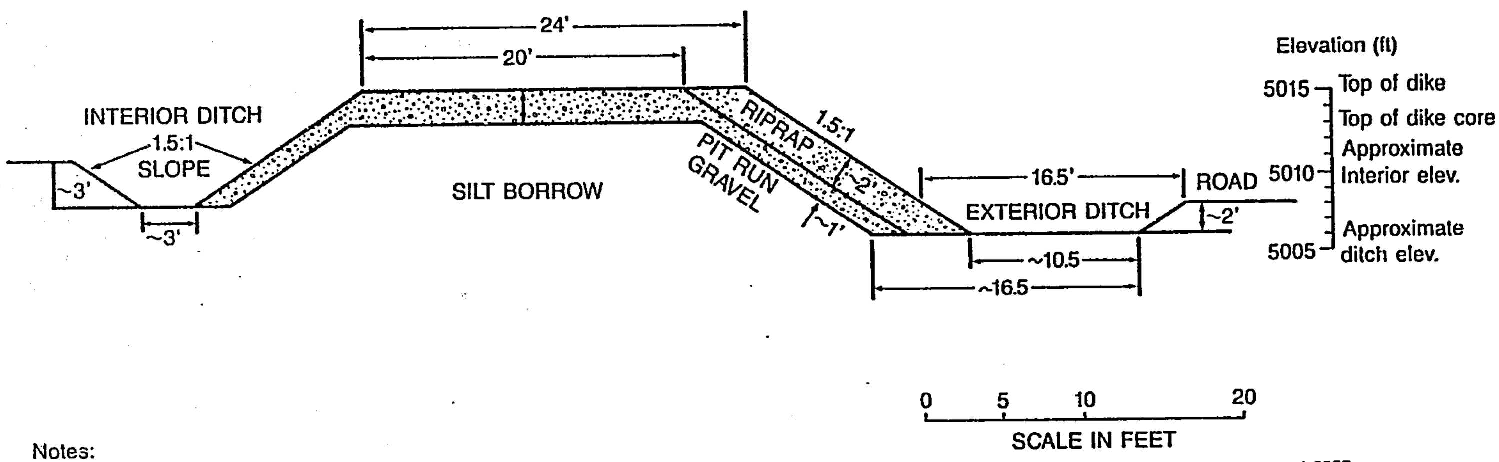


Figure 4-6. SDA runoff and perimeter drainage.



Notes:

1. Figure represents design section, not as-built.
2. Interior ditch section was nominal assumed geometry and does not represent proposed design.
3. Based on EG&G drawing 169199, attachment 2 of RFP No C86-131159.

Figure 4-7. SDA typical dike and perimeter drainage cross section.

proven successful in diverting local basin runoff and greatly reducing the risk of flooding.

Water samples are collected from the SDA sump pump area, when there is a sufficient amount of water to be collected, following periods of rainfall or snowmelt for analysis of gross alpha, beta, gamma spectroscopy, and selected radiochemistry (Figure 4-8). The surface water sample analysis data are published in the annual report, Environmental Surveillance for the EG&G Idaho Radioactive Waste Management Areas at the Idaho National Engineering Laboratory.

What is the annual precipitation at the RWMC?

Annual average total precipitation at the RWMC is 8.71 in., measured at Central Facilities Area (CFA), a station approximately 4 mi northeast of the SDA (Clawson et al., 1989). Snowfall is a major contributor to the total yearly precipitation. The annual average snowfall is 27.6 in., with a maximum yearly snowfall of 59.7 in. (Clawson et al., 1989). The mean 2 year surface runoff event within the SDA, consisting of snowmelt and precipitation, is 15 acre-ft of water.[3]

What is the likely cause of potential flooding at the SDA?

Local precipitation falling directly on the SDA cover and localized runoff are the most probable forms of surface water to affect the SDA. Because of the arid and semiarid nature of the RWMC, it is unlikely heavy precipitation will be of a great concern. However, several discrete events closely spaced may result in pulses of water infiltrating the soil cover and possibly contacting the waste, particularly if the rainfall events fall on a snow pack.

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[3]K. N. Koslow, SDA Retention Basin Capacity, EG&G Interoffice correspondence, KNK-02-83.

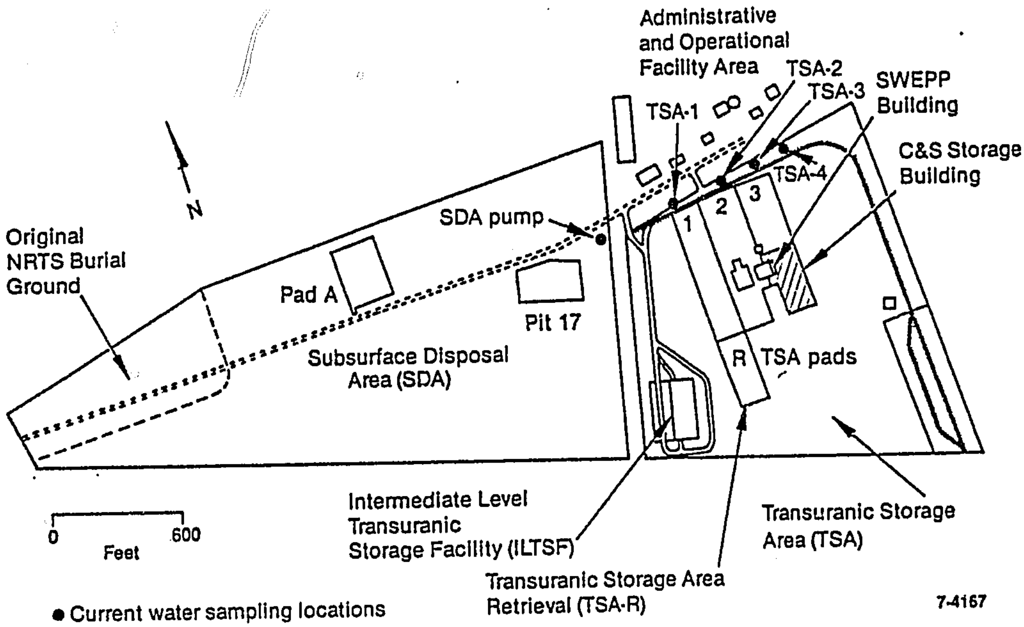

Figure 4-8. Surface water sampling locations.

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What are the implications of the surface water data for this model?

Two surface water features are salient to this model and the fate and transport of contaminants at the RWMC. These are the Big Lost River and surface water runoff.

The Big Lost River flows to the northeast, away from the SDA, with no drainage to the SDA. The Big Lost River does not pose a flood threat to the SDA and is not a surface water pathway for contaminant transport at the SDA. The diversion of Big Lost River water to the spreading areas results in infiltration of the ponded waters, which may influence the perched water near the SDA and the groundwater flows in this area, causing localized groundwater flow reversals (see Section 4.4).

Ponding and infiltration of surface runoff may result in perched water layers beneath the SDA, providing a possible transport mechanism. Precipitation that falls directly on the SDA cover may also infiltrate the soils and provide a water pathway for the transport of radionuclides and organics.

How is the surface water used at RWMC?

Surface water is present at the SDA only during periods of heavy rainfall and snowmelt. Runoff water is not used for domestic or industrial purposes, but it may be used by animals and plants. Surface water, when present in the spreading areas to the west of the SDA, attracts wildlife and waterfowl to the area. The SDA water needs are supplied by groundwater from the RWMC administration area production well.

What are the recharge considerations?

Field water balance assessments are necessary to predict the amount of recharge or deep percolation that may occur at a given site. Recharge predictions are subsequently used to predict soil water movement and contaminant transport through the unsaturated zone. Field water balance predictions require consideration of processes occurring in the atmosphere, plants, and the top layers of the soil profile. A combination of field data and computer modeling one being used to estimate the potential for recharge at the SDA. A generic description of the controlling processes can be found in Hillel (1971) pp. 226-228.

<u>What are the surface features and soil characteristics that impact the surface water hydrology at the SDA?</u>

Soil cover materials used at the SDA are composed of fluvial and lacrustrine deposits taken from the INEL Spreading Areas A, B, C, and D (Figure 4-2). The closest Spreading Area (Area B) is less than 1 mi from the SDA and is the main source area for the SDA soil cover material. The texture of the deposits is heterogeneous and consists of a mixture of sand, silt, and clay (Binda, 1981). The transported material is used to backfill and cover the waste burial trenches and pits. Crested wheatgrass (<u>Agropyron</u> <u>cristatum</u>) is planted to control erosion of the soil cover and increase water uptake. The depth of the soil cover is a few inches to a maximum of about 4 ft.

A small percentage of the ditches within the SDA lie directly over waste, and one-third of the ditches are located near waste boundaries. The ditches are typically 2.4 ft deep, with a bottom width of 1 to 2 ft, and side slope of 1H:1V. Ice may build up in the ditches in the winter months, decreasing the flow capacity. In an extremely wet year, water may pond in the ditches for up to 2 weeks (Barnes, 1988). Infiltration into the SDA cover may occur during these wet periods (December through May).

Currently, in several areas at the SDA, the waste is not covered with a vegitated soil. Each of these conditions reduce the rate of evapotranspiration and increase the potential for recharge. Final covers will be vegetated, and gravel will not be used. Assumptions the waste is covered with a vegetated soil cover are not correct for several areas at the SDA.

What studies have been conducted at the SDA related to surface water hydrology?

Field studies and computer simulations have been conducted to quantify the terms in the water balance equation and estimate recharge at the SDA. These studies were conducted to obtain information on site-specific soil including matric potential and neutron probe data; soil cover material properties, design, and performance; and plant uptake factors and root density data. Results of field studies contradict conclusions of some previous modeling studies. Such results illustrate the importance of considering actual site conditions (as opposed to idealized conditions) when conducting analyses and drawing general conclusions from the results.

What modeling studies have been performed related to the SDA soil cover?

A hydrologic simulation of Pad A was completed using CREAMS 1.8 and an assumed 500-year precipitation event characterized by (a) a maximum yearly precipitation of 25 in., (b) a maximum monthly precipitation for the month of May of 5 in., and (c) a maximum 24-hour precipitation of 3 in., (Crockett, 1983). This study concluded a typical stand of grass in 2 ft of uncompacted soil appears adequate to remove almost all water in the soil cap even under a 500-year precipitation event. However, the model did not consider conditions found at the SDA such as soil cracking, subsidence, and animal intrusion. Thus, the results only apply if the cover and vegetation are assumed to remain intact.

A study conducted in 1987 by Golder Associates evaluated the present SDA cover.[4] The study concluded that the cover was susceptible to subsidence, and was termed poor in terms of water infiltration and plant and animal intrusion. The infiltration rates vary from area to area, but it was concluded as much as 5 to 7 in. of water per decade has infiltrated the SDA

[4]Golder Associates, Master Evaluation of Cover Alternates and Surface Drainage Design at the Subsurface Disposal Area, 873-1163.002, 1987.

cover. Ten to thirty percent of the SDA cover readily allows for infiltration, in particular in areas near drainage ditches, depressions subject to ponding, and areas of shallow cover and a high sand content. The results of this study have been substantiated by field data.

Laundre' (1990a) documents a water balance modeling study using CREAMS and ERHYM-II (Wight, 1987). The results of the analysis were compared to field data from a test plot at the INEL Site. Initial predictions using tabulated data values from CREAMS did not match the field data. When the default input data were adjusted to account for actual field conditions, the predictions more closely represented the behavior of the actual system. This illustrates the importance of assuring that input data are based on site-specific conditions rather than a default set of parameters. Further calibration was conducted to obtain a better fit with the field data.

Predictions of performance of an intact, vegetated cover indicated that 2 ft of cover was insufficient, but 4 ft of cover material was sufficient to minimize deep percolation.

Laundre' (1990a) also addressed the impacts of animal burrows. Moisture contents were computed with CREAMS and ERHYM-II and compared to field measured values in a control plot and a plot with animal burrows. The models do not address burrows; thus, the comparison was made to indicate the difference between the standard model predictions and field data for a plot with burrows. Both models computed values that were less than the moisture contents measured in the two test plots. Furthermore, CREAMS predicted that there would be no deep percolation in the test plot, while ERHYM-II predicted that 1.1 in. of deep percolation would occur. Field data indicated 0.6 in. of deep percolation with no burrows and 0.9 in. with burrows. Thus, the ERHYM-II results appear to be conservative with respect to deep percolation, and CREAMS would not predict deep percolation even though it does occur.
What field and laboratory experiments have been conducted to investigate the hydraulic properties of the SDA soil cover?

A study was performed to describe the areal variations of the SDA soil cover's hydraulic characteristics (Borghese, 1988). The results of this study are inconclusive with regards to areal variations or trends of hydraulic characteristics. Vertical variations of hydraulic characteristics were minimal. The highest permeabilities were found in the first 2 to 6 in. of the soil cover, probably because of the interval being in the rooting zone of the cultivated grasses (Borghese, 1988). The K values for the saturated hydraulic conductivities ranged from a maximum of 2.8×10^{-5} ft/s to a minimum of 2.5×10^{-7} ft/s.

An analysis of instrument data from 1985 to October 1987 indicated wetter areas occurred where water collected at land surface during portions of the year (Laney et al., 1988). These areas included drainage and flood control ditches, small depressions where runoff or snowmelt accumulated, and areas flooded in the past. As the Golder report indicated, such areas need to be considered in modelling efforts, or the potential for infiltration can be underestimated.[5]

Vadose zone instrumentation indicates wetter areas exist along drainage and flood control ditches, small depressions where runoff or snowmelt accumulates, and areas flooded in the past (McElroy, 1990). Flux calculations show that fluxes in the wetter areas can be as much as three orders of magnitude larger than in dry areas. The average range of matric potentials for surficial soils is from saturation to -3.0 bars (McElroy and Hubbell, 1990). Neutron data indicated an active zone of moisture in the sediments extends to a depth of 6 to 7 ft below land surface (Laney et al., 1988).

Stable isotope and chemical data suggest that perched water under the SDA is due to lateral flow of water that has infiltrated from the diversion of Big Lost River flows to the spreading areas, with only minor contributions from atmospheric precipitation through the SDA cover (Rightmire and Lewis, 1987) (see Section 4.3).

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[5]IBID., Golder Associates.

A number of site-specific studies have been conducted related to the effect of plants on recharge. Studies have addressed transpiration, water uptake, and root distributions of plant species found at the INEL Site (Anderson et al., 1987; Toft et al., 1989; Reynolds 1990; Abbott 1989; Nowak et al., 1988). What are the implications for the conceptual model?

Studies to date have indicated that recharge has occurred and is occurring at the SDA. This may be attributed to flooding of pits or holes created by subsidence; water building up in ditches; unvegetated or gravel-covered areas (i.e., interim covers); and/or natural precipitation. Studies considering vegetated and intact cover materials have indicated that no (or possibly minimal) recharge would occur.

4.3 VADOSE ZONE

This section presents a conceptual model for the movement of water through the unsaturated zone (vadose zone) at the RWMC. The movement of water-soluble contaminants will be discussed in a qualitative manner.

The vadose zone is the area between land surface and the primary groundwater body, the Snake River Plain Aquifer. The vadose zone at the RWMC is approximately 590 ft thick. The vadose zone is an area where the water content of the geologic materials are less than its effective porosity, and the water is held by capillary forces under tension. This area is also commonly called the unsaturated zone because the pores are only partially filled with water. The vadose zone may have localized areas where saturation occurs. These zones are called perched water zones.

The water pathways through surficial sediments, basalt, and interbeds; effect of flooding; perched water; and contaminant movement will be discussed in the following section.

How does water move through surficial sediments at the SDA?

Figure 4-9 depicts processes by which water moves in the unsaturated zone from land surface to below the 240-ft sedimentary interbed. This portion of the model deals with movement of water through undisturbed sediments in the SDA and through the area filled with waste products in pits and trenches. Forty percent of the SDA was excavated to bury waste, and 60% of the SDA is undisturbed (Hubbell and Higgs, 1989).

Water infiltrates into surficial sediments from several sources of water such as direct precipitation, runoff from snowmelt, and flooding events. Runoff of snowmelt and localized surface ponding of water in the spring have the greatest opportunity to recharge sediments because of the large volume of water available and the low potential for evapotranspiration.

Generally, monitoring of soil moisture in the surficial sediments between pits and trenches indicates moisture increases closer to the basalt underlying the surficial sediments (McElroy and Hubbell, 1990). The first 6.5 to 8 ft of sediment below land surface is strongly affected by precipitation and evapotranspiration. Fluctuations in moisture content because of evapotranspiration are less pronounced at greater depths with nearly steady state conditions below 10 ft. Water movement is primarily downward below this depth. This suggests if water moves to approximately 8 ft below land surface, the water will continue to move downward with a rate of flow controlled by the unsaturated hydraulic conductivities and the hydraulic gradient of the geologic media.

A generalized soil moisture characteristic curve for surficial sediment is presented in Figure 4-10. This curve is from sediment that comprises approximately 80% of the surficial sediments in the SDA (Hubbell et. al, 1986). This fine grained sediment is characterized by a relatively high moisture content at saturation, which declines to residual moisture content with increasing tension (Figure 4-10). Unsaturated hydraulic conductivity of sediments show a decrease in hydraulic conductivity as moisture content decreases (Figure 4-11). The decrease in conductivity is due to decreases in

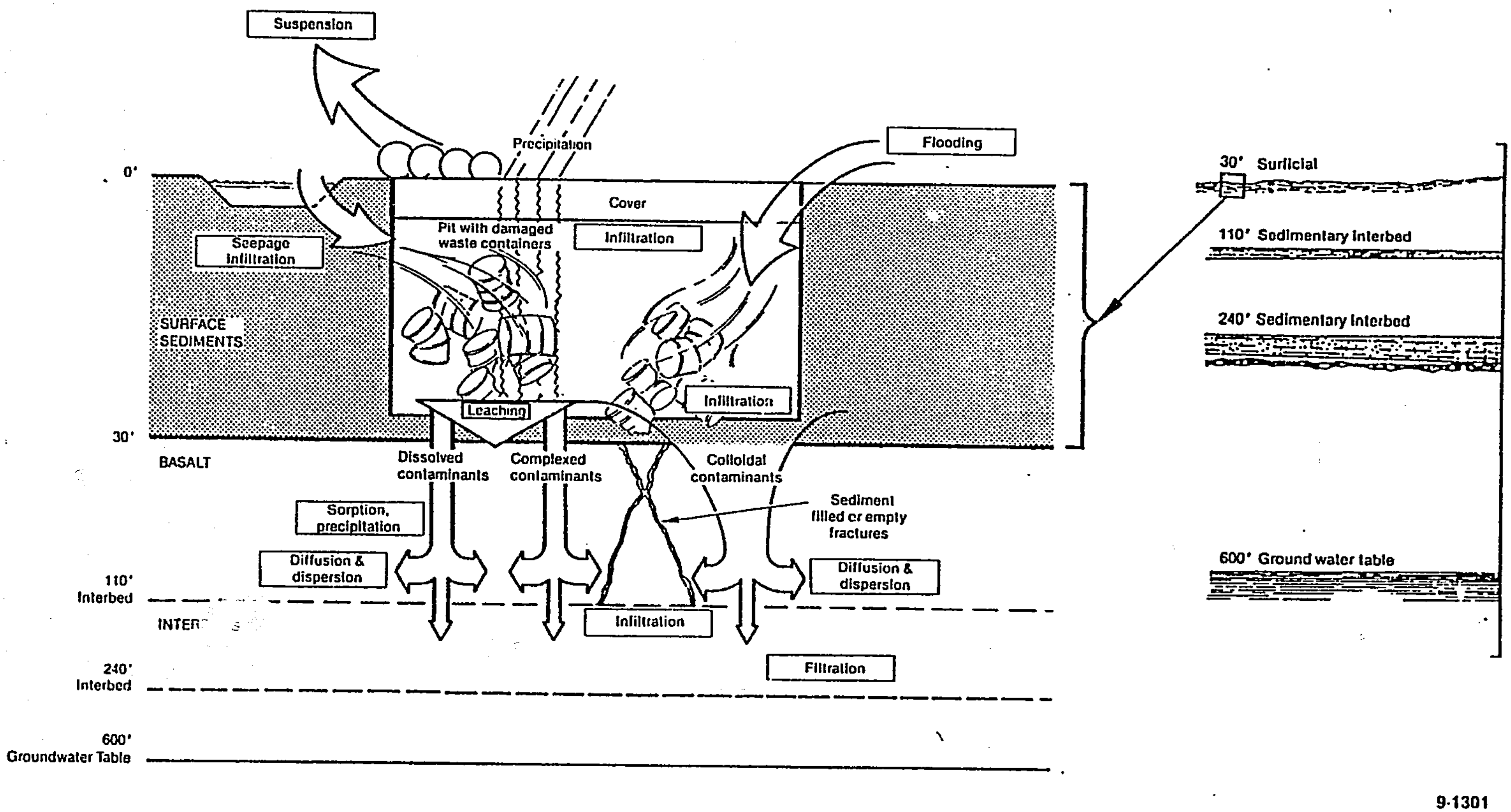

Figure 4-9. Schematic of water movement in the vadose zone, SDA.

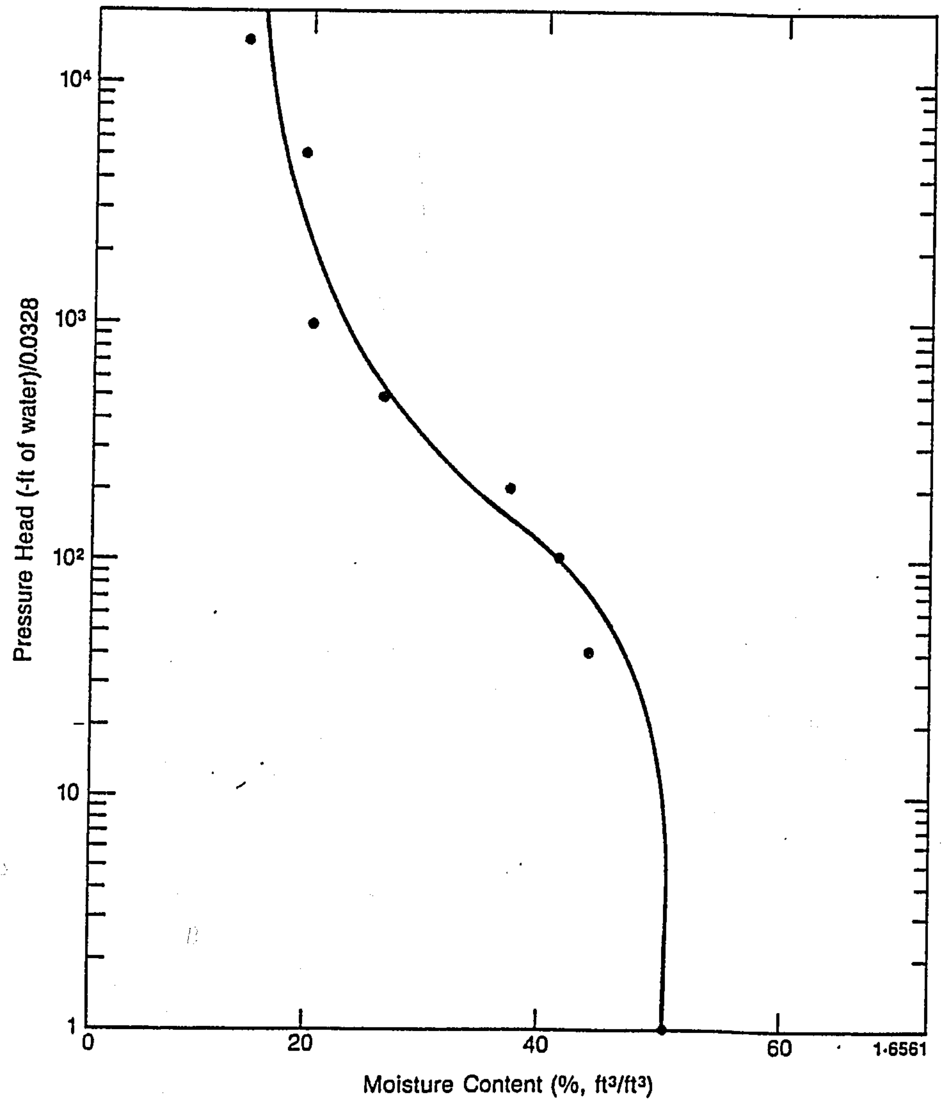

Figure 4-10. Soil Moisture characteristic curve for sediment at the SDA (McElroy and Hubbell, 1990).

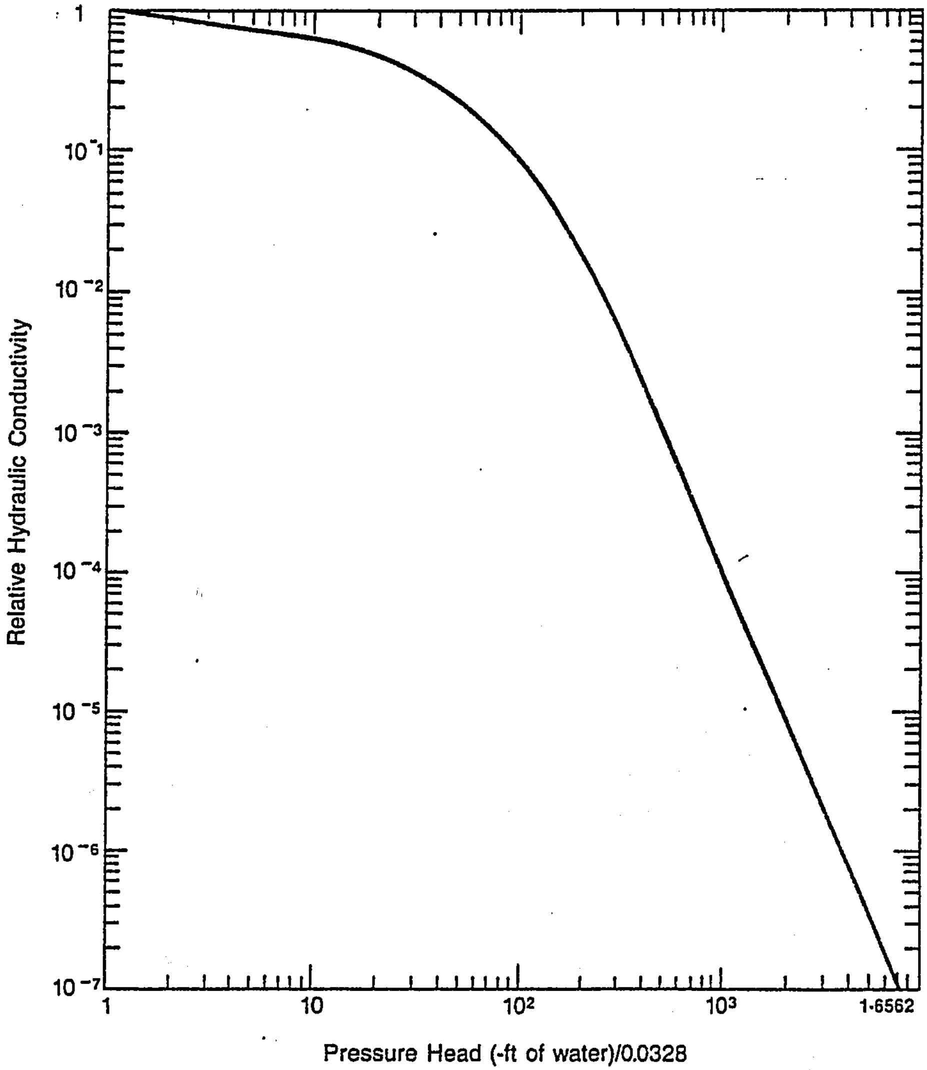

Figure 4-11. Relative unsaturated hydraulic conductivity for sediment in the SDA (McElroy and Hubbell, 1990).

the wetted cross sectional area available for flow. Decreasing water content several percent, by increasing tension, may lower unsaturated hydraulic conductivity by orders of magnitude within the media. Thus, the sediments can transmit water most rapidly when the sediments are wetter. Water flux through backfilled trenches and pits is significantly different than flux through natural undisturbed surficial sedimentary layers. Areas around pits and trenches have frequently undergone subsidence because of soil compaction and infilling of voids within the waste. Sediment has also been brought into the SDA to recontour the surface and to inhibit the formation of subsidence features. Previously, snowmelt water could flow into these subsidence features and directly into the waste. This water would move under the influence of gravity to the sediment/basalt interface. The volume of percolating water in contact with buried waste is unknown, but it is more important for contaminant transport than water movement through unexcavated sediments. The net downward flux through surficial sediments/waste within the SDA is highly nonuniform and is concentrated within surficial depressions and in high-permeability areas. The infiltration rate within the SDA is higher than in the surrounding area because of the disturbed nature of the sediments. Recent studies by the USGS (Magnuson et al., 1990) of chlorine-36 indicates a net downward velocity of only 4 in./yr for the past 30 years within sediments outside of the SDA. Standing water at land surface has been measured to move 6.9 ft in less than 24 hours (Kaminsky, 1990).

<u>How does moisture move from surficial sediments into the underlying basalt?</u>

Water moves from surficial sediments into basalt by several flow processes depending on the flux rate and hydrologic properties of the sediment and basalt (Figure 4-12). Water may flow from sediments into and through intergranular pore space in the basalt matrix (arrow 1). Flow may occur through the basalt in closed fractures and joints with capillary permeability (arrow 2). Flow may move through sediment-filled fractures (arrow 6), open fractures, or a combination of all of these effects.

Lateral water movement may occur in the sediment along the sediment/basalt interface, where two different materials meet, because of

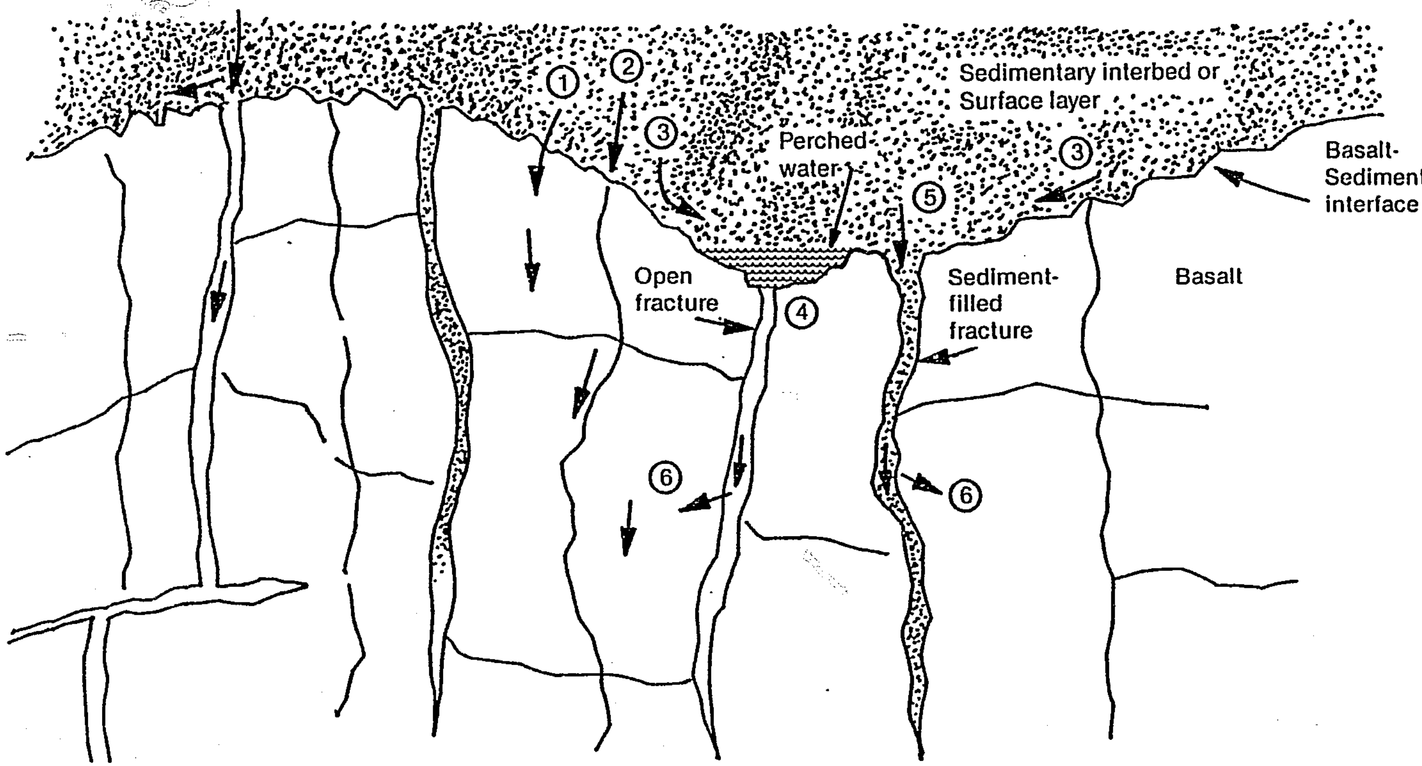

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Figure 4-12. Schematic of moisture movement across or along a basalt-sediment interface (DOE, 1988).

contrast in hydraulic properties (arrow 3). Water will flow from the sedimentary materials into sediment-filled cracks under unsaturated flow conditions (arrow 5). Water will not flow into or through open fractures in basalt unless perched or near-saturation conditions occur in overlying sediments (arrow 4). Water will move out of fractures into the basalt matrix as controlled by the differences in permeability between the fracture and the matrix (arrow 6). In general, the permeability of the basalt matrix (unfractured basalt) is lower than the permeability of the sediments. A small portion of water in sediments moves into the basalt matrix and sediment infilled fractures by unsaturated flow. If inflow of water through sediments exceeds the capacity of the underlying basalt to transmit water, the water contents (and matric potential) will increase to saturated conditions causing perched water above basalt. This water can move into open fractures within basalt by saturated flow processes. Perched water (approximately 0.2 ft) has been detected in sediments at the basalt/sediment interface inside the SDA. When saturated flow occurs, the majority of the water follows paths determined by joint networks. A smaller portion of the water moving through the open fractures will move into the basalt matrix and sediment filled fractures by capillary tension.

<u>How does water move through basalt layers?</u>

Water moves within fully or partially sediment filled fractures, joints, and vesicles and within the basalt matrix. The basalt matrix has a large surface area in contact with the sediment but has a low transport rate (low hydraulic conductivity). Fractures, joints, and vesicles have a much smaller contact area with the surficial sediment. Water moving under unsaturated flow will preferentially move through small openings in sediment or basalt, avoiding large openings. When sediment above the basalt becomes saturated, water moves faster through the basalt matrix (higher hydraulic conductivity) and begins to move into open spaces. Figure 4-13 presents a curve defining unsaturated hydraulic conductivity versus tension for basalt. This curve has been generated using the same assumptions used to derive curves for sediment (Maulem, 1976; van Genuchten, 1980). The curve indicates hydraulic conductivity decreases five orders of magnitude from saturated values (zero

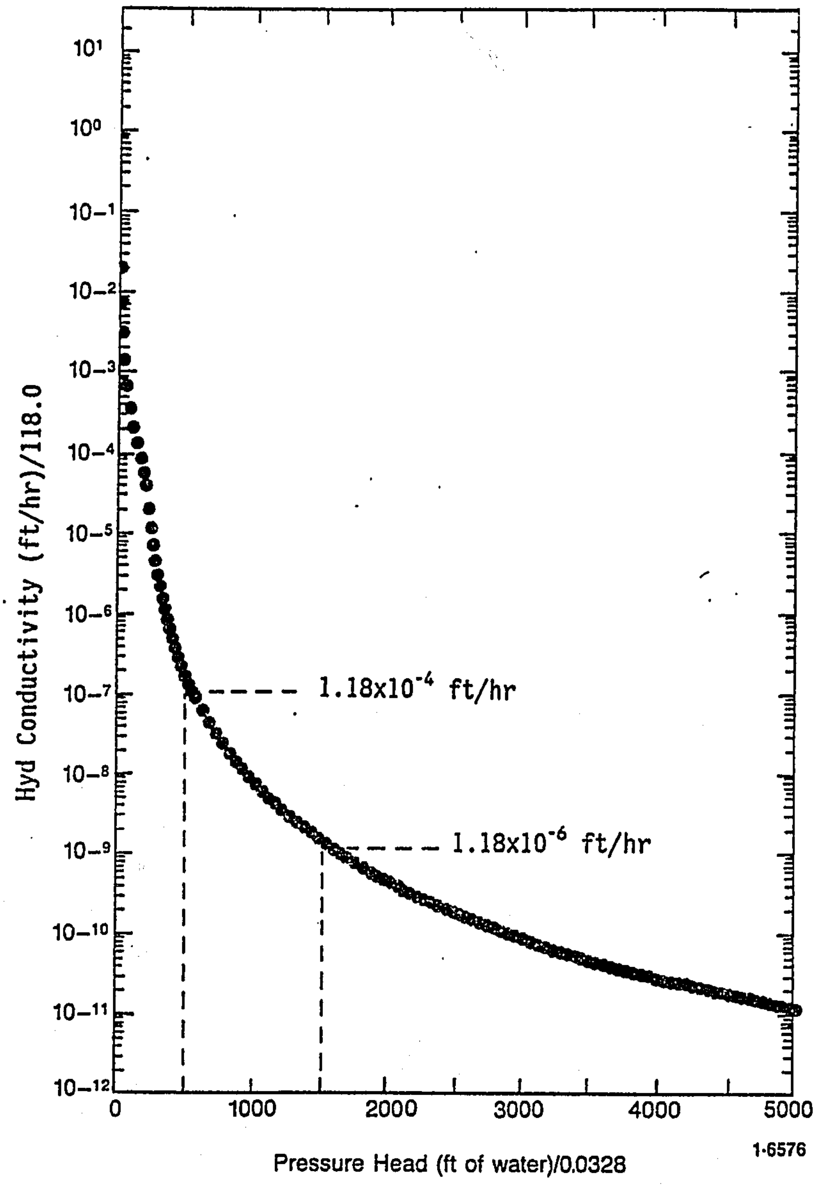

Figure 4-13. Unsaturated hydraulic conductivity of basalt from SDA (Bishop, 1990).

tension) to 1/2 bar tension (17 ft water). The greatest transport rates occur where saturated conditions form at the sediment basalt interface. Perched water can be formed at the sediment basalt interface that can move in open or sediment-filled joints. Because the basalt matrix has relatively low permeabilities, most water will be channeled into smaller flow paths, concentrating water into preferential paths. Perched water may form within basalt, where water flow is impeded by differences in hydraulic conductivity and/or where water inflow exceeds outflow. Perched water builds up in basalt or sediment until it develops sufficient pressure head to move through or around the perching layer.

When water reaches a sedimentary interbed, it wets sediments and may spread laterally. Lateral flow of percolating water may occur at the sediment-basalt interfaces because of contrasts in hydraulic properties. Water moving as saturated flow in a fracture or joint may cause localized perched zones on top of the interbed sediments if these sediments have a clay texture. If interbed sediments are course grained (i.e., sand), they may move through interbeds by finger flow and may perch in the interbed sediments on top of the underlying basalt or move into permeable basalt beneath.

Water movement below the first interbed occurs as described for the alternating basalt and sedimentary interbeds. Fluctuations in rate of water flow in the unsaturated zone decrease with distance from the recharge source at land surface. At some depth, the rate of flow approaches a constant rate. The interbeds act as reservoirs of water relative to the basalt and should dampen flow rate changes over time. Basalt above the water table has at most 2 to 3% moisture content in the pores, while the sediments have 15 to 30% moisture; therefore, the basalt has less of a dampening effect unless perched water zones have formed in them. The nature of water movement through the unsaturated sequence of fractured basalt and sedimentary interbeds are largely controlled by the hydraulic characteristic of the basalt and sedimentary geologic material and by the timing of seasonal pulses of water.

What effect would seasonal fluctuations in infiltration have on movement of water in the vadose zone?

Water moves into the surficial sediments at the RWMC through a combination of processes. Water is primarily available from surface runoff, precipitation such as flooding or rainfall events, snowmelt, and leakage from water conveyance systems such as the drainage ditches at the SDA. Water from one of these sources has the potential to infiltrate into the ground and recharge the surficial sediments.

The majority of water is available for infiltration in the spring from snowmelt. This results in pulses of water moving through the subsurface. Increased moisture contents were documented in the vadose zone monitoring instruments in the spring (Laney et al., 1988; McElroy, 1990). Observations from several wells in the SDA indicated an influx of up to 6 in. of water in one infiltration event in the spring of 1986. Water was detected in one of the perched water wells at 82 ft depth in the summer of 1989, which indicated a pulse of water had contacted this well. Water level measurements in another perched water well sampling at a depth of 230 ft indicated a seasonal trend in recharge to the well, suggesting pulses of water moving to this depth.

Pulses of water infiltration may allow contaminant transport to occur when the pulse of water moves through. This water then moves rapidly until it is sorbed into pores by capillary forces. The contaminant and water then are largely immobile until the next pulse wets the materials and moves the water and dissolved constituents. The pulses of infiltration become dampened with increasing depth. The materials with a high potential to retain moisture, such as fine-grained sediment and perched water zones, have a larger effect on dampening pulses of water. The water retained in the pores will have a long time to solubilize soluble constituents in the geologic material where it is held. Conversely, contaminants in the water may sorb onto materials in the basalt or sediments, lowering the concentration in the fluid and depositing contaminants in the geologic material.

What predictions of moisture movement have been made with regard to past flooding at the SDA?

The predominant working hypothesis for the mechanisms by which radionuclides have migrated in the subsurface is based on historic flooding of the SDA, which occurred in 1962, 1969, and 1982. During the floods, saturated or nearly-saturated flow occurred in the subsurface immediately beneath a flooded trench.

A modeling study documented in Walton et al. (1989) considered flooding in a hypothetical trench at the RWMC. In the simulation, 3.28 ft of water was ponded in the trench to represent the flooding. The study was two-dimensional and included both layered basalts and interbeds in the subsurface geometry. The hydraulic properties for both the basalts and sediments were based on the best data available at the time. The effect of fractures was included through the use of moisture-release curves derived in Wang and Narasimhan (1985).

The results presented in Walton et al. (1989) for the flooding events were strictly in terms of tracer concentrations. However, because a unit concentration was assumed in the flooded pits and the tracer was conservative, the tracer results mimic the wetting front and moisture movement can be inferred. The simulation results are shown in Figures 4-14 and 4-15. As can be seen from the figures, once the moisture front passes the surficial sediment-basalt interface, the front moves rapidly down through the representative basalt without significant spreading. The flooding simulation ended after 25 days, before perching could develop on top of the 110-ft interbed.

The Walton study of the effect of flooding on moisture movement in the subsurface shows the dramatic influence of ponded water at the surface. Saturated or nearly-saturated flow allows the fractures to carry water and results in fast travel times. High velocities of water may allow particulates to be suspended and transported.

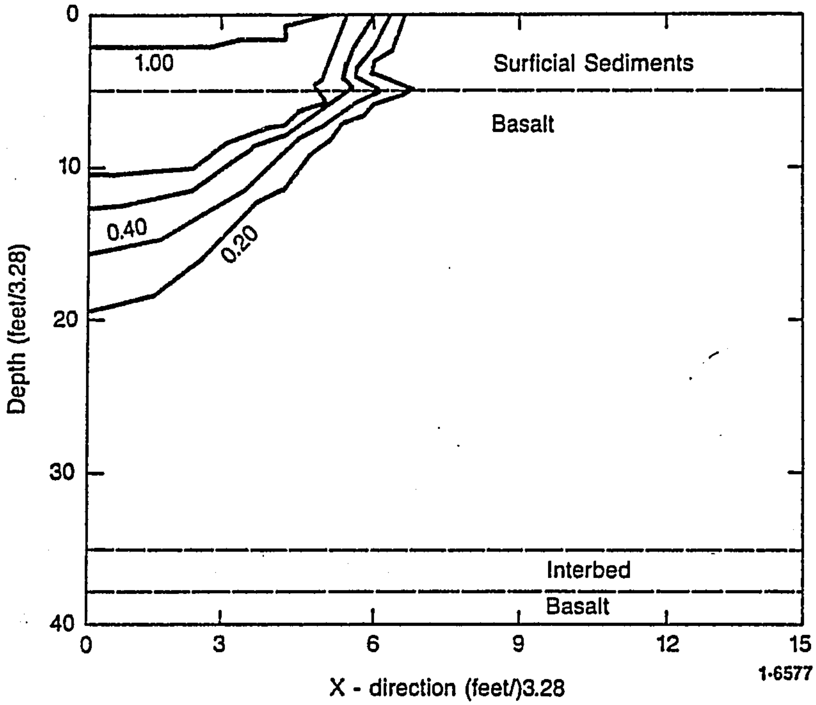

Figure 4-14. Conservative tracer migration after 10 days in response to flooding.

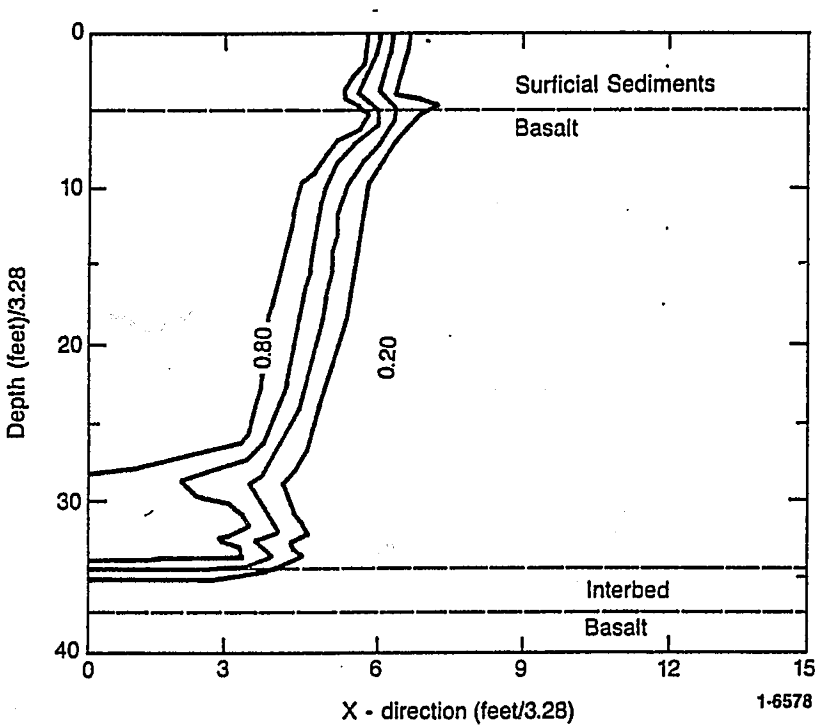

Figure 4-15. Conservative tracer migration after 25 days in response to flooding.

Does water preferentially move through the basalt matrix or through the network of interconnecting fractures?

Numerous studies have been performed on moisture movement of sediments, but little research has been done on the movement of moisture within unsaturated basalt. Discussions on water movement in basalt assumes the basalt acts similar to a sediment with the same pore size distribution. Under unsaturated conditions, water will preferentially move through small pore spaces within the basalt (the same as in sediment) rather than through large open fractures. The unsaturated hydraulic conductivity of basalt is generally lower than that of sediment at the same matric potential. This may allow formation of perched water within the sediment if water is being transmitted through the sediment at a higher rate than the basalt can transmit the water. The basalt then acts as a perching layer with the perched water in the sediment. The formation of perched water increases the matric potential and allows water to move into the network of inner-connecting fractures and joints within basalt.

Figure 4-11 presents the relative unsaturated hydraulic conductivity versus pressure head for a soil sample taken in the surficial sediments. The hydraulic conductivity shows a decrease as the matric potential increases. Assuming tension in the soil immediately above the basalt is at 1/2 bar tension, then the sediment has hydraulic conductivity equal to approximately 2×10^{-9} ft/s. Figure 4-12 presents unsaturated hydraulic conductivity versus tension for a basalt sample located below surficial sediments. This figure indicates the hydraulic conductivity at 1/2 bar tension (17 ft water) for this basalt would be 9×10^{-12} ft/s, two orders of magnitude lower than in the surficial sediment sample.

These data are based on a limited number of analyses. Table 4-1 presents the number of unsaturated hydraulic conductivity curves determined for cover material, surficial sediment, basalt, and interbeds along with the sources of data. These data suggest hydraulic conductivity is several orders of magnitude lower within the basalt matrix than within the surficial sediments

Table 4-1. Number of unsaturated hydraulic conductivity determinations for geologic materials at the SDA

Unsaturated Hydraulic Conductivity Measurements for	Reference	Number of Data Points
Cover materials	Borghese (1988)	4
Surficial sediments	DBS & Assoc. Inc. (1989)[6]	4
Interbeds	DBS & Assoc. Inc. (1989)[7]	16
Basalt (matrix only)	Bishop (1990)	30

based on the assumption that the matric potential is equal at the interface of the two materials.

Within the 110-ft and 240-ft interbeds, the matric potential has been measured at 1 1/2 bar tension. The unsaturated hydraulic conductivity curve in Figure 4-13 indicates the relative hydraulic conductivity is approximately 7×10^{-14} ft/s at this tension, which is for all practical purposes immobile. Figure 4-16 presents unsaturated hydraulic conductivity versus matric potential from sediment within the 240-ft interbed. The hydraulic conductivity of this sample is approximately 2×10^{-9} ft/s, three orders of magnitude higher than the basalt.

The low hydraulic conductivities of basalt at the field matric potentials (1/2 and 1 1/2 bar tension) suggest water primarily moves through fractures and joints instead of the matrix. Converting these unsaturated hydraulic conductivities into units of ft/yr and assuming an unit hydraulic gradient

[6] DBS & Assoc. (Daniel B. Stevens and Assoc. Inc.), 1989, Laboratory Analysis of Soil Hydraulic Properties from EG&G BEP-RWMC Project, Albuquerque, N.M.

[7] DBS & Assoc. (Daniel B. Stevens and Assoc. Inc.), 1989, Laboratory Analysis of Soil Hydraulic Properties of EG&G BEP-RWMC Project, Albuquerque, N.M.

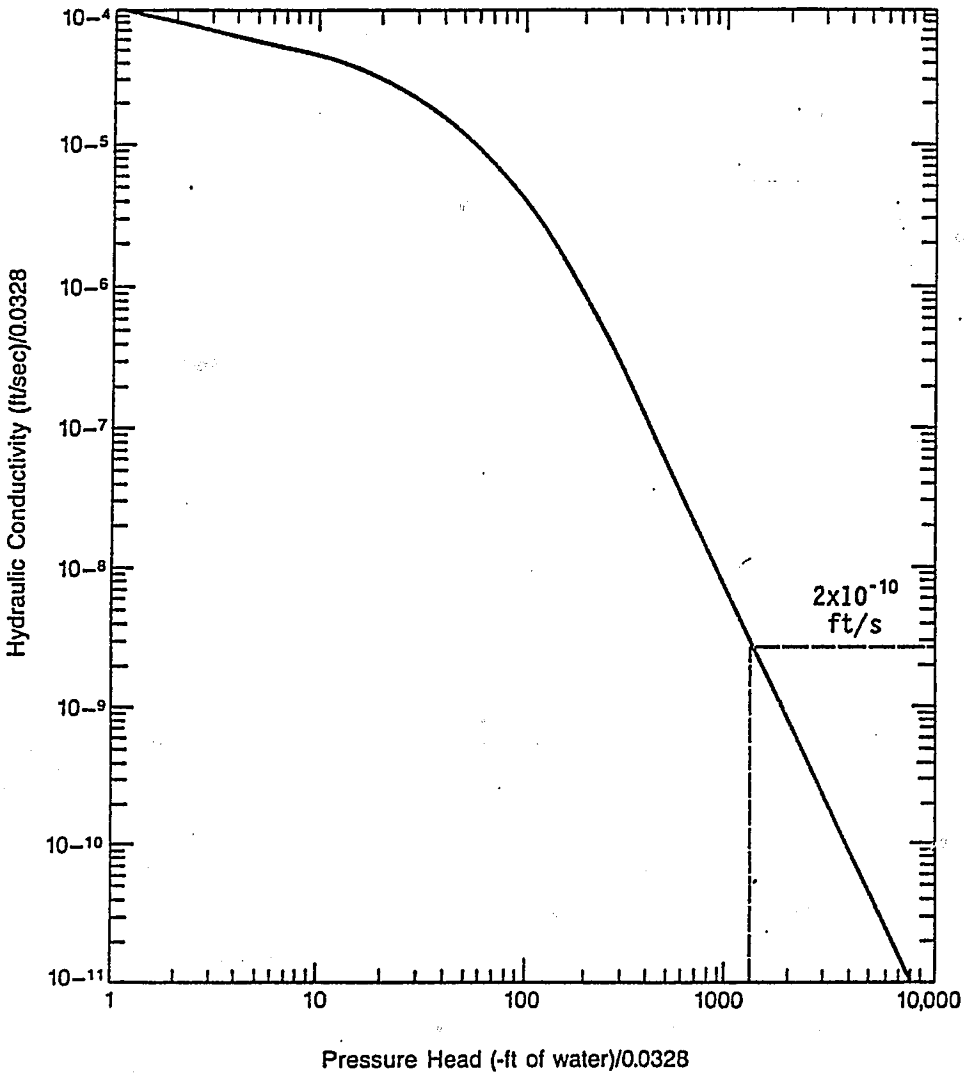

Figure 4-16. Unsaturated hydraulic conductivity of sediment from 240 ft. interbed (McElroy and Hubbell, 1990).

indicates a Darcian flux within the basalt between 0.0027 and 2.7 x 10^{-6} ft/yr. Assuming a moisture content of 1% using the Darcian flux of 0.0027 ft/yr yields a total movement of 0.79 in. since 1963. Thus, water movement in the basalt matrix occurs very slowly. Measured responses in water level in aquifer wells indicates much faster movement; therefore, the water must be moving primarily through fractures and joints.

<u>Is perched water present at the RWMC?</u>

Perched groundwater has been located in 6 of 45 wells drilled at the RWMC. Perched water has been found primarily above the sedimentary interbeds at approximate depths of 110 and 240 ft. Limited data suggest that perched water above the 110-ft interbed is discontinuous beneath the RWMC and obtains water in part from precipitation (Hubbell, 1990).

Water level data from the perched water zone at a depth of 240 ft suggest water is obtained from a combination of seasonal precipitation, flooding events, and lateral water movement from spreading areas west to south of the SDA. If this theory is correct, water moving through the unsaturated zone (and soluble contaminants) may be transported laterally significant distances before moving through the interbed. The volume of water moving from the spreading areas dilutes the contaminants in the water moving vertically from the burial grounds. This also increases the hydraulic gradients and unsaturated hydraulic conductivity of the geologic media, decreasing the transport time to the aquifer.

Data suggest perched water zones coming from the spreading areas cover only portions of the area beneath the RWMC. Perched water has only been detected in 4 of 30 wells that penetrated the interbed.

<u>How would the presence of perched water beneath the RWMC affect contaminant transport rates?</u>

Transport rates through unsaturated or semisaturated materials are dependent on the moisture content within geologic materials. Figure 4-16 presents a characteristic curve of moisture content versus hydraulic conductivity for a sediment at the RWMC. As the moisture content approaches saturation, the unsaturated hydraulic conductivity changes five orders of magnitude until it reaches the saturated hydraulic conductivity. The large increase in hydraulic conductivity (orders of magnitude) with minor increases in moisture content indicates flux rates will increase by orders of magnitude with small increases in water content.

The presence of perched water may also allow preferential flow paths to form. The saturated conditions may allow water to move through fractures and voids at rapid rates. This water would move through a smaller percentage of the total pore spaces than if moving through the matrix. Because flux rate is a function of pore volume, the moisture moves through this proportionally smaller area at a greater flux rate than if it were moving through an area with a greater pore volume.

As theorized in Hubbell (1990) perched water moving laterally, suggests contaminants could be moved laterally from the source area until it reaches a conduit that allows it to move downward past the perching layer. This may result in contaminants being moved away from the initial source area.

<u>What are the estimated water travel times through the vadose zone?</u>

The water travel time through the vadose zone is of critical interest because of its implications for contaminant transport. The primary factors that influence the travel time are the flux of water infiltrating at the surface, the hydraulic conductivities of the basalts and interbeds, and the characteristic curves that describe the relationship between matric potential and conductivity. When considering vadoze zone travel times, other mitigating factors must be taken into account. Foremost of these factors is what flow regime is being considered: saturated, nearly-saturated, or partially-saturated.

The flow regime is determined by the infiltration rate at the surface. A flooding event that causes sustained ponding of water on the surface results in a nearly-saturated or wet flow regime. Complete saturation of the vadose zone never occurs. Even under sustained ponding, entrapped air in both the fractured basalt and the interbeds reduces the conductivity. Flow under these circumstances is most likely to occur predominantly in the fractures. The water cascades down the fractures while the basalt matrix stays relatively dry.

On the other extreme, slow infiltration because of annual precipitation results in a partially-saturated flow regime. Somewhere between these two extremes is the effect of springtime snowmelt coupled with rainfall, which results in pulses of water infiltrating through the surficial sediments within the SDA (McElroy, 1990). These pulses persist at least down to the 240-ft interbed and may affect the flow regime all the way to the water table.

Nearly-saturated flow regimes provide an upper bound on travel times through the vadose zone. Hydraulic conductivities vary with saturation because of changes in the wetted cross-sectional area through which water can flow. As saturation and matric potential increase, hydraulic conductivity also increases. The higher conductivity results in faster travel times. An extreme upper value for travel time for the entire vadose zone can be inferred from Barraclough et al. (1966, p. 26), which reports a water velocity of approximately 100 ft/d from the surface to a perched water well near TRA through a basalt formation as a response to the presence of water in the Big Lost River Channel. This travel estimate would be for a case with ponding at the surface and no sedimentary interbeds to interrupt the downward movement of water. Robertson (1974) estimates travel times from the TRA waste ponds to the aquifer of 6 to 12 months. This estimate includes the influence of several interbeds.

A more realistic estimate of travel times under nearly-saturated conditions, which includes the mitigating influence of the sedimentary interbeds, can be made by comparing hydrograph records for nearby aquifer wells, records of flow in the Big Lost River, and discharge records to the spreading areas (0.5 mi from the RWMC monitoring wells). Hydrographs for aquifer Wells 88 and 89, which are located just west and southwest of the

RWMC, have been reported in Barraclough et al. (1976, p. 53) and Wood (1989, p. 23). Records of discharge to the spreading areas are given in Wood (1989, p. 31-33) and records of discharges in the Big Lost River are given in Barraclough et al. (1981, p. 15). A comparison of discharge peaks to the related rises and peaks in groundwater levels yields estimates of nearly-saturated travel times from the surface to the water table. The period from 1971-1974 yields a rough travel time estimate of 8 months to 1 year.[8] The period from 1980-1984 yields a faster estimate of 10 to 13 weeks (see Figure 4-17). The faster travel time results partly because the spreading areas are closer than the Big Lost River to the observation wells. Because the water has less horizontal distance to traverse, the water travel times are faster.

Partially-saturated flow regimes result in longer travel times. The primary reason is that open fractures in the basalt no longer act as conduits for water but rather act as barriers. At lower matric potentials, or dryer conditions, the fractures are not able to hold water and dry out. Once this occurs, water moving downwards under steady-state infiltration is forced to flow around the open fractures.

A stochastic Monte Carlo study of one-dimensional (vertical) flow and resulting travel times (Nguyen et al., 1991) was conducted as part of an ongoing risk assessment for the TRU waste buried in the SDA.[9] A key assumption used in this study was that the water moved strictly within the basalt matrix.

The Monte Carlo method was used to determine uncertainty in the saturated hydraulic conductivity of the basalts and sediments into the uncertainty in the travel time. Basalt characterization results (Knutson et al., 1990) were

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[8]Barraclaugh, J. B.; Personal Communication, October, 1990.

[9]H. D. Nguyen, S. O. Magnuson, R. G. Baca, 1991, Monte Carlo Simulation of Water and Radionuclide Transport in Variably Saturated Layered Formations, EG&G Idaho, Inc.

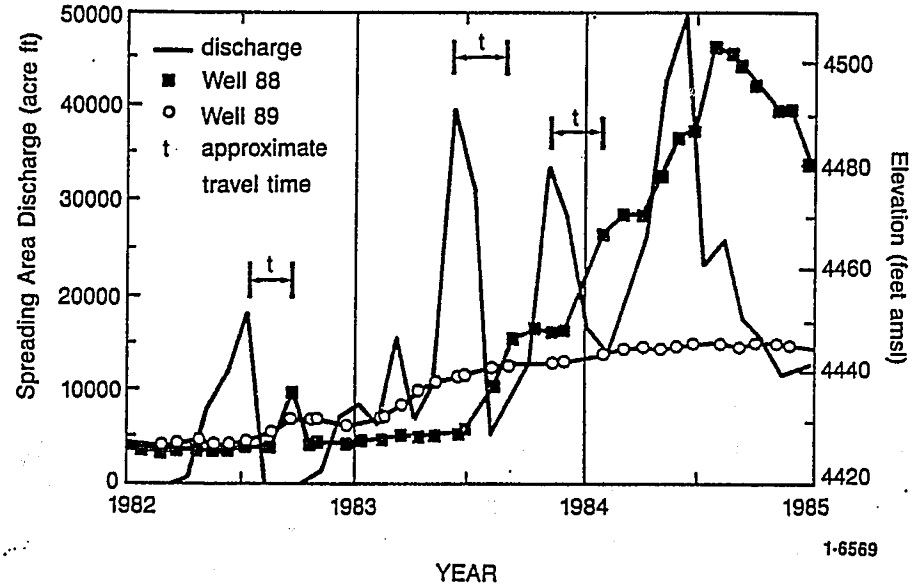

Figure 4-17. Comparison of spreading area discharge and RWMC well hydrographs.

used to estimate probability distribution functions for the hydraulic conductivity of the basalts. Similarly, probability distribution functions were estimated for the surficial sediments and interbeds using existing data (McElroy and Hubbell, 1990). The Monte Carlo method resulted in a range of possible travel times. The mean travel time was 560 years with a standard deviation of 80 years (see Figure 4-18). This standard deviation reflects uncertainty due only to variability in saturated hydraulic conductivity in the basalts and interbeds. All other parameters or hydraulic properties were considered constant and a steady-state net infiltration rate of 2 in./yr was assumed. To more closely model the infiltration rates, a stochastic input should be used to simulate actual pulses of surface water infiltration.

A preliminary deterministic simulation of flow within the vadose zone has also been conducted and is reported in the Draft Radioactive Waste Management Complex Performance Assessment (Case et al., 1990). In contrast with the stochastic modeling, deterministic modeling treats all inputs as known and constant. The assumptions used for the deterministic vadose model consisted of a multilayered system with a net steady-state infiltration of 0.50 in./yr at the surface. The hydraulic properties of the basalts and interbeds were based on the best estimates available at the time (Laney et al., 1988; Borghese, 1988; TerraTek, 1988).[10] The vadose travel time was estimated to be 950 years.

There are a wide range of values estimated for water travel time through the vadose zone. Estimates range from several months to 950 years. The estimated travel time depends on assumptions made for the infiltration rate at the surface and on the data available for hydraulic conductivity. With what is currently known about the hydrogeology of the RWMC, a more correct answer for the vadose zone travel time resulting from partially saturated flow under steady-state infiltration is from tens to hundreds of years. However,

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[10]A. I. Johnson, 1960, Laboratory Report on the Hydrologic and Physical Properties, Snake River Basin, Idaho, Hydrologic Laboratory U.S. Geological Survery, Denver, Colorado.

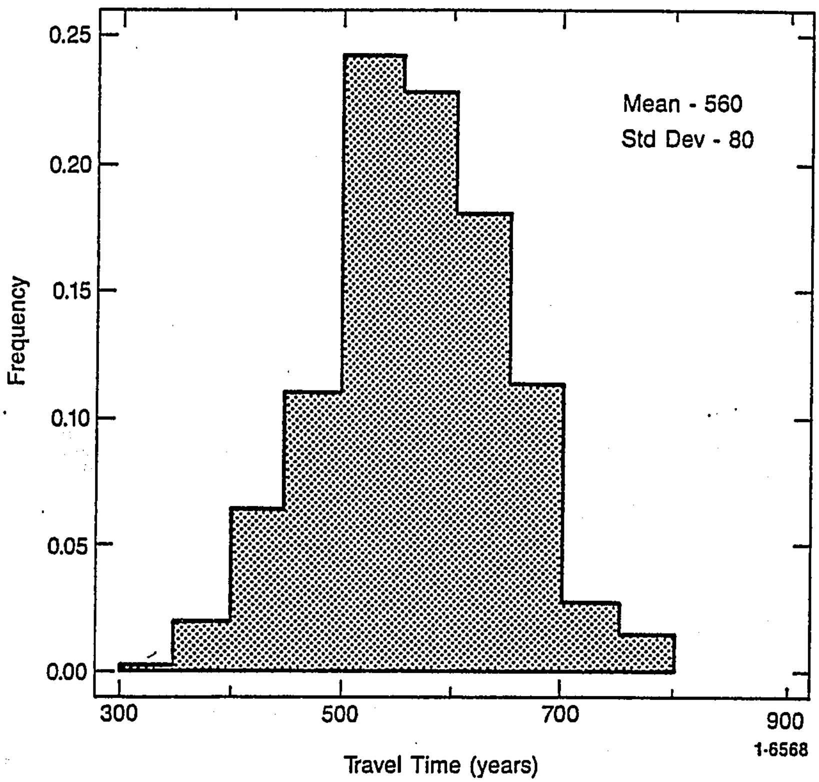

Figure 4-18. Vadose zone travel time histogram.

flooding events (nearly saturated flow) may raise the transport time to the range of several months.

How much water is present in the unsaturated zone at the SDA?

The volume of water contained in the unsaturated zone below the SDA is estimated to be 2.64 x 10^8 gal in the surficial sediment and sedimentary interbeds and 1.6 x 10^5 gal in the basalt. These calculations assume no perched water, using the average moisture contents of 20 and 2% in the sediment and basalt, respectively. The thickness of the surficial sediments and interbeds is calculated to be approximately 49 ft using data from Anderson and Lewis (1989), leaving 534 ft of basalt in the unsaturated zone.

4.4 GROUNDWATER

One pathway for migration of contaminants from the SDA to downgradient receptors is transportation by groundwater in the Snake River Plain Aquifer. The migration of contaminants in the aquifer can occur after contaminants migrate under partially-saturated conditions or in a vapor phase from buried waste downward through the basalt-sediment sequences to the aquifer. An understanding of flow in the aquifer is important because the direction and velocity of groundwater determines how fast and in what direction contaminants are transported.

What is the regional groundwater hydrology of the SDA?

The INEL is located on the eastern edge of the Snake River Plain, which overlies the largest potable aquifer in Idaho. The Snake River Plain Aquifer is defined as the continuous body of groundwater underlying nearly all of the eastern Snake River Plain. Lithologically, the aquifer is composed of a series of thin basalt flows, each generally 10 to 75 ft thick, with interbedded layers of fluvial, lacustrine, windblown, and pyroclastic sediments. Its lateral boundaries are formed at the contacts of the aquifer with less permeable rocks at the margins of the plain (Mundorff et al., 1964)

The aquifer is approximately 200 mi long and 30 to 60 mi wide and covers an area of about 9,600 $mi.^2$ A map showing the general location of the Snake River Plain Aquifer and the general direction of groundwater flow is shown in Figure 4-19.

Most of the aquifer permeability occurs along the upper and lower contacts of successive basaltic flows, which have large and irregular fractures, fissures, and other voids. This leads to a large degree of heterogeneneity and anisotropy in the hydraulic properties of the aquifer (Robertson, et al., 1974). The variety and degree of interconnected water-bearing zones complicates the direction of groundwater movement locally throughout the aquifer (Barraclough et al., 1981). The permeability of the aquifer varies considerably over short distances, but generally, a series of flows will include several excellent water-bearing zones. If the sequence of lava flows beneath the Eastern Snake River Plain is considered to constitute a single aquifer, it is one of the world's most productive (Mundorff et al., 1964).

The depth to the water table from land surface ranges from about 200 ft in the northeast corner of the INEL to approximately 1000 ft in the southeast corner. The average regional slope of the aquifer is 4 ft/mi from the northeast to the southwest with local variations. The thickness of the aquifer is difficult to estimate. Drilling information from the 10,365 ft deep geothermal test well INEL-1, drilled about 10 mi northeast of the RWMC, indicates that at least 2000 ft of basalt underlie the INEL (Prestwich and Bowman, 1980). However, not all of this thickness is part of the active flow system. Mann (1986) interpreted hydrologic data from the INEL-1 well and indicated that the aquifer is between 440 and 820 ft thick at that location. An earlier study, Robertson et al. (1974), indicated that the average thickness of the active portion of the aquifer is approximately 250 ft. The thickness of the aquifer will vary with different areas, and a distinct boundary between the different areas is not well defined.

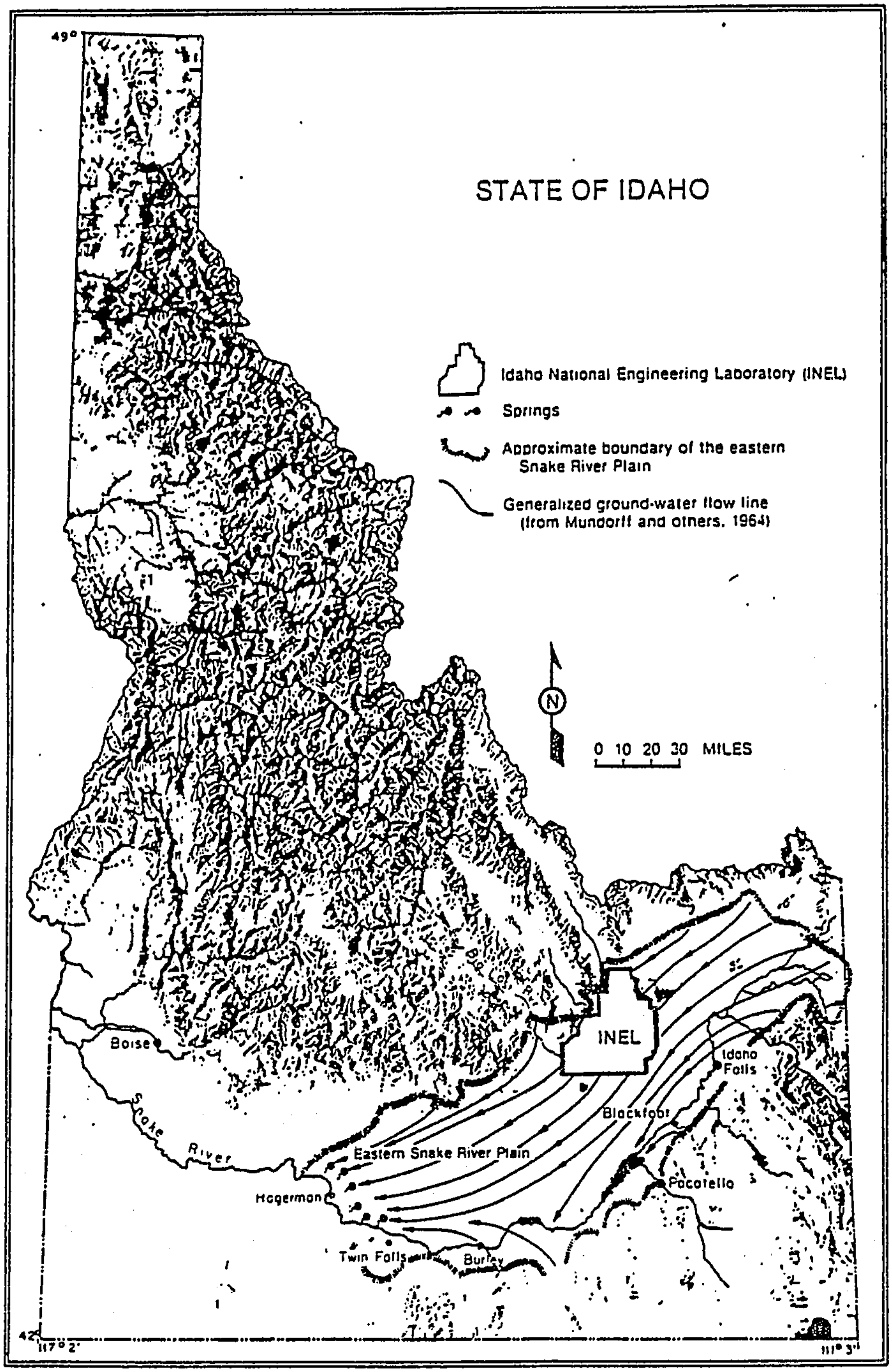

Figure 4-19. Relief map of Idaho showing the location of the INEL, Snake River Plain and generalized ground-water flow lines of the Snake River Plain Aquifer (adapted from Pittman et al., 1988).

What is the direction of groundwater flow in the Snake River Plain Aquifer?

Figure 4-20 shows the altitude of the water table at the INEL Site and the direction of groundwater flow in the Snake River Plain Aquifer beneath the INEL Site. Groundwater flow is primarily to the south-southwest. The groundwater flow velocity ranges from 5 ft/d to 25 ft/d; however, most of the flow ranges from 5 ft/d to 10 ft/d (Wood, 1989).

Water table maps represent conditions of the groundwater system at the time of measurement. The hydraulic gradient, groundwater flow direction, and groundwater velocity vary depending upon the fluctuations of the water table caused by groundwater recharge events, pumping, and other factors. However, the south-southwest direction of groundwater flow across the INEL Site appears to be stable regardless of appreciable changes in the storage of groundwater in the aquifer (Pittman et al., 1988).

What are the sources of recharge and primary discharge to the Snake River Plain Aquifer ?

Recharge to the Snake River Plain Aquifer originates from precipitation in the mountains north, east, and west of the Eastern Snake River Plain, (ESRP) (see Figure 4-19). Most of the inflow occurs as underflow from alluvial-filled valleys along the edges of ESRP. The Big Lost River, Little Lost River, Birch Creek, Medicine Lodge Creek, and Camas Creek terminate at sinks on the ESRP and recharge the Snake River Plain Aquifer. Recharge occurs through the surface of the plain from flow in the channel of the Big Lost River, its diversion areas, and from surface irrigation. Additionally, recharge may occur from melting of localized snowpacks during years in which snowfall accumulates on the Snake River Plain.

Groundwater from the Snake River Plain Aquifer is discharged to springs along the Snake River near Hagerman (see Figure 4-19), to springs near Blackfoot, to numerous irrigation wells, and to wells used by the INEL Site. The Snake River Plain Aquifer discharges a total of approximately 8.7 million

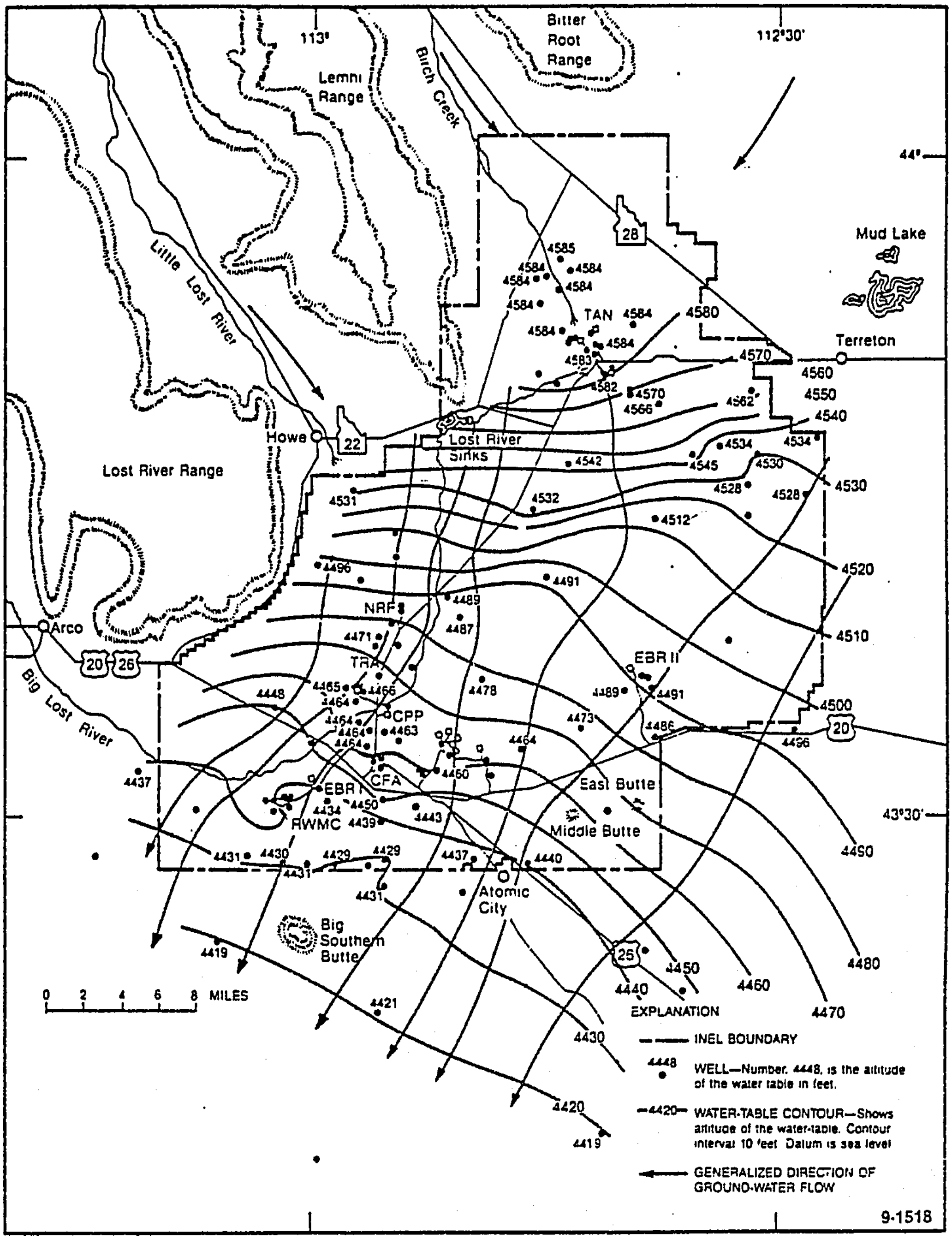

Figure 4-20. Altitude of the water table for the Snake River Plain Aquifer and general direction of groundwater movement, July 1985 (Pittman et al., 1988).

acre-ft/yr. The aquifer discharges about 7.1 million acre-ft of water annually to springs and rivers. Groundwater pumpage from the aquifer for irrigation totals about 1.6 million acre-ft annually (Hackett et al., 1986).

Thirty production wells have been installed at the INEL with 27 wells active (Pittman et al., 1988). The combined pumpage from these wells was about 6,450 acre-ft/yr during the early 1980s. This averages to about 5.7 million gal/d (Lewis and Jensen, 1985). Of the water pumped from the aquifer at the INEL Site, most has been discharged back to the Snake River Plain Aquifer through disposal wells (discontinued in 1984) and ponds (still in use). According to available pumpage and disposal records, nearly 63% of the water pumped was disposed of to the ponds (Pittman et al., 1988).

<u>What are some useful hydrologic properties for the regional aquifer?</u>

Some Snake River Plain Aquifer data that are useful for groundwater flow and contaminant migration simulation are defined and summarized below.

- The effective thickness of the aquifer below the INEL Site ranges from 250 ft (Robertson et al., 1974) to 820 ft (Mann, 1986), with an effective base from 840 to 1220 ft below land surface (Mann, 1986).

- Hydraulic conductivity is the rate at which water can move through a permeable medium (Fetter, 1988). (Mundorff et al., 1960) suggested average hydraulic conductivities of 2700 ft/d.

- Transmissivity is the product of the hydraulic conductivity and the determined the aquifer channel (via open borehole or perforated casing of the well). Transmissivities range from 134,000 to 13,400,000 ft^2/d (Robertson et al., 1974).

- Storage coefficient is the volume of water released from storage per unit surface area of aquifer per unit decline in the water table (Freeze and Cherry, 1979). Storage coefficients range from 0.01 to 0.06 (Hull, 1989).

- Porosity is the ratio of the volume of voids in an aquifer material to the total volume of aquifer material (Freeze and Cherry, 1979). Effective porosity refers to the pores that are interconnected. Effective porosity ranges from 5 to 15% (Robertson et al., 1974).

These aquifer properties are well determined on a regional scale. Their ranges in values are indicative of the complexity of the subsurface at the INEL Site.

<u>Is it necessary to characterize the Snake River Plain Aquifer in the vicinity of the RWMC?</u>

While the groundwater properties presented previously are useful for conducting groundwater flow and contaminant transport simulation, the data were collected over a large area and represent the regional properties of the aquifer. Characteristics of the aquifer might be significantly different in the area near the SDA.

<u>What efforts have been made to characterize the Snake River Plain Aquifer near the SDA?</u>

To better define the groundwater zone in the vicinity of the RWMC site, several boreholes have been drilled and monitoring wells have been installed. Wells USGS-87, #-88, #-89 and #-90 were drilled and installed in 1971 and 1972 for the USGS site investigation of geohydrology and to determine whether radionuclides or other contaminants were present. The wells were drilled to approximately 50 ft below the water table (to a depth of 626 to 646 ft to monitor the upper portion of the aquifer) (Wood, 1989). Wells USGS-117, #-119 and #-120 were drilled and installed in 1987 as part of a site investigation for organic compounds. Well USGS-117 was drilled to approximately 653 ft. Wells USGS-119 and #-120 were drilled to approximately 708 ft; therefore, they monitor slightly deeper aquifer water (Wood, 1989). Table 4-2 shows the total depths and the well construction details for the monitoring wells installed near the SDA.

Table 4-2. Summary of well construction for wells in the RWMC area (Wood, 1989).

Well Name	Year Drilled	Total Depth ft	Casing Construction: Material	Casing Construction: Cased Interval ft	Casing Construction: Screened and/or Open Interval(s) ft	Casing Construction: Screen Type	Well Logs: Geologist Log	Well Logs: Geophysical* Logs	Depth to Water When Drilled ft
EBR-1	1949	1075	Steel	0 - 750	600 - 750 750 - 1075	Perforated Open Hole	Yes	Yes	596.00
RWMC Production Well	1974	683	Steel	0 - 660	590 - 610 625 - 635	Perforated Perforated	Yes	Yes	571.00
USGS-9	1951	654	Steel	0 - 652	618 - 652 652 - 654	Slotted Open	Yes	Yes	601.00
USGS-86	1966	691	Steel	0 - 48	48 - 691	Open	Yes	Yes	643.70
USGS-87	1971	640	Steel	0 - 585	585 - 607 Caved to 607	Open Hole	Yes	Yes	582.70
USGS-88	1971	635	Steel	0 - 587	587 - 635	Open Hole	Yes	Yes	583.65
USGS-89	1972	646	Steel	0 - 576	576 - 646	Open Hole	Yes	Yes	590.64
USGS-90	1972	626	Steel	0 - 580	580 - 609 Caved to 609	Open Hole	Yes	Yes	574.62
USGS-105	1980	800	Steel	0 - 400	400 - 800	Open	Yes	Yes	668.83
USGS-109	1980	800	Steel	0 - 800	600 - 800	Slotted	Yes	Yes	619.72
USGS-117	1987	655	Steel/SS	0 - 555	555 - 653	Perforated	Yes	Yes	581.30
USGS-119	1987	705	Steel	0 - 639	639 - 705	Perforated	Yes	Yes	600.80
USGS-120	1987	705	Steel/SS	0 - 638	638 - 705	Perforated	Yes	Yes	611.45

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The location of the groundwater wells at the RWMC are shown in Figure 4-21. Also shown are the EBR-I (drilled in 1949) and the RWMC Production Well (drilled in 1974). All groundwater monitoring wells completed in the Snake River Plain Aquifer are located outside the boundaries of the SDA. The depth to the water table below the SDA is approximately 580 ft from the ground surface.

These wells have provided the following types of data:

- Stratigraphic information used to characterize the subsurface geologic materials and create geologic cross-sections of basalt-flow groups, sedimentary interbeds, etc.

- Aquifer properties such as hydraulic conductivity, transmissivity, and storage coefficient which were determined from field aquifer pumping tests

- Water table elevations that were used to determine the direction of groundwater flow and the influence of aquifer recharge and discharge

- Geochemistry data used to determine the chemical makeup of the groundwater and to detect possible contaminants.

<u>How does the stratigraphy affect groundwater movement at the RWMC?</u>

To a large degree, structural and textural characteristics of individual flows within flow groups control the movement of groundwater through the Snake River Plain Aquifer. Vesicular, highly fractured flow tops and fractured flow bases combine to form what is generally the most permeable part of the aquifer, unless fractures near this interface are filled with sediment. The dense, massive central portion of a flow can have very low permeability. The thickness and extent of these flow features is known to vary widely over relatively short distances in the Snake River Plain basalts, and departure from the idealized case is common (Mundorff et al., 1964).

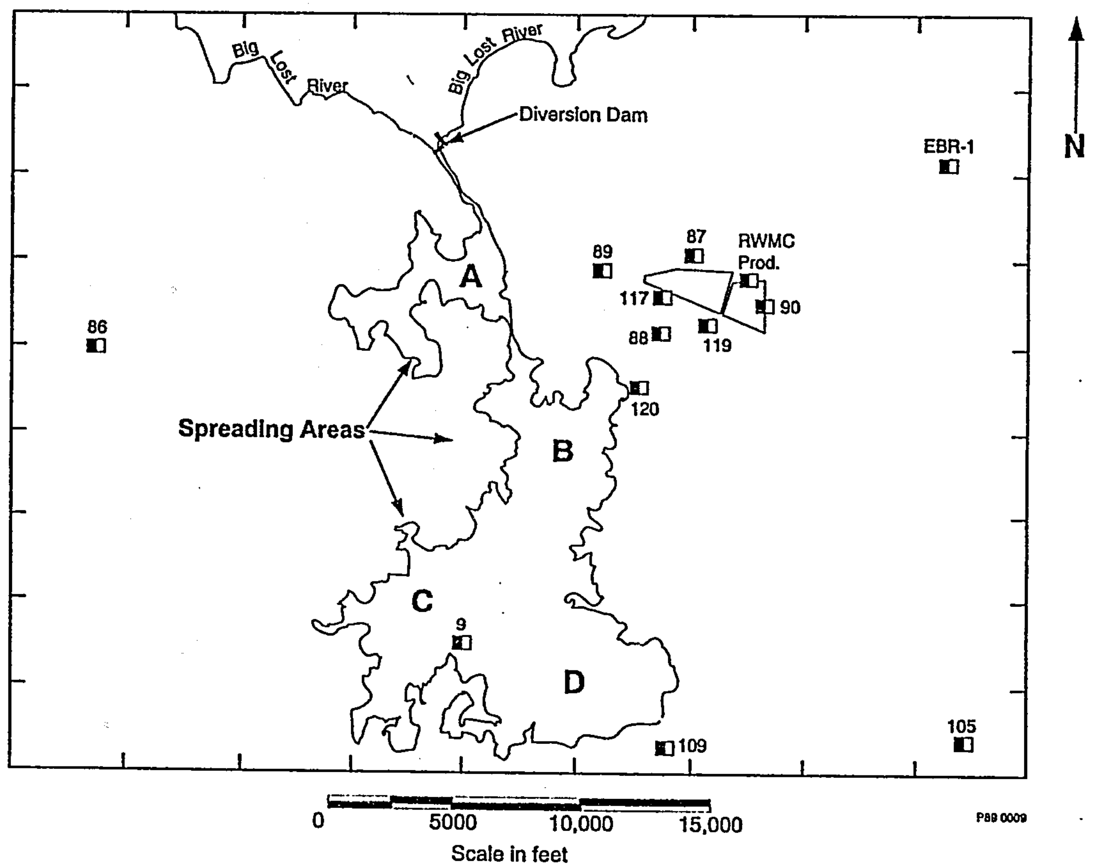

Figure 4-21. Location of wells in the RWMC area and Spreading Areas A, B, C, and D.

The difficulty of identifying and correlating individual flows limits developing a hydrologic model at the RWMC because the distribution of the flows within flow groups affects the vertical and horizontal aquifer properties. Sedimentary interbeds also have a significant impact on aquifer properties. Clay-rich interbeds impede the movement of groundwater, and coarse-grained interbeds may be more permeable than some dense basalts. In general, sedimentary interbeds have relatively lower hydraulic conductivity than the surrounding basalts. There will always be uncertainty associated with the correlation of permeable zones in the basalts because of the natural lack of continuity. However, taken as whole, the inhomogeneities of the basalts and sediments of the Snake River Plain Aquifer average out, and groundwater movement is predictable using standard methods when large areas of the aquifer are examined (i.e., distances measured in thousands of feet). Wood et al., 1989, discusses a water table map for the area near the CFA landfills (6 mi northeast of the RWMC). From this mapping it is apparent that at a small-scale and small-contour interval, the water table surface of the Snake River Plain Aquifer can be complex. This complexity reflects the variety and degree of interconnecting water bearing zones that affect the water table at a local scale but average out on a regional scale.

Are there significant sources of local aquifer discharge?

Aquifer discharge in the vicinity of the RWMC site is limited to pumping from wells RWMC Production and EBR-I. RWMC Production provides drinking and utility water for personnel working at the RWMC. During 1986 and 1987, 5.1 and 3.4 million gal, respectively, of groundwater were pumped from RWMC Production well. The average pumping rate over a 2-year period was 8 gal/min. Well EBR-I supplies water to the general public visiting the Experimental Breeder Reactor I (EBR-I) facility, and the pumping rate is less. Pumping from wells RWMC Production and EBR-I has a negligible effect on water table deviations because the Snake River Plain Aquifer is very prolific.

What impact does the INEL diversion system have on the aquifer near the SDA?

The INEL diversion system was constructed in 1958 to provide flood protection for the facilities at the RWMC. By diverting water from the main channel of the Big Lost River, water is spread out into natural depressions where it either evaporates or infiltrates to the aquifer. The combined capacity of the diversion areas is about 38,000 acre-ft. Since 1965, the diversion system has received about 1.2 million acre-ft of water with most of that water concentrated during wet periods in the mid-1960s and mid-1980s. During most years, water does not flow in the Big Lost River and the spreading areas are dry.

Most of the water that enters the spreading areas infiltrates to the aquifer. The average infiltration rates in the Big Lost River spreading area system were measured in 1965 and 1966 (Barraclough et al., 1967). The average infiltration rates for Spreading Areas A and B were 0.71 and 2.6 $ft^3/d/ft^2$ of pond bottom, respectively (Figure 4-21). In addition, the diversion channel's average infiltration rate was measured at 2.8 $ft^3/d/ft^2$ of channel.

Figure 4-20 presents the general direction of groundwater flow below the entire INEL Site. The elevation of the groundwater table is influenced by recharge from the diversion areas as indicated by the southward bulge in the 4440 ft contour line to the west and south of the RWMC. Water diverted from the Big Lost River infiltrates to the aquifer and creates a water table mound. The mounding causes the direction and rate of groundwater flow to vary beneath the RWMC. Further evidence of changes in groundwater altitude with time is apparent in the hydrographs shown in Figure 4-23. Rises in water levels in wells correlate to wet periods where water was diverted from the Big Lost River to the spreading areas. Two studies have been done at the RWMC to monitor changes in the water table caused by recharge from the spreading areas and other factors. The first study covered a 3 1/2-year period after Wells 87, 88, 89 and 90 were installed (Barraclough et al., 1976), and the second study covered an 18-year period (Wood, 1989). Both studies showed a strong

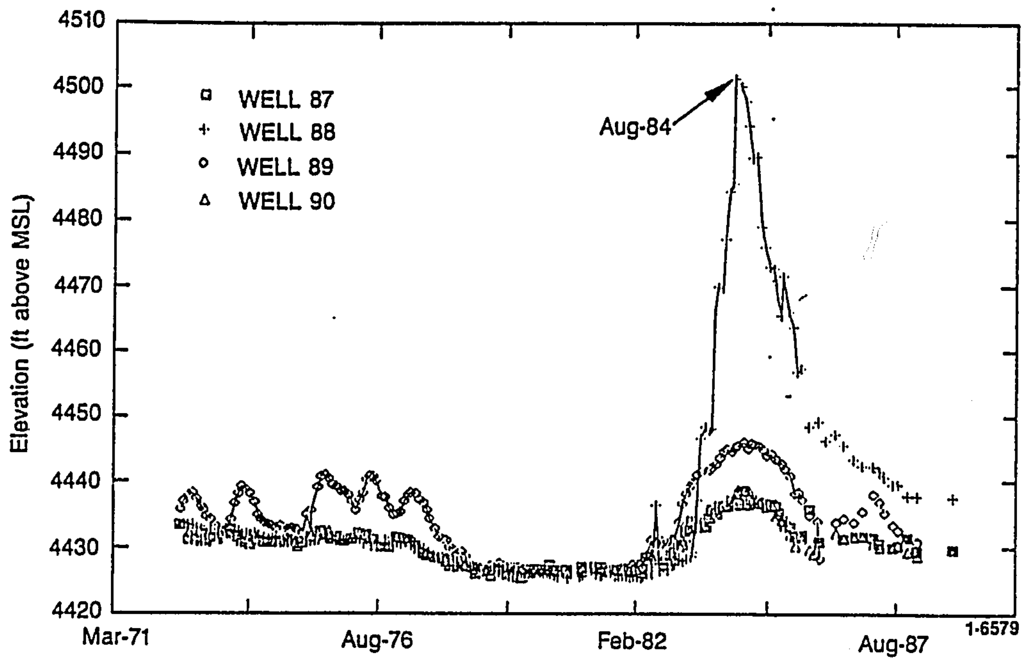

Figure 4-23. Well hydrographs for USGS Wells 87, 88, 89 and 90, 1972 through 1989. Based on USGS water level data.

correlation between surface water discharge to the spreading areas and mounding of the aquifer beneath the spreading areas.

Figures 4-24, 4-25, and 4-26 are water table contour maps comparing the influence of various states of the spreading areas on the water table based on data from the 4th quarter of 1980, the 3rd quarter of 1984, and the 1st quarter of 1989, respectively. Flow lines have been added to show the approximate direction of groundwater flow. Before the wet years, starting in 1983, the direction of flow in the aquifer near the RWMC was to the south (see Figure 4-24). This would approximately represent the steady-state condition. The water table map for 1983 (Figure 4-25) shows the water table responding to the infiltration in the spreading areas. The flow lines have changed direction to the southeast. The water table map for 1989 (Figure 4-26) indicates that the aquifer is almost recovered from the recharge stress caused by diversion of water to the spreading areas in the mid-1980s.

Based on the observed trend, if little or no water is diverted to the spreading areas, the water table gradient will continue to flatten out and approach the gradient of 1980. If significant amounts of water are diverted to the spreading areas, another water table mound will develop under the spreading areas, and the direction of groundwater flow will swing to the southeast as illustrated in Figure 4-25. It is clear that the direction of groundwater flow is dynamic in the RWMC area, dependent upon the amount of water diverted to the spreading areas and upon flow in the Big Lost River.

<u>What is the rate and direction of groundwater flow beneath the RWMC?</u>

The rate and direction of groundwater flow is directly influenced by the hydraulic gradient. In the area of the RWMC, the water table gradient changes markedly over time in response to recharge from the spreading areas. Because the direction and magnitude of the hydraulic gradient varies with time, calculating the direction of flow and the rate of flow is not a straightforward procedure; it is dependent on the time period under consideration. The down gradient direction from the RWMC ranges from southwest to east; the direction under low recharge conditions is to the

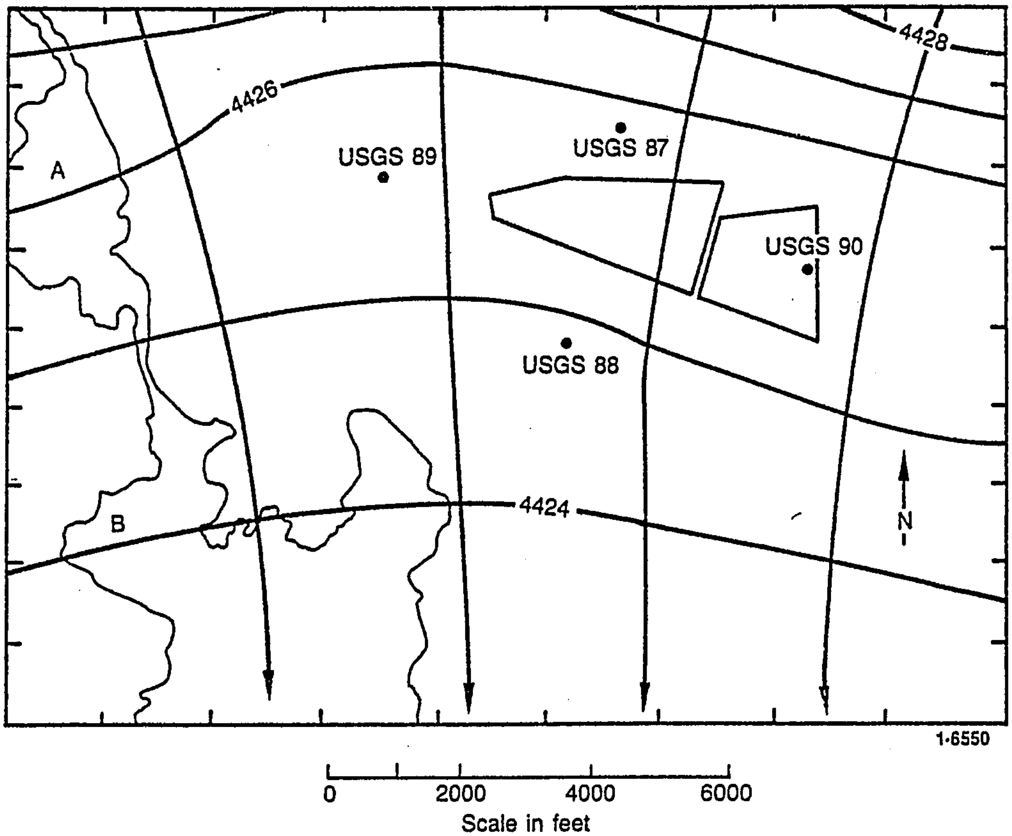

Figure 4-24. Altitude of the water table for the Snake River Plain Aquifer and general direction of groundwater movement, 4th quarter of 1980 (Wood, 1989).

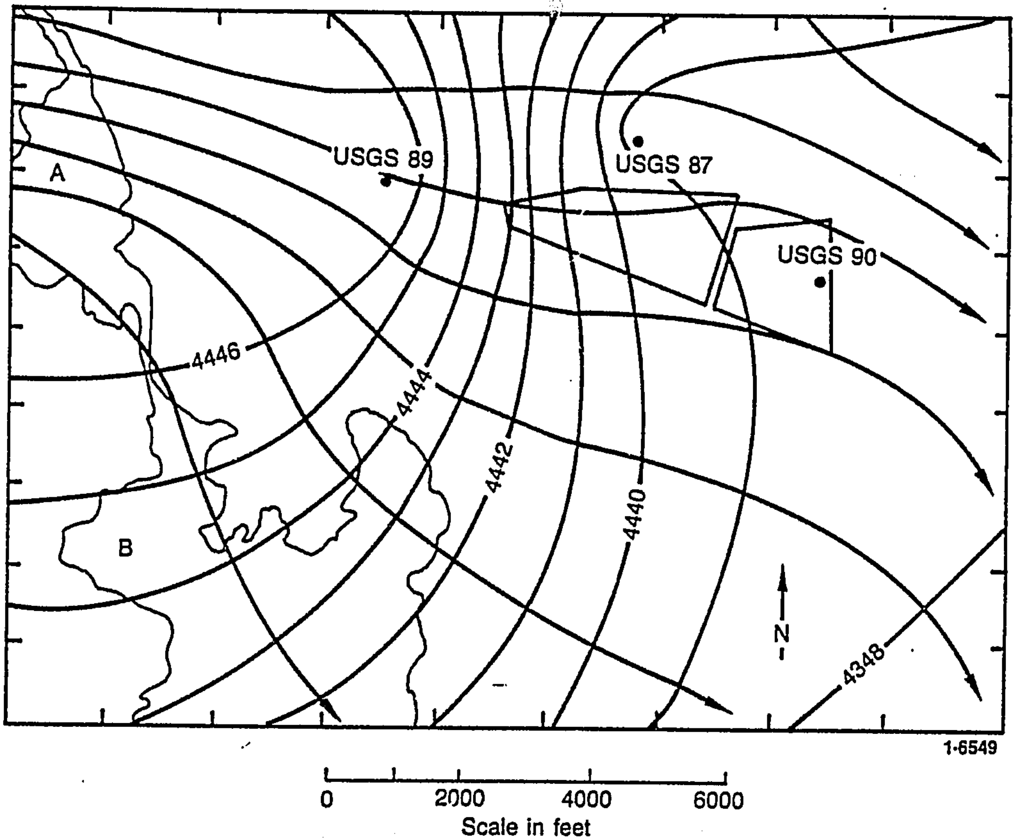

Figure 4-25. Altitude of the water table for the Snake River Plain Aquifer and general direction of groundwater movement during recharge from spreading areas, 3rd quarter of 1984 (Wood, 1989).

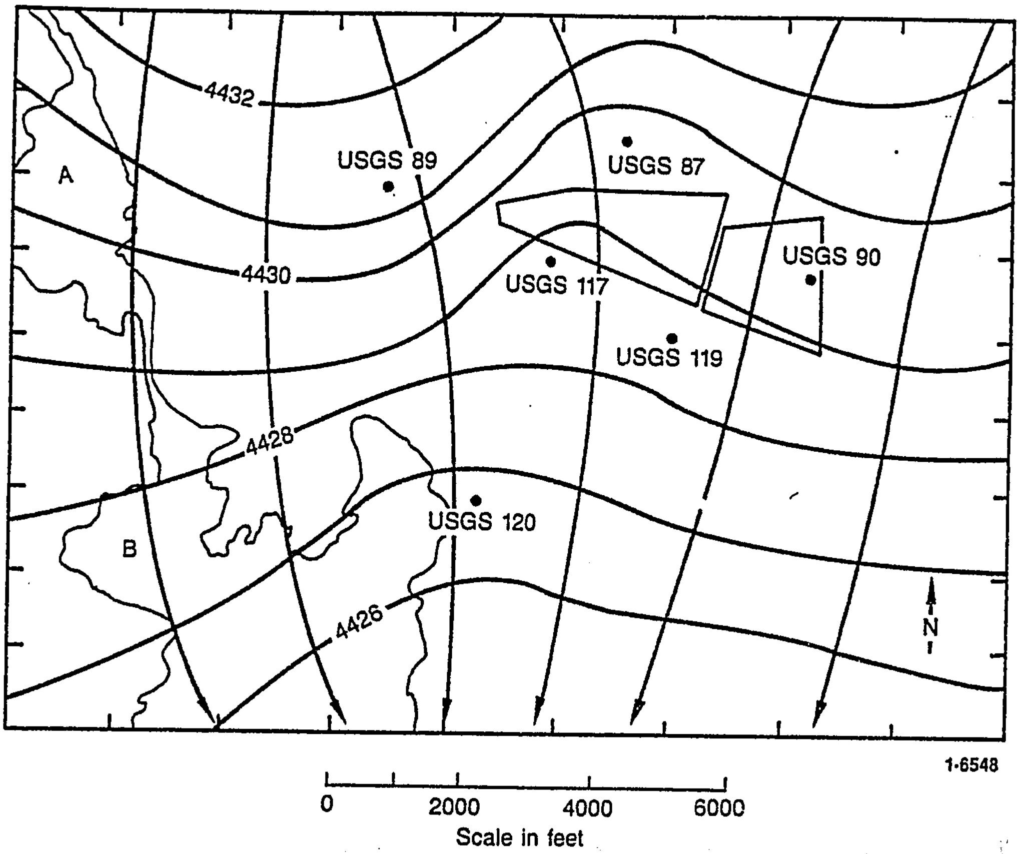

Figure 4-26. Altitude of the water table for the Snake River Plain Aquifer and general direction of groundwater movement, 1st quarter of 1989 (Wood, 1989).

south-southwest. Because conditions are transient, measured water levels may be the result of a pressure wave rather than the movement of water from one point to another, complicating the net direction of groundwater movement even over short time intervals.

For the purposes of calculating groundwater flow direction and rate, it was assumed that the simplifying assumptions of Darcy's law are valid for the SDA. Calculations based on Darcy's law have been used at ICPP (Wood et al., 1989), approximately 8 mi northeast of the RWMC. The results compared favorably to velocities obtained from a direct method that involved monitoring the travel time of tritium peaks between downgradient wells (Barraclough et al., 1967).

The gradient was estimated from each of the 3 maps presented in Figures 4-24, 4-25, and 4-26. For the stable water table case, 4th quarter 1980, the water table gradient was 3.3 ft/mi to the south-southwest, which results in a velocity of 5 ft/d (Wood, 1989). For the recharge case, the 3rd quarter of 1984, the gradient was 13.2 ft/mi in a southeasterly direction. The calculated flow rate for the period is 18 ft/d. For the 1st quarter of 1989, the gradient is 5.6 ft/mi in a south-southeast direction. The calculated flow rate is 7 ft/d. For comparison, tritium from TRA or ICPP was measured at the RWMC in 1975, which indicates a flow rate of about 4.1 to 4.4 ft/d, showing that the calculated flow rate from the steady state mapping is in very good agreement with measured values.

<u>What is the groundwater flow travel time from the RWMC to the INEL Site boundary?</u>

It is approximately 3.8 mi from the RWMC to the southern boundary of the INEL Site in the direction of regional groundwater flow. Using 4.1 to 5.0 ft/d velocities to calculate groundwater travel time, groundwater travels from the RWMC to the southern boundary of the INEL Site in 11.0 to 13.5 years.

Is there any evidence of high permeability or preferential flow patterns?

Basalt aquifers are classified as heterogeneous because the internal distribution of fractured zones and massive basalt can change substantially over relatively short distances. Estimating the direction and rate of groundwater flow near the RWMC is complicated by the anisotropic and heterogeneous nature of the Snake River Plain basalts. After studying water levels from Well 88, Wood (1989) stated that at least one zone within the aquifer may be hydraulically isolated from the active portion of the aquifer near the RWMC. It is assumed that preferential flow occurs at least on a scale of tens to hundreds of feet because interconnected voids have been observed in outcrops at that scale.

Specific to the RWMC, two lines of evidence suggest that preferential flow may occur: (1) carbon tetrachloride has not been measured in the two wells closest to the SDA, but it has been measured in downgradient wells (see Figure 4-21); and (2) measured transmissivities in the monitoring wells range over 5 orders of magnitude, indicating wide variations in formation permeability. In the first case, it is possible that carbon tetrachloride moved preferentially along a groundwater pathway past Wells 117 and 119 and was picked up in downgradient wells. The second case indicates that a range of permeabilities exists where preferential flow could occur.

Other evidence suggests that preferential flow may not be of any real significance (1) assuming homogenous and isotropic conditions prevail, the calculated rates of flow for the RWMC compare well with measured rates of flow; (2) contaminant plume tracking conducted by the USGS over many years indicates that contaminant migration occurs as through a porous medium; and (3) reasonable approximations of contaminant migration have been achieved using numerical models that assume uniform aquifer properties within nodes (Rood et al., 1989).

Local anomalies in the aquifer have been recognized for many years. The first hydrologist to study the Snake River Plain Aquifer recognized the anomalous behavior (Nace et al., 1959). The real issue is not if preferential flow occurs, but how significant is preferential flow at the RWMC. In other words, at what scale does the aquifer begin to behave as an equivalent porous medium? The random orientation of the intraflow zones within the basalts averages out as larger areas are considered. Contaminant plumes are more regular at larger offsets from the source. This generalization is substantiated at the RWMC by the lack of contamination in Wells 117 and 119.

For contaminant detection, the preferred monitoring locations at the RWMC are not immediately adjacent to the SDA; they are offset several hundred to 1000 feet. The monitoring locations increase the chances of detecting the release of contamination as the natural processes of diffusion and dispersion increase the areal extent of the contaminant plume.

How well are the three-dimensional groundwater flow parameters defined near the RWMC?

Data collected to date near the RWMC are an approximation of the hydraulic parameters in the horizontal direction. Use of these parameters provides a reasonable match to known travel times. No data are available on hydraulic parameters in the vertical direction, and the aquifer characteristics at depth are not defined. The aquifer transmissivity in the SDA region has not been measured with a major pumping test utilizing observation wells. The vertical hydraulic gradient and in situ porosity and dispersivity have not been measured. The vertical stratigraphy below the surface of the water table is poorly defined.

4.5 FEDERAL FACILITIES AGREEMENT OPERABLE UNIT STUDY

Information discussed in Section 4, focusing a water pathways for contaminant migration from the SDA, will be used for further study of Operable unit 7-06 groundwater pathway. This operable unit is described as the Snake River Plain aquifer beneath and within the immediate vicinity of the RWMC. The objective of this study is to detect the release, nature, and extent of contaminant migration from the RWMC within the Snake River Plain aquifer. A

Preliminary Scoping Track 2 Study will commence in FY 92 to conduct field investigation and laboratory analysis sufficient to make a decision to recommend no further action, or proceed with interim action, or RI/FS scoping. Data needs will be addressed in this Track 2 study.

4.5.1 Surface Water Recommendations

This section identifies surface water data needs that should be addressed to meet regulatory requirements. The review of previous investigations and data currently available regarding surface water impacting the SDA has revealed some data gaps that need to be addressed to successfully complete the RI/FS process. These data gaps include

- No current water budget for the SDA (ie. what is the inflow and outflow of all water at the SDA).

- A lack of SDA surface water runoff data including volumes and directions. Inadequate snowpack data for the SDA and the surrounding area.

- A lack of data on the water chemistry of the Big Lost River.

- Incomplete characterization of surface water/groundwater interactions.

- Incomplete characterization of the drainage patterns of the SDA and its surrounding area. Poor understanding of flood routing inside and outside of the SDA.

- A lack of precipitation and runoff chemistry data. No data are available for rainwater chemistry, and limited data are available for snowpack.

- No monitoring data of other potential hazardous wastes being discharged from the SDA other than radiological data.

The following studies are needed to address the data gaps identified above.

4.5.1.1 Water Balance Study. An overall water balance for the RWMC area is necessary. Many input and output parameters are required for the water balance, and several additional measurements are essential. The water balance measurements that are necessary are not limited to the surface water portion of the RWMC; however, only the recommendations dealing with surface water will be made in this section.

Snow surveys should be performed within the SDA and the outlying area to determine the contribution of snow to the overall precipitation in the area. These data should also be used to evaluate the potential of flooding from rapid snowmelt in the surrounding topographic depression. The amount of runoff that flows from the SDA during precipitation events should be measured and recorded. Information obtained from snow surveys can be used to estimate the maximum potential for infiltration through the pits and trenches at the SDA.

Data presented by Crockett (1983) should be evaluated for hazardous constituents that may have been found in the runoff channel. If data presented in the report meet criteria for use in the Remedial Investigation/Feasibility Studies (RI/FS) Program, they should be used for site characterization. If the data are not acceptable for the intended purpose, sediments and surface water leaving the RWMC should be sampled. Sampling of surface water discharge from the SDA should be repeated on a periodic basis for monitoring purposes.

Detailed mapping of the drainage patterns within and outside of the SDA is required to evaluate the flood routing capabilities of the current drainage system.

The water in the Big Lost River that runs into the spreading area should be analyzed periodically for general chemical constituents. The discharge of water to the spreading area needs to be accurately measured by a continuous record flow meter.

4.5.2 Vadose Zone

This section identifies vadose zone data needs that should be addressed in the RI/FS of the SDA. As a result of site characterization activities, an initial understanding of moisture movement in the subsurface of the SDA has been achieved. However, characterization is an iterative process. The data obtained over the past several years have raised more questions than they have answered; not an uncommon occurrence in site investigations. The vadose zone beneath the SDA is extremely complex because of its thickness, the fractured nature of the basalt, and the influence of the sedimentary interbed layers. Data gaps related to the movement of moisture and contaminants in the subsurface prevent the adequate understanding of the hydrology of the vadose zone. This understanding is necessary to meet regulatory requirements under CERCLA for risk assessment analyses and feasibility studies. The data gaps that need to be addressed in the site characterization program are listed below.

- Data on the thickness of soils or sediments beneath the waste in the pits and trenches and above the underlying basalts needs to be compiled and documented.

- The density, spacing, orientation, and interconnecting nature of fractures in the basalt flows have not been fully characterized; these fracture geometry characteristics will affect the hydraulic properties of the basalts.

- The physical properties including soil, sediment type, grain size distribution, hydraulic conductivity, air permeability, bulk density, and porosity of the disturbed and undisturbed surficial soils, interbeds, and basalts are not well defined.

- The horizontal and vertical extent and seasonal variation of perched water zones in the surficial sediments, basalts, and sedimentary interbeds are not well defined.

- The changes in permeability and porosity between basalt flows and sedimentary interbeds are not defined and will affect flow through the vadose zone and the presence, location, and extent of perched water zones.

- Soil-water chemistry is inadequately understood and should be analyzed to define geochemical controls on contaminant movement in the unsaturated zone.

- The distribution and concentrations of radiochemical, organic, and inorganic contaminants in the surficial soils, interbeds, and basalts located both inside and outside the SDA have not been fully evaluated and will be needed to perform a risk assessment.

- Soil infiltration and evapotranspiration rates are needed for characterization of soil-water movement through disturbed and undisturbed soils at the SDA.

- The water storage capacity and spatial distribution of the moisture content of surficial sediments have not been monitored on a long-term basis. These data will be needed to determine the volume of water moving through the surficial deposits.

- The hydraulic properties of the perched water zones are not known.

To address the previously described data gaps, the following studies are recommended.

4.5.2.1 Infiltration Study. The most important considerations in moisture movement through the vadose zone are how much water, which falls as precipitation or snow, infiltrates into the soil and moves down the water column and the timing of this infiltration. Variation in estimates of the flux of water moving through the system profoundly influences the travel times and the rate of contaminant movement for the vadose zone at the RWMC. Field scale infiltration tests need to be performed within the interior of the SDA to determine the unsaturated hydraulic conductivities in areas with new and old cover materials. These tests can be used to assess the infiltration capacity through various cover materials.

4.5.2.2 Interbed Soil Samples. Drilling techniques need to be reviewed to plan methodologies that would allow improved collection of sediment samples from the 110- and 240-ft interbeds. Currently, the recovery of these samples is poor especially in the 110-ft interbed. Increased recovery from sedimentary interbeds would allow better determination of the hydrologic and geochemical properties of these materials.

4.5.2.3 Vadose Zone Monitoring. Additional soil moisture monitoring instruments need to be placed inside the SDA to better characterize the distribution and rates of moisture movement within the unsaturated zone. The system placed within the SDA in 1985 and 1986 was experimental and was intended to give a general outline for future monitoring. Planning should be performed (a) for additional locations, (b) to determine the types of instruments needed to monitor matric potentials, and (c) to determine gradients and soil water fluxes as a function of time. This testing should also include collecting samples to improve defining of hydrologic properties.

The vadose zone monitoring system should include instruments emplaced within the massive and fractured basalts to determine the matric potential and groundwater flux over time. The expanded network would allow gradients to be calculated for the entire profile from land surface to at least below the 240-ft interbed.

Monitoring instruments should also be placed within buried waste in selected areas within the SDA. This will allow a comparison of the distribution of matric potential within the waste compared to areas that have not been disturbed by the addition of waste. Access for the monitoring instruments could be provided by the sonic drilling technique used at the SDA. Monitoring can be performed by placing neutron access tubes and sensors such as tensiometers, heat dissipation sensors, or gypsum blocks within the waste. Monitoring should be performed within portions of the burial grounds and outside of the burial grounds to compare moisture movement inside the waste and outside the waste.

The monitoring system should also include several locations near drainage ditches. The drainage system in the SDA may be a primary source of infiltrating water. Moisture monitoring in the surficial sediments at selected location would assess the relationship between surface drainage and groundwater infiltration.

Continued monitoring of the vadose zone is required to characterize groundwater infiltration rates, especially during wet years or flooding events. These monitoring data can be used to determine moisture movement over time. The existing period of record is approximately 3 years. Some trends have been observed, and more data are needed to determine if these trends persist in time.

4.5.2.4 Dispersivity Study. Dispersivity coefficients should be measured using field tracer tests that monitor the migration of a tracer front with time. The dispersivity coefficient describes geologic properties that control dispersion. Dispersion is used as a parameter in the advection-dispersion equation to simulate solute migration. Tracer studies identify the path that infiltrating water follows the vadose zone. These studies also provide data regarding downward flux of water, movement of water at the sediment and basalt interface, and hydrogeologic properties of the sediments and/or the buried waste.

Tracer studies should be conducted by flooding an artificial trench with tagged water to simulate the periodic flooding of buried trenches. Tracers monitored at the sediment/basalt interface along with sampling at various distances from the point of introduction will allow tracking of unsaturated water movement. Sampling using porous suction devices will provide data to map the rate, speed, and direction of water movement. Tracer studies will provide moisture and tracer movement data for model calibration and assist in determining the extent of lateral migration at the sediment/basalt interface.

4.5.2.5 Perched Water. The formation of perched water on top of basalt directly underlying the surficial sediments can have a major impact on the pathway for liquid contaminants moving through the vadose zone. The change in the flow regime from unsaturated conditions to saturated conditions increases the hydraulic conductivity by up to five orders of magnitude, thereby increasing the flux rate by this magnitude. Analysis of these perched water samples can be used to determine the presence of dissolved radionuclides and to determine the geochemical characteristics of moisture in the sediments and basalts.

Several vadose zone wells should be placed between the spreading areas and the RWMC to determine if water is moving laterally in the vadose zone toward the SDA. These wells should be designed to allow neutron access measurement and collection of waters. The presence of water moving from the spreading areas under the SDA within the vadose zone, particularly at a 240 ft depth, has a very strong effect on contaminant movement from the SDA. This source of water could decrease the transport times from the 240-ft interbed to the aquifer by many orders of magnitude because water would move from the unsaturated to saturate flow regime with corresponding increases in hydraulic conductivity.

Samples for cations, anions, metals, and semivolatiles need to be collected from all perched water wells at the RWMC. Well completion data from these wells should be closely examined to determine if suitable samples can be obtained from these wells. If samples cannot be obtained then additional wells should be drilled to intercept perched water. The perched water chemistry closely reflects the water quality within the basalt and the concentration of contamination moving through the vadose zone.

Accurate water level monitoring of vadose zone Wells 77-2 and 78-1 may reflect seasonal recharge at the RWMC. All the perched water wells should be monitored on at least a monthly basis (more frequently in the spring and summer) to determine if water is present and if so how much and how quickly the water accumulates. Fluctuation in the water level reflects recharge occurring within the SDA. These data indicate if flooding or seasonal precipitation contributes water to the perched water zones over the course of the year.

A well needs to be drilled adjacent to Well 88 to determine if it is affected by perched water moving laterally from the spreading areas (causing a rise within the well) or whether the new well reflects the water level in the Snake River Plain Aquifer at this location.

In addition to field studies of perched water, a physical model should be constructed that allows testing of perched water on top of basalt. A combination of tracers and moisture monitoring equipment can be installed in the fractured basalt in order to monitor the movement of water through the basalt, both under saturated and unsaturated conditions.

4.5.2.6 Horizontal Drilling in Interbeds. Technology exists to drill and sample horizontally within the interbeds for distances exceeding 300 ft. This drilling would provide a large number of samples for analyses of radionuclides and other contaminants in the interbeds. The horizontal holes could then be instrumented for monitoring.

4.5.2.7 Basalt Core Analyses. Analyses should be performed on basalt samples immediately beneath the surficial sediments to determine if radionuclides, metals, or other hazardous constituents have or are accumulating within the basalt beneath the subsurface. Boreholes completed for the subpit/acid pit sampling demonstration would be ideal for this task. The bottom of the boreholes could be cemented to provide a seal, then drilling and sampling would be conducted with a small diameter rod coring tool to collect basalt core in the underlying basalt. This sampling would also yield information about whether the contaminants are moving through the basalt matrix or through sediment-filled and nonsediment-filled fractures. Knowledge of the pathway is integral to modeling calculations, and it has significant implications for transport and concentrations of radionuclides for the long-term assessment of stability of waste at the SDA. Similar analyses should be performed on core samples from the sediment/basalt interface at the interbeds.

Sediment infilled fractures from cores throughout the RWMC should be analyzed to determine grain size, mineralogy, and radionuclide distribution on existing cores and on new cores collected. Mineralogical properties and geochemical properties should be determined on the sediment infilled fractures. An examination of the fracture infill material may indicate whether the infill was deposited by sheet wash or trickle flow within the fractures.

Moisture release and hydraulic conductivity of representative basalt samples from the RWMC also need to be measured to characterize the unsaturated hydraulic properties of the basalt. This study would also provide insight into whether the fractures or the basalt matrix dominated flow.

4.5.2.8 Surficial Sediment Characterization. Characterization of surficial sediments at the SDA should be improved. Samples from augured holes need to be analyzed for saturated and unsaturated hydraulic properties, cation exchange properties, and geochemical parameters. Representative samples need to be collected from both the cover material and undisturbed materials. It is possible there is a laterally extensive clay layer with a high cation exchange capacity in portions of the SDA. This information is important for predicting locations where waste may be underlain with low permeability, high cation exchange sediments.

4.5.3 Groundwater Zone

Existing hydrologic and geochemical data collected from the SDA have been examined and interpretations and conclusions are presented in Sections 4.4 and 5. (Geochemistry). A number of inherent strengths and weaknesses exist in the available data. A fundamental strength is the presence of several monitoring wells and the information obtained from these wells over a long time period.

These wells have provided preliminary information used to develop a general understanding of the groundwater dynamics near the SDA and to establish the basis for future site characterization work. Characterization of a groundwater system is usually an iterative process where data and observations derived from previous boreholes are used to guide the placement of future boreholes. The USGS has completed the first and second iterations of the site characterization program with the wells drilled in 1972 and 1987.

The hydrology of the SDA is very complex, and nearly every aspect of this environment complicates the conceptual understanding of how contaminants might move from the SDA. Some of the characteristics that make the SDA difficult to characterize include infrequent, yet intense runoff events that reverse the local groundwater gradient; basalt strata that is complex, difficult to correlate, and shows evidence of preferential flow; a vadose zone that is thick and complex; and flooding of pits and trenches that has caused pulse releases of contaminants from the SDA. Because of these and other factors, additional characterization efforts are required. The data gaps pertaining to groundwater and its contaminants inhibit the development of a comprehensive understanding of site hydrology to meet regulatory requirements. These data gaps are identified below and should be addressed during the site characterization program.

- The direction of groundwater movement beneath the SDA is poorly defined because of gaps in the well coverage. Better definition of the flow field at the SDA and the influence of recharge water from the spreading areas on the hydraulic gradient is needed. The area affected by local gradient reversals and the configuration of the gradient reversals over time are poorly defined. Additional groundwater wells would fill gaps in the present coverage.

- The presence and effects of vertical groundwater gradients at the SDA have not been characterized. There are no data regarding potential vertical movement of water/contaminants in the aquifer system. Additional wells completed over discrete intervals at different depths are required.

- The total thickness of the Snake River Plain Aquifer is not defined near the SDA. The partitioning of contaminants in the aquifer (i.e., suspended solids, precipitates, and miscible solids) is also unknown.

- The effects of preferential flow paths controlled by basalt features (fractures and rubble zones) and interbeds in and around the SDA are poorly understood. Additional field data are needed to characterize the SDA stratigraphy and aquifer properties.

- Hydraulic properties of the aquifer are known only from single well pumping tests with low pumping rates. Pumping tests that stress the aquifer need to be conducted near the SDA.

- The horizontal and vertical extent of groundwater contamination beneath the SDA is poorly defined. Additional wells to fill data gaps and to collect samples at various depths in the aquifer are needed.

- Background water quality data need to be obtained, and potential sources of contamination upgradient from the SDA need to be evaluated. The total contribution of contaminants to the SDA from upgradient sources is currently unknown.

- A transient numerical model that accounts for recharge from the spreading areas needs to be completed to track contaminant pathways over time.

To provide an estimate of the effort required to address the data gaps identified above, a series of tests and recommendations have been developed. The following section briefly describes activities that are needed to complete the characterization of the groundwater zone near the SDA to meet regulatory requirements.

4.5.3.1 Groundwater Monitoring Network. A network of wells is required to fill data gaps where the present well coverage is sparse or nonexistent and to obtain hydraulic and contaminant data at depth in the aquifer. These wells could be designed to serve as EPA monitoring wells for long-term compliance and postclosure monitoring. Additionally, one or more wells should be located to provide background water quality samples.

4.5.3.2 Large Scale Aquifer Test. Previous aquifer tests have been inadequate for a number of reasons including no observation wells and their small scale; therefore, a pumping test with one or more observation wells must be performed at the RWMC to provide transmissivity and storativity data for use in contaminant transport modeling and risk assessment. During the development of the RWMC production well, the USGS monitored drawdown; however, the collected data were not suitable for calculating accurate transmissivity because of a variable pumping rate and infrequent water level readings. The USGS conducted small scale tests on monitoring wells using sampling pumps over short sections of the aquifer. Aquifer data collected to date at the RWMC is insufficient to satisfy regulatory requirements for identifying the extent of contamination and ground water pathways. The large scale aquifer test will be conducted in a well screened over a significant portion of the active aquifer to evaluate the full aquifer transmissivity at the RWMC. Such a test would involve a pumping rate of approximately 1000 gpm for 7 days.

Ideally, the production well will be located upgradient from the SDA facility, out of the contaminant plume from the SDA. There are two reasons for this: (1) to make disposal of the pumped water easier from a regulatory standpoint and (2) to provide the RWMC with a clean water source for drinking water once the pumping test has been completed.

Calculations have been made to estimate the drawdown for the pumping test using the best estimate of aquifer parameters at the RWMC. Based on the estimated drawdown and the need to be upgradient from the RWMC, the best location for the test well is within 75 ft of USGS 87 and proposed M9D. At that offset, USGS 87 and M9D will have over 2 ft of drawdown. In addition, one additional observation well should be drilled at a right angle to a line connecting USGS 87 and the test well at an offset of approximately 150 ft. This will allow for directional calculation permeability and time distance analysis of the data.

4.5.3.3 Large Scale Infiltration Test. To satisfy data deficiencies identified in earlier sections of this report, a large scale infiltration test will be conducted using the pumped water from the pumping test described in Section 3.2. The infiltration test will be a cost effective use of the water that is produced from the pumping test and will define transport through the unsaturated zone. Transport through the unsaturated zone is a critical pathway for the movement of contaminants from the SDA to down gradient receptors. Definition of this pathway is essential for risk assessment calculations.

The infiltration test will involve berming a 5-acre plot. For convenience, the 5-acre plot should be set within 2000 ft of the test well so that the piping distance is kept to a minimum. Preliminary calculations show that travel through the vadose zone will take longer than 1 week; therefore, returns from pumping will not be a problem for the pumping test. The final location will be determined by the availability of acreage with relatively thick soil cover. The USGS test plot is located in this area, and possibly, some of the USGS vadose zone monitoring equipment could be used for the large scale infiltration test. Vadose monitoring ports will be installed at three locations near the perimeter of the plot. The ports will be located at depths above, in and below the major interbeds. The 5-acre plot will be flooded with water from the pumping test for 1 week (the duration of the pumping test). An environmentally clean tracer will be mixed with flood water for tracking the downward migrating plume. Several thousand feet of irrigation pipe will be required for delivering the water pumped from the aquifer well to the 5-acre plot. It is anticipated that the vadose zone wells will need to be monitored for several months to completely track the plume. The test plot will be located near one or more ground water monitoring wells so that movement in the ground water can be monitored.

4.5.3.4 Contaminant Plume Delineation. Each of the wells drilled would also improve the delineation of contaminant plumes beneath the SDA. This plume delineation needs to occur vertically because little is known about the vertical extent of contamination. The delineation would also yield insight into the three-dimensional behavior of the aquifer.

4.5.3.5 Integrated Numerical Modeling Study. The existing data presented in this report and new data obtained from the tests recommended in this report should be incorporated into a transient three-dimensional numerical model. This task would serve to model the contaminant pathway through the vadose zone and in the groundwater. Nearly all the recommendations made in this report lend themselves to a numerical analysis. Because of the complex nature of hydrology at the SDA, a numerical model is required to integrate the many parameters into an understanding of the many potential contaminant pathways.

5. GEOCHEMICAL MODEL

The definition of the geochemical environment is important to the understanding of past and future migration of waste from the RWMC. The mobility of radionuclide or metal contaminants in the groundwater pathway is directly related to its concentration in the waters exiting the RWMC (i.e., increasing the concentration at the source results in increased release). Organic waste can migrate as dissolved aqueous species and be released to the atmosphere by gaseous diffusion. Mobility of contaminants is a function of the concentration at the source and the retardation processes along the flow paths. Any chemical process that affects either the concentrations of or the retardation of contaminants affects their mobility. The geochemical model includes geochemical processes important to the migration of waste in the subsurface.

5.1 CHARACTERIZATION GOALS

Geochemical characterization goals are to collect the appropriate generic and site-specific data to evaluate the geochemical processes affecting the mobility of contaminants from the RWMC. In addition, appropriate data must be collected to support a defensible risk assessment for remediation options. Because of the difficulties associated with using empirical models to reliably estimate the geochemical behavior of materials (e.g., soils, waters, and contaminants) for long periods of time, the geochemical model relies on process-based descriptions of geochemical behavior.

Quantifying geochemical process requires a speciation-solubility-sorption computer code with supporting thermodynamic and sorption data bases. The MINTEQ computer code is an ideal candidate for this application. Four types of site specific characterization data are required for the use of a geochemical code:

1. Water compositions for all segments of the flow path (soil waters, perched waters, and groundwater). The characterization should

include redox parameters (e.g., Eh and dissolved oxygen) and redox speciation (e.g., Fe^{2+}/Fe^{3+}).

2. Primary and secondary mineralogies of soils, basalts, and interbed sediments.

3. Chemical form of disposed contaminants (most important for organic wastes).

4. Distribution of contaminants among soil phases.

Generic data requirements include thermodynamic data for solid phases, aqueous species, and organic liquids. In addition, sorption constants (e.g., K_ds and surface complexation constants) for solid phases are required.

5.2 Source Term Geochemistry

The RWMC source term is the disposed waste and surrounding soils. For the purposes of the report, the soil thickness to basalt is included as part of the source term.

What is the geochemical environment in the pits and trenches?

An understanding of the geochemical environment in the pits and trenches is important because the release and transport of radionuclides is dependent on the geochemical environment in two ways:

1. The degradation and corrosion rate of the primary waste container depends on the geochemical environment (primarily the redox conditions). Many containers may have been breached at the time of emplacement and some waste was disposed of without primary containment in the acid pit (see Section 8.2).

2. Solubility and sorptive behavior of radionuclides and other contaminants depends on the geochemical environment (particularly

redox conditions, pH, and the concentrations of major cations and anions in the soil water).

Seasonal soil water samples from suction lysimeters installed at the RWMC have been collected. These water samples are chemically analyzed for major and minor cations and anions, pH, and redox parameters. In addition, in situ water temperatures and concentrations of organics are needed. These data have not been validated and evidence exists suggesting that silica flour used in lysimeter installation alters soil water chemistry (Rauson and Hebbell, 1988). In addition, detailed mineralogical characterization of the soils are needed to adequately interpret the results of the geochemical code.

Evaluation of the water chemistry, mineralogy, and computer analyses will provide information of the geochemical environment including the minerals controlling water composition and pH and the fugacity of carbon dioxide in the soil. These answers will provide geochemical constraints on the development of a numeric source term model that is needed for risk assessment.

The mineralogy of the soil (alluvium) at the SDA has been determined by Rightmire and Lewis (1987).[1] The alluvium ranges from 0 to 25 ft thick with an average thickness of 13 ft and is composed of airborne and waterlain sediments. The sediments are primarily silt size but may contain up to 50% clay size particles. The average modal mineralogy (volume %) of the silt size fraction is 30% quartz, 13% calcite, 17% feldspar, and 40% clay minerals. The clay minerals include approximately 32% illite, 30% mixed-layered illite-smectite, 26% smectite, and 12% kaolinite. The mineralogy of the clay size fraction is 27% quartz, 1% calcite, 16% feldspar, and up to 70% clay minerals. The clay minerals are dominantly smectite and illite with minor kaolinite.

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[1] S. A. Rawson, 1989. FY-89 Summary Report: Preliminary Evaluation of Geochemical Controls on Radionuclide Migration at the Radioactive Waste Management Complex (RWMC), Draft, Idaho National Engineering Laboratory, Idaho Falls, Idaho.

<u>How can the concentrations of contaminants be determined?</u>

The flux of contaminants from RWMC is a function of the flow of ground and surface water through the waste pits and trenches and the concentration of contaminants in the water. Contaminants in the pits and trenches exist in three conceptual distinct inventories: (1) as emplaced, (2) sorbed or precipitated in soils, and (3) in aqueous solution.

To bound source concentrations of identified radionuclides and metal contaminants, the aqueous concentration of a contaminant at the source is assumed to be controlled by the solubility of some potentially occurring radionuclide or metal contaminant bearing phase [e.g., $Pu(OH)_4$, $SrCO_3$, and $PbCO_3$]. The reason for choosing this solubility-based approach is twofold:

- Solubility limited aqueous concentrations provide a conservative source term for release and risk assessment calculations

- Fewer data are required to calculate solubility limited concentrations than are required to use a leach rate model to calculate concentrations.

The calculation of solubility requires a solubility product for the phase of interest and aqueous speciation of ions for the geochemical environment in pits and trenches. Speciation calculations require definition of the types of and abundance of inorganic and organic ligands available at the site. In particular, the association of strong organic chelating agents such as ethylenediaminetetraacetic acid (EDTA) and tributylphosphate (TBP) with the inorganic contaminant (both radionuclides and metals) may lead to significant complexation and transport of radionuclides and metal contaminants as organic complexes. In addition to complexing metals, many of the organic species (e.g., chlorinated solvents) are of environmental concern.

Developing a defensible source term model requires identifying the type of phases that retard radionuclides at the RWMC. Ideally, an individual solid phase that is composed of stoichiometric amounts of radionuclide elements could be identified (e.g., $SrCO_3$). However, it is more likely that radionuclides will be adsorbed onto metal oxides, incorporated into clay minerals by cation exchange, or coprecipitated with major elements into minerals such as calcite. As a result, multiple extractions of the collected sediments will be conducted to quantify the distribution of radionuclides. The purpose of the extractions is to define the fractions of radionuclides that reside in ion exchange sites (extraction with ammonium acetate), hydrous metal oxides (extraction with sodium citrate/sodium dithionite), carbonate minerals (extraction with a calcium chelating agent), organic materials (oxidative extraction), and within crystalline sediments (extraction with hydrofluoric-nitric acid). In addition, intact samples will be analyzed to evaluate the completeness of recovery during the extraction processes.

The results of the leaching extractions will be used to define the focus of the source term model. For example, if americium is found to occur exclusively with carbonate minerals (based on extraction results), an emphasis will be placed on the carbonate chemistry of americium in developing source term model. Numerical results from the extractions will not be used directly in developing a source term model; rather the qualitative results will be used to identify important processes to be considered in developing of a numerical source term model. These qualitative results will be used to define the possible chemical reactions to be considered for the site-specific chemical model. Numerical results for the site-specific chemical model will be calculated using MINTEQ assuming metastable equilibrium.

Any extraction method has the potential for overlap (e.g., some of the hydrous metal oxides may be dissolved during the cation exchange extraction) (Kheboian and Bauer, 1987). Therefore, great care must be used in selecting the extractants and the design of the extraction flow charts to minimize overlap. At present, the extraction methods for RWMC samples have not been developed. However, a method similar to that developed in Tessier et al., (1979) will probably be used.

The geochemical work to date (Bischoff and Hudson, 1979; Humphrey, 1980; Humphrey and Tingey, 1978; McKinley and McKinney, 1978a; 1978b) has been summarized for concentrations of radionuclide in soils associated with the waste pits.[2] These earlier studies are limited to determining radionuclide concentrations for bulk samples; no attempt was made to determine how the radionuclides are bound in the soil. The results show evidence of contaminant migration in the soils, with concentrations decreasing away from the pit/soil interface.[3] In addition, evidence is presented of pulse migration of radionuclides, possibly associated with flooding events and colloid or pseudocolloid transport.

A limited number of radionuclide concentrations from lysimeters have been reported (Laney et al., 1988).[4] Two samples contained detectable quantities of radionuclides. One sample contained 3×10^{-4} µCi/ft^3 Sr-90. The other sample contained detectable Pu-238 or Am-241.

The major limitation to defining the concentration of radionuclides in pits and trenches is the identification of the solid phase that limits radionuclide concentrations.

<u>What effect can organic waste have on migration of radionuclides?</u>

Predicting the mobility of inorganic contaminants at the RWMC requires that the potential effects of mixed organic contaminant water fluids on the transport and solubility properties of inorganic contaminant be understood. Two potential types of interactions between organics and radionuclides may occur.

1. Disposed organic ligands such as EDTA will increase radionuclide concentrations by the formation of complexes.

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[2] Ibid., Rawson.

[3] Ibid., Rawson.

[4] Ibid., Rawson.

2. Disposed organic solvents will form a mixed aqueous solvent with hydration properties significantly different than pure water.

The first point is a form of speciation. The second point is discussed here.

The thermodynamic and transport behaviors of ions in aqueous systems are dominated by ionic charge and the physical properties of water (in particular, the density and the high dielectric constant). In addition, nonspecific adsorption of ions on mineral surfaces is also affected by the physical properties of water. Introducing organic solvents into an aqueous phase will result in changes of the fluid phase density as well as significantly decrease the dielectric constant for the mixture. These changes will result in changes in the thermodynamic properties of aqueous ions (and the solubility and adsorption behavior) in mixed solvents.

Theoretical models have been developed to describe the transport and thermodynamic properties of aqueous ions in water-electrolyte solutions for wide ranges of temperatures and electrolyte concentrations. The model in Helgeson et al., (1981), referred to as the Helgeson-Kirkham-Flowers (HKF) activity coefficient model, was evaluated for the accuracy in application to the RWMC. The HKF model explicitly accounts for the effects of changes in the dielectric constant of the aqueous phase (as functions of temperature, pressure, and concentration) on the thermodynamic properties of electrolytes; therefore, it is an ideal model for the inclusion of organic solvents. In addition, the HKF model was modified to include for a large number of aqueous ions. The modification of the HKF model for organic-aqueous mixtures and incorporating the model into the MINTEQ geochemical code would provide the capability to numerically model contaminant behavior in mixed solvents at the RWMC. In addition, the MINTEQ data base should be updated to include additional organic ligands.

A critical literature review of the complexation of actinides, cobalt, nickel, strontium, iron, sodium, potassium, calcium, and magnesium with EDTA and TBP is required and currently being conducted by Dr. Everett Shock of

Washington University, St. Louis, Missouri. The literature for acetate and oxalate complexes is also being reviewed to evaluate the effect of environmental degradation products of EDTA. In addition, the systematic relationships among stability constants are being evaluated, and estimated values of selected constants are being calculated. The results of this review are being incorporated into the MINTEQ geochemical code to allow calculation of the speciation of radionuclides.

<u>What controls the release rate of contaminants from the primary source?</u>

Release and migration of radionuclides at the RWMC may have occurred via several methods:

- Migration resulting from floods and diversion waters
- Continuous migration throughout the year
- Episodic migration in response to events such as snowmelt or precipitation events.

To develop a quantitative understanding of how waste has been distributed in the past and how waste may migrate in the future, these methods must be evaluated.

The resolution of questions regarding waste migration from pits and trenches will be addressed by both limited intrusive investigation, and the development of a process based numerical source term computer code. This code will contain provisions for solubility and sorption limited releases from waste, daily variation in infiltration rates, and time-distributed container failure. Furthermore, this code would incorporate as input speciation, solubility limits and effects of organic contaminants as described previously. Utilizing this model a variety of scenarios could be studied numerically and the sensitivity of radionuclide migration to input parameters and processes evaluated.

Walton et al., (1989) developed a process based numeric source term model of the RWMC. The process assumptions of the model are

- The waste is emplaced in trenches and pits. The waste may or may not initially be enclosed or enclosed in steel drums and boxes. Also, free liquid was disposed in the acid pit.

- Over time the containers fail, and the material is available for leaching.

- Water passing through the waste pits leaches out radionuclides. This leaching may be slowed by adsorption on the waste materials or backfill and by solubility limitations.

- The radionuclides may be sorbed in the soil layer below the waste, delaying release and providing additional time for radionuclide decay.

- The sediment/basalt interface is defined as the boundary for release of radionuclides from the source.

A computer code incorporating these assumptions was used to calculate the release of Am-241 from Pit 9 (Walton et al., 1989). While the example calculation uses reasonable parameter values, it is not intended as a definitive calculation of Pit 9 releases. All the numbers chosen for the simulation are approximate. Solubility of Am-241 is assumed to be 2×10^{13}. mol/ft^3. The distribution coefficient is 48 ft^3/lbm. The distribution coefficient and solubility are assumed to be identical for the waste and the soil below the waste. The pit was open from November 1967 to June 1969. November 1967 is defined to be time = 0 in the calculations. The waste is assumed to be deposited at a constant rate over the time period when the pit is open (1.6 years or 5×10^7 seconds). The surface area of the pit is around 43,056 ft^2. The pit is assumed to contain 10 ft of waste with 19 in. of subsoil over the basalt. Fifty percent of the pit is backfilled with 5 ft of backfill. All the waste is assumed to be in drums initially. The drum failure rate is 3.2×10^{-9} s^{-1}. These assumptions mean there is 23,000 ft^3 of waste in drums or a deposition rate of 4.6×10^{-3} ft^3/s. The initial concentration of Am-241 in the waste is 2.66 mol/230,000 ft^3 = 1.16×10^{-5} mol/ft^3.

The percolation rate of water is assumed to occur at an average rate of 1.04×10^{-9} ft/s. This rate is assumed to be constant except for flooding events that occurred in 1969 and 1982. During the 1969 flood, 6 in. of water is assumed to have percolated through the waste over a period of 2 weeks. The percolation rate during the flood was 4.3×10^{-7} ft/s during the time period between 4.733×10^{7} s and 4.854×10^{7} s. During the 1982 flood, 33 in. of water is assumed to have infiltrated the waste over a period of 2 weeks. The percolation rate during the 1982 flood was 2.3×10^{-6} m/s for the time period 4.576×10^{8} to 4.588×10^{8} s.[5]

Figure 5-1 is the modelled release rate of americium-241 into the basalt (note the dominant impact of the 1969 and 1982 flooding events). The floods give large pulses of release during the flooding events. Additionally, the floods lead to an increased rate of release subsequent to the flooding event because each flood leaches more americium into the subsoil. As the amount of americium in the subsoil increases, leaching into the basalt is enhanced.

In summary, a mathematical and numerical model has been developed to estimate the release of radionuclides from the RWMC waste pits. An example simulation of americium in Pit 9 suggests that flooding events had a dominant role in causing releases. However, the simulation is an example of model capabilities and application, not an analysis of the RWMC. The input data only approximately represent Pit 9; they have not been checked for internal consistency and/or accuracy.

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[5] M. J. Vigil, 1988, Estimate of Water in Pits During Flooding Events, Project File No. 3x2M PP 130, BWP-12,EG&G Idaho Inc., Idaho Falls, Idaho.

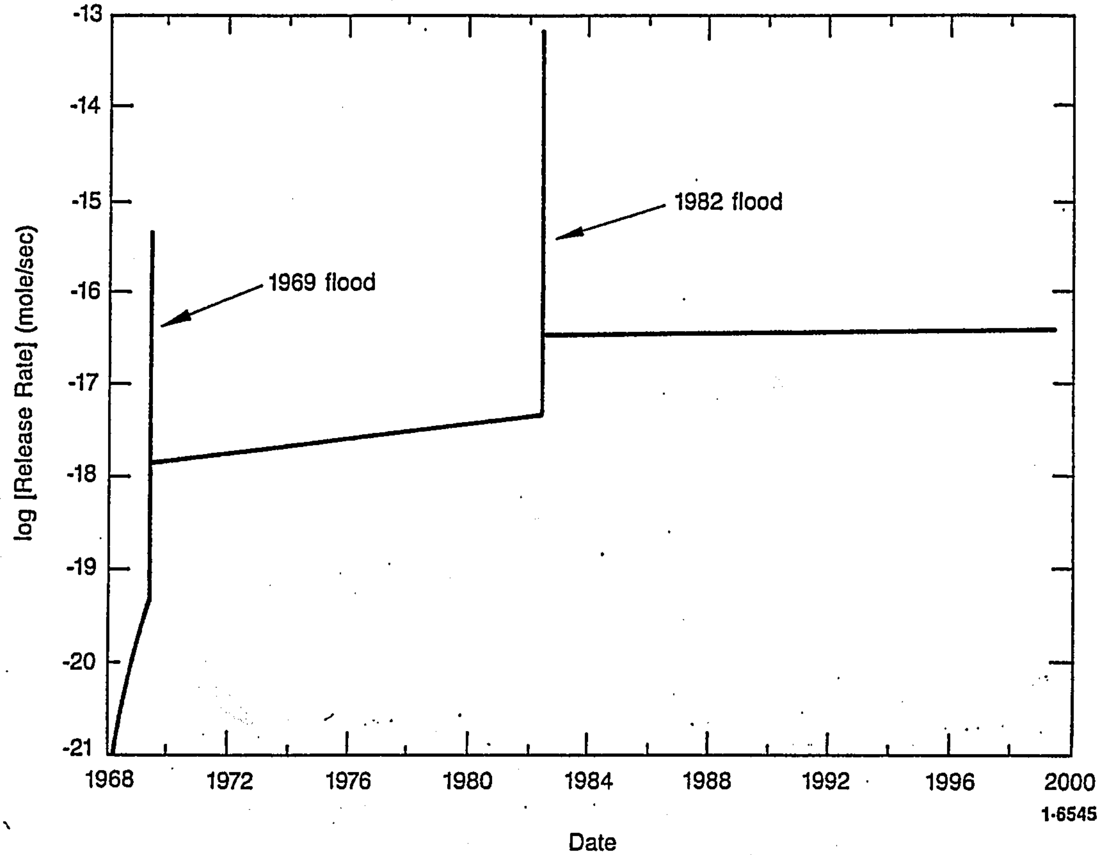

Figure 5-1. Release rate of americium-241 into the underlying basalt.

What processes control the generation and release of organic vapors?

The dominant processes that lead to release of chlorinated organic solvents from the RWMC are vapor transport and advective transport of an aqueous phase containing the dissolved solvent. The aqueous concentration can be treated as because of its limited solubility as described previously. The release of vapors can be treated in a manner analogous to a solubility limit (i.e., the partial pressure of the organic volatile at the source is limited to the equilibrium partial pressure of the liquid-vapor system). Because the disposed organic solvents are not a single compound, relationships between the concentration of an organic contaminant in a solvent mixture (with or without water) and its equilibrium, partial vapor pressure is needed. In addition, factors such as temperature and adsorption on sediments that affect the partial equilibrium vapor pressure must be quantified.

The disposal of chlorinated organic volatile compounds (such as carbon tetrachloride) in the SDA has resulted in the release of these contaminants into the atmosphere and the Snake River Plain Aquifer. Understanding the mechanisms that control release is important so the effects and extent of contamination can be evaluated.

Walton et al., (1989) presented a computer code that incorporates process based models that account for the migration of chlorinated organic solvents. In the model, it is assumed that the mixed organic solvents exhibit ideal solution behavior (i.e., obeyed Raoult's Law). In addition, the effects of adsorption of chlorinated organics onto sediments are considered to be negligible. The model results indicate that vapor transport is the dominant mode of release and is a strong function of temperature, with peak releases occurring in the summer. Further, the release rate is a function of the partial pressures and mole fractions of the pure phases and the majority of organics released are vented to the atmosphere.

5.3 SOLUTE TRANSPORT GEOCHEMISTRY

Radionuclide migration from the pits and trenches at the SDA into the subsurface has occurred in response to the movement of water through the waste, into the vadoze zone, and to the underlying aquifer. The discussion of solute transport of radionuclides is limited to the basalts and sedimentary interbeds within the vadoze zone beneath the waste pits and trenches and the saturated basalts of the aquifer. Four key issues have been identified for solute transport geochemistry. Included within the following sections is a discussion of why each issue is important and a strategy to resolve the issue.

<u>How does the water-rock chemistry affect contaminant migration?</u>

The reaction of soil water with basalts and sediments alters the soil water geochemistry. These changes can affect the aqueous speciation of contaminants as well as the sorption of contaminants onto subsurface minerals. In addition, the reaction of groundwater with basaltic minerals can lead to the formation of secondary mineral assemblages with different solubility and adsorption properties than the primary mineral assemblages.

Composition of groundwater in the Snake River Plain Aquifer reflects the results of interactions between water and basalt along the flow path. The role of water-rock interactions in defining groundwater composition is quantified by evaluating changes in composition as a function of location (age) along the aquifer flow path. The evaluation will utilize the available USGS water quality data for the Snake River Plain Aquifer. Mass transfer modelling, using a computer code such as EQ6, will be conducted to reproduce the observed trends in groundwater composition. The mass transfer modelling will define important water-rock interactions controlling water composition. The effects these interactions have on contaminant mobility can be evaluated by considering fundamental processes and can be expressed as K_ds. Because most available transport codes are formulated to use K_d values, calculating K_ds from fundamental processes using geochemical code provides a link between geochemical water-rock interactions and contaminant transport.

Numerous values of K_ds for radionuclides have been experimentally determined for sorption on basalt. The large ranges of values for strontium, cesium, americium, and plutonium from the Nuclear Energy Agency Sorption Data Base (Ticknor and Büegger, 1989) are displayed in Figure 5-2. Large ranges measured for K_d values are common because of the dependence of K_d on experimental conditions (see Section 5.1.3).

<u>How does chemical retardation depend on flow path?</u>

Flow paths can significantly influence the extent of water-rock interactions and contaminant retardation. The flow path determines both the amount of time water is in contact with a given volume of rock and the mineralogies that the water encounters. For example, if water flows rapidly through fractures in the vadoze zone, limited time for water-rock interactions will be available. Mineralogies will be dominated by oxidizing secondary clays and carbonates that are the major fracture filling phase. If water flow is dominated by movement through the basalt matrix, longer times are available for water-rock interactions, and the contaminants will encounter more reducing conditions characteristic of the primary basalt mineralogies along the flow path. In addition, the effectiveness of size filtration of colloids is strongly influenced by groundwater flow rates (Lieser et al., 1990).

The strategy to determine the role of flow path on water rock interaction involves two parts; (1) the geochemical aspects and (2) the determination of hydrologic flow path.

<u>What factors control colloid formation and mobility?</u>

The formation of colloids (i.e., non settling or slowly settling small particles composed of contaminants or sorbing contaminants) is important in the transport of radionuclides at some sites (Penrose et al., 1990; Lieser et al., 1990). Because colloids are transported at the advective velocity of groundwater, contaminants can migrate much farther than would be expected if ionic transport and retardation had occurred.

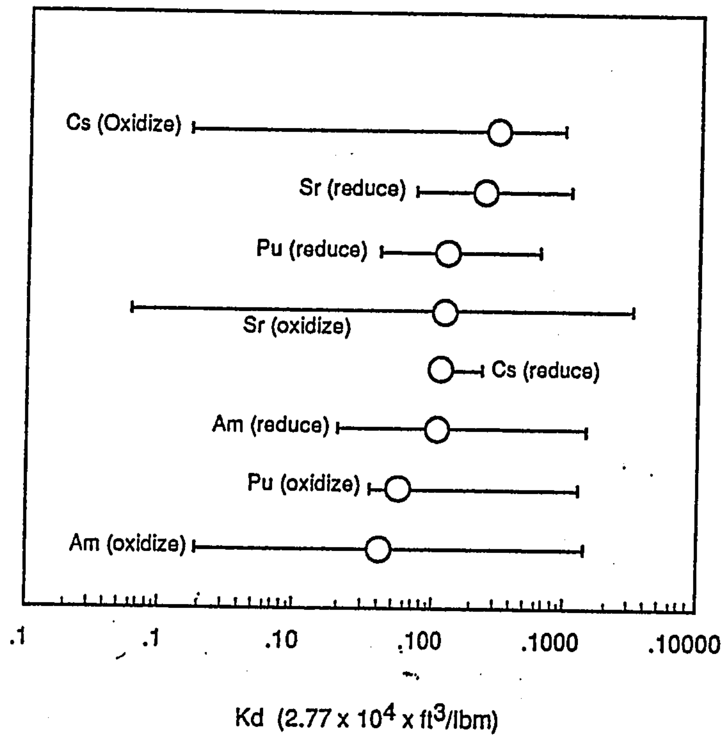

Figure 5-2. Ranges for radionuclide K_d values for sorption on basalt.

Two types of colloids have been recognized. The first are true colloids that are formed from sparingly soluble metal oxides contaminants such as tetravalent plutonium. The second are pseudocolloids that are formed by the absorption of contaminants ions onto naturally occurring colloids of iron, silica, and alumina. No RWMC site-specific studies on colloid mobility have been conducted although it has been speculated that colloids may be important for the transport of plutonium and americium at the RWMC.[6] Because colloid formation is typically a nonequilibrium process, colloid formation and migration will be site specific.

First, contaminated soils from beneath a waste pit (e.g., Pit 9) will be examined by electron microscopic methods to identify the size and types of contaminated particles. If possible, concentration distributions with depth will also be evaluated to define, filtration effects in the soils.

Second, batch experiments will be conducted using soils and synthetic soil waters in an attempt to define an upper bound of colloid formation. The colloids will be size separated using filtration and ultra-centrifugation, and the relative abundance of true and pseudo colloids will be determined. In addition, column experiments will be conducted with colloid containing waters, and the filtration effects of the soils on colloid concentrations will be evaluated. These experiments will define the relative importance of colloidal transport in the movement of contaminants within the vadoze zone beneath the RWMC.

Third, samples of ground water will be collected to determine the abundance of natural colloids in the Snake River Plain Aquifer. Experiments will be conducted to determine the sorption of contaminant onto natural colloids. Results from these experiments will indicate the capability of groundwater to transport contaminants bound to colloids in the saturated zone.

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[6] Ibid., Rawson, 1989

What geochemical effects contributed to the migration of plutonium and americium?

The USGS has conducted environmental monitoring at the RWMC to determine if radionuclides have migrated into the deep subsurface.[7] Americium and plutonium were found in the 110-ft sedimentary interbed, and plutonium was found in the 240-ft interbed. Because both plutonium and americium form very insoluble solids and are both strongly sorbed onto sediments and basalts, it is not likely that these actinides moved as dissolved species and were precipitated or sorbed in the interbeds. Therefore, the mechanism(s) controlling actinides movement over the observed distances need to be determined.

Actinides may have been transported by three potential mechanisms:

1. Dissolution of actinide bearing solids in the waste pit followed by transport as dissolved aqueous species and precipitation or sorption into or onto the interbed sediments

2. Advective transport of microscopic actinide particles from the waste pits through fractures in the basalts during flooding events and filtration of the particles within the interbed sediments

3. Advective transport of true or pseudo actinide colloids from the waste pits through fractures in the basalts and filtration retardation of the colloids within the interbed sediments.

As has been discussed previously, the first mechanism is not likely. If the second mechanism is dominant, then the flooding events may account for the observed radionuclide migration. The selective extraction studies of subpit soil samples described in Section 5.2.2 should resolve if actinide particles have moved in the subsurface. If the third mechanism is dominant, the timing of migration becomes important. It is unknown whether advective transport of

[7] Ibid., Rawson, 1989

colloidal material occurs only during periods of high water flow (i.e., flooding of the pits) or if colloidal transport is an ongoing process occurring during any period of infiltration.

5.4 Federal Facilities Agreement Operable Unit Study

Geochemical processes which affect the migration of waste in the subsurface, discussed in Section 5, will be used for further study of Operable Unit 7-05 Surface Water Pathway and Surficial Sediments. The surface water pathway is described as surficial sediments that may have been contaminated by surface water runoff from the RWMC to the Big Lost River drainage system. The objective of this operable unit is to sample surficial sediments at and near the RWMC to determine release or potential for release to the surface water pathway. A Preliminary Scoping Track 2 study will commence FY 92 to conduct field investigation and laboratory analysis sufficient to make a decision to recommend no further action, or proceed with interim action, or RI/FS scoping. Data needs will be addressed in this Track 2 study.

6. ATMOSPHERIC MODEL

An atmospheric model provides a useful means to describe the processes that affect the fate and transport of air contaminants. It requires a discussion of (1) the processes by which contaminants become airborne and (2) mechanisms by which contaminants are dispersed or transported by the atmosphere.

6.1 CHARACTERIZATION GOALS

<u>Is the air pathway recognized as a major potential exposure pathway?</u>

The atmosphere is recognized as a major potential exposure pathway for the migration of releases. Unlike other environmental media, the air pathway is characterized by short migration times, relatively large exposure areas, and a virtual inability to mitigate the potential consequences of a release after the contaminant enters the atmosphere. It also acts as both a source and sink for air contaminants.

<u>What are sources of air contaminants?</u>

The primary means by which contaminants become airborne are through the volatilization and upward migration of organics in buried waste as well as the disturbance of contaminated surface soils. These processes generate contamination as fugitive sources (i.e., they are not discharged to the atmosphere in a confined flow stream). Fugitive sources are normally associated with landfills and contaminated surface areas.

To characterize the potential fate of the contaminants, it is important to distinguish emissions as gas phase or particulate matter emissions. The emission mechanisms and mechanisms of transport associated with gas phase and particulate matter releases differ (EPA 1989a; 1988).

What are the mechanisms by which gas phase emissions may migrate from buried containers to the air pathway?

Gas phase emissions primarily involve organic compounds but may also include certain metals. Gaseous emissions can be released through mechanisms including volatilization, biodegradation, photodecomposition, and hydrolysis.

Volatilization is the most important mechanism for gas phase air releases. It occurs when molecules of a dissolved or pure substance escape to an adjacent gas layer. For wastes at the surface, this results in immediate transport into the atmosphere. Volatilization from subsurface wastes results in a concentration gradient in the soil-gas from the waste to the surface. The rate of emissions is limited by the rate of diffusion of contaminants to the soil-air interface. Therefore, volatilization is an important process for the release of gaseous emissions from both surface contamination and contaminants in the shallow subsurface.

Several processes can act to reduce the concentration of a given contaminant and, thereby, diminish its overall rate of emissions. Biodegradation may be an important mechanism in decreasing gas-phase emissions from wastes in the upper layers of the soil. Biodegradation takes place when microbes break down organic compounds via metabolic processes. The rate of organic compound decomposition depends on the structure of the compound; the metabolic requirements of the microbes; and the amount of moisture, oxygen, and nutrients available to the microbes. Photodecomposition occurs when a hazardous chemical absorbs light and reacts or when the chemical reacts because of light absorption by surrounding elements. Hydrolysis occurs when a chemical reacts with water.

What are the mechanisms by which particulate matter become airborne?

Disturbing soil can cause significant atmospheric dust. The dust generation process is caused by two basic physical phenomena: (1) entrainment of dust particles by the action of wind erosion of an exposed surface under moderate to high wind speeds and (2) pulverization and abrasion of surface materials by mechanical disturbances.

Hazardous substances, such as metals, can also be adsorbed onto particulate matter and, therefore, be transported with the inert material. The hazardous constituents of concern in a particulate release may involve constituents that are either absorbed or adsorbed onto the particulate or constituents that actually comprise the particulate. These constituents may include volatile and semivolatile organic compounds, metals, and nonvolatile toxic organic compounds.

Is wind erosion a major contributor to atmospheric pollutant loading?

Wind erosion can be a major source of fugitive dust emissions under moderate to high wind conditions. The soil erodibility factor is a function of the soil size distribution. In addition to particle size, a number of factors affect the amount of material that will become suspended by wind erosion including vegetation cover, soil erodibility, surface roughness and cloddiness (tendency to exist in clumps), surface soil moisture content, and the amount of soil surface (length) exposed to the eroding wind force. Vegetation reduces the effect of erosion by retaining the soil particles, thus, protecting the soil from the wind.

What are the effects of transport and diffusion?

Once released to the ambient air, a contaminant is subject to simultaneous transport and diffusion processes in the atmosphere. Atmospheric transport/diffusion conditions are significantly affected by meteorological, topographic, and source factors; however, topography is not a major consideration at the RWMC because of the relatively flat terrain in the region.

What are the fundamental soil characteristics that affect the generation or emissions of airborne contaminants?

Soils characteristics contribute to the rate of contaminant release. The effectiveness of a soil cover is dependent on (a) its thickness, integrity, and moisture content; (b) the soil porosity; (c) the presence of natural organics and microbes; (d) and properties and concentrations of contaminants including the vapor diffusion coefficient of the component, concentration of the component in the vapor space, and the mole fraction of each component. Short-term emissions are also dependent on the incremental changes in ambient temperature and barometric pressure.

The natural organic matter content of soil strongly influences the rate at which organics are transported through the soil (i.e., higher natural organic content retards the transport of contaminants). This is because the immobile natural organics, which have high surface areas, adsorb the organic contaminants through lipophilic interactions. The presence of microbes in the soil capable of degrading organic contaminants could also affect overall contaminant transport (EG&G, 1988).

Moisture content (or water saturation) is a measure of the amount of water in the interconnected voids; it determines if a soil layer behaves as a barrier to vapor transport or as a preferential pathway.

6.2 POTENTIAL RELEASE MECHANISMS

This section provides a brief discussion of those activities, processes, or conditions, that affect the emission of contaminants to the air pathway at the RWMC.

What are the release mechanisms contributing to the release of gaseous and liquid phase contaminants at the RWMC?

The breaching of buried waste containers in the subsurface soils of the SDA has allowed both gaseous and liquid phase contaminants to escape. The gases may percolate or diffuse upward through the soil column, to the air-soil surface interface, and eventually to the atmosphere. The volatile fraction of liquid contaminants will evaporate and undergo the same diffusion process. This process serves as the major mechanism for long-term releases of volatile organic contaminants from the buried waste containers within the SDA to the air pathway.

Surface spills or leaks of gaseous or liquid volatile contaminants are not common occurrences at the RWMC; therefore, they are an insignificant contributor to the long-term atmospheric contaminant loading. However, if a spill or leak occurred, diffusion would be a significant contributor to short-term atmospheric pollutant levels.

What mechanisms or parameters at the RWMC affect the rate of volatilization of contaminants from subsurface soil layers to the atmosphere?

Evidence has shown that volatile organics are escaping from degraded waste containers buried in the SDA and are entering the air pathway.[1] The dominant factor controlling the rate of release of volatile organics from subsurface soils to the atmosphere is the release rate of the chemicals from their containers after container degradation (Shuman et al., 1985). The rate of emissions is controlled by the rate toxic vapors diffuse through the soil cover. The diffusion rate is largely dependent on the chemical properties of the contaminant and physical and chemical properties of the soil including soil porosity, the phase transfer coefficient, liquid-phase transfer concentration of the contaminant in the soil, soil moisture, and temperature.

[1] G. S. Groenewold & P. N. Pink, 1987, Interoffice Correspondence, Sampling and Analysis of RWMC SDA Air, Soil Gas and Well Gas, GSC-63-87, December.

The depth of the soil cover affects the length of time required for contaminants to reach the soil-air interface.

Locations where pervasive fractures occur in the basalts or where structures such as wells or boreholes have been drilled for monitoring activities provide a direct pathway for volatiles to diffuse to the atmosphere. Drops in atmospheric pressure can act to accelerate the rate of release of volatiles through these penetrations and may be particularly relevant to the discussion of short-term release rates at the RWMC.

<u>Do surface spills or leaks contribute to the contaminant levels at the RWMC?</u>

In the event of a surface spill or leak of contaminants, the rate at which the volatiles will evaporate and become airborne will vary with the chemical properties of the contaminant, the age of the spill, and the depth to which the spill has penetrated soil layers. Historically, surface spills and leaks are not a contributor to volatile organic contamination at the RWMC. Venting of drums, which is done in the nearby Drum Vent Facility, may contribute negligibly to organic contaminant levels.

<u>What are the sources of particulate radioactivity at the RWMC, and which mechanisms contribute to the release of particulate contaminants to the air pathway?</u>

Particulate radionuclides may be found at both the surface and subsurface soil layers. At the SDA, subsurface soil layers around degraded buried containers exhibit elevated radionuclide levels. Surface contamination is due to a number of factors including the following:

- Contaminated subsurface soils may be exposed during retrieval operations, allowing the transport of contamination to soil surfaces. However, retrieval operations are conducted within containment structures provided with high-efficiency particulate air filtration, and the contribution to particulate radioactivity levels should be negligible.

- Recent flooding events, discussed in EG&G (1984, 1988), may have served as a means for particulate radioactivity to be transported from subsurface to surface layers. New dikes and ditches were designed to accommodate and withstand a major local runoff, even in the presence of deep snowdrifts (EG&G, 1988). Therefore, this mechanism should not serve as a source for particulate radioactivity in the future.

- Fine particulate radioactive materials may percolate to surface layers in a fashion similar to that described for gaseous emissions.

- Biotic pathways can result in the movement of contaminants from subsurface to surface layers via the life processes of plants and small animals. These processes include uptake of radionuclides by plants and the activities of small animals including burrowing, consumption of plants or soil, death, and decay.

Areas such as surface layers of the SDA where the soil is (a) fully exposed to the forces of the prevailing wind (i.e., not sheltered by nearby structures); (b) disturbed by operating vehicles and equipment; and (c) dry, erodible, and not covered with vegetation are likely to have significant particulate emissions. However, the emphasis of this study is on the fraction of total particulate loading that contains the radioactivity.

<u>Is wind erosion a significant contributor to fugitive dust emissions?</u>

Wind erosion can be a major source of fugitive dust emissions at the RWMC under moderate to high wind conditions. Fine particles may be transported over considerable distances. Features of the RWMC that contribute to the atmospheric particulate loading potential include the lack of vegetation cover, dry climate, and resultant minimal surface soil moisture content.

The surface of the SDA is relatively smooth and provides a long fetch, or length, of soil surface exposed to the eroding wind force. However, the recent addition of dirt embankments overlaying Pad A and along the perimeter of the SDA provides some break in the surface, increasing the roughness and turbulence in this localized zone. In the spring of 1984, flood control programs culminated in raising the dike surrounding the SDA by a height of between 6 and 8 ft. The dike surrounding the SDA is currently at a top elevation of 5015 ft, corresponding to actual heights above the SDA of between 2 to 15 ft. A smaller dike also surrounds the open LLW pit in the SDA. Rock riprap has been placed on both dikes to reduce erosion potential. In addition, the low-level wind flow patterns in the immediate vicinity of the RWMC are influenced by structures and local terrain features. There are several structures in the eastern area of the RWMC including the guard house, operational and office buildings, and waste storage structures in the TSA. The terrain is fairly flat in the vicinity of the RWMC; however, elevations to the west and northwest of the SDA rise as much as 60 ft within about 100 ft of the boundary of the SDA.

What RWMC operations contribute to the generation of fugitive dust through mechanical disturbance?

Any mechanical disturbance of soil will increase the fugitive dust emissions. Some of the more common mechanical disturbances at the RWMC include vehicular traffic, soil removal, recontouring, retrieval operations, and air rotary drilling.

Vehicular traffic on unpaved access roads results in fugitive dust emissions. Unpaved roads align the perimeter of the SDA and TSA and cross these areas to allow site access and monitoring. The quantity of dust emissions from a given segment of unpaved road varies linearly with the volume of traffic. Field investigations have shown that emissions depend on parameters such as average vehicle speed, average vehicle weight, average number of wheels per vehicle, road surface texture, and road surface moisture (EPA, 1985). However, water is currently being used for dust control on SDA roads. It is estimated that 3000 to 9000 gal of water are used per application (EG&G, 1988). Access roads that follow the perimeter of the SDA contain some gravel, which effectively decreases the exposed surface area and lessens the amount of dust generated.

Heavy equipment is used on a routine basis. Heavy equipment including graders, loaders, and scrapers are employed for a few hours each day and about 4 days per week.

Another periodic source of fugitive emissions at the RWMC is soil movement. Soil movement operations at the RWMC include soil removal, addition to and recontouring of soil cover, waste retrieval, and construction activities. Such operations are common at the RWMC, and recontouring is a continual operation.

Activities associated with well drilling, core drilling, and air rotary drilling (e.g., heavy equipment traffic and drilling) serve as additional mechanisms for fugitive dust generation. Air rotary drilling is scheduled to occur about 40 days during the summer of 1991. Well drilling operations employ rigs two times per week, and core drilling is done seasonally.

<u>What RWMC site characteristics affect the rate of release of contaminants to the air pathway?</u>

There are many RWMC site characteristics that affect the rate of contaminant release. Some of these factors are thickness and integrity of the soil cover, soil characteristics, properties and concentrations of contaminants, presence of natural organics and microbes, and day-to-day operations.

The RWMC employs a soil cover to isolate buried waste and provide shielding for workers. The effectiveness of the present SDA cover varies widely in soil composition, thickness, and hydraulic properties.

The moisture content of surface layers also affects the rate at which particulates enter the atmosphere because of wind erosion and mechanical disturbances. Surface water is present at the SDA only during periods of heavy rainfall and snowmelt, which generally occur in the spring. The main water sources for the SDA come from (a) flood water caused by local high ground runoff (largely prevented from entering the SDA by surrounding dikes), (b) seepage from low flow rates in drainage ditches, (c) seepage from ponded water (alleviated by the regrading project), and (d) direct precipitation (snow and rain) onto the SDA.

The light color of much of the soil column (light tan loess) implies that the soil is low in natural organic matter (EG&G, 1988).

6.3 Site Meteorology

What are the meteorological parameters that affect the release, transport, and dispersion of air contaminants from the RWMC?

Climatic conditions, temperature, precipitation, atmospheric pressure, and winds are the meteorological parameters that affect the release of air contaminants from the RWMC. Parameters affecting transport and dispersion of pollutants include wind speed, wind direction, and atmospheric stability. Data used to describe the climatic and meteorological conditions were obtained from the CFA meteorological monitoring station from 1950 to 1988 as reported in Clawson et al. (1989). The CFA monitoring station is located approximately 6 mi east-northeast of the RWMC, and it is expected to exhibit conditions very similar to that of the RWMC site. Wind speed and wind direction are also collected at a site just northeast of the TSA. Available summary data from this site are provided.

What are the regional terrain features that affect the meteorology of the site?

The INEL Site is located within the Snake River Plain, which has a generally continental climate. The average elevation is slightly more than 5000 ft above mean sea level (MSL). The local topography has a profound effect on the region's climatology. Because air masses that traverse the area must first pass over a mountain range and subsequently precipitate much of their moisture, the region receives little rainfall and is classified as semiarid. The relatively dry conditions and infrequent low clouds also allow intense solar heating during the day and rapid radiational cooling at night, resulting in a large diurnal temperature range (Bowman et al., 1984). Furthermore, local terrain features include (1) the Lost River, Lemhi, and Bitterroot-Centennial Mountain ranges, which rise to about 11,000 ft above MSL to the west of the INEL Site and are generally oriented northeast to southwest; (2) long, deep mountain valleys immediately northwest of the INEL Site oriented northwest to southeast; and (3) two buttes, located in the southeast corner of the INEL Site, rising about 1500 ft above the valley floor. These features serve to reorient and channel the prevailing westerly flow.

<u>What are the meteorological parameters necessary to assess the atmospheric dispersion potential or evaluate emissions?</u>

This section provides summary data suitable for input to atmospheric dispersion modeling or emissions estimation calculations. Additional climatological data for the INEL Site is available in Clawson et al. (1989).

<u>What temperatures are representative of conditions at the RWMC?</u>

The average annual temperature recorded at CFA is 42°F, with July being the hottest month (average 68°F) and January the coolest (average 16°F). Seasonal average temperatures for the period of record are 18.8°F winter, 41.1°F spring, 64.7°F summer, and 43.1°F fall. Monthly average temperatures range from a 38°F average nighttime low temperature to a 45°F average daytime high temperature. Extreme temperatures of -47°F to 101°F have been recorded.

<u>What is the precipitation pattern?</u>

Meteorological records for the CFA indicate that the mean annual total precipitation is slightly less than 9 in., and it is fairly well distributed throughout the year. At least 1/2 in. of precipitation falls each month, with higher values (about 1.2 in.) during the months of May and June. The maximum precipitation in a 24-hour period was 1.6 in., recorded during the month of June. Mean annual precipitation as snow is 27 to 28 in. The maximum recorded monthly snowfall was 22 in., and the maximum 24-hour snowfall totalled almost 9 in. Precipitation, in some form, occurs on the average of 28 days each year. Average snow depth during the months of December through March ranges from 2 to 4 in./mo. Snowfall extremes of 6 to 8 in. have occurred during a few 24-hour periods. Extreme snow depths have reached the 2-ft mark on several occasions.

<u>What levels of atmospheric pressure are applicable to the area?</u>

Atmospheric pressure has been measured at the CFA monitoring station. Atmospheric pressure is reported as an actual measured value (i.e., not adjusted to sea level). For the period 1950 to 1964, the average pressure was 25.06 in. of mercury (in. Hg). Extreme values have ranged from as high as 25.69 in. Hg to as low as 24.26 in. Hg. Analyses of extreme daily pressure maxima and minima indicate the development of more intense pressure systems in the winter months (mean daily pressure change of 0.2 in. Hg) when compared to summer months (mean daily pressure change of 0.1 in. Hg) (Clawson et al., 1989). The annual mean daily pressure change is 0.15 in. Hg. The maximum atmospheric pressure change in a 1-hour period is expected to be 0.1 in. Hg based on the maximum 24-hour pressure change of 0.68 in. Hg.

<u>What are the wind patterns?</u>

Seasonal and annual wind speed and wind directional frequency distributions (wind rose diagrams) for CFA are provided in Figure 6-1. From a directional standpoint, the seasonal transition brings only minimal redistribution of wind flow. A more pronounced difference is seen in the percent frequency of calm conditions, which occur most often during the winter (17%) and occur least often during the fall (6%).

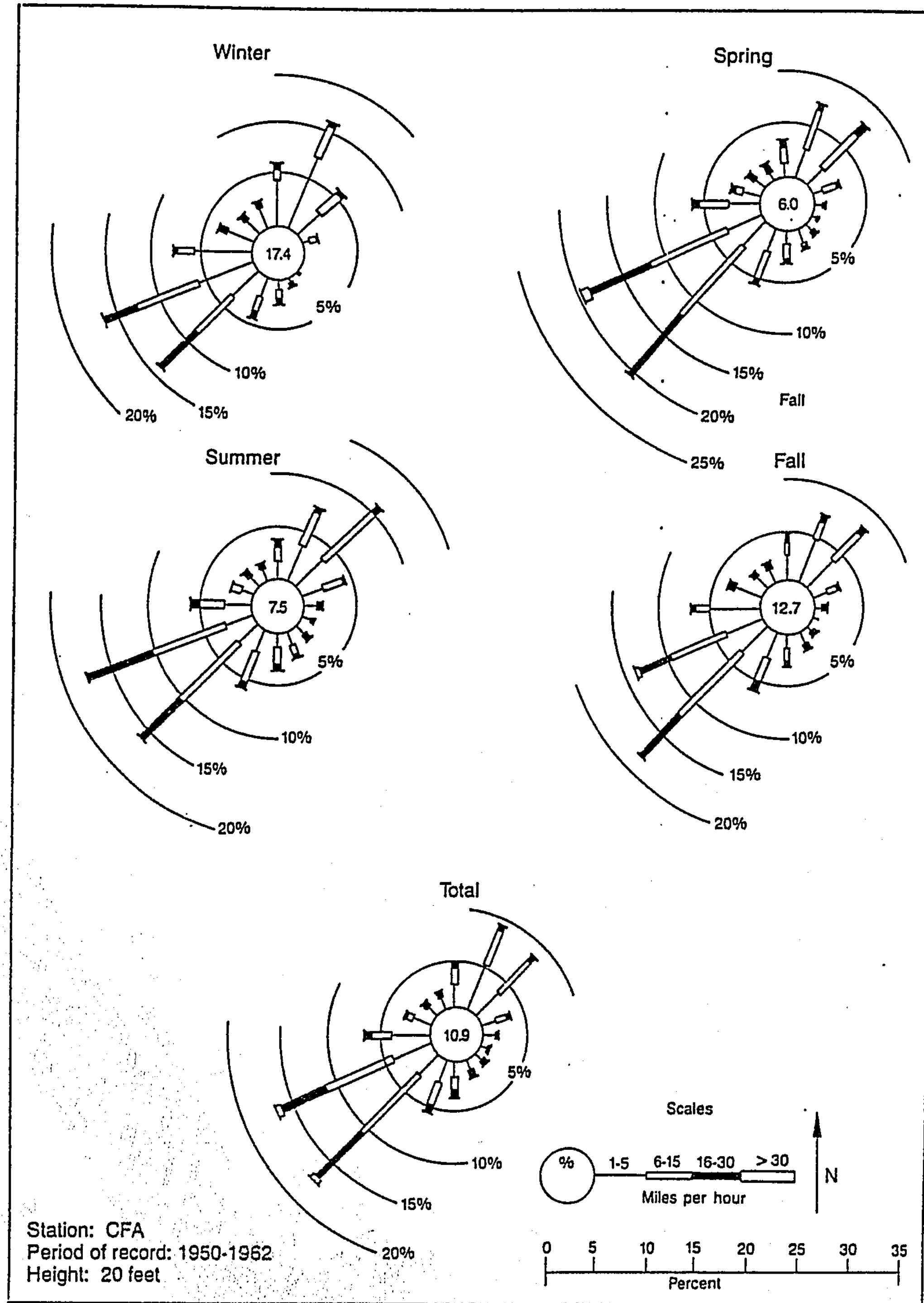

Figure 6-1. Annual and seasonal wind roses for CFA.
Source: Clawson, et al. (1989).

An annual wind rose is available from the RWMC monitoring station from 1980 to 1982 (Figure 6-2). Data were collected at the 50-ft level. On an annual basis, prevailing winds are generally from the south-southwest to west-northwest. These directions comprise about 70% of the distribution, with a predominance of winds from the southwest. A secondary maximum with winds from the northeast quadrant account for about 18% of the distribution. The primary wind directions are also associated with the strongest relative wind speeds. Winds above (13 mph) occur about 9% of the time. For comparative purposes, the annual wind rose for CFA is also provided in Figure 6-2. This distribution is similar to that of the RWMC, but it shows a slightly stronger influence of local topography, evident in the stronger bimodal distribution. The dominant directions remain from the west-southwest, with somewhat less of a westerly component, and the secondary maximum at CFA is somewhat stronger than that at the RWMC.

Average monthly wind speeds range from 5 to just over 9 mph at the 20-ft level. The maximum hourly average wind speed recorded at the 20-ft level was 51 mph with west-southwesterly flow. The maximum instantaneous wind gust measured at CFA at the 20-ft level was 78 mph. Low-level (20 ft) wind gusts $\geq$ 60 mph have been measured throughout the year.

<u>What are the parameters that describe the dispersion potential of the site?</u>

Atmospheric dispersive potential is a function of wind speed, atmospheric stability, and the depth of the mixing layer (that depth of atmosphere through which pollutants may be effectively mixed). Dispersion may be considered on a long-term basis, such as annual or seasonal, or on short-term basis, 1 hour to 1 month. This section provides a discussion of local influences that affect wind flow, long- and short-term dispersion conditions, and other parameters necessary to simulate (model) atmospheric dispersion.

<u>What local influences affect flow patterns?</u>

The low-level wind flow patterns in the immediate vicinity of the RWMC are influenced by structures and local terrain features. There are several

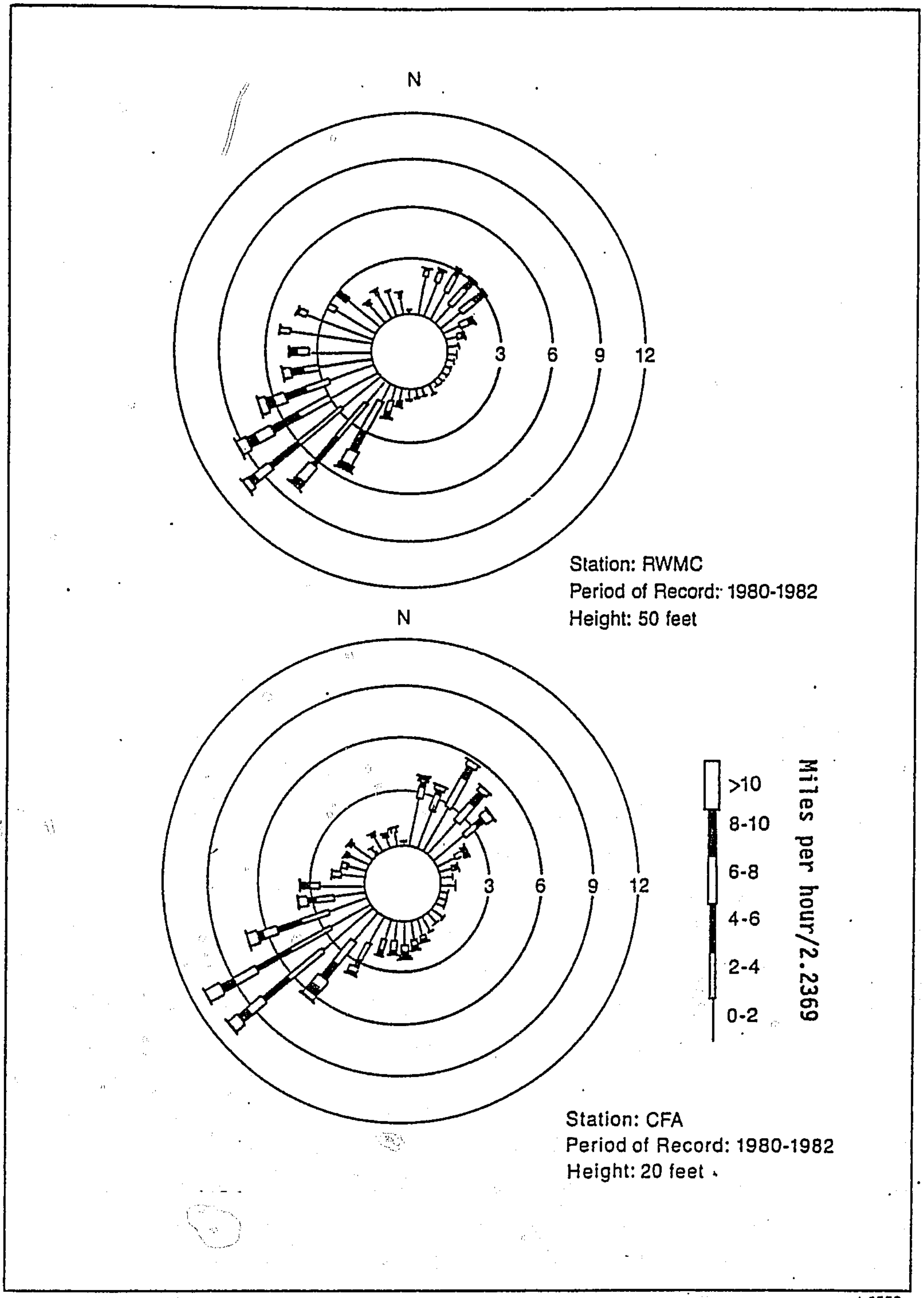

Figure 6-2. Annual wind roses for RWMC and CFA.
Source: Clawson, et al. (1989).

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structures in the eastern area of the RWMC including the guard house, operational and office buildings, and waste storage structures in the TSA. The terrain is fairly flat in the vicinity of the RWMC; however, elevations to the west and northwest of the SDA rise as much as 60 ft within about 100 ft of the boundary of the SDA.

What are the parameters that describe the long-term, average meteorological conditions?

A joint frequency distribution (JFD) of wind speed, wind direction, and atmospheric stability class has been compiled for the years 1981 through 1985 and is presented in Table 6-1. RWMC is credited as the source of the data; however, because stability data are not collected at the RWMC, it is believed that these data were collected at the CFA station. A cursory review of the data indicates that the distribution is very similar to that of CFA for other time periods. It is assumed that the data are from the 20-ft level. The data recovery rate for this period was 85%.

Various information can be gleaned from the data provided in Table 6-1. A wind speed frequency distribution has been derived and is provided in Table 6-2. The distribution is skewed toward lower wind speeds. More than 70% of the time, wind speeds are less than 11.0 ft/S. Similarly, a frequency distribution of atmospheric stability has been constructed and is provided in Table 6-3. These data indicate a high frequency of stable conditions, which occur almost 50% of the time. This combination of low wind speeds and stable conditions restrict atmospheric dispersive potential, thus, contributing to the buildup of pollutant levels. As discussed in Clawson et al. (1989), the combination of stable atmospheric conditions and higher frequency of calm winds occurs most frequently during the winter season.

Mixing heights for the area range from a low of about 800 ft during summer mornings, to more than 6500 ft during spring and summer afternoons. The average annual mixing height is approximately 3800 ft (Holzworth, 1972).

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Table 6-1. Annual joint frequency distribution data for the RWMC[a]

Stability Class	Direction	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total
A	WSC 1	7	7	22	31	24	15	12	10	24	34	39	45	30	11	6	12	329
	WSC 2	6	9	30	33	8	9	5	2	12	36	81	59	11	11	7	2	321
	WSC 3	1	1	19	26	6	2	0	1	5	29	89	39	7	4	2	3	234
	WSC 4	0	2	7	3	0	0	0	1	2	27	64	50	1	1	0	0	158
	WSC 5	0	0	0	0	0	0	0	0	0	2	9	24	1	0	0	0	36
	WSC 6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	WSC 7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B	WSC 1	98	134	106	86	59	31	28	36	56	64	120	124	124	141	68	67	1342
	WSC 2	20	138	267	138	29	16	13	14	38	123	286	175	84	55	27	27	1450
	WSC 3	5	50	150	51	7	1	6	6	12	115	358	164	26	14	11	7	983
	WSC 4	5	19	38	11	0	0	0	1	3	57	241	208	34	7	3	3	630
	WSC 5	0	3	6	1	0	0	0	1	0	11	51	96	3	0	1	0	173
	WSC 6	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	2
	WSC 7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C	WSC 1	221	323	191	99	51	44	38	47	64	91	189	240	358	411	214	162	2743
	WSC 2	36	274	491	138	36	20	22	44	62	182	503	280	170	122	48	39	2467
	WSC 3	19	64	229	45	10	2	6	19	39	171	591	347	129	33	21	16	1741
	WSC 4	9	42	64	21	2	3	2	4	12	96	331	353	97	16	0	1	1053
	WSC 5	0	2	20	4	0	0	0	1	2	17	93	179	24	2	5	2	351
	WSC 6	0	1	1	0	0	0	0	0	0	0	13	16	2	0	0	0	33
	WSC 7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D	WSC 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	WSC 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	WSC 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	WSC 4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	WSC 5	0	2	2	1	0	0	0	0	0	6	41	104	20	0	1	0	177
	WSC 6	1	4	4	2	1	0	0	2	2	13	69	167	17	0	0	0	282
	WSC 7	0	1	0	0	1	0	0	0	0	1	2	12	0	0	0	0	17
E	WSC 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	WSC 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	WSC 3	29	104	155	66	13	2	15	32	27	431	995	431	189	43	45	28	2605
	WSC 4	8	29	84	27	4	1	5	7	9	225	460	281	88	14	7	2	1247
	WSC 5	0	18	27	2	0	0	0	0	0	45	97	101	25	2	1	0	318
	WSC 6	0	5	1	0	0	0	0	1	0	1	4	11	4	0	0	0	27
	WSC 7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 6-1. (continued)

Stability Class	Direction:	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total
F	WSC 1	607	596	297	142	98	72	62	66	103	231	505	790	15[illegible]5	2083	978	643	8808
	WSC 2	177	610	466	156	72	43	66	96	83	459	1294	907	70[illegible]	434	170	116	5853
	WSC 3	3	21	25	13	0	1	1	4	4	33	101	50	22	13	5	8	302
	WSC 4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	WSC 5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	WSC 6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	WSC 7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Sum of Columns	1250	2458	2702	1096	420	262	281	395	559	2499	6625	5242	3703	3417	1620	1136	33665
	Calm Hours	117	399	828	0	0	2262 (Classes A, B, C, D, and F, respectively)											3608
	Total Hours																	37271

a. Source: Adapted from Case et al. (1990). Period of Record: 1981 - 1985. Height: See text. Data Recovery Rate: 85%.

b. WSC = Wind speed class. Wind speed classes 1, 2, 3, 4, 5, 6, and 7 represent 0.33-5.15 ft/s, 5.15-11.00 ft/s, 11.00-18.34 ft/s, 18.34-27.13 ft/s, 27.13-35.93 ft/s, and greater than 35.93 ft/s, respectively.

Table 6-2. Annual wind speed frequency distribution[a]

Midpoint of Wind Speed Class (ft/s)/3.28	Frequency (%)
calm	9.7
0.7	35.5
2.5	27.1
4.5	15.7
6.9	8.3
9.6	2.8
12.5	0.9

a. Data have been extracted from Table 6-1. The midpoint of the maximum wind speed class has been estimated to be 41.0 ft/s.

Table 6-3. Annual frequency distribution of atmospheric stability class[a]

Stability Category	Frequency (%)
A	3
B	13
C	25
D	1
E	11
F	46

a. Data have been extracted from Table 6-1.

Table 6-4. Wind speed and stability class combinations used for short-term dispersion estimates[a]

Stability Class	30-ft Wind Speed (ft/s)/3.28								
	1	2	3	4	5	8	10	15	20
A	*	*	*						
B	*	*	*	*	*				
C	*	*	*	*	*	*	*		
D	*	*	*	*	*	*	*	*	*
E	*	*	*	*	*				
F (rural only)	*	*	*	*					

a. Source: EPA (1988)

What are the parameters that describe the worst-case, short-term meteorological conditions?

Worst-case, short-term dispersion conditions are not easily quantified because they vary according to the pollutant source. For instance, stable conditions, a low mixing height, and minimal wind speed might represent the worst-case dispersion conditions for pollutants emanating from nonbuoyant or slightly buoyant sources; however, high wind speeds might be more effective in contributing to the atmospheric loading of fugitive dust from soil disturbance or wind erosion. For the most part, limited dispersion conditions are described by a combination of low wind speeds and shallow mixing layer.

6.4 Source Term Estimation Techniques

How will an RWMC source term be estimated?

This section details methodologies for estimating an atmospheric emissions source term suitable for use in determining the potential impact of airborne contaminants from the RWMC. A methodology suitable for estimating the emissions from volatile organics is provided, and the approach for determining emissions of radioactive particulates is detailed in this report. Both short-and long-term emissions estimates should be made. The short-term estimates (on the order of 1 to 24 hours) should depict scenarios (i.e., operation or conditions) leading to maximum emissions rates, and long-term values shall represent average or typical conditions likely to occur during a seasonal or annual period.

How will gaseous phase emissions be estimated?

Some of the containers holding the contaminants buried at the RWMC have deteriorated, resulting in the release of contaminants into the soil. There is evidence that organic contaminants have volatilized and are diffusing upward through the soil cover to the atmosphere.[2] To assess the role of the atmospheric pathway, it is necessary to estimate the release rate of the various constituents. A number of methods for estimating volatile releases have been proposed by the EPA for use in assessing emissions from landfill sites and are discussed in EPA (1988, 1989b). A review of these approaches and assumptions, their applicability to the RWMC, their suitability for a screening-level assessment, available information, and the ease in which they may be applied led to the determination that equations credited to the Research Triangle Institute (RTI), as described in EPA (1989b), are most suitable for characterizing volatile organic emissions from the RWMC.

<u>What is an appropriate estimation technique for volatile emissions?</u>

As discussed in EPA (1988), the RTI equation is based on an equation developed by Farmer et al. (1978) to estimate the effectiveness of various landfill cover types and depths in controlling volatile releases. This equation, based on Fick's First Law of steady-state diffusion, assumes that diffusion into the atmosphere occurs at a plane surface where concentrations remain constant. It ignores biodegradation, transport in water, adsorption, and production of landfill gas. Diffusion of the toxic vapor through the soil cover is the controlling factor. Further, it assumes that there is a sufficient mass of toxicant in the landfill so that depleting the contaminant will not reduce the emission rate.

The RTI equation also incorporates the decline in emission rate over time. The total instantaneous emission rate is a function of the total initial emission rate at the time of landfill closure. As the contaminant is released into the atmosphere, there is less contaminant in the soil, resulting in a lower release rate. The equation for calculating the instantaneous release rate takes into account the depletion of the contaminant by the use of a decay constant. The decay constant is taken as the ratio of the emission rate at the time of landfill closure to the total mass of the constituent in the landfill. It is not expected that depleting the contaminant will

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[2] Ibid., Groenewold and Pink, 1987

appreciably affect the contaminant release rate at this time or in the near future. Therefore, the following equation, which does not take into account depletion, may be used as a conservative estimation of volatile organic emissions. This estimation is reasonable as long as a significant percentage of the original contaminant mass remains, and it will result in the calculation of a higher emission rate than that predicted by the RTI instantaneous equation. Thus, the RTI equation without taking into account the effects of depletion over time is

$$E_i = E_{1i} + E_{2i} \qquad (6\text{-}1)$$

where

E_i = total initial emission rate of component i at time of closure (lbm/s)

E_{1i} = emissions associated with diffusion through the cap (lbm/s)

E_{2i} = emissions associated with barometric pumping (lbm/s).

The equation for E_{1i} is presented below.

$$E_{1i} = \frac{AD_i}{L}\left[\frac{P_A^{10/3}}{P_T^{2}}\right]\frac{(C_i - C_s)}{453.5924} \qquad (6\text{-}2)$$

where

A = landfill surface area (ft^2)

D_i = vapor diffusion coefficient of component i in air (ft^2/s)

L = depth of soil cover (ft)

P_A = soil cap air-filled porosity, (ft^3/ft^3) This parameter includes the effect of moisture on soil porosity

P_T = total soil porosity of the soil cap (ft^3/ft^3). This parameter indicates the porosity of dry soil

C_i = concentration of component i in the vapor space beneath the cap (lbm/ft^3)

C_s = concentration of component i in the air above the cap (lbm/ft^3).

In order to more readily employ the RTI equation, a couple of conservative assumptions may be employed. These include assuming the soil is completely dry (as a worst-case) and the concentration of the contaminant in the air above the soil is negligible. The latter assumption causes the term C_s to drop from the equation.

The equation for E_{2i} presented in EPA (1989b) is designed to predict the contribution of barometric pumping to the total volatile emissions rate. This term is based on changes in ambient temperature and barometric pressure with time. Over an annual period, it is expected that positive and negative contributions because of barometric pumping will tend to cancel; thus, the effects of barometric pumping may be ignored for long-term estimations. However, barometric pumping could affect short-term maximum release rates. The equation for E_{2i} is presented below.

$$E_{2i} = \frac{C_i h A E_{fw}}{453.5924}\left[\left(\frac{P_r}{P_1}\right)\left(\frac{\frac{5}{9}T_1 + 255}{\frac{5}{9}T_r + 255}\right) - 1\right]\frac{1}{(\Delta t)} \tag{6-3}$$

where

C_i = concentration of constituent i in the gas within the landfill (lbm/ft^3).

h = thickness of waste bed within landfill (ft)

A = landfill surface area (ft^2)

E_{fw} = air porosity fraction of fixed wastes (dimensionless)

P_r = reference barometric pressure (in Hg).

P_1 = final barometric pressure (in Hg).

T_r = reference landfill temperature (°F).

T_1 = final landfill temperature (°F).

t = time interval over which change in pressure and/or temperature occurs (s).

<u>What parameters must be characterized for use in the emissions rate equation for volatile releases?</u>

The use of the RTI equation to characterize emission rates of the various volatile organics that may be leaching from breached containers and diffusing to the atmosphere at the SDA requires that a number of parameters be known or estimated. It is also necessary to determine how the equation may best be employed to represent the situation. Because the various pits/pad of the SDA cannot be assumed to contain wastes in the same relative ratios (i.e., the mole fractions of the toxic components will differ), it is necessary to treat each pit or pad as a separate landfill.

The term A in the RTI equation denotes the landfill surface area in feet squared. Because the emissions from each pit are to be predicted independently, it would not be appropriate to use the entire area of the SDA. Instead, the area of each individual pit/pad should be used. These areas have been estimated from scale drawings of the RWMC and are provided in Table 6-5. The areas of the trenches are not provided because they could not be determined from the scale drawings.

Table 6-5 Estimation of pit areas at the SDA[a]

Pit	Shape	Length & Width Dimensions (ft)	Projected Area (ft)
1	Rectangle	100 x 400	40,000
2	Trapezoid (See note b)	1000 x 250/50	110,000
3	Parallelogram	125 x 400	50,000
4	Rectangle	125 x 950	119,000
5	Trapezoid	350 x 200/450	114,000
6	Trapezoid	125 x 425/475	56,250
7	See note c		
8	Rectangle	75 x 375	28,125
9	Parallelogram	100 x 400	40,000
10	Trapezoid	100 x 1150/850	100,000
11	Trapezoid	100 x 225/250	23,750
12	Parallelogram	100 x 250	25,000
13	Triangle	125 x 400	25,000
14	Triangle	50 x 1000	25,000
15	Trapezoid	100 x 925/900	91,250
16	Trapezoid	475 x 25/50	21,500
17	Rectangle	200 x 300	60,000
18	Rectangle	200 x 300	60,000
19	Rectangle	200 x 300	60,000
20	Rectangle	200 x 300	60,000
Acid Pit	Rectangle	200 x 100	20,000
Pad A	Rectangle		

a. The areas of the pits were calculated by assuming pits are simple geometric shapes. The dimensions of the pits are simple geometric shapes. The dimensions of the pits were estimated from a scale drawing (EG&G No. 416511) and rounded to the nearest 25-ft interval.

b. Pit number 2 is a trapezoid surrounding Pit Number 1. The area of Pit Number 1 is subtracted from the trapezoid to get the area for Pit Number 2.

c. The boundary of Pit Number 7 could not be determined.

The term L in the RTI equation represents the depth of the cover soil in feet. This term affects the rate of emissions because increased soil depth will increase the vapor path through which the contaminants must diffuse. The depth of the soil cover should be determined for each pit before estimating emissions from the pit.

The parameters P_A and P_T in the RTI equation are the air-filled soil porosity and the total soil porosity, respectively. The total soil porosity is the porosity of dry soil; air-filled soil porosity reflects soil moisture. The presence of water in a soil cover increases the geometric complexity of the soil pore system (because water adheres to soil particles), thus, effectively increasing the vapor path and decreasing the flux rate of volatile compounds through the soil cover by effectively decreasing the porosity (EPA, 1980). Farmer et al. (1978) suggests, however, that when designing a landfill cover, only the total porosity value be used (EPA, 1980); therefore, the design will consider worst-case (i.e., dry) conditions. This is accomplished by substituting P_T for P_A in the equation. The result is that the porosity term reduces to $P_T^{4/3}$ in the RTI equation.

The porosities of a representative group of soil samples from the SDA are presented in Table 2-11 of the RCRA Facility Investigation Workplan (EG&G, 1988). The porosities from samples taken at Wells 92, 94, and 95 were measured as 34.3, 30.5, and 41.0%, respectively. Other samples taken at Boreholes W6, W9, and W24 were analyzed in November 1989, by Daniel B. Stephens and Associates, Inc. for EG&G Idaho, Inc.[3] The results indicated that the soil porosity at Borehole W6 was 48% at a depth of 1.7 to 2.7 ft and 45% at a depth of 11 to 11.8 ft. The soil porosity at Borehole W9 was 48% at a depth of 6 to 7 ft and also 48% at W24 at a depth of 7.4 to 8.3 ft.[4] The cover at the SDA is regraded often; therefore, it is likely the soil porosity is not constant. It is recommended that the soil porosity of each individual

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[3] DBS & Assoc. (Daniel B. Stevens and Assoc. Inc.), 1989, <u>Laboratory Analysis of Soil Hydraulic Properties from EG&G BEP-RWMC Project.</u> Albuquerque, NM.

[4] Ibid., DBS & Assoc.

pit be determined. However, if this is not possible, the available data suggest that a value of 50% would be a conservative estimate.

The vapor diffusion coefficient in air, D_i, is a property of the contaminant and indicates the speed at which a contaminant diffuses in the air. This property also plays a role in how quickly the contaminant diffuses through the soil media. The diffusion coefficients are calculated using a methodology proposed by Fuller (Perry and Chilton, 1973) as detailed in EPA (1988). Diffusion coefficients for contaminants that have been found at the RWMC (EG&G, 1988) have been calculated using Fuller's Method and are provided in Table 6-6.

Calculating the diffusion coefficient requires the input of temperature. This is necessary because as the temperature increases, the speed of the contaminant molecule increases, which causes the diffusion rate to increase. The diffusion coefficients are presented in Table 6-6 for 41 and 68°F. The value of 41°F represents the average annual temperature at the INEL site (Clawson et al., 1989); the diffusion coefficient associated with this temperature should be used to estimate average emissions. The value of 68°F is the average July temperature for the CFA (Clawson et al. 1989); the diffusion coefficient at this temperature should be used to predict maximum short-term emissions. If the diffusion coefficients are required for any component or temperature not given in Table 6-6, the coefficients can be calculated using guidance in EPA (1988).

The value of C_i is the concentration of the component i in the soil vapor space. Because the amounts of contaminants differ from one pit to the other, it is important to determine the concentration of the component for each pit. This concentration is the product of the saturation vapor concentration of the component (C_{si}) and the mole fraction (M_i) of the component in the waste ($C_i = C_{si} \times M_i$). The mole fraction is given as the number of moles of component i per total number of moles of all components in the waste, or essentially, the fraction of the contaminant in the volatilizing gas. This is an important consideration if many constituents are escaping from a container because the various contaminants are essentially competing for the same vapor space.

Table 6-6. Diffusion coefficients of organic compounds detected at the SDA

Compound	Formula	Molecular Weight	Atomic Volume	Vapor Pressure at 20°C (in Hg) x 25.4	Diffusion Coefficient (ft^2/sec) x 918.3 at 41°F	Diffusion Coefficient (ft^2/sec) x 918.3 at 68°F
Carbon tetrachloride	CCl_4	154	94.5	90	.07262	.07962
Chloroform	$CHCl_3$	120	76.89	160	.08081	.08860
Dichlorodifluoromethane	CCl_2F_2	102	105.5	42.50	.07207	.07901
1,1 dichloroethane	$C_2H_4Cl_2$	99	75.96	180	.08286	.09084
1,1 dichloroethylene	$C_2H_2Cl_2$	97	106.96	500	.07206	.07900
Tetrachloroethane	C_2Cl_4	166	111.00	14	.06747	.07397
Toluene	C_7H_8	92	111.14	22	.07133	.07821
1,1,1 trichloroethane	$C_2H_3Cl_3$	133	97.44	100	.07259	.07958
Trichloroethylene	C_2HCl_3	131	93.48	60	.07396	.0811
1,1,2 trichlorotrifluoroethane	$C_2Cl_3F_3$	187.5	166.5	270	.05606	.06146

a. Source for vapor pressure: Verschueren (1983).

The saturation vapor concentration is a function of the chemical properties of the contaminant and can be determined by the following equation (EPA, 1980):

$$C_{si} = 62.4298 \frac{(p)(MW_i)}{R(T+460)} \tag{6-4}$$

C_{si} = saturation vapor concentration of component i (lbm/ft^3)

p = vapor pressure of the component (in Hg)

MW_i = molecular weight of component i (lbm/mole)

R = molar gas constant (21.8492 in mHg ft^3/mole°R)

T = absolute temperature of the component i (°F).

The vapor pressure and molecular weights for contaminants found at the SDA are presented in Table 6-6. The vapor pressure for the compounds is presented for 68°F (Verschueren, 1983). The vapor pressure for other relevant temperatures could not be found, but it is sufficient to use the value at 68°F because this represents a conservative calculation.

The temperature of the component is also needed to determine the saturation vapor concentration. Temperatures were recorded at various soil depths between 2 and 11 ft (Davis and Pittman 1990). These temperatures ranged from 30 to 68°F. Data were taken 10.5 ft from the vertical culvert at the east test trench at noon during 1987. While it would be preferable to use site-specific data from the SDA, it is not expected that these temperatures will vary significantly.

To predict emissions because of barometric pumping, some additional inputs are required. The variables P_r and T_r in Equation (6-3) refer to the atmospheric pressure and temperature of the air above the soil cap at the beginning of the time period that the atmospheric changes are taking place, while P_1 and T_1 in Equation (6-3) are the pressure and temperature after the atmospheric changes have occurred. Delta t is the time period, in seconds, over which the atmospheric changes take place. These values can be used to determine the short-term increase in emissions rate because of an expected maximum change in these values or representative typical short-term atmospheric changes.

Two other terms for which values are not known are h, the thickness of the waste bed within the landfill and E_{fw}, the air porosity fraction of fixed wastes. The thickness of the waste bed is the average distance, in feet, from the bottom of the waste pit to the top of the buried wastes. It may be possible to obtain this value from waste burial records. The air porosity fraction of fixed wastes represents the porosity of the interval between the bottom of the waste pit and the top of the buried waste. It is not expected that this value is available; therefore, a conservative estimate may have to be used.

How will particulate matter emissions be estimated?

Data from the composite analysis of RWMC air samples during the past 4 years indicate that suspension of surface contamination at the RWMC is not a pathway that has contributed measurably to airborne particulate radioactive contamination. The detected isotopic concentrations are consistently two to three orders of magnitude below applicable derived concentration guides (DCGs), reference values provided by the U.S. Department of Energy (DOE) for conducting radiological environmental protection programs at Operational DOE facilities and sites for the public, and do not differ significantly from airborne concentrations detected at control sample locations where no mixed waste was buried (Tkachyk 1988, 1989, 1990; EG&G 1990). This suggests that current soil monitoring, contouring, and other surface contamination control measures are adequate to continue supporting a similar level of operational activities at the RWMC, given no major changes in the parameters that impact this pathway. Additionally, it is not expected that the biotic pathway (i.e., plant root uptake or the burrowing of small mammals) will contribute to the migration and ultimate release of radioactive particulates to the air pathway for some time because of the depth and maintenance of the soil cover (Case et al., 1990)

Nonetheless, certain conditions such as high winds and dry soils and certain operational activities (see characterization goals discussion) may significantly increase either soil contamination levels or fugitive dust generation. These should be analyzed for their potential effects on a case-by-case basis.

<u>What are the sources of particulate matter emissions to be estimated?</u>

Mechanical disturbance of granular material exposed to the air causes significant atmospheric dust. This dust is termed fugitive because it is not discharged to the atmosphere in a confined flow stream. Fugitive dust at the RWMC arises because of wind erosion or mechanical disturbances such as vehicular traffic, contouring operations, waste retrieval operations, and other soils handling activities.

<u>How are air emissions of particulate matter because of wind erosion quantified?</u>

Emissions from wind erosion across cleared or unprotected soil surfaces have been estimated by use of the U.S. Department of Agricultures (USDA) wind erosion equation. The wind erosion equation was originally developed to estimate soil losses from cropland, but it has been adapted (PEDCo, 1976) to predict the suspended particulate fraction of total soil losses and has been applied to evaluate exposed soil surfaces other than cropland.[5]

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[5] (PEDCo - Environmental Specialists, Inc.), 1976, <u>Evaluation of Fugitive Dust Emissions From Mining, Task 1. Report: Identification of Fugitive Dust Sources Associated with Mining</u>, Prepared for U.S. EPA, Industrial Environmental Research Laboratory, Cincinnati, Ohio, April.

The modified wind erosion equation is as follows:

$$E = (a)\ (I)\ (K)\ (C)\ (L')\ (V') \tag{6-5}$$

where

E	=	emission factor (ton/acre-yr)
a	=	percentage of total wind erosion losses that would be measured as suspended particulate (dimensionless)
I	=	soil erodibility (ton/acre-yr)
K	=	surface roughness factor (dimensionless)
C	=	climatic factor (dimensionless)
L′	=	unsheltered field width factor (dimensionless)
V′	=	vegetative cover factor (dimensionless)

The variables a and I depend on soil type. Commonly used values are listed below.

Surface soil type	a	I, ton/acre-year
Rocky, gravelly	0.025	38
Sandy	0.010	134
Fine (silt)	0.041	52
Clay loam	0.025	47

The soil at the RWMC has been characterized as a mixture of sand, silt, and clay.[6] The particular soil type at the SDA should be determined and the appropriate values for a and I (possibly based on the relative fractions of each soil type) should be used in the wind erosion equation.

Values for K can vary between 0.5 and 1.0; 0.5 denotes a surface with deep furrows and ridges, which protects against wind erosion, and 1.0 denotes a

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[6] Ibid., DBS & Assoc, 1989

smooth erodible surface. Because the soil at the SDA is not plowed or roughened during regrading, a K factor of 1.0 should be used in the wind erosion equation.

Climatic factors C for use in the equation have been determined for most parts of the country by USDA.[7] The suitable value for this region is 0.1.

The value of the field width factor (L′) depends on the distance of unprotected field in the direction of primary wind flow. For reclamation areas in irregular terrain where the field width is only about 1000 ft, the L′ value is approximately 0.7. For exposed areas like the RWMC with greater than a 2000 ft wide unprotected area, a field width value of 1.0 is appropriate. The vegetation cover factor depends on the effectiveness of plant life in protecting (adhering or stabilizing) the soil surface. Because the SDA is regraded often, no vegetation cover exists and the value of "V′" is 1.0.

Given the above assumptions, the fugitive dust because of wind erosion is approximately 0.12 tons per acre-yr. Because the SDA is approximately 88 acres in area, the fugitive dust because of wind erosion is approximately 11 tons/yr.

<u>How are air emissions of particulate matter because of mechanical disturbances quantified?</u>

Fugitive dust because of mechanical disturbances results from two major sources at the RWMC: vehicle traffic and soil movement. Some of the soil movement activities include cover soil removal or addition, recontouring of the cover soil, waste retrieval, and construction. However, waste retrieval is accomplished in enclosures; therefore, fugitive dust emissions because of these operations are assumed to be negligible.

Typical ranges of emission factors for vehicle traffic and soil movement are presented in Table 6-7. The values presented in Table 6-7 should be used

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[7] Ibid., PEDCo, 1976

for screening purposes only. If more precise estimates are required, the equations presented in Table 21 of EPA (1989b) should be used.

An estimate for fugitive dust resulting from heavy construction operations is presented in Section 11.2.4 of EPA (1985). According to this reference, an approximate emission factor for construction operation is 1.2 tons/acre of construction per month of activity. The estimate is based on field measurements of suspended dust emissions from apartment and shopping center construction projects. This value applies to construction operations with (a) medium activity level, (b) moderate silt content (about 30%), and (c) semiarid climate.

<u>What methodologies are applicable for use in estimating the contaminant fraction of suspended particulates?</u>

The above described methods for estimating fugitive dust levels will provide appropriate screening-level emission factors for total suspended particulates. Once total suspendible dust generation levels have been calculated, the amounts of hazardous substances expected to enter the atmosphere in fugitive dust can be projected using either of the following approaches (EPA, 1988):

- Multiply the amount of dust generated by the weight percent of the toxic substance in soil or waste. This approach does not take into account factors relating to such aspects as particle size or adsorption potential, which can affect the amount of contaminant actually entering the atmosphere as dust.

- Multiply the estimates for total dust generation by percentages (by weight) of the substances of concern in actual fugitive dust samples obtained with onsite air monitoring. This approach takes into account those chemical-specific and site-specific factors that affect release of contaminated dust in the field.

Table 6-7. Typical ranges of emission factors

Activity	Particulate Matter[a]	Notes
Excavation	0.004-0.172 lbm/ton	Overburden
	0.030-0.44 lbm/ton	Topsoil
<u>Transport</u>:		
Unpaved roads	2.9 lbm/VMT	Estimated from equation
Dry industrial paved roads	0.049-0.33 lbm/VMT	Medium and heavy vehicles
Heavily-loaded industrial roads	0.205-0.26 lbm/VMT	Light duty vehicles
Dumping	0.010-0.10 lbm/ton	Continuous
	0.030-0.06 lbm/ton	Batch
	0.050-0.32 lbm/ton	Diatomite
<u>Storage</u>:		
Inactive Piles	0.27 $lbf/in^2/d$ 0.11 lbm/ ton	Wind erosion only
Active Piles	1.1 $lbf/in^2/d$, 0.42 lbm/ton	8-12 h/d activity
Active/Inactive Piles	0.8 $lbf/in^2/d$, 0.32 lbm/ ton	5 active d/week
Grading	0.012 lbm/ton	Overburden replacement
TSP	11.9 lbm/hr	Grading spent diatomite
4.92 E-5 to 8 E-5	5.5 lbm/hr	Grading spent diatomite
<8 E-6	0.07 lbm/hr	Grading spent diatomite
<4.92 E-5	5.7 lbm/hr	Grading spent diatomite

a. Units are pounds-mass per ton of soil moved, pounds-mass of emissions per vehicle mile traveled (VMT), pounds-mass of emissions per square inch of storage pile surface area per day, or pounds-mass of emissions per hour of grading.

What parameters must be characterized for use in the emissions rate equation for particulate matter releases?

Application of the above described screening-level equations and emission factors for estimating particulate matter releases requires that surface soil types be identified. This is required to assign appropriate values for a, the portion of total wind erosion losses that would be measured as suspended particulate, and I, soil erodibility.

6.5 ATMOSPHERIC TRANSPORT MODEL DESIGN ANALYSIS

How can an air quality dispersion model be used in the assessment of fate and transport of air pollutants at the RWMC?

Air quality dispersion models represent powerful tools in assessing pollutant concentrations, and in evaluating compliance with atmospheric pollutant standards. In assessing the resultant downwind concentrations of emissions of either organic volatiles or fugitive dust from RWMC sources, an air quality dispersion model will provide a suitable means to predict relative downwind concentrations. The EPA has recommended a number of air quality dispersion models for the simulation of various meteorological, release, and receptor conditions. One model that is particularly applicable to this situation is the Industrial Source Complex (ISC) model (EPA, 1987a). It is part of EPA's (User's Network for Applied Modeling of Air Pollutants) UNAMAP series, which are suggested by EPA to provide a consistent basis for selecting the most accurate models and data bases for use in air quality assessments. The ISC model is 1 of 10 models identified by EPA as suitable for regulatory applications. In particular, the ISC model is recommended by EPA for simulations involving complex sources, that include area and fugitive dust sources, and it is suitable for use in both initial and second-level screening of source impacts (EPA, 1986a; 1986b). As such, it is expected to provide conservatively high estimates. In addition, it can be run in a regulatory default mode suitable for regulatory compliance applications.

It is recommended in a screening analysis that the model should be employed and model inputs developed to provide a conservative estimate of downwind ground-level contaminant concentrations. The EPA recommends that modeling protocol be discussed with the EPA regional meteorologist for concurrence before initiating a modeling study (EPA, 1986a; 1986b).

6.6 FEDERAL FACILITY AGREEMENT OPERABLE UNIT STUDY

The process by which contaminants become airborne, and mechanisms of transport, discussed in this section, will be used as reference for further study of Operable Unit 7-04 Air Pathway. This operable unit is described as the affected air surrounding the RWMC. The objective of this study is to determine any contaminant release, or potential for release, of radioactive and non-radioactive hazardous substances to the air from the RWMC. A Preliminary Scoping Track 2 study will commence in FY 92 to conduct field investigation and laboratory analysis sufficient to make a decision to recommend no farther action, or proceed with interim action, or RI/FS scoping. Data needs will be addressed in this Track 2 study.

7. BIOTIC MODEL

7.1 CHARACTERIZATION GOALS

The INEL has been the focus of research aimed at understanding the complex ecological interactions in this scrub-steppe biome and the role that specific organisms play in the uptake and transport of radionuclides. Since the 1950s, both abiotic and biotic factors have been investigated in various ecosystems and taxa at the INEL. A variety of plants, insects, small mammals, game and top level carnivores have been investigated in aquatic and terrestrial ecosystems to determine their abundance, their ecological role at the INEL, and their relative importance in radionuclide uptake and transport. This section (a) identifies the ecological components of the INEL, specifically the RWMC; (b) provides a conceptual example of radionuclide uptake and biotic transport mechanisms by trophic levels for major ecosystems at the INEL; and (c) identifies gaps in the data base compiled at the INEL for biotic transport pathways.

<u>What constitutes an ecosystem</u>?

An ecosystem is the fundamental unit in ecology that consists of complex interactions between biotic and abiotic factors. As defined in Odum (1971), an ecosystem is "any unit that includes all of the organisms (i.e., the community) in any given area interacting with the physical environment so that a flow of energy leads to clearly defined trophic structure, biotic diversity, and material cycles (i.e., an exchange of materials between living and nonliving parts) within the system is an ecological system or ecosystem." Ecosystems consist of several basic components including (a) inorganic substances involved in material cycles; (b) organic compounds (e.g., proteins and carbohydrates) that link biotic and abiotic factors; (c) climatic regime; (d) producers (autotrophs); (e) macroconsumers (heterotrophs) that ingest other organisms or particulate organic matter; and (f) microconsumers such as saprophytes and detritivores that are important in the breakdown and recycling of nutrients from dead and decaying materials (Odum, 1971). Macroconsumers feed on primary consumers, and in some cases, tertiary consumers that occupy the top of food chains.

At the INEL, over 20 distinct vegetation communities support a variety of wildlife that comprise the terrestrial biota. More specifically, the SDA contains flora and fauna characteristic of a scrub-steppe biome. A representative food web consisting of several trophic levels at the SDA is indicated in Figure 7-1.

<u>What are the benefits of an ecosystems approach</u>?

An ecosystems approach would be useful in tracking the uptake and transport of radionuclides across trophic levels and ultimately to human receptors. At the SDA, a variety of burrowing and deep rooting species are potential pathways of subsurface intrusion of shallow burial sites and transport of radionuclides to the surface. For example, deer mice, Townsends' ground squirrels, and harvester ants are known to penetrate soil covers at the SDA and transport radionuclides to the surface (Figure 7-1). In addition, deep rooting plants such as big sagebrush and crested wheatgrass can penetrate soils at the SDA and transport subsurface radionuclides to primary consumers such as deer mice and sage sparrows.

Once on the surface, radionuclides transported by these organisms provide an additional source of airborne and groundwater contamination that could be assimilated by a variety of consumers including humans. Levels of radionuclides slightly above background have been detected in tissue samples from SDA small mammals, harvester ants, deep rooting plants, and top-level carnivores. Top-level carnivores such as the coyote and rough-legged hawk may feed on contaminated small mammals that have penetrated subsurface pits or have fed on aerial portions of contaminated deep rooting plants. Game species such as sage grouse, pronghorn, and mourning dove are also known to transport radionuclides by consuming contaminated deep rooting plants at the SDA. In addition, a variety of detritivores can potentially transport radionuclides through ingestion of contaminated coyote feces or dead animals. Thus, each

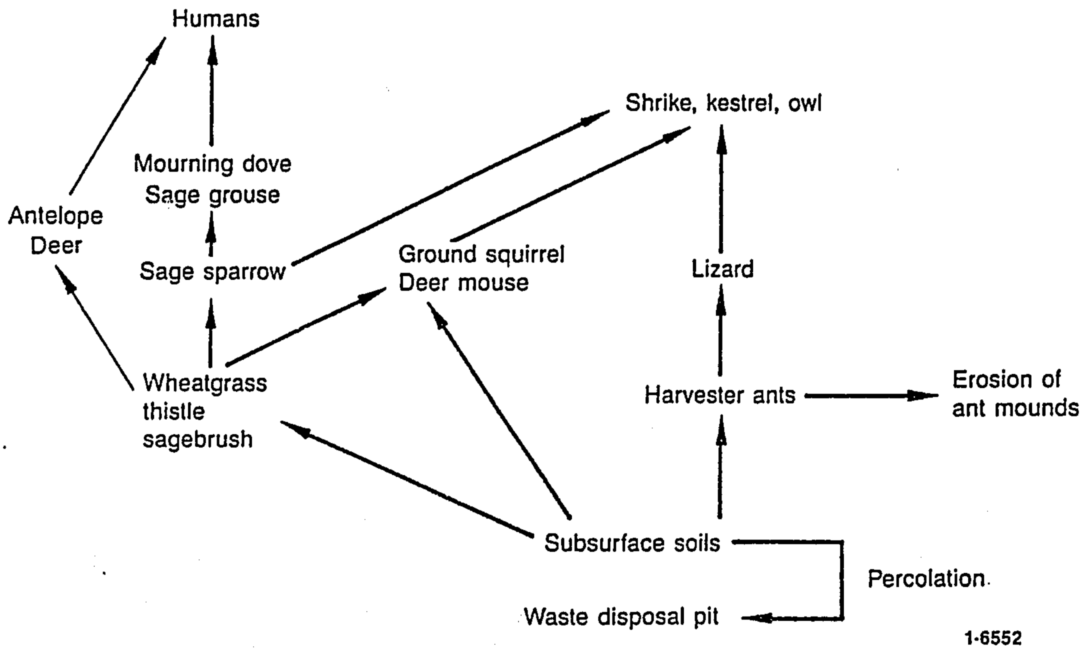

Figure 7-1. Hypothetical ecological vectors as radionuclide transport pathways at the Subsurface Disposal Area.

trophic level is potentially involved in uptake of radionuclides and transport by key vectors to other trophic levels.

7.2 SUMMARY AND DESCRIPTION OF THE INEL ECOSYSTEM

7.2.1 Background

What is the history of the INEL Site ecosystem?

In 1975, the INEL was dedicated as one of five DOE National Environmental Research Parks (NERPs). It is an outdoor laboratory used to study ecological relationships and the effects of man's activities on natural systems. In addition, it provides a unique setting for scientific investigation because the public has been excluded from much of the area for the past 30 years. Ecological data collected from the Idaho NERP provide a basis for analyzing environmental changes over time and assessing the effect of man's influence on the environment.

7.2.2 Flora

What types of flora are located at the RWMC?

Extensive surveys of INEL site vegetation were carried out in 1952, 1958, and 1967, using 150 permanent transects established and maintained for this purpose (Harniss and West, 1973.) Vegetation has also been described in McBride et al., (1978) and Jeppson and Holte (1978). The common and scientific names for the flora discussed here are presented in Table 7-1. Only the common names will be used in this section.

The 500,000 acres of the INEL Site are located within an ecosystem that is dominated by big sagebrush, bluebunch wheatgrass, Indian ricegrass and perennial forbs. Most of the trees on the INEL Site are scattered along the Big Lost River and in the Twin Buttes area (McBride et al., 1978; Cholewa and

Table 7-1. Representative plant species occurring at the INEL Site

Common Name	Scientific Name
Cactacea (Cactus family)	
Pin cushion cactus	Corypantha missouriensis
Prickly pear cactus	Opuntia
Chenopodeacea (Goosefoot family)	
Winterfat	Ceratoides lanata
Shadscale saltbush	Atriplex confertifolia
Nuttall saltbush	Atriplex nuttalli
Compositae (composite or Sunflower family)	
Big sagebrush	Artemisia tridentata
Low sagebrush	Artemisia arbuscula
Rabbitbrush	Chrysothamnus spp.
Hawksbeard	Crepis spp.
Yellow salsify	Tragopogon dubius
Wild lettuce	Lactuca serriola
Thistle	Cirsium spp.
Gray horsebrush	Tetradymia canescens
Dandelion	Taraxacum officinale
Cruciferae (Mustard family)	
Bladder pod	Lesquerella Kingii
Cupressaceae (Cypress family)	
Juniper	Juniperus spp.
Cyperaceae (Sedge family)	
Sedge	Scirpus spp.
Grameneae (Grass family)	
Bluebunch wheatgrass	Agropyron spicatum
Thickspike wheatgrass	Agropyron dasystachyum
Crested wheatgrass	Agropyron cristatum
	Agropyron desertorum
Indian ricegrass	Oruzopsis hymenoides
Needle-and-thread grass	Stipa comata
Squirreltail grass	Sitanion hystrix
Blue grass	Poa spp.
Great Basin wild rye	Elymus cinereus
Wild barley	Hordeum jubatum
Cheatgrass	Bronius tectorum

Table 7-1. (continued)

Common Name	Scientific Name
Hydrophyllaceae (Waterleaf family)	Phacelia inconspicua
Phacelia	
Juncaceae (Rush family)	
Rush	Jancus spp.
Leguminoseae (Pea family)	
Painted milk vetch	Astragalus ceramicus
Wooly pod milk vetch	Astragalus purshii
Milk vetch	Astragalus gilviflorus
Milk vetch	Astragalus kentrophyta
Polygonaceae (Buckwheat family)	
Oxytheca	Oxytheca dendroidea
Salicaceae (Willow family)	
Willow	Salix spp.
Plains cottonwood	Populus deltoides
Scophulariaceae (Figwort family)	
Speedwell	Veronica sp.
Typhaveae (Cattail family)	
Cattail	Typha latifolia

Henderson, 1983). The INEL study area consists of a mosaic of over 20 vegetation communities and almost 400 plant species.

Sagebrush provides the largest habitat on the INEL Site and is important as a source of water and food to many animal species that inhabit the area. Vegetation in low-lying areas and along playa borders consists primarily of alkaline-tolerant species including shadscale saltbush, nuttal saltbush, and winterfat. Prickly-pear cactus, painted milk vetch, and skeletonweed are common in sandy areas in the north. Willows, baltic rush, and povertyweed grow along the Big Lost River channel.

Juniper communities grow in the northwest and southeast portions of the INEL Site (Figure 7-2). These communities are generally associated with increasing elevation and are found near East and Middle Buttes and in the foothills of the Lemhi Range. Although these communities are restricted in distribution, they provide important nesting habitat for raptors (Craig, 1979) and are used by a variety of passerine birds.

At the RWMC, most of the SDA has been seeded with crested wheatgrass. These seedings have flourished since the 1950s when they were planted on disturbed sites (Marlette and Anderson, 1983). Russian thistle, summer cypress, and halogeton (invader species) are found on disturbed sites not seeded with wheatgrass. A grass community dominated by Indian ricegrass also occurs in a relatively narrow band near the eastern border of the INEL Site. Other plants observed within the SDA include threetip sage, tansy mustard, common dandelion, bushy birdsbeak, cheatgrass, rabbitbrush, desert parsley, longleaf phlox, gray horsebrush, hoary false yarrow, and goatsbeard.

Knowledge of the rooting depth of SDA vegetation is important in evaluating which plants should be used for reseeding and which should be monitored for radionuclide concentrations. One SDA study comparing radionuclide uptake by crested wheatgrass (rooting depth 30 in.) with that by Russian thistle (rooting depth 3 to 15 ft) showed higher radionuclide concentrations in the deeper-rooted species (Arthur, 1982). Examples of other

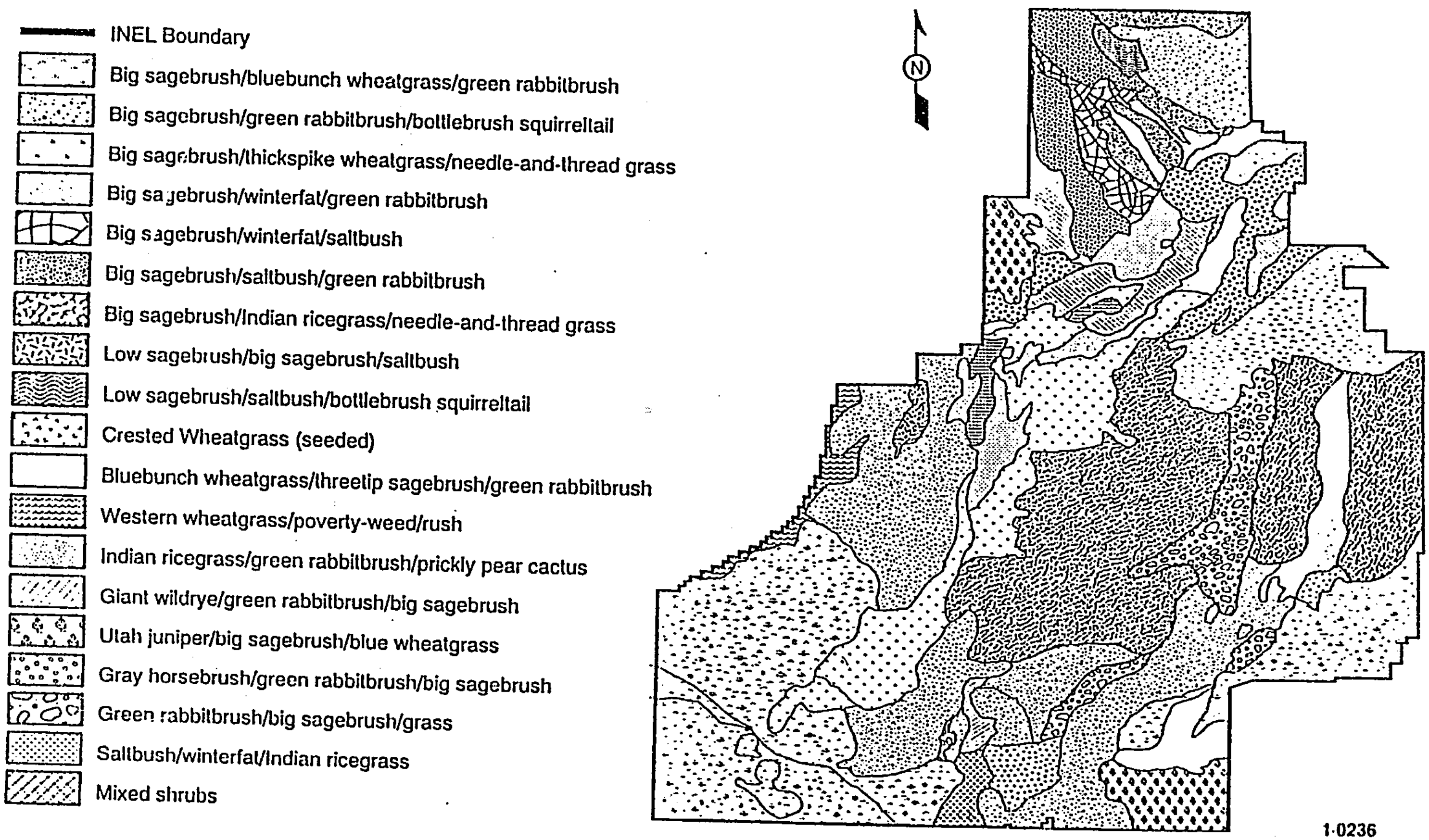

Figure 7-2. INEL vegetation map (McBride et al., 1978).

deep-rooting species are rabbitbrush and sagebrush. General examples of shallow-rooting plant types are grasses and annual forbs.

Irrigated farmland intersperses with sagebrush habitats and borders much of the INEL Site. Most farmland is planted alfalfa, but fields of wheat, potatoes, and irrigated pasture are also planted (Gates, 1983). These areas are inhabited extensively by a number of passerine species as well as by four species of game birds: mourning doves, ring-necked pheasants, gray partridge and sage grouse. About 37% of the INEL Site is grazed by cattle and sheep; however, no grazing occurs on the RWMC (see Figure 7-3).

Aquatic habitat on the INEL Site consists of evaporation and percolation ponds, which are located near the Big Lost River and associated sinks and spreading areas. Plains cottonwood is the primary riparian species that is sparsely distributed along the river flood plain.

A survey of rare plants on the INEL Site was initiated in 1981. To date, the survey has identified the following: painted milk vetch and wooly pod milk vetch (formerly under Federal review for endangered or threatened status); corpyphantha, large-flowered gymnosteris, bladder pod, and oxytheca (on the Idaho State Watch List); and thistle milk vetch, which was previously unknown to occur in Idaho[a]; (Cholewa and Henderson 1983). Plants on the Idaho State Watch List are considered rare and of special interest in Idaho; however, their populations are not in jeopardy, and they may be common elsewhere. Additional information is presented in Bowman et al. (1984) and Cholewa and Henderson (1983).

Total vegetative biomass in the SDA was estimated as 80,000 lb; crested wheatgrass and Russian thistle comprised 60,000 and 17,900 lb of the vegetative biomass, respectively (Arthur, 1982).

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[a] Unpublished research results from State of Idaho rare plant meeting, March 25, 1989.

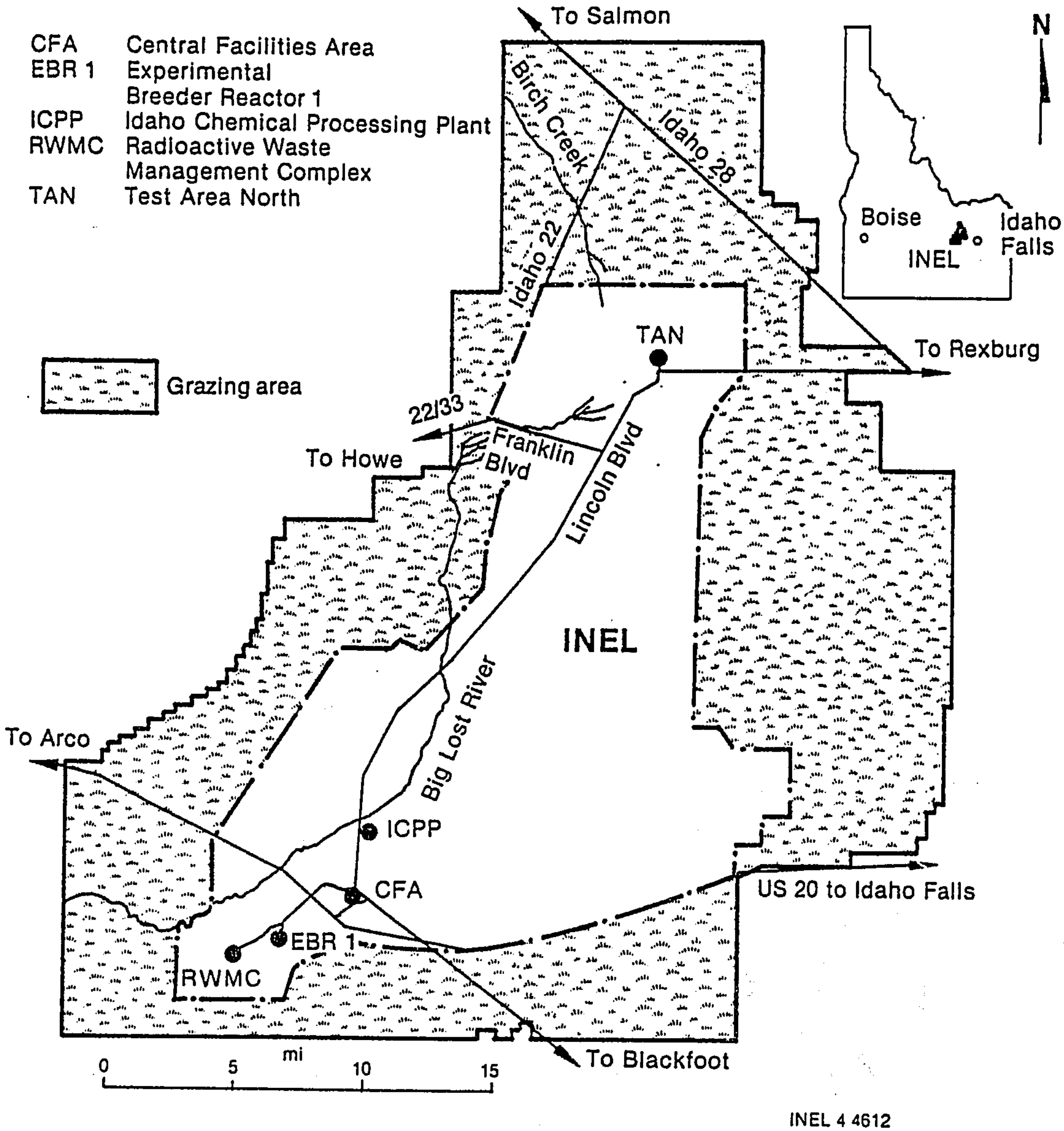

Figure 7-3. Permitted grazing areas at the INEL.

7.2.3 Fauna

<u>What types of fauna are located at the INEL Site?</u>

The INEL Site supports a variety of wildlife including insects, small mammals, birds, reptiles, and a few large mammals. The common and scientific names for the fauna are presented on Table 7-2. Only the common names will be used in this section.

A diverse insect population consisting of at least 150 families and 14 orders occupies the rangeland ecosystems of the INEL Site (Stafford and Barr, 1983). The majority of the abundant species belongs to the orders hymenoptera and Diptera, and most species are parasitic or predatory. Insects are essential components of complex food chains at the INEL Site and are involved in decomposition of plant and animal material, pollination, aeration, and soil turnover (Halford, 1981; Stafford and Barr, 1983; Stafford, 1983).

One amphibian and nine reptilian species have been observed at the INEL Site. The Great Basin spadefoot toad remains burrowed in the soil until moisture conditions are suitable for breeding. The sagebrush lizard and the short-horned lizard are abundant. The western skunk and the leopard lizard have also been observed. Four species of snakes, including the Great Basin rattlesnake and the Great Basin gopher snake, have been recorded. The western terrestrial garter snake and desert striped whipsnake are present in lesser numbers and have more restricted distributions.

Aquatic life on the INEL Site is limited and depends mainly upon the flow of the Big Lost River. During several months of the year, and even during some entire years, the river does not flow. However, the diversion system (southern boundary of the INEL Site) and the Big Lost River sinks (northern boundary of the INEL Site) support water flow during spring run off and periods of high rainfall. Fish species observed in the Big Lost River include rainbow trout, mountain whitefish, eastern brook trout, Dolly Varden char bull trout, Kokanee salmon, and the shorthead sculpin (Overton et al., 1976).

Table 7-2. Representative animal species occurring at the INEL Site

Common Name	Scientific Name
Amphibians and Reptiles	
Anura (amphibians)	
Great Basin spadefoot toad	Spea intermontana
Squamata (reptiles)	
Short-horned lizard	Phyrnosoma douglassi
Sagebrush lizard	Sceloporus graciosus
Gopher snake	Pituphis malanoleucus
Western rattlesnake	Crotalus virdus
Birds	
Ciconiiformes (herons, bitterns, and relatives)	
White-faced ibis	Plegadis chihi
Anseriformes (ducks)	
Mallard	Anas platyhynchos
Pintail	Anas acuta
American widgeon	anas americana
Northern shoveler	Anas clypeata
American green-winged teal	Anas acuta
Redhead	Aytha amaricana
Lesser scaup	Aythya affinis
Common goldeneye	Bucephala clangula
Bufflehead	Bucephala albeola
Ruddy duck	Ozyura jamaicensis
Hooded merganser	Mergus strepera
Falconiformes (hawks and falcons)	
Osprey	Pandion haliaetus
Bald eagle	Haliaetus leucocephalus
Ferruginous hawk	Buteo regalis
Rough-legged hawk	Buteo lagopus
Red-tailed hawk	Buteo jamaicensis
Swainson's hawk	Buteo swainsoni
Golden eagle	Aquila chryseatos

Table 7-2. (continued)

Common Name	Scientific Name
Merlin	Falco columbarius
Peregrine falcon	Falco peregrinus
Gyrfalcon	Falco rusticolus
Prairie Falcon	Falco mexicanus
American Kestrel	Falco sparverius
Galliformes (grouse and pheasants)	
Gray partridge	Perdis perdix
Chukar	Alectoris chukar
Ring-necked pheasant	Phasianus colchicus
Blue grouse	Dendragapus obscurus
Sage grouse	Centrocercus Urophasianus
Gruiformes (rails and coots)	
American coot	Fulica americana
Charadriiformes (shorebirds)	
Long-billed curlew	Numenius americanus
Common snipe	Gallinago gallinago
Columbiformes (doves and pigeons)	
Mourning dove	Zenaida macroura
Stringiformes (owls)	
Burrowing owl	Athene cunicularia
Long-eared owl	Asio otus
Passeriformes (perching birds)	
Horned lark	Eremophila alpestris
Barn swallow	Hirundo rustica
Black-billed magpie	Pica pica
American robin	Turdus migratorius
Sage thrasher	Oreoscoptes montanus
Brewer's sparrow	Spizella breweri
Sage sparrow	Amphispiza belli
Western meadowlark	Sturnella neglecta
Brown-headed cowbird	Molothrus alter

Table 7-2. (continued)

Common Name	Scientific Name
Mammals	
Chiroptera (bats)	
Little brown bat	Myotis lucifugus
Long-eared bat	Myotis evotis
Small-footed myotis	Myotis leibii
Big brown bat	Eptesicus fuscus
Townsend's big-eared bat	Plecotus townsendii
Lagomorpha (rabbits)	
White-tailed jack rabbit	Lepus townsendii
Black-tailed jack rabbit	Lepus californicus
Nuttal cottontail	Sylvilagus nuttallii
Pygmy rabbit	Sylvilagus idahoensis
Rodentia (rodents)	
Yellow-bellied marmot	Marmota flaviventris
Townsend's ground squirrel	Spermophilus townsendii
Richard's ground squirrel	Spermophilus richsardsonii
Least chipmunk	Eutamias minimus
Great Basin pocket mouse	Pergmathus parvus
Ord's kangaroo rat	Dipodomys ordii
Western harvest mouse	Reithrodontomys megalotis
Deer mouse	Peromyscus maniculatus
Northern grasshopper mouse	Onuchomus leucogaster
Bushy-tailed wood rat	Neotoma cinerea
Montane vole	Microtus mantanus
Sage vole	Lagurus curtatus
Pocket gopher	Thomomys sp.
Carnivora (carnivores)	
Badger	Taxidea taxus
Bobcat	Lynx rufus
Coyote	Canis latrans
Long-tailed-weasel	Mustela frenata
Mountain lion	Felis concolor
Spotted skunk	Spilogale gracilis
Artiodactyla (even-toed ungulates)	
Mule deer	Odocoileus hemionus
Pronghorn	Antilocapara americana

a.(Arthur et al., 1983.)

Birds are an integral component of the Great Basin ecosystem. At one time or another during a typical year, 164 bird species are found at the INEL Site, and fourteen additional species have been listed as possible inhabitants (Reynolds, 1986). Twenty-nine species of game birds have been recorded on the INEL, 23 of which are waterfowl (including coots and the common snipe). Sage grouse are the most common resident game bird on the INEL Site, which provides important wintering and breeding habitat for the species (Connelly, 1982; Connelly and Ball, 1983). The ring-necked pheasant, gray partridge, chukar, and blue grouse are uncommon.

Sixty-nine species of passerine perching birds have been recorded on the INEL Site. Of these, the most common species include the horned lark, black-billed magpie, American robin, sage thrasher, Brewer's sparrow, sage sparrow, and western meadowlark. These species can be found throughout the INEL Site (Peterson and Best, 1983).

The INEL is an important nesting and wintering area for 22 species of raptors. American rough-legged hawks, American kestrels, prairie falcons, and golden eagles are the most abundant raptors observed on the INEL Site during the nonbreeding season. Most raptor nests are restricted in distribution and are located in deciduous trees along the Big Lost River and in juniper stands near Kyle Canyon in the northwest portion on the INEL Site or near Twin Buttes to the southeast (Reynolds, 1986).

Sixteen of the thirty-seven species of mammals at the INEL Site are rodents (Reynolds, 1986). Townsend's ground squirrels, least chipmunks, Great Basin pocket mice, Ord's kangaroo rats, western harvest mice, deer mice, bushy-tailed wood rats, and montane voles are the most common small mammals on the INEL Site. These animals are also relatively common throughout sagebrush regions of the intermountain west.

Five species of bats inhabit the lava-tube caves on and adjacent to the INEL Site . The small-footed myotis and Townsend's big-eared bat hibernate on the INEL Site, while the remaining bat species are considered migratory (Markham, 1987).

Four species of leporids occur on the INEL Site: black-tailed jack rabbits, white-tailed jack rabbits, Nuttal cottontails; and pygmy rabbits. All but the white-tailed jack rabbits are considered abundant. In addition, six species of carnivores occur on the INEL Site. Of these, the coyote, long-tailed weasel, and the badger are considered uncommon (Reynolds, 1986). The bobcat ranges throughout the INEL Site but is generally uncommon. The mountain lion is considered rare. The spotted skunk is generally uncommon but can be found in basalt outcrops.

The INEL Site supports resident populations of mule deer and pronghorn. Mule deer are considered uncommon and are generally concentrated in the southern and central portion of the INEL Site. They occur in greater numbers on the buttes and mountains surrounding the INEL Site. Pronghorn are found throughout the INEL Site and are generally considered abundant (Arthur et al., 1983). Most pronghorn in southeastern Idaho are migratory (Hoskinson and Tester, 1980). During winter months, 4500 to 6000 pronghorn may reside on the INEL Site.

The bald eagle and the American peregrine falcon are the only species observed on the INEL Site that are classified as Federally-endangered. Sixty-five observations of bald eagles were made at the INEL Site during the winter of 1981-1982, and 17 eagles were observed roosting in Howe, Idaho, just west of the INEL Site (Craig et al., 1983). Bald eagle counts were conducted once each year during mid-winter surveys; the counts are as follows: 4 (1983); 3 (1984); 2 (1985); 5 (1986); and 1 (1987) (Markham, 1987). No nest sites have been reported in the RWMC. The peregrine falcon has been observed infrequently on the northern portion of the INEL Site, but not in the vicinity of RWMC (Arthur et al., 1983). The population status, roosting requirements, and dispersal of these species are currently being studied at the INEL Site and results of these studies will be presented in further publications (Markham, 1987).

Several species of wildlife observed on the INEL Site are of special concern to the Idaho Department of Fish and Game (Gleisner, 1983) and the BLM. These species include the ferruginous hawk, the merlin, the osprey, the burrowing owl, the white-faced ibis, the long-billed curlew, and the bobcat. However, only ferruginous hawks, burrowing owls, long-billed curlews, and bobcats are found regularly on the INEL Site.

The INEL Site is within the Pacific and Central Flyway, which is used by a variety of migratory songbirds, waterfowl, and raptors. Most ducks use the INEL Site manmade ponds and flooded playas as resting areas during migration; therefore, these manmade features may act as important vectors in transporting contaminants accumulated across aquatic trophic levels (Halford and Markham, 1983). In addition, each of the raptor species in the area is likely to migrate or undergo seasonal movements across the INEL Site. Consequently, raptors could also act as a significant pathway for transport of radionuclides or other contaminants across terrestrial trophic levels and may be important in dispersing contaminants off of the INEL Site.

7.2.4 Important Wildlife Habitats

What important wildlife habitats are found at the INEL Site?

Important habitats are those that are necessary for maintaining viable wildlife population or which have a limited distribution on the INEL Site and could be eradicated by perturbation, such as a fire or flood. Because many wildlife species on the INEL Site are sagebrush obligates, either directly or indirectly, these sagebrush habitats provide critical winter and spring range.

Juniper communities on and adjacent to the INEL Site are important to nesting raptors (Craig, 1979) and several species of songbirds. The Big Lost River sinks provide wetlands in an area where this habitat type is generally lacking. When water is present, the sinks are inhabited by a large number of waterfowl and shorebird species (Arthur et al., 1983). The relatively limited areas of these habitats and their importance to wildlife suggest that they should also be considered important. In addition, the limited and dispersed plains cottonwoods provide essential nesting locations for numerous raptors at the INEL Site.

7.3 MICROBIOLOGY

What microbes are present in soils at the RWMC?

The microbial populations within the soils at the RWMC have not been adequately characterized, although one study documented in Colwell (1988) did investigate the microbiology at the surface and subsurface of RWMC. Analyses of biologically relevant gases in the unsaturated subsurface near the RWMC indicated an environment capable of sustaining aerobic activities of many microbes. While denitrifying and methanotrophic bacteria are apparently absent from the 240-ft interbed sediments, both groups exist in the RWMC surface soils (Colwell, 1988). It is commonly known that methanotrophic bacteria can degrade low molecular weight halocarbons (Bouer and McCarty, 1983).

7.4 BIOTIC TRANSPORT PATHWAYS

Radioecological research was initiated at the SDA in October 1977 to determine the role of ecological components in radionuclide uptake and transport throughout the RWMC area. Initial assessments involved radionuclide concentration levels in small mammals, Russian thistle, and crested wheatgrass in developing a biotic monitoring program.

Biota tissues were analyzed for specific radioisotopes to provide information on radionuclide buildup within the animal tissue, plant uptake, and possible transfer of radionuclides. Before these studies, many short-term studies were conducted at the RWMC. They include a 1972-1973 study in which deer mice were collected near the SDA and analyzed for activation products, fission products, and TRU nuclides.

Subsequent studies have evaluated small mammal species composition, diversity, local movements, and densities (Groves and Keller, 1983); small mammal radiation doses (Arthur et al., 1983); radionuclide concentration in coyote feces (Arthur and Markham, 1982); and radionuclide concentrations in vegetation (Arthur, 1982).

Since 1978, the Environmental Monitoring Group of EG&G Idaho in conjunction with the Radiological and Environmental Sciences Laboratory (RESL) have collected and analyzed tissue samples from mourning doves, sage grouse, cottontail rabbits, small mammals, Russian thistle, and crested wheatgrass (EG&G, 1989).

7.4.1 Receptors and Pathways

<u>What does this biotic model illustrate</u>?

This model of the RWMC depicts the relationship between receptors and the primary source of disposed contaminants. Contaminants are connected to the receptors by the pathways shown. The model is divided into a description of the receptors and major pathways, a summary of contaminant sources and modes of release, and contaminant movement through the subsurface. The major receptors of contaminants from the SDA include humans and terrestrial and aquatic biota.

Three potential pathways could play a role in delivering contaminants to receptors. Surface water is a pathway because of the proximity of the Big Lost River. Groundwater is a pathway because of the location of the production well used to supply water to the SDA and production wells used to provide water to grazing livestock and wildlife. Air (or wind) is a pathway for contaminant movement to receptors because of the volatile organic compounds and fine-grained dusts associated with the SDA (See Figure 7-4)[b].

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[b] Unpublished research results from the RI/FS work plan for the SDA, RWMC at the INEL, EG&G Idaho, Inc., December 1989.

What are the release mechanisms for contamination?

Modes of exposure to contaminants include ingestion, uptake inhalation, dermal contact, or exposure to photionizing radiation. Contaminants may be released from primary source (stored waste) to water and surficial sediments through the following secondary mechanisms:

- Surface water runoff
- Blowing dust particles
- Volatile emissions
- Infiltration and leaching
- Flora and fauna uptake

The above secondary release mechanisms move contaminants directly into the surface water, groundwater, air pathways, flora, etc., from the surficial sediments.

7.4.2 Transport to Plants

How could radionuclides be transported to vegetation?

Radionuclides can enter plants by uptake from soil, deposition from air, or sorption from water. Radionuclides in soil may pass into the root and be incorporated into plant tissues, or they may adhere to the root surface. Radionuclides in air or water can deposit on plant surfaces, where they may be absorbed into the tissues.

The accumulation of radionuclides in plants is often expressed as a concentration ratio. This ratio is the concentration of the radionuclide in the plant divided by the concentration in the soil. Concentration ratios for

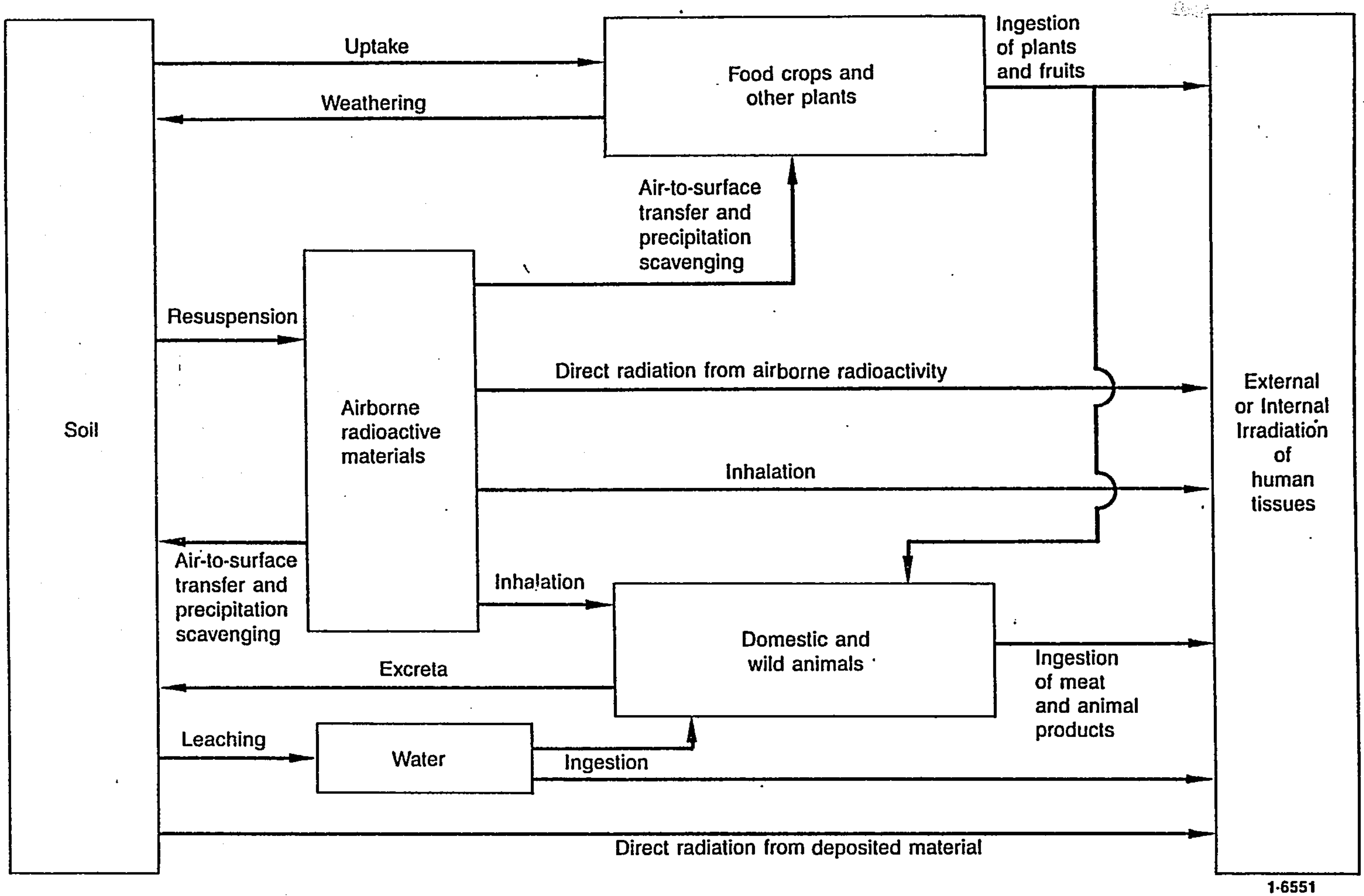

Figure 7-4. General pathways for transport of radionuclides from soil to man.

most radionuclides are less than one. For radionuclides of plutonium, the concentration in plants is about one thousand times less than in soil (Miller et al., 1980) (see Table 7-3).

7.4.3 Transport to Animals

<u>How could radionuclides be transported by plants to animals?</u>

Radioactive materials can pass from plants to herbivores (plant-eating animals) through ingestion of contaminated plant material. Radionuclides inside the plant and those attached to plant surfaces could enter the animal. Herbivores could also ingest radionuclides associated with soils or sediments. For insoluble radionuclides in arid, dusty environments, inhalation may be a more significant pathway than ingestion. Inhaled radionuclides can be absorbed into the body from the lung or from the gastrointestinal tract after being swallowed. A potential pathway for radionuclide transport from the RWMC is small mammal activities.

RESL has implanted small mammals at the RWMC with radiation detectors. RESL's studies show that a statistically significant portion of the small mammal population inhabiting the SDA burrows or lives close to the buried waste (Arthur and Markham, 1982).

Predatory animals can ingest radionuclides from the tissues of herbivores. The total amount of radionuclides an organism consumes depends on the amount of food consumed and the concentration of radionuclides in that food. Predators at the RWMC are not part of human food chains.

Knowledge of radionuclide concentrations in meat and milk is important to calculate dose to man. Transfer of a radionuclide from the animal's diet to meat or milk has been measured in the field and in controlled experiments. Results are expressed as a transfer coefficient. The transfer coefficient is

Table 7-3. Plant-soil concentration ratios for forage and for plants for human consumption[a]

Element	Forage[b]	Human Consumption[c]
Be	0.00042	0.00006
Mn	0.12	0.029
Co	0.038	0.0094
Ni	0.076	0.019
Sr	1.2	0.29
Cs	0.15	0.011
Ce	0.039	0.0062
Pb	0.14	0.0139
Po	0.0042	0.00026
Ra	0.091	0.013
Ac	0.010	0.0025
Th	0.0027	0.00035
Pa	0.010	0.0025
U	0.0061	0.00029
Pu	0.0020	0.00022
Am	0.0021	0.00040

a. Source: Miller et al., (1980), except for Be, which is based on NRC (1977).

b. The concentration ratio is the radionuclide concentration in the entire aboveground portion of the plant at maturity per unit dry weight divided by the radionuclide concentration in soil per unit dry weight.

c. The concentration ratio is the radionuclide concentration in the edible portion of the plant at maturity per unit fresh weight divided by the radionuclide concentration in soil per unit dry weight. The concentration ratio is for the edible portion of vegetables, fruits, and grains.

the ratio of the ultimate concentration in meat or milk to the daily intake of the radionuclide. Transfer coefficients are usually much less than one, showing very little transfer to edible tissues at the RWMC (Table 7-4).

7.5 PHYSICAL AND CHEMICAL FORM OF RADIONUCLIDES

What governs the general movement and concentration of radionuclides?

The general movement and concentration of radionuclides in ecosystems are governed by many factors including the physical and chemical nature of the radionuclides. Although each element has unique chemical properties, different radionuclides of the same element have different half-lives. This difference can result in varied environmental consequences.

Biological concentration of radionuclides is affected by the physical and chemical form of the radionuclide. In general, chemically active, soluble forms are most readily taken up and concentrated by organisms. For example, soluble Cs-137 is readily assimilated by animals, unless it is enclosed in insoluble or inert particles.

Innate characteristics and behavior of organisms greatly affect the accumulation of radionuclides. Different animal or plant species in the same area can vary tremendously in their content of radionuclides.

Radionuclide concentrations vary between different members of a species or different tissues with an individual. For example, two plants growing side by side may vary in concentration by an order of magnitude. Concentrations in the seeds, leaves, and stems of a given plant may also vary by an order of magnitude or more. An animal's movements, range, food habits, and other behavior affect radionuclide intake and loss. Some natural populations accumulate radionuclides in measurable quantities because they live and feed near contaminated areas.

Table 7-4. Transfer coefficients to meat and to milk for human consumption[a]

Element	F_m $\frac{0.035}{(day/ft^3)}$[b]	F_f $\frac{0.454}{(day/lbm)}$[c]
Be	0.00000091	0.001[d]
Mn	0.00033	0.00039
Co	0.0029	0.0097
Ni	0.0010	0.0020
Sr	0.0014	0.00059
Cs	0.0071	0.015
Ce	0.000060	0.00075
Pb	0.00026	0.001
Po	0.00034	0.0040
Ra	0.00040	0.00050
Ac	0.0000050	0.0000036[d]
Th	0.0000050	0.0000036[e]
Pa	0.0000050	0.0000036[d]
U	0.00037	0.0000036[e]
Pu	0.00000010	0.0000010
Am	0.00000041	0.0000036

a. Source: Ng (1982) unless otherwise noted.

b. 0.035 pCi/ft^3 milk ÷ pCi/day ingested by cow.

c. 0.454 pCi/lbm beef (wet weight) ÷ pCi/day ingested by cow.

d. Value taken from NRC (1977).

e. Assumed to be the same as the measured value for americium.

Topography and climatatic interactions affect whether ecosystems will accumulate or lose radionuclides through time. Some ecosystems concentrate radionuclides, whereas some are continually flushed by turbulent air or water. Mountain tops or ridges exposed to strong wind action are examples of flushed ecosystems. Conversely, ecosystems that have evolved in quiet, protected areas accumulate radionuclides.

Plants and animals in ecosystems that have abundant available mineral nutrients usually contain relatively low concentrations of radionuclides. This is because available mineral nutrients dilute analogous radionuclides, leading to reduced uptake and greater excretion of the radionuclides (Case et al., 1990).

7.5.1 Predicting the Movement of Radionuclides in the Environment

What predictions have been made for biotic transport of radionclides?

For predictive modeling, site-specific environmental data are preferable, but not always available. Therefore, data collected from similar locations can often be used for scoping calculations. Much information has been obtained on the behavior of fallout radionuclides, naturally occurring radionuclides, and stable elements. Laboratory studies also have been conducted to quantify individual steps in environmental transport processes.

Because of the potential hazards associated with the RWMC, an environmental monitoring program was instituted to ensure effective isolation of radioactive waste from the biosphere in a safe and environmentally acceptable manner. The Environmental Surveillance Program of the RWMC was designed to address the following main goals: (a) develop and implement a capability to predict future impacts; (b) utilize pathway analyses and source characterization to evaluate transport mechanisms and potential environmental impacts; and (c) utilize pathway analyses, source characterization, and statistical methods to design individual sampling activities and experiments.

In addressing these goals, a computer simulation code capable of assessing radionuclide transport through air, water, and biotic pathways was selected (Shuman et al.,1985). The DOSTOMAN program code was considered to be best suited for the purpose. This program code was acquired from DOE's Savannah River Laboratory and modified to fit the requirements at the RWMC. Detailed conceptual and mathematical descriptions of the model are included in this discussion as well as results of model applications to the site (Case et al., 1990).

In modeling the radioactive waste disposal site, two distinct models were used. Model 1 dealt with the early disposal site (EDS), which is within the 88-acre disposal area (Figure 7-5). It addresses that part of the RWMC in which a mixture of TRU and hazardous waste was buried between 1952 and 1964. Model 2 dealt with the current disposal site (CDS), the portion of the RWMC at which waste was disposed of since 1964 (Figure 7-6). Pathways by which the transport of radionuclides are affected were chosen to include those typically examined in radiological assessment, and additional pathways of potential importance to the RWMC.

The DOSTOMAN code is capable of calculating compartment inventories of radioactivity for all model segments defined. The generated output data permitted tracking the movement of radionuclides within and from the disposal site during the entire period of simulated time intervals. Tables 7-5 and 7-6 show transport process sensitivity rankings for both models at 100 years following initiation of disposal operations.

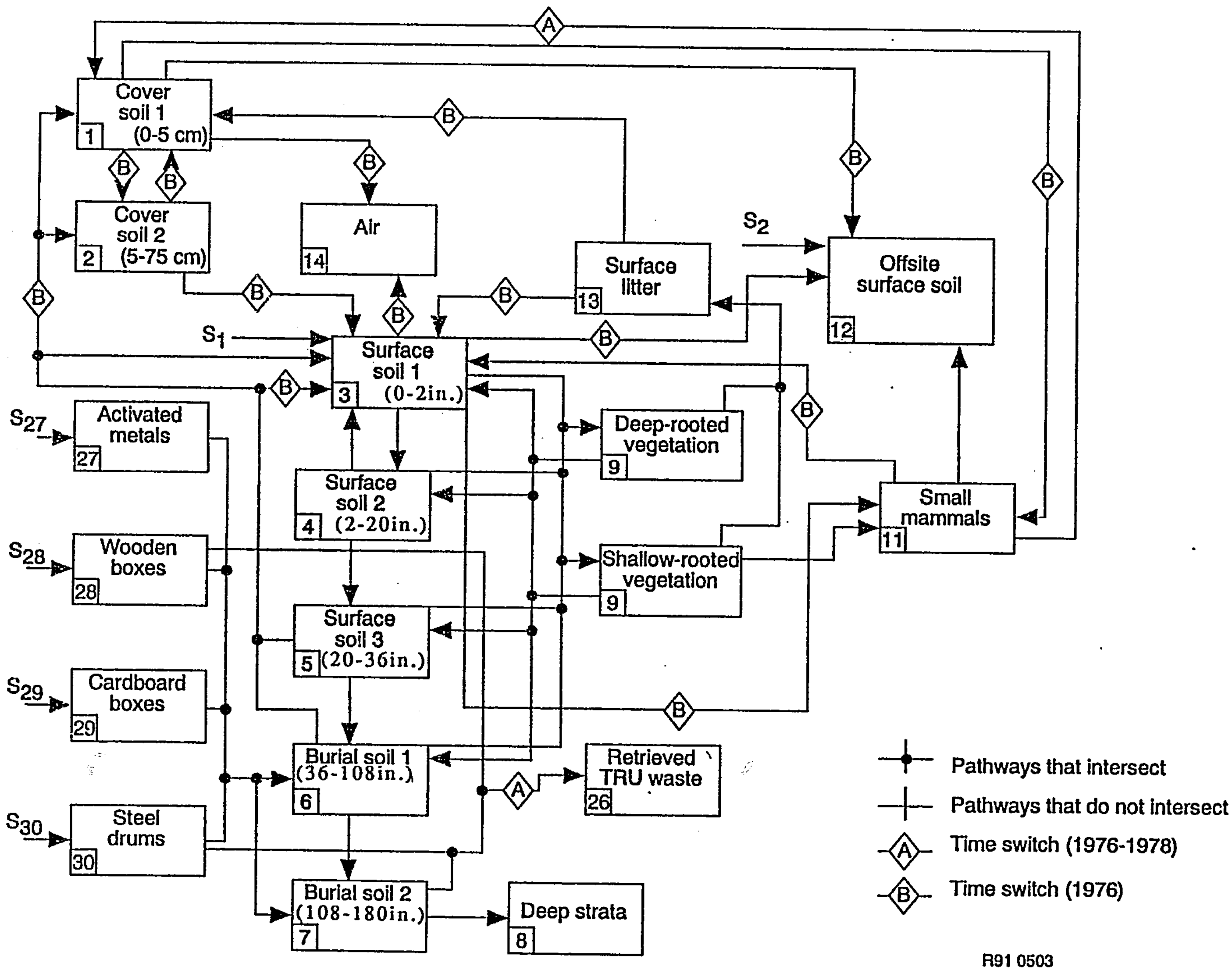

Figure 7-5. Conceptual diagram of the EDS model of the RWMC during the operational period.

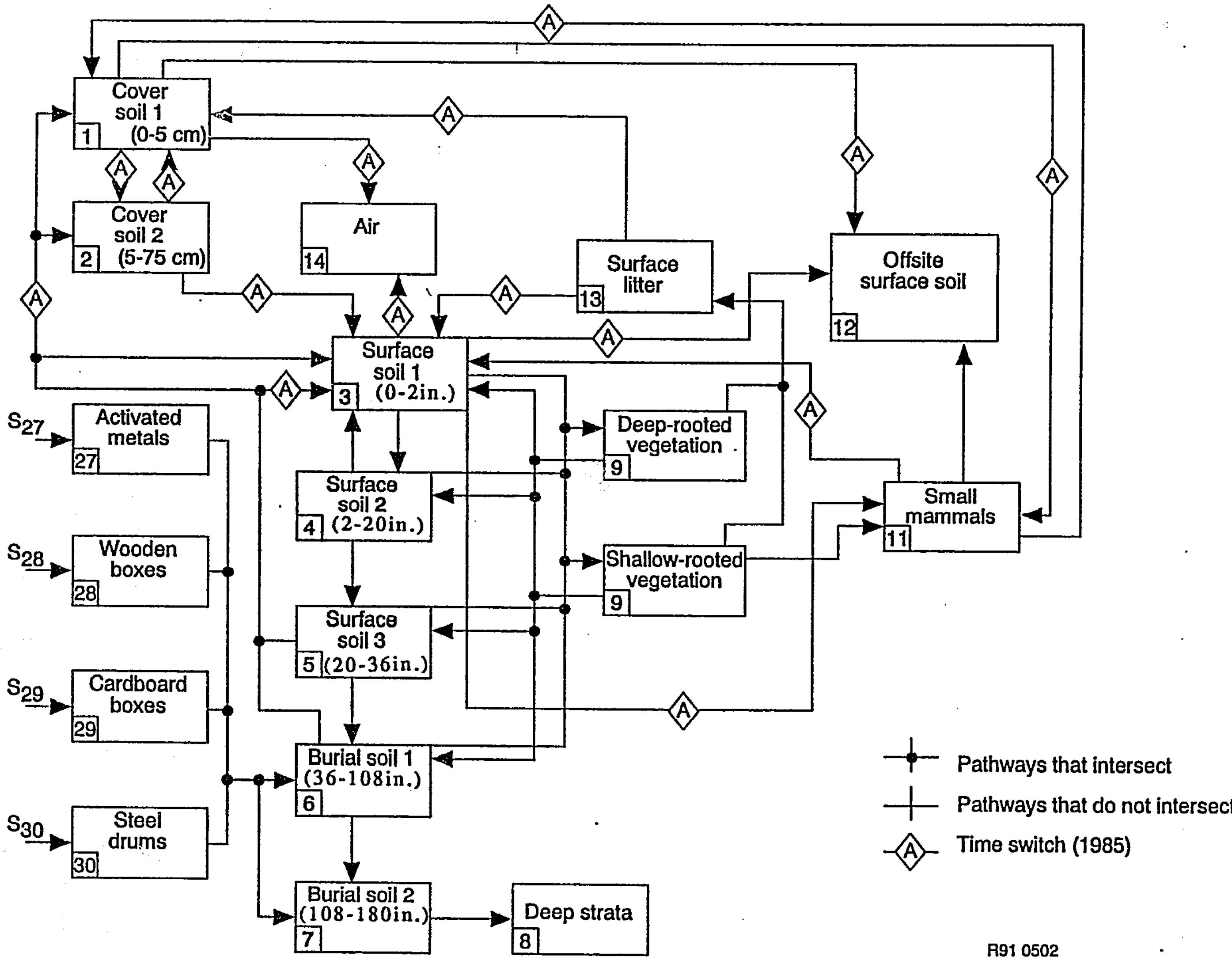

Figure 7-6. Conceptual diagram of the CDS model of the RWMC during the operational period.

Table 7-5. Transport process sensitivity ranking for the EDS model at 100 years following initiation of disposal operations[a]

Ranking	Co-60	Sr-90	Cs-137	Pu-239	Am-241
1	Waste release	Plant uptake	Plant uptake	Waste release	Waste release
2	Plant uptake	Waste release	Waste release	Small mammal burrowing	Plant uptake
3	Resuspension	Plant death	Resuspension	Resuspension	Resuspension
4	Plant death	Resuspension	Plant death	Plant uptake	Small mammal burrowing
5	Surface litter decay	Hydrologic transport in unsaturated zone	Surface runoff	Surface runoff	Surface runoff
6	Surface runoff[b]	Surface runoff	Small mammal burrowing	Plant death	Plant death
7	Small mammal burrowing[b]	Small mammal ingestion[b]	Surface litter decay	Hydrologic transport in unsaturated zone	Hydrologic transport in unsaturated zone
8	Hydrologic transport in unsaturated zone	Surface litter decay[b]	Hydrologic transport in unsaturated zone	Small mammal ingestion	Small mammal ingestion
9	Small mammal ingestion	Small mammal burrowing	Small mammal ingestion	Small mammal death and elimination	Surface litter decay
10	Small mammal death and elimination	Small mammal death and elimination	Small mammal death and elimination	Surface litter decay	Small mammal death and elimination

a. Source: (Case et al., 1990)
b. Rankings are tied for the indicated radionuclide.

Table 7-6. Transport process sensitivity ranking for the CDS model at 100 years following the initiation of disposal operations[a]

Ranking	Co-60	Sr-90	Cs-137
1	Plant uptake	Plant uptake	Waste release
2	Waste release	Waste release	Plant uptake
3	Small mammal burrowing	Small mammal ingestion	Small mammal burrowing
4	Small mammal ingestion	Small mammal burrowing	Small mammal ingestion
5	Hydrologic transport in unsaturated zone	Surface runoff	Hydrologic transport in unsaturated zone
6	Surface runoff	Resuspension	Resuspension
7	Resuspension	Hydrologic transport in unsaturated zone	Surface runoff
8	Plant death	Plant death	Plant death
9	Surface litter decay	Surface litter decay	Surface litter decay
10	Small mammal death and elimination	Small mammal death and elimination	Small mammal death and elimination

a. Source: (Case et al., 1990)

7.6 RESEARCH STUDIES OF TERRESTRIAL ECOSYSTEMS

What research programs have been instituted at the INEL Site?

The Environmental Surveillance Program Data Management System (ESPDMS) has been developed for environmental radiation monitoring activities at waste management facilities. The purpose of the ESPDMS is to maintain computer data bases [i.e., air, water, soil, thermoluminescent dosimeter (TLD), vegetation, nitrate, and subsurface]; to store and sort data after analysis; to provide a method of tracking trends of monitoring data; and to help generate monitoring reports.

The biotic monitoring program at the RWMC is part of an INEL-wide comprehensive environmental monitoring program. It was instituted to (a) determine if biota are transporting radionuclides from buried waste or contaminated soil, (b) provide guidance to RWMC operations regarding general biotic conditions that may compromise waste containment, and (c) detect significant trends in the radionuclide concentrations in biotic samples. The results of the monitoring activities are used as indicators of the biotic conditions at the RWMC where the primary concern is the possibility that radionuclides in buried waste may be brought to the surface by animal burrowing or plants uptake (EG&G, 1989). Table 7-7 outlines the environmental monitoring activities performed at waste management facilities at the INEL by the Environmental Monitoring Unit of EG&G Idaho.

Vegetation studies of plant uptake of radionuclides at the INEL Site have focused primarily on (a) determining if deep rooting plants are a mechanism for waste pit intrusion and subsequent uptake of radionuclides and (b) analyzing inventories of radionuclides in aerial portions of plants. Aerial portions of plants are important because they can potentially transport subsurface contaminants through dispersal of leaves, consumption by herbivores, and use by birds as nesting materials.

Table 7-7. Environmental monitoring activities performed at waste management facilities

Facility	Sample	Description	Frequency of Analysis	Type of Analysis
RWMC SDA	Air	8 low-volume air samplers operated at 0.14 m^3/min (includes 1 control and 1 replicate)	Biweekly Biweekly Monthly Quarterly	Gross alpha Gross beta Gamma spectrometry Radiochemistry[a]
	Water surface	4-L samples from SDA and control location	Quarterly, but depends on precipitation	Gross alpha Gross beta Gamma spectrometry Radiochemistry[a,b,c]
	Subsurface (sampled by the USGS)	2-L samples from each of 6 wells	65-m wells annually 183-m wells quarterly Production well quarterly	Gamma spectrometry H-3, Sr-9, Pu-238 Pu-239, -240, Am-241 Specific conductance Chloride, sodium, nitrate
	Direct radiation surface gamma	Truck-mounted VRM-1 detector system	Semiannually	External radiation levels
	Ionizing (conducted by RESL and EG&G Idaho)	25 TLD packets (RESL), 2 TLD packets (EG&G Idaho) and 7 background communities (RESL)	Semiannually	External radiation levels
	Small mammal	3 composites in each of 5 major areas (plus 1 control area)[c]	Annually, but species sampled varies each year	Gamma spectrometry Radiochemistry[a]
	Soil	5 locations in each of 5 major areas (plus 1 control area)	Biennially	Gamma spectrometry Radiochemistry[a]
	Vegetation	3 composites in each of 5 major areas (plus 1 control area)[c]	Annually, but species sampled varies each year	Gamma spectrometry Radiochemistry[a]

Table 7-7. (continued)

Facility	Sample	Description	Frequency of Analysis	Type of Analysis
	Visual inspection	Tour SDA and TSA	Monthly	Results reported for any required corrective action
Stored Waste Examination Pilot Plant	Air	5 low-volume air samplers operated at 0.14 m^3/min.	Biweekly Biweekly Monthly Quarterly	Gross alpha Gross beta Gamma spectrometry Radiochemistry[a]
	Water (surface)	4-L samples from TSA-1, TSA-2, TSA-3, and control locations	Quarterly, but depends on precipitation	Gross alpha Gross beta Gamma spectrometry Radiochemistry[a]
	Soil	9 locations sampled plus 2 control areas	Biennially	Gamma spectrometry Radiochemistry[a]
Waste Experimental Reduction Facility	Air	4 low-volume air samplers operated at 0.14 m^3/min (includes 1 control and 1 replicate)	Biweekly Biweekly Monthly	Gross alpha Gross beta Gamma spectrometry
	Direct radiation	11 TLD packets (EG&G Idaho) and 7 background communities (RESL)	Semiannual	External radiation levels
	Soil	15 surface samples	Triennially[d]	Gamma spectrometry
	Vegetation	15 locations (includes 3 controls)	Triennially	Gamma spectrometry

Source: (Tkachyk et al., 1989)

Maximum soil stability and minimum movement of waste from burial areas are the primary goals for waste containment at the RWMC. Consequently, research has focused on determining if deep rooting plants are capable of penetrating pit covers and mobilizing subsurface contaminants to the surface where a variety of primary consumers could potentially be exposed to them.

Reynolds and Fraley (1989) found that the roots of big sagebrush extended to an average depth of 7.4 ft, and Great Basin wildrye had roots up to 6.5 ft deep at the SDA. Maximum lateral spread of the roots of both of these species was 3 ft and occurred at a depth of 1.3 ft. In addition, preliminary findings of studies in progress indicate root penetration of up to 5.3 ft for sodar and crested wheatgrass at the INEL Site (Markham, 1987). Based on these findings, a soil cover of 2 to 4.6 ft may not be adequate to reliably prevent root intrusion and radionuclide uptake by deep rooting plants. A variety of biological barriers are now being tested at RWMC to determine more effective ways of preventing intrusion by deep rooting plants into these waste pits (Markham, 1987).

Studies of aerial portions of vegetation at the INEL Site corroborate the findings of deep rooting plant studies. Arthur (1982) documents a study that detected above background concentrations of radionuclides in the shoots of crested wheatgrass and Russian thistle on the SDA, and concluded that the roots of these plants could translocate subsurface contaminants to terrestrial food chains. Concentration of Pu-240, Pu-239, Pu-238, and Am-241 in aerial portions of Russian thistle and crested wheatgrass at the SDA were significantly higher than those from offsite areas (Arthur and Markham, 1983). However, despite soils that were contaminated with Cs-137, Arthur et al. (1983) states that the study was unable to detect significant concentrations of this radionuclide in above ground portions of crested wheatgrass at the Stationary Low-Power Reactor No. 1 facility (SL-1). These results indicated that plants uptake radionuclides, but levels of concentrations may vary according to the specific radionuclide.

Because of the significance of deep-rooting plants as transport vectors for radionuclides at the RWMC, the DOE and the EG&G Idaho Environmental

Monitoring Unit are presently monitoring radionuclide uptake by vegetation at the SDA and SL-1 facilities. These studies primarily monitor radionuclide concentrations in above ground portions of Russian thistle and crested wheatgrass.

At the INEL Site, insects have been studied for their role in transporting subsurface contaminants through burrowing and decomposition activities. Studies of three species of carrion beetles indicate that these species are important in the movement of dead animals through terrestrial food chains; therefore, they may act as an important vector of radionuclide transport (Veith and Keller, 1983). However, this study did not determine whether carrion beetles or dead animals had significant concentrations of radionuclides.

Recently, it has been suspected that harvester ants (because of their subsurface burrowing activities) may be involved in transport of radionuclides at the INEL Site. Preliminary studies suggest that ant mounds have higher levels of contaminants than soils at control sites and that soils beneath ant mounds are also contaminated with radionuclides (Markham, 1987). Studies are currently underway to determine the extent of contamination in ant colonies at several locations at the INEL Site. Although information is inconclusive on the role of harvester ants in transporting radionuclides up the food chain, such transport is possible considering the variety of insectivorous and predaceous species that occur at the INEL Site.

Honeybees also have been used as an indicator of contaminant migration at the INEL Site. Honeybees can pick up various contaminants, including radionuclides, while foraging for nectar (Markham, 1987). Bees from the TRA, Naval Reactor Facility and ICPP at the INEL Site had significantly elevated levels of Cs-137, Co-60, and Cr-51.

Small mammals are an important component of terrestrial food chains because they are the primary food base for top-level carnivores such as raptors, bobcats, and coyotes. Most small mammals in arid communities construct extensive burrow systems that may penetrate subsurface disposal pits

(Reynolds and Laundre, 1988). Burrowing mammals can mobilize contaminants at shallow radioactive disposal sites by several mechanisms including transport enhancement, intrusion and active transport, and secondary transport through food chains (Reynolds and Laundre, 1988). For example, elevated radionuclide levels have been found in small mammals, soils excavated by small mammals, and coyote scat near the shallow burial sites (Arthur et al., 1983; Arthur and Markham, 1982, 1983).

Because burrowing mammals are potentially important vectors of radionuclide transport, burrow characteristics have been intensively studied (Arthur et al., 1983; Markham, 1987; Reynolds and Laundre, 1988). At the SDA, the Townsend's ground squirrel had the deepest and most extensive burrows of several small mammals studied. Burrows of this species were as deep as 1.4 ft. In addition, burrows of Ord's kangaroo rat were up to 0.9 ft, and burrows of montane voles and deer mice were generally no deeper than 0.5 ft deep. Reynolds and Laundre (1988) concluded that if waste were buried in more than 0.5 ft of soil, as is typically the case at the SDA, deer mice and voles would be relatively unimportant vectors in radionuclide transport.

However, Arthur and Janke (1986) reported that 49% of deer mice examined at the SDA had significant contamination levels despite soil depths of over 0.6 ft covering the pits. This suggested that deer mice are capable of burrowing deeper than reported. Because of the tendency of Townsend's ground squirrel and Ord's kangaroo rat to burrow deep within the soil, they are considered important vectors in radionuclide transport of subsurface contaminants (Reynolds and Laundre, 1988).

Game species represent an important link between radionuclide uptake at the INEL Site and transport to human populations surrounding the INEL Site. Although the entire INEL is closed to sport hunting, radionuclides could be transported offsite by wide ranging animals such as pronghorns and sage grouse. In studies conducted by Connelly and Ball (1983), it was found that sage grouse could transport radionuclides offsite because of seasonal migration; however, the potential dose received by a person consuming a contaminated grouse was not considered a significant health risk.

In general, the variety and concentration of radionuclides in grouse muscle and digestive tract samples were generally lower than those reported for waterfowl (Halford, 1981) and mourning doves (Markham and Halford, 1982). For example, Cs-137 concentrations were approximately three times higher in mourning doves and over 400 times greater in waterfowl than in sage grouse (Connelly and Ball, 1983).

Top-level carnivores are important indicators of the overall health of terrestrial biota. Although top-level carnivores are potentially exposed to radionuclides through trophic transport mechanisms, most research at the INEL Site has focused on predator-prey relationships and population dynamics of this group. Top-level carnivores are important because they are capable of concentrating contaminants from lower trophic levels and transporting them over considerable distances where they could expose additional trophic levels by way of carrion consumption and fecal consumption by detritivores (e.g., coyote feces).

Studies on the INEL Site have attributed elevated levels of Am-241 in coyotes to ingestion of contaminated small mammals (Arthur and Markham, 1983; Arthur et al., 1983). Coyote feces at the SDA had four times the activity of this radionuclide in comparison to control areas (Arthur and Markham, 1983). Tissues of raptors at the INEL Site have been found to contain detectable concentrations of Cs-137 (Craig, 1979). However, this radionuclide was 4 to 290 times higher in small mammals than in nesting raptors at the TRA and ICPP. These results suggest that radionuclides originating at the TRA and ICPP are passed to raptors through their prey; however, concentrations in raptors are apparently diluted by consumption of uncontaminated rodents. Rodents with detectable concentrations of radionuclides were primarily limited to an area within 2.2 mi of these facilities.

7.6.1 Summary of Results

The following paragraphs, tables, and figures present a chronological summary of the results of samples collected at the RWMC between 1985 and 1990 involving biotic transport pathways.

During 1985, radiation measurements on soil samples that were excavated by small mammals gave similar results to those obtained on routine soils (Reyes, et al., 1985; Arthur and Markham, 1983)(see Table 7-8).

In 1986, at the SDA, 18 mammalian species were sampled; deer mice tissues had the highest concentration of radionuclides (see Table 7-9). However, these studies indicated that the RWMC did not contribute significant amounts of radionuclides to the surrounding environment (Arthur and Janke, 1986).

No gamma-emitting radionuclides were detected above the concentration of the control in any of the small mammals (ground squirrels) or vegetation (Russian thistle) collected in 1987 (Arthur et al., 1987; Reyes et al., 1987) (see Tables 7-10 and 7-11). The relatively low concentrations of radionuclides measured in the excavated soils by small rodents suggest that neither waste nor waste-contaminated soils were contacted by the animals during excavation (see Tables 7-12, 7-13, and 7-14).

All detected gamma-emitting radionuclides reported in 1987 were within the range of concentrations measured by RESL in vegetation at the RWMC (see Tables 7-15 and 7-16). In general, the concentrations of specific alpha- and beta-emitting radionuclides are comparable to the concentrations measured in a routine sample of Russian thistle obtained in 1984 by EG&G Idaho Inc. at the RWMC (Table 7-17).

Comparisons were made in 1988 between (a) soil types for the average volume and the proportion of the total volume of soil excavated from the 4-in. increments for each species and (b) the relative number of burrows and proportion of the total soil removed beneath the minimum thickness of soil

Table 7-8. Excavated soil samples from small mammal burrows[a]

Location	Radionuclide	Concentration[b] (454 X 10^{-6} μCi/lbm)
1-2	Co-60	0.77 ± 0.14
	Sr-90	0.11 ± 0.01
	Pu-239, -240	0.37 ± 0.04
	Am-241	1.3 ± 0.2
1-3	Ce-144	0.90 ± 0.16
2-1	Am-241	0.66 ± 0.9
	Sr-90	0.4 ± 0.1
	Pu-239, -240	0.22 ± 0.05
2-2	Cs-137	0.94 ± 0.24
4-1	Am-241	2.1 ± 0.2
	Sr-90	0.6 ± 0.1
	Pu-239, -240	1.0 ± 0.2
4-2	Am-241	32.0 ± 3.0
	Pu-238	0.32 ± 0.04
	Pu-239, -240	16.5 ± 0.8
4-3	Sr-90	0.5 ± 0.1
	Cs-137	0.45 ± 0.10
	Pu-239, -240	0.46 ± 0.09
	Am-241	1.8 ± 0.5
5-1	Cs-137	0.38 ± 0.12

a. Soil sampling locations (Reyes et al., 1985)

b. Analytical uncertainties presented are ± 1σ (standard deviation).

Table 7-9. Radionuclide concentration (454 pCi/g) in wildlife collected in and adjacent to the SDA and at control areas in southeastern Idaho[a]

Species	Tissue	Area	Sample Size	Sr-90	Cs-137	Pu-238	Pu 239, 240	Am-241
				Mean Radionuclide Concentration ($\overline{X}$ + SD 454 pCi/lbm)[b]				
Coyote[b]	Feces	SDA	24	2.0 ± 1.6	3.4 ± 6.5	0.013 ± 0.027	0.5 ± 1.2	0.4[c] ± 0.9
		Control	12	0.9 ± 0.2	0.7 ± 0.5	0.003 ± 0.004	0.006 ± 0.003	0.003 ± 0.002
Horned lark	Carcass	SDA	9	--[d]	1.07 ± 2.51	--	--	--
		Control	5	--	0.21 ± 0.16	--	--	--
Great Basin rattle snake	Carcass	SDA	3	--	0.32 ± 0.21	--	--	--
		Control	0					
Invertebrates	Composites	SDA	3	2.4 ± 3.2	0.47 ± 0.55	0.008 ± 0.011	0.078 ± 0.11	0.022 ± 0.020
		Control	1	0.7	3.7	BDL	BDL	BDL
Deer mice[e]	Carcass	SDA	21	721[c] ± 1061	57.3[c] ± 122	0.01 ± 0.03	0.04 ± 0.11	0.01 ± 0.02
		Control	5	0.6 ± 0.6	0.20 ± 0.07	0.002 ± 0.003	0.002 ± 0.007	0.003 ± 0.002
	Hide		21	417[c] ± 612	78.5 ± 132	0.54[c] ± 1.96	0.36[c] ± 0.66	0.27 ± 0.83
		SDA	5	1.3 ± 0.9	2.4 ± 0.5	0.002 ± 0.002	0.007 ± 0.006	0.039 ± 0.050
		Control						
Sage Grouse[f]	Muscle	SDA	14	--	0.3 ± 0.09	--	--	--
		Control	20	--	0.3 ± 0.2	--	--	--
Nuttall's[g]	Carcass	SDA	10	0.30 ± 0.24	0.14 ± 0.33	0.001 ± 0.0004	0.004 ± 0.003	0.010[c] ± 0.009
		Control	5	0.37 ± 0.09	0.16 ± 0.12	0.001 ± 0.001	0.002 ± 0.001	0.001 ± 0.001
	Hide		10	0.45 ± 0.18	0.18 ± 0.15	0.002 ± 0.002	0.009 ± 0.010	0.029 ± 0.046
		SDA	5	0.44 ± 0.15	0.31 ± 0.07	0.004 ± 0.003	0.002 ± 0.001	0.002 ± 0.001
		Control						
Mourning Dove[h]	Muscle	SDA	12	--	0.63	--	--	--
		Control	11	--	0.75	--	--	--

a. Arthur and Jauke, (1986).
b. Arthur and Markham (1982).
c. Significant difference (P/0.05) between SDA and control area concentration for this radionuclide.
d. Sample not analyzed for this radionuclide.
e. Arthur et al., (1983).
f. Connelly and Ball (1983).
g. Janke and Arthur (1985).
h. Markham and Halford (1982a).

Table 7-10. Radionuclide concentrations in deer mice tissues collected at the SDA and at the control area in southeastern (454 x 10^{-6} μci/lbm) Idaho

	Lung		GI Tract		Pelt		Carcass	
	SDA	Control	SDA	Control	SDA	Control	SDA	Control
Cs-137 X±SD	456 ± 1418	2.6 ± 1.5	35.4 ± 72.4[a]	0.22 ± 0.25	78.5 ± 132	2.4 ± 0.5	57.3 ± 122[a]	0.20 ± 0.07
Range	1.7-6210	1.7-4.3	0.3-291	BDL-0.51	2.1-535	1.8-2.7	0.32-437	BDL-0.24
n	21	3	21	3	21	3	21	3
Sr-90 X±SD	4.5 ± 15.3	0.30 ± 0.00	56.7 ± 180	3.4 ± 2.9	417 ± 612[b]	1.3 ± 0.9	721 ± 1061[b]	0.6 ± 0.6
Range	0.30-71.0	0.30-0.30	BDL ± 790	0.5-6.3	0.67 ± 2010	0.3-2.3	1.2-3600	BDL-1.17
n	21	3	19	3	21	3	21	3
Pu-238 X±SD	0.19 ± 0.16[b]	0.049 ± 0.041	0.17 ± 0.57[b]	0.006 ± 0.010	0.054 ± 1.96[b]	0.002 ± 0.002	0.01 ± 0.03	0.002 ± 0.003
Range	0.007-0.80	0.006-0.040	0.004-2.52	0.001-0.024	0.003-9.00	0.0008-0.0050	0.0006-0.12	0.0002-0-006[b]
n	21	5	19	5	21	5	21	5
Pu-239,240 X±SD	0.11 ± 0.12	0.23 ± 0.39	0.27 ± 0.39[b]	0.011 ± 0.006	0.36 ± 0.66	0.007 ± 0.006	0.04 ± 0.11	0.002 ± 0.007
Range	0.001-0.41	0.019-0.93	0.007-1.18	0.004-0.021	0.005-3.07	0.002 ± 0.016	0.0006-0.51	0.009-0.02
n	21	5	19	5	21	5	21	5
Am-241 X±SD	0.031 ± 0.44	0.17 ± 0.29	0.21 ± 0.34[b]	0.011 ± 0.008	0.27 ± 0.83	0.039 ± 0.050	0.01 ± 0.02	0.003 ± -/002
Range	0.02-1.70	0.02-0.70	BDL-1.50	BDL ± 0.023	BDL-3.86	BDL-0.127	BDL-0.07	BDL-0.006
n	21	5	19	5	21	5	21	5

a. Reyes et al., 1987.
b. Significant ($p < 0.05$) difference in radionuclide concentrations between SDA and control area deer mice tissues.

Table 7-11. Estimated deer mice population and total radionuclide inventories (nCi) in deer mice population inhabiting the SDA and the control area during a 1-yr period

	Area						
	A	B	C	D	Periphery	SDA Total	Control
Population Size	1407	1383	1364	1154	852	6160	6160[a]
Radionuclide							
Pu-238	0.1	6.1	0.9	0.2	0.1	7.4	0.1
Pu-239,240Pu	0.1	2.4	1.2	1.3	0.6	5.5	0.1
Am-241	0.2	3.0	0.4	0.5	0.2	4.3	0.5
Sr-90	1733.4	1380.1	4734.0	2931.3	4768.5	15547.3	40.4
Cs-137	2738.0	371.3	1453.8	2584.0	69.0	7216.1	59.5
Total						22780.6	101.8

a. The number in the control area was assumed to be equal to the number in the SDA.

Table 7-12. Comparison of 1986 Plutonium-239, -240 biotic excavated soil activity concentration measurements with historical maximum surface and biotic excavated soil activity concentration values

Location	1986 Excavated Soil Concentrations ($10^{-6}\mu Ci/g$)	1982 and 1984 Maximum Surface Soil and/or Excavated Soil Concentrations on the SDA ($10^{-6}\mu Ci/g$)
RWMC active area	0.20	1.0 (surface) 0.37 (excavated)
RWMC Pad A	0.04 0.14 0.28	0.53 (surface) 16.5 (excavated)
RWMC previously flooded areas	0.47 9.0	4.8 (surface)
RWMC TSA	0.33	0.18 (surface)

Table 7-13. Comparison of 1986 Americium-241 biotic excavated soil activity concentration measurements with historical maximum values for surface soils

Location	1986 Excavated Soil Concentrations ($454\times10^{6}\mu Ci/lbm$)	1982 and 1984 Maximum Surface Soil and/or Excavated Soil Concentrations ($454\times10^{-6}\mu Ci/lbm$)
RWMC active area	0.07	5.4 (surface)
		0.13 (excavated)
RWMC Pad A	0.11	
	0.28	1.0 (surface)
	0.15	32 (excavated)
RWMC previously flooded area	0.70	9.8 (surface)
SWEPP	0.05	0.47 (surface)
	0.37	

Table 7-14. Comparison of Cesium-137 concentrations in 1986 biotic excavated soil samples with historical maximum concentrations measured in surface and excavated soils

Location	1986 Excavated Soil Concentrations ($454\times10^{6}\mu Ci/lbm$)	1982 and 1984 Maximum Surface Soil and/or Excavated Soil Concentrations ($454\times10^{-6}\mu Ci/lbm$)
RWMC active area	0.40	1.2 (surface)
	0.80	
RWMC Pad A	0.43	0.45 (surface)
	0.38	1.0 (excavated)
RWMC previously flooded area	0.13	0.70 (surface)
		0.45 (excavated)

Table 7-15. RWMC active area perennial vegetation alpha- and beta-emitting radionuclide concentrations

Nuclide	Concentration (454Ci/lbm)[a] 1	2	3	Control
Sr-90	$2.8 \pm 0.3 \times 10^{-7}$	$2.9 \pm 0.3 \times 10^{-7}$	$2.6 \pm 0.3 \times 10^{-7}$	$8 \pm 3 \times 10^{-8}$
Pu-238	BDL[b]	BDL	BDL	BDL
Pu-239-240	$2.8 \pm 0.8 \times 10^{-9}$	$1.5 \pm 0.2 \times 10^{-8}$	$3.7 \pm 0.9 \times 10^{-9}$	BDL
Am-241	BDL[b]	BDL	BDL	BDL
U-234	$3.9 \pm 0.5 \times 10^{-8}$	$2.3 \pm 0.3 \times 10^{-8}$	$3.5 \pm 0.4 \times 10^{-8}$	$1.3 \pm 0.2 \times 10^{-8}$
U-235	$1.8 \pm 0.6 \times 10^{-9}$	$1.6 \pm 0.5 \times 10^{-9}$	$2.3 \pm 0.6 \times 10^{-9}$	BDL
U-238	$4.0 \pm 0.6 \times 10^{-8}$	$2.9 \pm 0.4 \times 10^{-8}$	$3.8 \pm 0.5 \times 10^{-8}$	$1.1 \pm 0.2 \times 10^{-8}$

a. Analytical uncertainties are $\pm 1\sigma$.

b. BDL = below detection limit.

Table 7-16. RWMC perennial vegetation gamma-emitting radionuclide concentrations

Location	Concentration (454×10^{-7} µCi/lbm) Cs-134	Cs-137
1	--	0.88 ± 0.23
1	--	1.9 ± 0.3
1	--	1.9 ± 0.3
Control	--	1.5 ± 0.3
Control	1.02 ± 0.16	3.5 ± 0.4
Control	--	2.0 ± 0.3

Table 7-17. Specific alpha- and beta-emitting nuclides found in Russian thistle samples

		Concentration[a] (10^{-6} μCi/g)			
Area	Sample	Sr-90	Pu-238	Pu-239,-240	Am-241
Active	Routine (1986)	2.3 ± 0.1	0.027 ± 0.005	1.05 ± 0.08	0.046 ± 0.008
Active	Routine (1986)	BDL[b]	BDL	0.2 ± 0.03	BDL
Previously flooded area	Routine (1986)	1.1 ± 0.1	0.08 ± 0.01	3.1 ± 0.3	0.18 ± 0.02
Control	Routine (1986)	BDL	BDL	BDL	BDL
--	RESL	52	0.02	0.02	0.08
Active	Contaminated sample (1984)	1,000,000	200	BDL	3
Previously flooded area	Routine (1984)	2	BDL	BDL	0.05

a. Analytical uncertainties presented are ± 1σ.

b. BDL = below detection limit.

covers over buried LLW (Reynolds and Laundre, 1988). Burrows of the montane voles and deer mice rarely extended below 20 in., and neither volumes nor depths were influenced by soil disturbance. Townsend's ground squirrels had the deepest and most voluminous burrows that, along with the Ord's kangaroo rat burrows, were more prevalent beneath 20 in. in disturbed soils (see Table 7-18).

Gamma-emitting nuclides detected were Co-60, Cs-134, Cs-137, Sb-125, Eu-152, and Eu-154. Cs-137, the most prominently detected radionuclide, occurred in one sample at the Active Pit Area in the SDA. Four out of seven composite samples detected Co-60 while only two composite samples detected Cs-134, Eu-152, and Eu-154. Sb-125 was detected only in one composite sample (Tkachyk et al., 1988).

Results of the radiochemical analysis showed detectable quantities of Sr-90, Pu-238, Pu-239, Pu-240, U-234, and Am-240. Although a lack of previous comparable data precludes any conclusions concerning the significance of the detections, both the U-234 and Sr-90 concentrations were similar to those measured at the RWMC in 1985 (see Tables 7-19 and 7-20).

No gamma-emitting radionuclides that could be attributed to waste management activities at the RWMC were detected in the perennial vegetation samples. Cs-137 was detected in 5 of 21 crested wheatgrass samples. These 1988 concentrations were all within the range of previous results reported by RESL.

Results of the radiochemical analysis showed detectable quantities of Sr-90, Pu-240, Pu-239, U-238, U-235, and U-234. No conclusion can be drawn concerning the significance of the uranium concentrations because of the lack of available historical data. The concentrations of both Sr-90 and Pu-239, Pu-240 in 1988 were below those levels reported by RESL in the crested wheatgrass and Russian thistle. Detection of Sb-125 in crested wheatgrass samples at two RWMC locations is likely a result of gaseous effluent releases

Table 7-18. Mean ± standard deviation volume per burrow of soil excavated from decimeter increments in undisturbed and disturbed soils by four species of rodents on the INEL

Depth Interval (ft/30.5)[a]	Species: Townsend's ground squirrels $\bar{X} \pm SD(n)$[b]	Ord's kangaroo rat $\bar{X} \pm SD(n)$	Deer Mice $\bar{X} \pm SD(n)$	Montane vole $\bar{X} \pm SD(n)$
0-10				
UND	1.1 ± 0.9 (20)[c]	1.3 ± 1.7 (19)	0.4 ± 0.2 (26)	0.6 ± 0.6 (25)
DIS	0.5 ± 0.5 (10)	1.3 ± 1.9 (4)	0.5 ± 0.4 (17)	0.8 ± 0.8 (23)
11-20				
UND	2.9 ± 2.0 (20)	3.4 ± 3.0 (19)[c]	1.1 ± 0.9 (26)	0.8 ± 0.6 (21)
DIS	1.6 ± 1.8 (10)	0.6 ± 0.4 (4)	0.8 ± 0.8 (12)	0.9 ± 0.6 (22)
21-30				
UND	4.4 ± 5.2 (16)[c]	2.5 ± 3.2 (15)	1.4 ± 1.4 (14)*	0.9 ± 0.7 (9)
DIS	1.3 ± 0.9 (8)	1.0 ± 0.9 (4)	0.3 ± 0.1 (4)	0.8 ± 0.7 (10)
31-40				
UND	1.9 ± 1.3 (11)[c]	1.7 ± 2.5 (5)	0.7 ± 0.6 (6)	0.6 ± 0.4 (2)
DIS	0.7 ± 0.4 (6)	1.2 ± 0.3 (4)	0.4 ± 0.3 (2)	0.2 ± 0.0 (2)
41-50				
UND	1.3 ± 1.4 (7)	0.5 ± 0.2 (2)	0.8 ± 0.5 (3)	1.9 --(1)
DIS	0.6 ± 0.3 (6)	2.1 ± 1.6 (2)	0.4 --(1)	d
51-60				
UND	0.9 ± 0.5 (3)	1.6 --(1)	d	0.2 --(1)
DIS	1.4 ± 1.2 (6)	1.7 ± 0.9 (2)	d	d
61-70				
UND	0.9 ± 0.5 (3)	3.4 --(1)		
DIS	0.9 ± 0.9 (6)	1.3 ± 1.1 (2)		
71-80				
UND	0.7 ± 0.3 (3)	d		
DIS	1.6 ± 2.4 (4)	0.3 --(1)		
81-90		0.3 ± 0.1 (2)		
UND	0.4 ± 0.2 (3)			
DIS	2.7 ± 2.4 (3)	d		
91-100				
UND	0.7 ± 0.3 (3)			
DIS	2.3 ± 0.8 (3)			

Table 7-18. (continued)

Depth Interval (ft/30.5)	Species: Townsend's ground squirrels $\overline{X}$ ± SD(n)	Ord's kangaroo rat $\overline{X}$ ± SD(n)	Deer Mice $\overline{X}$ ± SD(n)	Montane vole $\overline{X}$ ± SD(n)
101-110				
UND	1.3 ± 0.6 (3)			
DIS	6.7 ± -- (1)			
111-120				
UND	2.0 ± 0.6 (3)			
DIS	7.4 ± -- (1)			
121-130				
UND	12.1 ± 7.6 (3)			
DIS	1.5 ± -- (1)			
131-140				
UND	2.0 -- (1)			
DIS	--			
X ± SD(n)	11.8 ± 8.4 (20)	7.2 ± 7.7 (19)	1.7 ± 1.8 (26)	1.5 ± 1.2 (25)[c]
UND	9.4 ± 10.2 (10)	7.3 ± 3.6 (4)	1.3 ± 0.9 (17)	2.1 ± 1.5 (23)
DIS				

a. UND = undisturbed
DIS = disturbed.

b. $\overline{X}$ = (mean) ± SE (standard error)

c. Significant difference between means of couplet.

d. No burrowing activity found at or below this depth in this soil for this species.

Table 7-19. RWMC small mammal gamma radionuclide concentrations

	Concentration (454×10^{-7} µCi/lbm)					
	Active Area				TSA	
Nuclide	1	2	3	Inactive Area	1	2
Co-60	--[a]	2.9 ± 0.8	6.7 ± 0.7	--	1.5 0.3	1.9 ± 3
Cs-134	--	--	11.8 ± 0.8	--	--	2.7 ± 0.5
Cs-137	6.1 ± 0.8	3.3 ± 0.8	520 ± 40	4.1 ± 0.8	--	11.8 ± 1.2
Sb-125	--	7.8 ± 1.2	--	--	--	--
Eu-152	52.4 ± 1.8	14.3 ± 1.8	--	--	--	--
Eu-154	--	39 ± 3	7.4 ± 1.3	--	--	--

a. "--" indicates radionuclide not detected.

Table 7-20. RWMC small mammal alpha- and beta-emitting radionuclide concentrations

	Concentration (454 µCi/lbm)			
Nuclide	Active Area	Previously Flooded Area	TSA	Control
Sr-90	$6.5 \pm 0.5 \times 10^{-7}$	$3.7 \pm 0.4 \times 10^{-7}$	$8.3 \pm 0.4 \times 10^{-6}$	$2.8 \pm 0.4 \times 10^{-7}$
Pu-238	$8 \pm 2 \times 10^{-9}$	BDL[b]	$9 \pm 1 \times 10^{-9}$	BDL
Pu-239, -240	$3.0 \pm 0.2 \times 10^{-7}$	$2.7 \pm 0.8 \times 10^{-8}$	$9.9 \pm 0.8 \times 10^{-8}$	BDL
Am-241	BDL	$3.5 \pm 0.8 \times 10^{-8}$	$7 \pm 2 \times 10^{-8}$	BDL
U-234	$2.8 \pm 0.4 \times 10^{-8}$	$4.0 \pm 0.6 \times 10^{-8}$	$2.4 \pm 0.3 \times 10^{-8}$	$2.6 \pm 0.4 \times 10^{-8}$
U-235	BDL	BDL	BDL	BDL
U-238	$2.5 \pm 0.4 \times 10^{-8}$	$5.1 \pm 0.9 \times 10^{-8}$	$2.0 \pm 0.3 \times 10^{-8}$	$2.6 \pm 0.4 \times 10^{-8}$

a. Analytical uncertainties are $\pm 1\sigma$.

b. BDL = below detection limit.

at the ICPP; because elevated levels of Sb-125 attributed to ICPP operation were detected in RWMC air samples during 1987 (see Table 7-21).

Studies on deer mice collected at the RWMC conducted by the Environmental Monitoring Unit at EG&G Idaho showed no positive detection above background levels for gamma-emitting nuclides in any samples or in control samples, (EG&G, 1988, 1989).

Samples of Russian thistle and crested wheatgrass collected in 1988 and 1989 from the five major areas of the RWMC were analyzed by gamma spectrometry. No gamma-emitting radionuclides were detected in any of the samples. Selected samples were submitted for radiochemical analysis for alpha- and beta-emitting radionuclides. There were no detectable concentrations of alpha emitters in any sample. There were detections of beta-emitting Sr-90 at levels slightly above those of the control samples, but they were similar to contractions reported in previous years from Russian thistle samples collected at the RWMC (EG&G, 1988, 1989).

During 1990, special attention has been devoted to the presence of harvester ants, which are a major component of western rangeland ecosystems. Relatively little is known about their role in soil/water interaction. Therefore, soil moisture from the mounds of harvester ants was estimated monthly with a neutron probe at 8-in. intervals to a depth of 40 in.

Based on monitoring results and dose calculation, there are no expected health effects in the offsite population within a 50-mi radius surrounding the RWMC[c].

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[c] Unpublished research results of J. L. Petty, S. L. Lopez, and K. C. Wright, EG&G Idaho, Inc., Idaho Falls, Idaho, July 1990.

Table 7-21. RWMC vegetation gamma-emitting radionuclide concentrations in crested wheatgrass.[a]

	Concentration (454×10^{-7} μCi/lbm)		
Location[b]	Cs-134	Cs-137	Sb-125
1	--[c]	--	--
1	--	--	--
1	--	--	--
2	1.5 ± 0.2	1.7 ± 0.3	--
2	1.3 ± 0.3	--	--
2	--	1.0 ± 0.2	--
3	--	--	--
3	--	--	1.8 ± 0.4
3	--	--	--
4	--	--	--
4	--	--	--
4	--	--	--
5	1.07 ± 0.14	3.7 ± 0.4	1.6 ± 0.3
5	--	1.5 ± 0.3	--
5	--	0.69 ± 0.19	--
Control 1[d]	--	--	--
Control 1	--	--	--
Control 1	--	--	--
Control 2[e]	--	--	--
Control 2	--	--	--
Control 2	--	--	--

a. Tkachyk et al., 1988

b. Crested wheatgrass was collected from five major areas of the RWMC.

c. "--" means no measurement detected.

d. Control from lake beds.

e. Control from T-12 access road (approximately 5 km northeast from SDA).

7.7 Summary of Biotic Characterization Needs

What are examples of preliminary study options for closing existing gaps in the RWMC data base?

Trophic Levels

The majority of studies performed at the INEL Site have focused on individual species; specific taxonomic groups (e.g., small mammals and vegetation); and a limited number of trophic levels for assessing radionuclide uptake and transport. Few studies have inventoried radionuclides through trophic levels in the same locations. Such an analysis is necessary to determine the degree of radionuclide transfer between trophic levels and the potential for transport of radionuclides to offsite areas where humans may become exposed to contaminants.

Some research on trophic levels has been performed at the INEL Site, primarily by Arthur and his coworkers. At the SDA, Arthur and Markham (1983) examined concentrations of five transuranics and Sr-90 in contaminated soils and vegetation and 2 reptilian, 18 mammalian, and 31 avian species. Burrowing mammals were identified as an important vector for potentially transporting radionuclides from subsurface pits through the food chain to top-level carnivores such as coyotes. In a related study, Arthur et al. (1983) examined Cs-137 levels in contaminated soils, vegetation, insects, small mammals, and coyotes at the SL-1 area. Elevated Cs-137 levels were detected mainly in surface and excavated soils and deer mice. However, no contamination was detected in other components of the food chain, and no mechanisms for trophic levels of migration of radionuclides were discussed.

A trophic level analysis would focus on primary producers, primary consumers, and top-level consumers. Representatives of primary producers include big sagebrush, crested wheatgrass, and Russian thistle. Primary consumers include game species such as the sage grouse and mourning dove, and nongame species such as the sage sparrow. Top-level consumers potentially included in this option would be the American kestrel, loggerhead shrike, burrowing owl, long-eared owl, and short-horned lizard.

The particular producers chosen for trophic level analysis were selected because they have the deepest and most extensive root system of plants studied at the INEL site and are, therefore, most likely to penetrate shallow surface disposal pits at the SDA. Earlier studies have identified these species as biological intruders at the SDA and potential vectors of radionuclide transport through food chains (Arthur, 1983). Consequently, these species form the basis for monitoring a producer trophic level at the SDA. Monitoring deep rooting plants will enable the RWMC to determine the extent of subsurface intrusion and the need for more effective characterization at the SDA.

The sage sparrow was selected to represent primary consumers that potentially feed on contaminants brought to the surface by deep rooting plants. Townsend's ground squirrel was selected as a representative of primary consumers known to penetrate shallow burial sites at the SDA. This species has the most extensive burrows of small mammals studied at the INEL Site. Deer mice have also been suspected of penetrating subsurface disposal areas and were selected because of their relative abundance and ease of sampling.

Harvester ants were selected because they may also be involved in subsurface intrusion and transport of radionuclides at the SDA. Limited observations indicate that this species is capable of penetrating solid covers and transporting radionuclides to the surface. Contaminated mounds constructed from subsurface soils could provide a source for airborne contamination and transport of radionuclides to secondary consumers such as the short-horned lizard.

Attempts will be made to coordinate harvester ant sampling with studies in progress at the INEL Site. In addition, soil samples should be taken from areas surrounding deep rooting plants, burrowing small mammals, and ant mounds to further determine the significance of subsurface intrusion by these potential vectors.

Both the sage grouse and mourning dove were selected because these species have exhibited elevated levels of radionuclides possibly obtained from contaminated plants at the SDA . Consequently, monitoring these primary consumers would provide additional information on mobilizing radionuclides from deep rooting plants and potential transport to humans.

Because sampling of top-level carnivores is generally limited by their low abundance, a final determination on specific species to include as representatives of this trophic level will be made following completion of initial field reconnaissance. Potential representatives of this trophic level include some of the less mobile raptors such as shrikes, kestrels, and owls (long-eared and burrowing). These species were selected because they feed primarily on small mammals or birds. Therefore, it is likely that they may consume burrowing mammals that have penetrated subsurface disposal sites or birds that may have consumed seeds of deep rooting plants.

Shrikes are also likely to feed on lizards that may have assimilated radionuclides from consumption of contaminated ants. Where possible, attempts will be made to supplement kestrel sampling by positioning nest boxes to induce nesting in the study area. Where possible, field investigations will be coordinated with ongoing studies of raptor nesting ecology at the INEL Site.

This study would provide the most comprehensive inventory of an individual ecosystem at the INEL Site. It would provide a foundation for pathway analyses and serve as a point of reference for monitoring radionuclide migration through trophic levels during the remediation process. The final product of this analysis would be a detailed inventory of radionuclides in major trophic levels and baseline information for establishment of remediation criteria at the SDA.

Based on existing literature, there are five major areas in need of further study:

1. Trophic level and pathway analyses of major ecosystems at the RWMC

2. Synthesis and integration of flora and fauna studies

3. Monitoring of select trophic levels for radionuclide uptake and transport

4. Identification of key monitor species for inventories of radionuclide uptake

5. Identification of most probable contact routes to humans and critical pathways for human exposure.

Data on these areas of interest could be collected or synthesized from existing data bases using either an ecosystem pathways analysis or vector analysis.

Few studies at the RWMC have used an ecosystem approach to monitoring radionuclide uptake and transport. There are several advantages to an ecosystem approach: (a) it provides detailed inventories of major trophic levels within an ecosystem, (b) it identifies specific trophic levels where radionuclides are concentrated, (c) it can be used for tracking the overall health of ecosystem components and biota, and (d) it can be used to identify potential risks to surrounding human populations.

One major application of this approach might include estimating how clean an area needs to be to avoid adverse biotic and human health effects. For example, it is widely known that predators at the top of food chains are biological indicators of environmental conditions that also affect human populations. Therefore, top-level carnivores can be used to assess the overall health of biota surrounding the RWMC.

Additional indicator species could be assessed based on social relevance, biological relevance, and susceptibility to hazards.

Pathway analysis could also be used to estimate contamination at specific trophic levels and to define what levels of remediation are needed to lower risks to biota and surrounding human populations. This type of analysis has not been conducted at the RWMC. These studies could serve as a model for a monitoring program at the RWMC site.

A monitoring program could also be developed for the RWMC using specific vectors to track radionuclide levels in select pathways. The primary focus of this program would include identification and biological inventories of key vectors at select points in time, strategic sampling of most probable contact routes to humans, monitoring of critical pathways to particular receptors, and determination of risks to biota and humans.

Future studies could also include changes in community structure and function, sensitive plant species located near the RWMC, identification of sensitive habitiats, and heavy metal and PCB contamination in species associated with the RWMC.

7.8 Federal Facilities Agreement Operable Unit Study

Information discussed in this section, including radionuclide uptake and biotic transport mechanisms, will be used as future reference for all appliable operable unit studies.

8. SOURCE TERM AND NATURE AND EXTENT OF CONTAMINANT MOVEMENT

8.1 RADIOACTIVE WASTE MANAGEMENT COMPLEX DISPOSAL HISTORY

What is the history of the RWMC?

The RWMC, formerly known as the Burial Ground, was established in 1952 as a controlled disposal area for solid radioactive waste generated by the National Reactor Testing Station (NRTS). The NRTS was designated by the Atomic Energy Commission (AEC) as an interim burial ground for the region from 1960 to 1963. During the remainder of the decade, questions were brought up concerning the wisdom of storing TRU waste above the Snake River Plain Aquifer. By 1965, the National Academy of Sciences, Committee on Geological Aspects of Radioactive Waste Disposal, indicated that leakage of plutonium waste from corroding steel drums was inevitable. Segregating TRU waste from LLW in pits and trenches began in 1964.

During 1969, the burial of TRU waste was evaluated; it was decided that because of potential flooding and environmental hazards, no TRU materials would be buried during the winter or spring months. The TSA was established in 1970 for the aboveground storage of waste greater than 10 Nci/g of TRU radionuclide activity.

The RWMC has been expanded as demand for waste storage has increased. Currently, the RWMC consists of the 88-acre SDA, the 56-acre TSA, and the 22-acre administrative area (see Figure 8-1).

What is the history of the SDA?

By 1957, the original SDA was nearly filled and was expanded from 13 to 88 acres. This expansion included the Acid Pit, located in the south-central region of the SDA (Figure 8-1). This pit was used for the disposal of radioactive and nonradioactive laboratory solvents and acids from

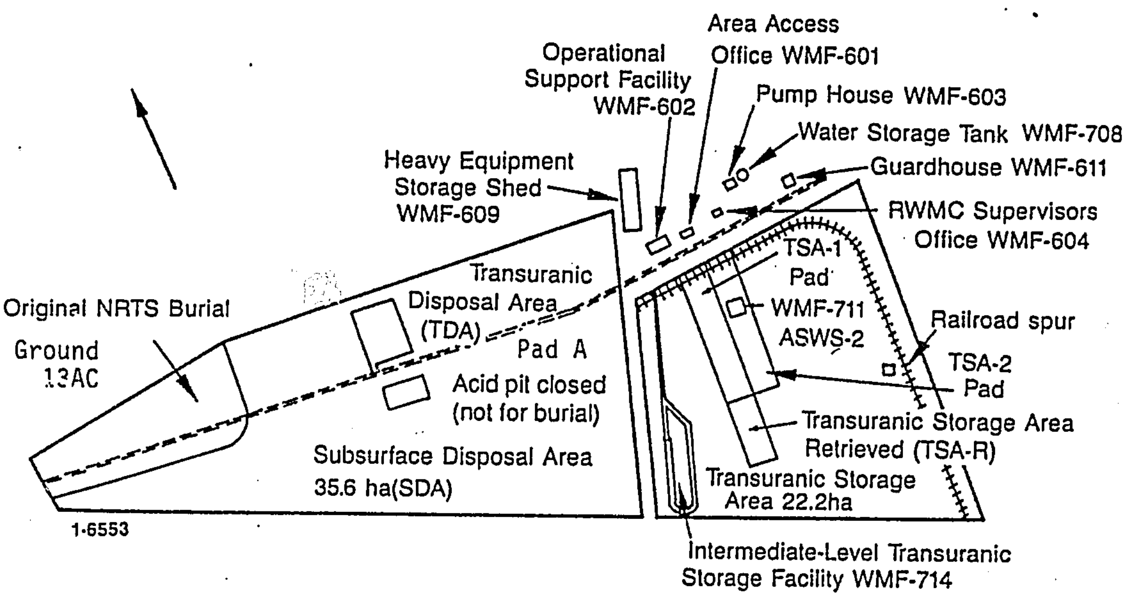

Figure 8-1. Generalized layout of the Radioactive Waste Management Complex.

January 1, 1954, to January 1, 1961 and possibly into the late 1970s (Wells and Vigil, 1989).

Storage areas at the SDA consist of Pad A in the north-central portion of the SDA and 20 pits, 18 soil vault rows, and 58 trenches scattered across the SDA.

The first trench was excavated in July 1952 to dispose of mixed fission product (MFP) waste generated at the NRTS. These storage locations range from 100 to 1000 ft in length, are generally 5 to 8 ft wide, 12 ft deep, and are excavated on 16 ft centers. Typically, the trenches were covered with 3 ft of soil to reduce the radiation level to less than 1 mR/h at a point 3 ft above surface. All ranges of radioactive waste were buried in the trenches. The trenches were used more frequently as waste disposal became more controlled. Trenches were eventually phased out and replaced by soil vaults.

Excavation of pits began in 1957 to accommodate large, bulky items from the Rocky Flats Plant (RFP) that would not fit in existing trenches. Pits were dug to many dimensions. The pits are large, with surface areas up to several acres, and most have been dug to basalt roughly 15 to 20 ft deep. The basalt was generally covered with 2 ft of soil before filling the pit with waste, and 3 ft of soil was the usual pit cover.

Soil vaults are cylindrical holes drilled into the ground for disposal of waste with radiation levels in excess of 500 Mr/h, usually beta-gamma waste, at 3 ft from the container surface. Vault diameters vary from 1.3 to 6.5 ft and average 12 ft in depth. If basalt was encountered during drilling, 2 ft of soil was placed on the bottom of the hole before waste emplacement. Soil vaults were covered with 3 ft of soil after waste emplacement.

Pad A is a disposal area located in the north central part of the SDA. It was completed in September 1972 for the disposal of uranium and non-TRU waste. Pad A was extended in 1973 and 1976 to a final dimension of 240 x 335 ft. The pad is constructed of asphalt and is underlain by basalt. Waste containers were stacked in layers on the asphalt pad and covered with an average of 3 ft of soil. About one half of the receptacles are covered with plywood and polyethylene.

<u>What is the history of the TSA?</u>

The AEC issued the Policy Statement Regarding Solid Waste Burial on March 20, 1970 (Vigil, 1989). This policy requires waste contaminated with TRU nuclides to be segregated and stored for 20 years to permit future retrieval. TSA was established to store and cover TRU waste on aboveground pads to comply with this directive.

TSA Pad 1, consisting of 8 cells, was completed in October 1970. Pad 1 received waste from November 1, 1970, to October 25, 1975. The final cover consists of 0.6 in. thick plywood, a nylon-reinforced polyvinyl cover, and 2 to 3 ft of soil in that order over the drums (Figure 8-1).

TSA Pad 2 was opened in September 1975. The pad is made up of four cells and has the same dimensions and construction as Pad 1. The southern portion of the Pad is covered by an air-support weather shield to allow all-weather operation. Pad 2 is currently open (Figure 8-1).

TSA-R pad was constructed in December 1976 to provide 20-year storage of TRU waste retrieved during the Initial Drum Retrieval and Early Waste Retrieval demonstrations between 1974 and 1978. Closure of TSA-R Pad occurred during FY-79 and consisted of covering the pad with planking, plywood, polyethylene sheeting, and 2 ft of soil. The portion of the pad not used for storage of retrieved waste is used to temporarily store waste from the RFP and Mound Laboratory (Figure 8-1).

8.2 Classes of Waste and Contaminant Types

What are the sources of the wastes disposed at the RWMC?

The RWMC has received a wide variety of waste types including low-level and TRU radioactive waste, inorganic waste, and organic waste that in some cases is also radioactive. The majority of these wastes were generated at the INEL and the RFP. Wastes from the INEL have generally gone into the trenches at the SDA.

Waste from the RFP has been deposited at the RWMC in 1954. Waste transported to the INEL from the RFP was extremely varied in nature. This debris was dumped in Trenches 1 through 10 and mixed with INEL-generated waste from 1952 to 1957. Beginning in 1957, the waste was placed in pits due to the increase in size of shipments. Most often the waste was placed in 30- and 55-gal drums, or wooden crates if it was exceptionally bulky.

Approximately 90% or 181,515 ft^3 of the offsite waste (excluding RFP) was shipped from the Nuclear Regulatory Commission (NRC)-Region V, Lawrence Radiation Laboratory, Rockwell International - Atomics International Division, and General Atomic Company from 1960 to 1963. A list of all offsite waste generators with shipped waste volumes for the years 1954 to 1970 is available in Vigil (1989). The total volume of waste shipped (excluding RFP was 204,173 $ft.^3$

The NRC shipped approximately 27,948 ft^3 of waste originally destined for sea disposal to the RWMC during 1961. The waste was contained in 55-gal drums, wooden boxes, steel culverts, and buoys. An estimated 2712 of these drums culverts, and buoys contain dry waste solidified in concrete. Pit 2 and/or 3 and/or Trenches 22, 23, and/or 24 are possible locations of this waste material.

The RWMC received approximately 79,156 ft^3 from Lawrence Radiation Laboratory including TRU radionuclides, MFP, and mixed activation product

(MAP) contaminated material. Rockwell International shipped an estimated 49,168 ft^3 of waste to the RWMC, and General Atomic Company shipped a total of 25,243 ft^3 of waste to the RWMC.

What are the primary sources of waste disposed of/stored at the RWMC?

The opening of Trench 1 in 1952 initiated the receipt of radioactive waste to the RWMC. Early shipments consisted of both intermediate-level and low-level solid MFP from INEL facilities. Vigil indicates that the volume of LLW at the SDA is probably about 1,180,000 ft^3 rather than the earlier predicted 500,000 ft^3 value. The volume and radioactivity of site-generated wastes sent to the RWMC from 1960 to 1969 totals 43,855,124 ft^3 and 4239 KCi, respectively (Table 8-1). Receipt of RFP TRU waste began in 1954. From 1954 through 1957 no segregation of TRU and MFP waste was done, resulting in mixed waste disposal in Trenches 1 through 10.

In 1957, the TRU waste shipped from the RFP increased in bulk and could no longer be placed in trenches. This resulted in the opening of the waste pits. A consequence of this was the segregation of much of the TRU waste from the MFP waste. However, pits were used intermittently to dispose of large items that were contaminated by MFP.

LLW and TRU waste intermixed with beta-gamma waste in the pits and trenches at the SDA is estimated to be 2,000,000 and 500,000 ft^3, respectively. The TRU waste at the SDA has an estimated activity of 252,975 Ci at emplacement (Table 8-2). Beta-gamma waste mixed with the TRU waste has an estimated activity of 583,000 Ci at emplacement (Table 8-3). It is estimated that an additional 2,900,000 ft^3 of beta-gamma waste is buried at the SDA. A total of 5,400,000 ft^3 of TRU and beta-gamma waste has been buried at the SDA.

What are the sources of hazardous wastes disposed/stored at the SDA?

Organic wastes have been sent to both the SDA (1966 to 1970) and TSA (1970 to present). The total volume of potentially hazardous waste buried at

Table 8-1. Solid waste contributed by INEL site facilities to the SDA, 1960-1969[a]

Facility Area	Volume ($ft^3/35.31$)	Radioactivity (kCi)
Naval Reactor Facility	4,420,000	3,000.00
Test Reactor Area	310,000	1,000.00
Idaho Chemical Processing Plant	165,000	100.00
Test Area North	140,500	27.00
Argonne National Laboratory	84,000	107.00
Central Facilities Area	40,500	0.20
Organic Moderated Reactor Experiment	24,300	0.20
Gas Cooled Reactor Experiment	24,300	2.00
Special Power Excursion Reactor Test	5,400	0.04
Auxiliary Reactor Area	5,100	3.00
Total	1,241,100	1,239.44

a. Source: Vigil (1989).

Table 8-2. Radionuclide content of buried TRU waste

Uranium and TRU Radionuclide	Emplaced Curies	Percent	Buried Waste As of Jan. 1, 1985[a] Curies	Percent
Pu-238	571.4	0.225872	462.0	0.367641
Pu-289	21043.0	8.3182	19789.0	15.7473
Pu-240	4860.0	1.921135	4564.0	3.63185
Pu-241	178425.0	70.53057	54234.0	43.15726
Pu-242	0.2	7.91E-05	0.2	0.000159
Am-241	48007.0	18.97694	46548.0[b]	37.04
Cm-244	0.0	0.0	0.0	0.0
U-233	0.5	0.000198	0.5	0.000398
U-235	0.3	0.000119	0.3	0.000239
U-238	68.0	0.02688	68.0	0.054112
Total radioactivity	252975.0	100.0	125666.00	100.0
Total weight of TRU waste, (lbm/0.45359)[c]		381.0	356.9	
Total weight of U-235 and U-238 (lbm/0.45359)		203322.0	203322.0	
TRU content, (Ci/ft^3)		0.115	0.036	

Source:

a. Does not include the beta-gamma waste present.

b. Includes Am-241, produced by the decay of Pu-241 after emplacement.

c. Including U-322, in accordance with the definition of transuranic contaminated solid waste. Because of rounding errors, values shown may differ slightly from values obtained by converting curies of individual radionuclides to pounds-mass and adding.

Table 8-3. Estimated radioactivity in LLW mixed with buried TRU waste[a,b]

Nuclide	Half-Life[c] (years)	Emplaced Curies	Emplaced Percent	As of July 1, 1985[d] Curies	As of July 1, 1985[d] Percent
Ni-59	80,000.00	1,500	0.3	1,500.0	20.2
Co-60	5.27	99,000	17.0	4,214.3	56.8
Sr-90	29.00	1,000	0.2	536.5	7.6
Cs-137	30.17	1,000	0.2	576.2	7.8
MAP[e]	5.27	6,000	1.0	255.4	3.4
MFP[f]	30.17	500	0.1	288.1	3.9
UI (beta/gamma)[f]	3.00	5,500	0.9	21.5	<0.3
Short-lived beta-gamma emitters	<<1[g]	468,500	80.3	Negligible	<0.0
Total		583,000	100.0	7,419.0	100.0

Source:

a. From Vigil (1989).

b. Estimates include Pits 6, 9, and 10.

c. Values are taken from the Chart of the Nuclides, Naval Reactors, DOE, April 1977.

d. Although LLW was buried with the TRU waste from 1954 through 1964, about one half of the activity was buried in 1962 and 1963. Therefore, these simplified calculations of radioactive decay were based on an assumed burial date of January 1, 1961 (24-year decay by the year 1985) for all of the LLW.

e. MAP = mixed activation products. Decay calculations are based on the half-life of Cobolt-60, the dominant radionuclide.

f. MFP = mixed fission products. Decay calculations are based on the half-life of Cesium-137, the dominant radionuclide.

g. UI (beta/gamma) = unidentified beta/gamma emitters. Decay calculations are based on an estimated value of the effective half-life.

h. Much less than 1 year.

the SDA is estimated to be 48,344 ft^3 (see Table 8-4). An estimated 11,816 ft^3 of this waste is TRU-contaminated organic waste. Contributors to the total volume also include 23,400 gal of oils in Oil-Dri, 10,200 gal of acids in absorbent materials, 27,600 gal of sodium-containing chemicals, and 6,900 gal of caustic materials. Machining oil, carbon tetrachloride, used oils, trichloroethane, and trichloroethylene are the main components of the organic waste (Vigil 1989).

The most complete documentation of the quantity and types of organic wastes at the RWMC is for RFP-generated waste (see Table 8-5). Organic waste did not arrive from RFP until August 1966; a backlog of waste from RFP generated from 1953 to 1966 was shipped from 1967 to 1968 (Kudera, 1987). The RFP sent an estimated 88,400 gal of organic waste for burial at the SDA (Vigil, 1989) (Table 8-5).

Approximately 24,400 gal of the organic waste is estimated to be carbon tetrachloride. The remaining volume consists of approximately 39,000 gal of Texaco Regal Oil and 25,000 gal of miscellaneous organic wastes (trichloroethane, trichloroethylene, perchloroethylene, and used oils such as lubricating oils). Most RFP organic waste has been mixed with calcium silicate to form a grease or paste-like material. Small amounts of absorbent were also mixed in the waste.[1]

The TSA at the RWMC is estimated to have 351,000 gal of organics in storage. Approximately 83,200 gal are estimated to be carbon tetrachloride. The remainder consists of approximately 124,800 gal of Texaco Regal Oil and 142,900 gal of miscellaneous organic wastes. The miscellaneous wastes include used oils, trichloroethane, trichloroethylene, perchloroethylene, and small amounts of toluene, benzene, and others.

How and where were these wastes disposed of?

Existing data describing exact contents of the pits, trenches and vaults is limited. As a general rule, pits contain waste from RFP and trenches contain waste from INEL facilities (see Table 8-6). All available information on the

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[1] F. Cerven and T. L. Clements, Jr., 1987, Estimate of Hazardous Waste Constituents in the RWMC Subsurface Disposal Area, EG&G Idaho, Inc., EDF-TNT-010-87.

Table 8-4. Estimates of hazardous materials disposed of in the RWMC SDA[a]

Material	Volume (ft^3)	Volume (gal)
Rags[b]	4,500.00	NA
Oil (in adsorbent)	3,100.00	12,400
Lead	6,400.00	NA
Asbestos/lagging	3,500.00	NA
Ethylene glycol	50.00	390
Mercury	300.00	2,240
Acids (HF, HCl, in adsorbent)	1,400.00	10,200
Organics (e.g.,ether)	900.00	6,700
Santo Wax[d]	7,100.00	53,700
Sodium, sodium compounds and pipe	3,700.00	27,600
Batteries	20.00	NA
Benzene	3.00	20
Animal carcasses and feces	2,500.00	NA
Vehicles[e]	860.00	NA
Cyanide	<0.35	NA
Meat w/botulinus	0.25	NA
Tritium vials	64.00	NA
Zirconium chips	1,100.00	NA
Caustic compounds (e.g., NaOH in adsorbent)	930.00	6,900
Paint chips and cans	210.00	1,600
Gasoline (absorbed)	180.00	1,300
Ammonia bottles	7.00	NA
Thallium oxide	<3.00	NA
TRU Texaco Regal Oil	5,215.00	39,018
TRU carbon tetrachloride	3,263.00	24,413

Table 8-4. Estimates of hazardous materials disposed of in the RWMC subsurface disposal area (SDA) (Cont.)

Material	Volume (ft^3)	Volume (gal)
TRU other organics	3,338.00	24,968
Total	4,8344.00	222,450[f]

Source:

a. From Vigil (1989).

b. The quantity identified assumes 5% of the total rag inventory at the RWMC is oil/solvent soaked.

c. NA = Volume, in gallons, is an inappropriate measure for these materials.

d. Santo Wax is from the Organic Moderated Reactor Experiment; it may not be a hazardous material.

e. Vehicles disposed of at the RWMC were assumed to be driven into the pits with fuel, oil, antifreeze, and batteries left in place. The volume indicated represents 5% of the total vehicle volume.

f. Gallons are not volume equivalent because of some solid materials.

Table 8-5. Organics shipped from the RFP to the INEL

Year	RWMC Status	Number of Drums	Volume in (gal): Texaco Regal Oil	Carbon Tetra-chloride	Other Organic[a]	Total
1966-1969[b]	Buried	8,709	39,018	24,413	249,680	883,990
1970-1987[c]	Stored	9,284	124,842	83,226	142,876	350,944

a. Mostly 1,1,1-trichloroethane, trichloroethylene, perchloroethylene, and used oil.

b. Gallons estimated for 1966 and 1969.

c. Volumes up to June 1987.

Table 8-6. Available information on types of waste by location

Location	Waste
Pit 1	SL-1, TRU
Pit 2	SL-1, Hg, acids, beta-gamma, other material
Pit 3	SL-1, Aircraft Nuclear Propulsion rad. waste, TRU, acids, beta-gamma, other material
Pit 4	Acids, other material, TRU and non-TRU, MFP waste
Pit 5	TRU-organics
Pit 6	TRU-ort., PCB
Pit 7	TRU[a]
Pit 8	TRU[a]
Pit 9	NRF-waste oil, TRU-organics, polyclorinated biphenyl (PCB)[a]
Pit 10	MFP, TRU-org., PCB[a]
Pit 11	TRU
Pit 12	TRU
Pit 13	TRA-mercury
Acid Pit	Acid, organic, rad[b]
Trench 1	MFP, mixed waste
Trench 2	MFP, mixed waste
Trench 3	MFP, mixed waste
Trench 4	MFP, mixed waste
Trench 5	MFP, mixed waste
Trench 6	MFP, mixed waste
Trench 7	MFP, mixed waste
Trench 8	MFP, mixed waste
Trench 9	MFP, mixed waste
Trench 10	MFP, mixed waste
Trench 27	TAN-mercury[a]

a. This waste component is questionable.

b. Records of disposal practices at the Acid Pit are limited. Liquid wastes of many types may have been disposed here without records.

types of wastes in the pits and trenches is present in the Radioactive Waste Management Information System (RWMIS) data base. This is the most comprehensive and complete record source for the RWMC.

Approximately 60% of the waste in pits, trenches, and vaults is contained in 30- to 55-gal steel drums, 30% has been placed in cardboard and fiberboard receptacles, and 5% is in plywood boxes. Large items, such as vehicles and equipment, were deposited without containers.

The DOE utilizes four computerized data bases for storing information covering waste disposal at its facilities. These include

- The Solid Waste Information Management System (SWIMS) which contains information on the generation and storage and/or disposal of solid radioactive waste at all DOE facilities

- The Radioactive Waste Management Information System (RWMIS) which consists of INEL data on radioactive airborne or liquid effluents and the solid radioactive waste stored and/or disposed at the RWMC.
- The Transuranic Contaminated Waste Container Information System (TCWCIS) which contains data on individual containers of stored TRU waste received at the RWMC.

- The Environmental Restoration Information System (ERIS) which contains the Geographic Information System (GIS) used by the Environmental Restoration Program to store and use geological, hydrological, chemical sampling and site characterization, meteorological, source-term, and management oriented data.

What uncertainties exist regarding waste disposal?

The following uncertainties exist:

- Records of disposed wastes at the SDA are incomplete, particularly for the early years of waste disposal. Documents containing information on waste disposal in trenches are lacking.

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- The volume, type, and curie level of wastes disposed of in the Acid Pit are not well established. A significant amount of the organics and acids may have been radioactively contaminated.

- Soil vaults contents have not been covered in a complete manner.

8.3 Secondary and Tertiary Sources of Contamination

What are secondary and tertiary sources of contamination?

Secondary sources of contamination are confined to materials that include the initial waste containment area and result from container integrity failure and the subsequent release of contaminants into the surrounding fill material. Tertiary sources of contamination are soils and/or rocks outside the initial containment area that contain contaminant concentrations above background conditions.

For example secondary contaminant sources of the RWMC result from container integrity failure releasing contaminants, leaching of contaminants from containers, and retention of contaminants in the soil surrounding the container. Tertiary sources of contamination occur when contaminants migrate from the initial containment area.

Secondary radionuclide sources have been identified during the Initial Drum Retrieval and the Early Waste Retrieval demonstration conducted in the mid to late 1970s. Plutonium, americium, strontium, cesium, europium, uranium, and cobalt have been detected in pit backfill material and in the soils below pit floors.

The USGS began drilling to determine if radionuclides had migrated to the deep subsurface at the SDA (Barraclough et al., 1976). Samples from the 240-and 110-ft interbeds from six boreholes were collected and analyzed for radionuclide contamination. The analyses indicated that both interbeds were contaminated (Barraclough et al., 1976).

Further drilling was conducted by the INEL prime contractor in 1975 to confirm the previous results. However, no radioactive waste was detected in the subsurface, and the USGS results were suspected to be because of artificial contamination (Burgus and Maestas, 1976; DOE, 1983).

The presence of Pu-240, Pu-239, Pu-238 and Am-241 in the 110-ft interbed has been confirmed by independent analyses (Laney et al., 1988). Radionuclides have not been confirmed in the 240-ft interbed but are indicated to be present by many of the drilling studies. Sufficient evidence exists to consider the 110-ft interbed a tertiary contaminant source.

Detectable levels of hazardous volatile organic compounds in groundwater samples were discovered in wells around the RWMC during the summer of 1987 (Mann and Knobel, 1987; Laney et al., 1988). Detectable quantities of carbon tetrachloride, chloroform, 1,1,1-trichloroethane, and trichloroethylene were found in several RWMC wells, but only one sample was above EPA drinking water standards. Wells used in the sampling effort include RWMC Production Well; Well 92 (perched water); and Wells 86, 87, 88, 89, 90, 92, 105, and 109 (Figure 8-2) (Laney et al., 1988).

Resampling of the wells in October 1987 yielded repeated detections of organics in waters from Wells 87, 88, 90, and 92 (Laney et al., 1988). Highest volatile organic compound concentrations, primarily carbon tetrachloride, trichloroethylene, and 1,1,1,-trichlorothane, were found in Well 88. This well is down gradient from the SDA. Wells 89 and 90 show organics near the detection limit of analyses. The vadose zone below the SDA is considered a tertiary organic source.

8.4 Extent of Contaminant Movement from RWMC

A variety of studies have been undertaken since 1970 to assess contaminant migration from pits and trenches at the SDA. These have included sampling of undisturbed surface sediments, sediments from and below pits and trenches, sedimentary interbeds, vadose zone water, and groundwater.

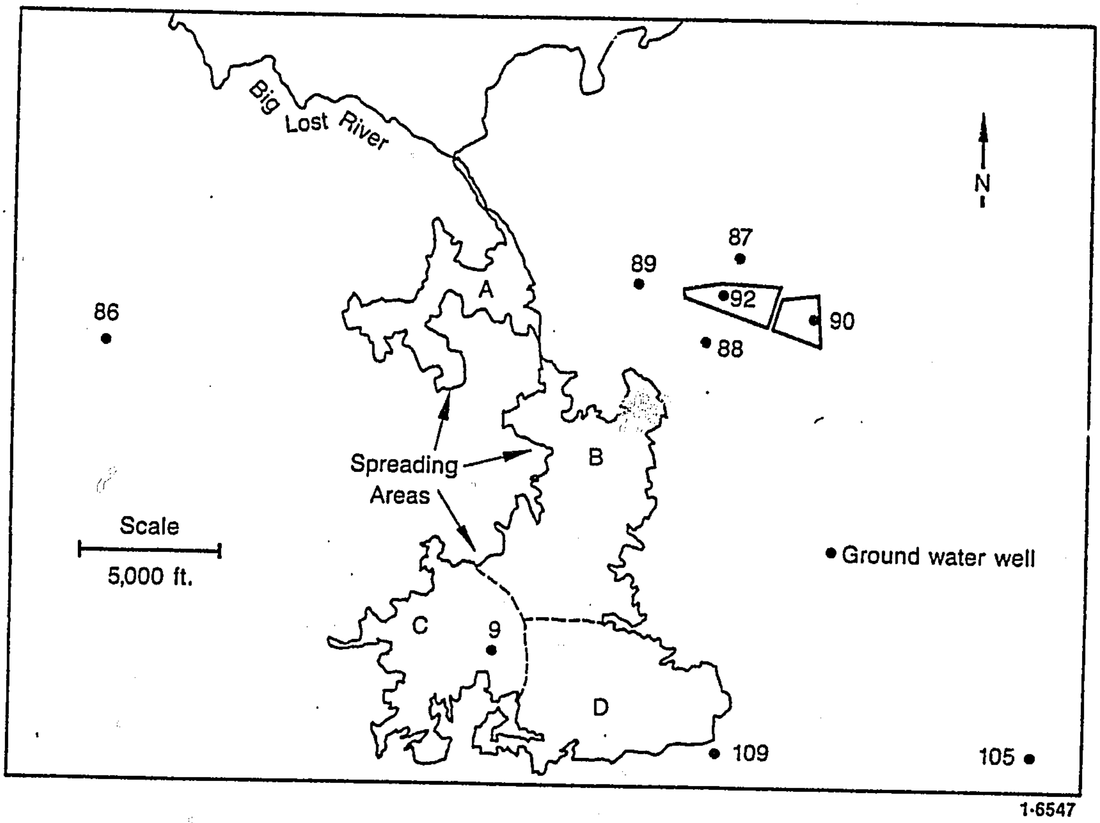

Figure 8-2. Location of wells in the RWMC area and Spreading Areas A, B, C, and D, (Hubbell, 1990).

What radionuclides have been found in surficial sediments at the SDA?

Undisturbed surficial soils associated with the SDA were found to contain only naturally occurring radionuclides (Schmalz, 1972). Detectable quantities of Pu-240, Pu-239, Pu-238, Am-241, Cs-137, Sr-90, Co-60 and Eu-154 have been found in recent studies of the SDA surficial sediments (Hubbell et al., 1985, 1987; Laney et al., 1988). Table 8-7 contains all positive radionuclide detections (99% confidence) in the surficial sediments.

What radionuclides have been found in sediments in and around pits and trenches at the SDA?

The Initial Drum Retrieval and Early Waste Retrieval demonstrations were conducted to test retrieval techniques and to determine the extent of radionuclide migration in sediments in and below SDA pits and trenches. The Initial Drum Retrieval demonstration focused on drums buried between 1968 and 1970 (McKinley and McKinney, 1978a; 1978b). Approximately 92% of the drums recovered had good integrity, with only 6% of the drums from Pit 11 and none from Pit 12 showing external alpha contamination (McKinley and McKinney, 1978; 1978b). Sample analysis by isotope-specific radiochemistry shows contamination to be concentrated at the pit/subsoil interface with a marked decrease or absence of contamination below the interface.

During the Initial Drum Retrieval sets of soil samples, IDR-1, IDR-2, and IDR-3 were collected for isotope-specific radiochemistry from beneath Pits 11 and 12, respectively (Humphrey and Tingey, 1978; Humphrey, 1980). All three series include samples from the pit/subsurface interface and at intervals down to basalt (Table 8-8). The IDR-3 series focused on sediments located beneath drums and boxes of Pit 12.

Preliminary probes of Pits 6, 9, and 10 found Initial Drum retrieval techniques to be inadequate for drum retrieval in older pits and trenches. Pit 6 was found to have drums and loose waste on the south side with high concentrations of removable contamination. Pit 9 waste was containerized in two-thirds drums and

Table 8-7. Radionuclide concentrations in surficial sediments (radionuclide concentrations positive at 3 sigma)[a]

Sample Number	Depth (ft)	Pu-239,240 (454 E-15 Ci/ lbm)	S.D.[b]	Pu-238 (454 E-15 Ci/ lbm)	S.D.	Am-241 (454 E-15 Ci/ lbm)	S.D.	Sr-90 (454 E-15 Ci/ lbm)	S.D.	Cs-137 (454 E-15 Ci/ lbm)	S.D.	Co-60 (454 E-15 453.6 Ci/ lbm)	S.D.	Eu-154 (454 E-15 Ci/ lbm)	S.D.
91-7'10	7.8-8.9	26.0	4.5												9
92-5'0	5-7.5							240	70						
93-13'10	13.8-14							400	90						
D-13/D02	1.2-1.7	1130.0	50.0	260.0	20.0	1520	60	190	30	72	10				
W01-C12M	3.42							58	19						
W02-C24M	1.67	2560.0	140.0	45.0	4.0	2460	110	520	30	1800	70				
W02-C27M	6.92	1440.0	40.0	41.0	4.0										
W02-C31M	13.83											60	20		
W03-C32M	1.67	550.0	20.0	13.0	2.0	1630	60	200	20	100	11				
W03-C33M	6.92					13		270	20						
W03-C36M	13.83					74	3								
W04-C38M	1.67	82.0	5.0	8.8	1.8	92	5			42	10	24	8		
W04-C39M	3.42	28.0	3.0	5.2	1.7		5								
W04-C46M	16.08											160	30		
W04-C49M								74	19						
W08-C109M	1.5					53	4			64	12				
W08-C110M	3.25	13.0	2.0			1160	30	790	40	47	11				
W08-C111M	5.17	235.0	10.0							550	30	360	17		
W12-C54M	3.42	4.7	1			8	2			86	12				
T12-C55M	1.67							110	20	96	13				
T12-C56M	3.42														
T12-C57M	4.67	5.5	1.6												
W16-C108M	4.58	163.0	9.0					190	40						
W19-C60M	1.5											220	50	29	9
W19-C61M	3.25														
W19-C69M	16.58							190	30	152	13				
W20-C76M	1.58	147.0	7.0	18	2	72	4			430	20	49	10		

Table 8-7. (continued)

Sample Number	Depth (ft)	Pu-239,240 (454 E-15 Ci/lbm)	Pu-239,240 S.D.[b]	Pu-238 (454 E-15 Ci/lbm)	Pu-238 S.D.	Am-241 (454 E-15 Ci/lbm)	Am-241 S.D.	Sr-90 (454 E-15 Ci/lbm)	Sr-90 S.D.	Cs-137 (454 E-15 Ci/lbm)	Cs-137 S.D.	Co-60 (454 E-15 453.6 Ci/lbm)	Co-60 S.D.	Eu-154 (454 E-15 Ci/lbm)	Eu-154 S:D.
W23-C80B	1.5	1100.0	50.0	42	10	800	40								
W23-82M	5.0	8.0	2.0					200	30	312	18				
T23-C91M	1.58	4530.0	150.0	66	13	7500	200								
T23-C92M	3.42	24	3			65	4								
T23-C96M	9.5			234	12										
PA01-C122M	1.58	8400.0	200.0	380	40	16200	500	190	30	230	17				
PA02-C130M	1.67	103.0	6.0	7	2	294	12			61	11				
PA02-C131M	4.5	33400.0	600.0	6400	200	154000	3000	1280	40	187	15				
PA02-C132M	6.25	820.0	70.0	130	30	4370	190	670	30						
W05-C224M	0.83	22.0	3.0	60	5					188	13				
W06-C233M	0.83					13	2			113	12				
W09-C284M	0.83	73.0	2.0	11	2	2280	60			29	9				
W13-C258M	0.83									109	12				
W13-260M	4.17					28	3	200	40						
W13-C261M	6.83	23.0	3.0			55	4			58	11				
W24-C209M	1.58		3.0							27	8				

a. Source: Humphrey (1980).
b. Standard deviation, Humphrey (1980).

Table 8-8. Radionuclide concentrations in samples from beneath Pit 12[a]

Sample Number	Pu-239,240 (454 E-15 Ci/lbm)	S.D.[b]	Pu-238 (454 E-15 Ci/lbm)	S.D.	Am-241 (454 E-15 Ci/lbm)	S.D.	Cs-137 (454 E-15 Ci/lbm)	S.D.	Co-60 (454 E-15 Ci/lbm)	S.D.	Ce-144 (454 E-15 Ci/lbm)	S.D.
IDR-1-1	3.5	1.0	3.7	1.1	0.0	1.0	2.0	2.0	0.0	2.0	10.0	7.0
IDR-1-2	1.9	0.9	1.9	0.8	-0.2	1.0	10.0	3.0	0.0	2.0	-14.0	7.0
IDR-1-3	1.4	0.8	1.6	0.9	0.0	2.0	3.0	2.0	3.0	2.0	3.0	7.0
IDR-1-4	1.6	0.8	1.4	0.9	1.0	2.0	0.0	3.0	-20.0	20.0	-10.0	8.0
IDR-1-5	0.6	0.9	1.8	0.9	-1.0	1.0	2.0	2.0	-2.0	2.0	-3.0	8.0
IDR-1-6	77.0	4.0	2.3	1.0	250.0	10.0	2.0	3.0	-2.0	2.0	10.0	10.0
IDR-2-1	158.0	7.0	2.4	1.4	440.0	20.0	-1.95	3.5	3.26	2.5	-14.3	8.2
IDR-2-2	107.0	8.0	3.0	2.0	300.0	20.0	-1.37	2.1	7.46	2.1	-4.74	8.1
IDR-2-3	72.0	5.0	20.0	13.0	240.0	10.0	2.4	2.5	5.5	2.3	3.07	8.6
IDR-2-4	0.0	1.0	0.0	1.0	0.6	1.1	-0.65	1.9	-4.15	3.1	5.22	15.0
IDR-2-5	0.0	1.0	-0.8	1.9	-0.7	0.9	-0.16	2.3	-2.28	2.8	7.87	7.1
IDR-2-6	75.0	5.0	2.5	1.5	540.0	20.0	-0.46	2.3	0.6	2.5	4.13	7.3
IDR-3-1	49.0	4.0	-0.20.9	0.8	120.0	6.0	7.34	2.2	3.0	1.9	40.0	14.0
IDR-3-2	18.0	3.0	9.0	0.6	55.0	4.0	7.79	2.0	-3.04	3.0	-5.89	7.5
IDR-3-3	260.0	20.0	-0.6	4.0	540.0	30.0	1.97	2.2	-0.17	2.2	26.7	14.0
IDR-3-4	6.0	2.0	0.09	0.8	2.0	2.0	5.73	2.3	-4.15	2.7	-14.7	7.4
IDR-3-5	14.0	2.0	9.0	0.97	49.0	6.0	9.12	3.5	-2.36	2.5	19.9	13.0
IDR-3-6	170.0	10.0		2.0	460.0	20.0	3.92	2.1	2.88	1.9	-3.3	7.9

Source: Humphrey (1980). a.
b. Standard deviation Humphrey (1980).

one-third plywood boxes. At least 50% of the drums were breached, and remaining drums were wrapped in poly bags. The conditions and type of waste in Pit 10 resembles that of Pit 9 with visible corrosion of drums. Contamination of soils below older pits is considered higher than that found at Pits 11 and 12 because of the poor container conditions.

The Early Waste Retrieval project was conducted to determine the feasibility of buried waste retrieval at the older pits and trenches at the RWMC (McKinley and McKinney, 1978b). Pit 2 was selected for the study because of the high probability for poor drum integrity and its flooding in February 1962. Trenches 8 and 10 were added to the study because of their proximity to Pit 2. All drums retrieved from Trench 8 were breached, and up to 70% of the drums from Pit 2 and Trench 10 were severely deteriorated.[2] Sampling beneath Pit 2 indicated that most of the radionuclides have been contained within 2 ft of the pit bottom with trace amounts being detected down to 6 ft. Soil samples contained Pu-240, Pu-239, Pu-238, Am-241, Cs-137, Sr-90, and Co-60.[3] Table 8-9 contains the sample information from Pit 2.

Pit 1 and Trenches 1, 5, 7 and 9 were also explored (McKinley and McKinney, 1978b). Drums in Pit 1 were found to be in fair to good condition, however, surrounding soils were contaminated. Drums in Trenches 1 and 5 were in very poor condition, much of the waste in Trench 7 was unconfined, and drums were in good condition in Trench 9 but loose waste was also present.

<u>What radionuclides are present in the vadose zone?</u>

Monitoring to determine if radionuclides had migrated into the deep subsurface began in 1971 with the drilling of six boreholes to the 240-ft interbed. Migration was indicated by the detection of Pu-240, Pu-239, Pu-238, and Am-241 in the 110-ft interbed and Pu-240 and Pu-239 in the 240-ft interbed (Table 8-10) (Barraclough et al., 1976).

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[2] S. A. Rawson, 1989. <u>FY-89 Summary Report: Preliminary Evaluation of Geochemical Controls on Radionuclide Migration at the Radioactive Waste Management Complex (RWMC).</u>

[3] Ibid., Rawson.

Table 8-9. Radionuclide concentrations in samples from beneath Pit 2[a]

	Pu-239,240		Pu-238		Am-241		Sr-90		Cs-137		Co-60		Ce-144	
Sample Number	(454 E-15) Ci/lbm	S.D.	(454 E-15) Ci/lbm	S.D.	(454 E-15) Ci/lbm	S.D.	(454 E-15) Ci/lbm	S.D.	(454 E-15 Ci/lbm	S.D.	(454 E-15 Ci/lbm	S.D.	(454 E-15 Ci/lbm	S.D.
EWR-1-1	42.0	3.0	1.0	1.0	4.0	2.0	9.0	4.0	-1.0	2.0	13	3	7	12
EWR-1-2	0.8	0.7	0.1	1.1	1.6	1.5	3.0	4.0	-1.0	2.0	3	2	10	10
EWR-1-3	0.5	0.7	-0.2	0.6	0.0	2.0	8.0	4.0	2.0	2.0	3	2	0	10
EWR-1-4	47.0	6.0	1.4	1.5	13.0	4.0	0.0	4.0	20.0	2.0	3	2	0	2
EWR-1-5	460.0	20.0	7.0	3.0	39.0	4.0	900.0	40.0	150.0	100.0	-80	80	-1200	900
EWR-1-6	310000.0	8000.0	6000.0	600.0	52000.0	3000.0	3000.0	100.0	236.0	7.0	8	2	13	5
EWR-1-7	11300000.0	30000.0	22000.0	2000.0	196000.0	9000.0	4100.0	200.0	1090.0	30.0	170	6	0	6
EWR-2-1	2.5	1.1	2.2	1.1	2.0	2.0	0.0	5.0	-1.0	4.0	16	6	0	20
EWR-2-2	94.0	3.0	2.1	0.6	13.0	3.0	0.0	3.0	3.0	2.0	53	5	-4	9
EWR-2-3	86.0	5.0	2.0	1.0	17.0	2.0	0.0	3.0	-2.0	2.0	25	4	-15	7
EWR-2-4	134000.0	3000.0	2200.0	200.0	16700.0	700.0	30.0	4.0	11.0	6.0	23	8	0	8
EWR-2-5	11000000.0	500000.0	22000.0	3000.0	15500000.0	40000.0	940.0	60.0	120.0	10.0	190	10	0	30
EWR-2-6	283000.0	6000.0	5000.0	300.0	35000.0	2000.0	560.0	30.0	63.2	0.6	74	7	-30	20
EWR-3-1	5.2	1.3	0.4	1.8	1.5	1.0	2.0	4.0	-5.0	3.0	-2	2	-1	8
EWR-3-2	8.8	1.5	1.4	0.7	3.3	1.1	0.0	4.0	1.0	2.0	3	3	0	8
EWR-3-3	3.0	0.9	0.3	0.6	3.6	1.1	0.0	3.0	3.0	2.0	-2	2	1	7
EWR-3-4	9.2	1.4	0.5	0.8	3.2	1.1	0.0	3.0	4.0	2.0	0	2	-4	6
EWR-3-5	2560.0	70.0	56.0	5.0	510.0	10.0	89.0	6.0	6.0	2.0	2	2	-4	6
EWR-3-6	21800.0	400.0	470.0	30.0	8400.0	100.0	73.0	6.0	11.0	2.0	1	1	0	10
EWR-3-1A	161.0	3.0	3.5	0.6	38.0	3.0	4.0	3.0	2.0	2.0	2	2	0	7
EWR-3-2A	34.0	2.0	2.0	0.8	30.0	4.0	0.0	3.0	0.0	2.0	0	2	18	13
EWR-3-3A	214.0	5.0	2.8	1.0	64.0	6.0	1.0	3.0	-2.0	2.0	3	3	9	8

Table 8-9. (continued)

Sample Number	Pu-239,240 (454 E-15) Ci/lbm	Pu-239,240 S.D.	Pu-238 (454 E-15) Ci/lbm	Pu-238 S.D.	Am-241 (454 E-15) Ci/lbm	Am-241 S.D.	Sr-90 (454 E-15) Ci/lbm	Sr-90 S.D.	Cs-137 (454 E-15 Ci/lbm	Cs-137 S.D.	Co-60 (454 E-15 Ci/lbm	Co-60 S.D.	Ce-144 (454 E-15 Ci/lbm	Ce-144 S.D.
EWR-3-4A	274.0	6.0	6.6	1.2	73.0	7.0	0.0	3.0		3.0				8
EWR-3-5A	410.0	10.0	12.0	2.0	85.0	7.0	19.0	4.0	-4.0	2.0	3	3	4	8
EWR-3-6A	9400.0	300.0	230.0	30.0	1970.0	50.0	129.0	8.0	7.0	3.0	-1	2	6	8

a. Source: Humphrey (1980).

b. Standard deviation Humphrey (1980).

Table 8-10. Radionuclide concentrations in sedimentary interbeds (radionuclide concentrations positive at 3 sigma)[a]

			Pu-239,240		Pu-238		Am-241		Sr-90		Cs-137		Co-60	
Sample Number	Depth (ft)	Interbed	(454 E-15) Ci/lbm	S.D.[b]	(454 E-15) Ci/lbm	S.D.	(454 E-15) Ci/lbm	S.D.	(454 E-15) Ci/lb	S.D.	(454 E-15) Ci/lbm	S.D.	(454 E-15 Ci/lbm	S.D.
91--233'9	33.75-236.2	240							1200	100				
91--236'6	236.5-237	240	140.0	7										
91--243'2	43.16-245.0	240							500	90				
92--88'6	88.5-90	110							300	90				
92--223'	223-225.5	240							300	90	130	30	230	20
93--98'	98-101	110	110.0	7	8	1.5					100	20	62	12
93--101'	101-103	110	230.0	11	9	3.0	63.0	12.0	690	110				
93--101'dup	101-103	110	540.0	12	14	3.0	150.0	22.0						
93--103'	103-105	110	81.0	11			45.0	6.0	400	100				
94--98'4	98.33-98.42	110							150	50				
94--262'3	62.25-264.5	240									180	30	250	30
95--112'	112-113.25	110									220	10		
95--226'9	26.75-229.2	240									230	30	240	30
96--100'6	100.5-101	110	45.0	2	6	1.5								
96--110'	110-112.92	110					230.0	20.0						
96--110'dup	110-110.5	110					30.0	6.0						
96--122'9	22.75-123.5	110												
76-1-8	221	240									49	6		

Table 8-10. (continued)

Sample Number	Depth (ft)	Interbed	Pu-239,2 (454 E-15 Ci/lbm)	S.D.[b]	Pu-238 (454 E-15 Ci/lbm)	S.D.	Am-241 (454 E-15 Ci/lbm)	S.D.	Sr-90 (454 E-15 Ci/lb)	S.D.	Cs-137 (454 E-15 Ci/lbm)	S.D.	Co-60 (454 E-15 Ci/lbm)	S.D.
76-1-8dup	221	240									42	5		
76-3-4	97.5-97.8	110	16.8	5			8.4	1.4						
76-4A-2	97.8	110					6.4	1.7			550	40		
78-2-6 (A)	235.7	240					33	3						
78-3-3 (B)	226.9	240									7	2		
78-3-7 (B)	242.4	240							12	4				
78-5-1 (A)	101.7	110			3.1	1.0								
78-5-8 (B)	240.3	240	13	2	3.0	1.0								
D-34 FS/D02	230-230.33	240			6.5	1.9								
D-34 LS/D02	230-230.33	240	58	2	32.2	1.7								
D-34 LS/4000/	230-230.33	240			1.5	0.4								
D-34 LS/4000/	230-230.33	240			3.3	0.6								
D-42 FS/TW1	101-101.16	110	740	40	17.0	2.0	440	20						
D-42 LSs/TW1	101-101.16	110	610	30	11.8	1.7	470	20						
D-43A FS/TW1	01.16-101.5	110	197	13	4.6	1.4	103	8						
D-43 FSs/TW1	01.16-101.5	110	190	13	6.3	1.7	106	9						
D-43 LSs/TW1	01.16-101.5	110	200	13	6.5	1.6	137	11			8	2		
79-1-2 (A)	114.8	110												
79-2-1 (A)	99.1	110	61	4			31	3						
79-2-1 (B)	99.9	110	56	4			22	2						
79-2-2 (A)	99.9	110	34	3			13	3						

Table 8-10. (continued)

Sample Number	Depth (ft)	Interbed	Pu-239,2 (454 E-15 Ci/lbm	Pu-239,2 S.D.[b]	Pu-238 (454 E-15 Ci/lbm	Pu-238 S.D.	Am-241 (454 E-15 Ci/lbm	Am-241 S.D.	Sr-90 (454 E-15 Ci/lb	Sr-90 S.D.	Cs-137 (454 E-15 Ci/lbm	Cs-137 S.D.	Co-60 (454 E-15 Ci/lbm	Co-60 S.D.
79-2-2 (B)	101.7	110	37	3			18	2						
79-2-3 (A)	101.7	110	38	3			24	3						
79-2-3 (B)	103.0	110	36	3			20	3						
79-2-4 (B)	103.0	110											5.2	1.7
79-3-1 (A)	100.7	110											28.0	2.0
79-3-1 (B)	106.2	110											25.0	2.0

a. Source: Humphrey (1980).

b. Standard deviation Humphrey (1980).

A 1975 study that was conducted to validate the previous detections did not find any evidence of radionuclide contamination, and the extent of contamination was revised (Burgus and Maestas, 1976; DOE, 1983).

Six wells were drilled to the 240-ft interbed in 1976 and two deep boreholes were drilled in 1977 to monitor for radionuclides at the RWMC (Humphrey and Tingey, 1978) . Positive detections of Pu-240, Pu-239 in the 110-ft interbed and Cs-137 in the 240-ft interbed were made, but no detections were made in a second sample set taken from drill core (Table 8-10) (Humphrey, 1980).

Samples taken during the 1978 drilling campaign showed Pu-240 and Pu-239 in the 110-ft interbed, and Pu-238 in the 240-ft interbed. However, sample splits did not indicate any contamination, and proof of migration was debatable (Humphrey, 1980). Samples from drilling activities in 1979 also indicated contamination in the interbeds. Both portions of sample splits from four samples of the 110-ft interbed showed positive determinations for at least one of the following nuclides: Pu-240, Pu-239, Pu-238, Am-241, and Co-60. Eight other samples had detections of Sr-90, Cs-137, or Co-60 in one portion of the split sample. These samples came from both the 110-ft and 240-ft interbeds. These data have not been published (Table 8-10).

A new drilling program was conducted in 1986-1987 to conclusively determine if radionuclide migration had occurred at the RWMC. This program was based on using techniques to avoid cross-contamination of samples. Samples taken during the drilling of two deep boreholes in 1986 indicated radionuclide activity in the 240-ft interbed, but sample splits did not confirm the initial results (Table 8-10).

Confirmation of Pu-240, Pu-239, Pu-238, and Am-241 in the interbed was made with samples taken during the 1987 drilling (Laney et al., 1988). Detections were made on samples taken from the first 23 ft below the basalt interface in the interbed. Samples taken at deeper intervals in the interbed also showed contamination, but no confirmation analyses were performed.[4] A Pu-240, Pu-239

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[4] Ibid., Rawson.

concentration versus depth below the basalt/interbed interface shows an order of magnitude drop in concentration from 0.1- to 0.4-ft below the interface (Figure 8-3). The sediments that comprise the 0.4-ft interval are finer grained than those below and may inhibit deeper migration as indicated in the concentration profile. Possible explanations of the profile include either trapping of particulate plutonium because of reduced pore size and/or the finer grained material is a more effective adsorbent.[5]

A different mechanism of migration is suggested by the concentration profile for Am-241 (Figure 8-4). The profile resembles that of plutonium from the interface to a depth of 0.4-ft, however, americium concentrations increase at this point, suggesting that americium does not respond to the change in grain size/mineralogy as plutonium.[6]

Investigations on the distribution of contaminants in the basalts are limited. Barraclough et al., (1976) used gross gamma counting techniques on basalt cuttings from Wells 87, 88, 89, and 90 located outside the SDA boundaries. No evidence for waste migration was indicated by the reported values. However, the presence of trace amounts of gamma emitting waste can not be ruled out, and alpha and beta emitters would not be detected by this method.

<u>What radionuclides have been detected in soil water and perched water?</u>

A network of pressure vacuum Lysimeters has been installed at the SDA. Water samples from the lysimeters are periodically sent for gamma spectroscopy and radiochemistry analyses. Positive detections of radionuclides in the soil waters have occurred in samples taken from lysimeters 08 and 09 located in Borehole 23. Sr-90 was detected with an activity of 4.203E-15 Ci/ft^3 from a depth of 7.67-ft in lysimeter 09 in June 1986.[7] In May 1987, either Pu-238 and/or Am-241 with an

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[5] Ibid., Rawson.

[6] Ibid., Rawson.

[7] Ibid., Rawson.

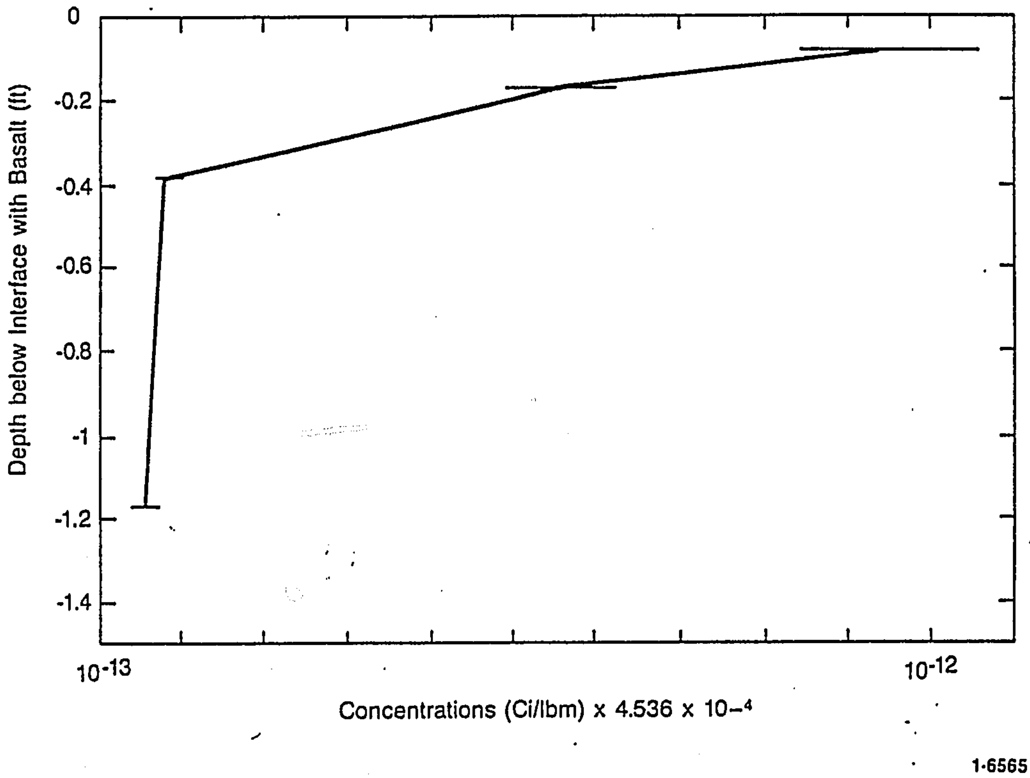

Figure 8-3. Variation in the activity of Pu-239 + 240 with depth below the interface between the basalt and the 110-ft interbed.[8]

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[8] Ibid., Rawson.

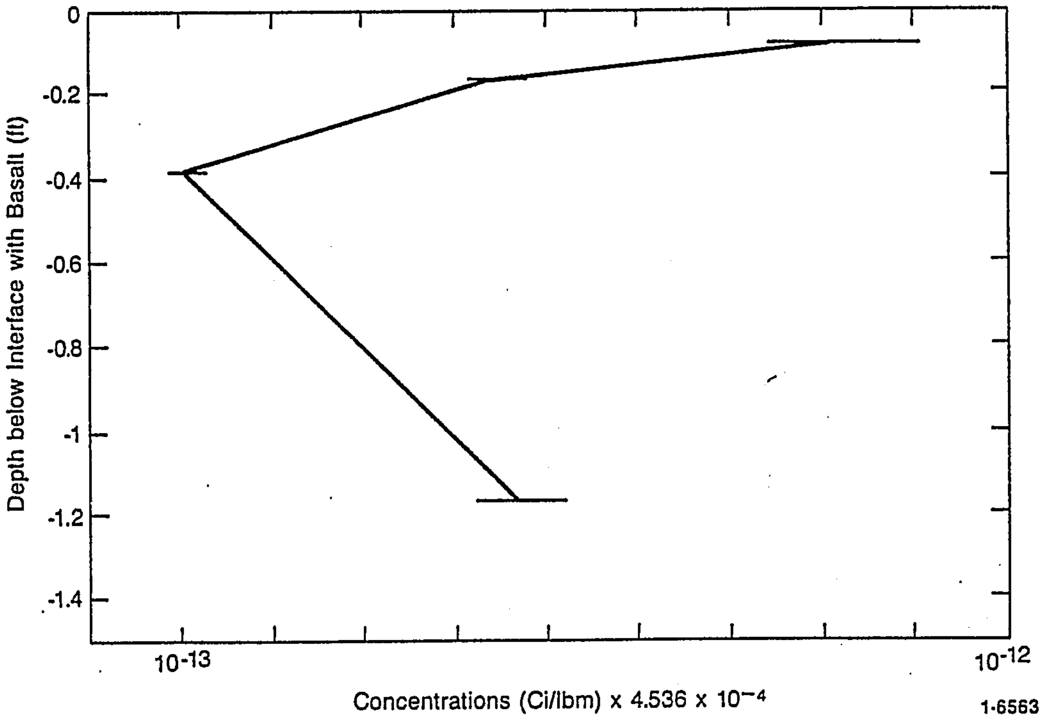

Figure 8-4. Variation in the activity of Am-241 with depth below the interface between the basalt and the 110-ft interbed.[9]

[9] Ibid., Rawson.

activity of 1.8E-14, +/- 4.59 E-15 Ci/ft^3 from 11.08 ft in lysimeter 08 was detected (Laney et al., 1988).

Detection of radionuclides in the lysimeters may be inhibited by adsorption, precipitation, and/or colloid formation in response to the high surface area of the silica flour used in the lysimeter installations. Therefore, a lack of radionuclide detections may result from processes related to the installation material and not natural processes.

Perched water has been found in Wells 77-2 and 78-1 above the 110-ft interbed and in Wells 92, 93, 96, and 8802D above the 240-ft interbed (Hubbell, 1990). Water from Wells 92, 8802D, 78-1 and 77-2 have been analyzed for radionuclide and tritium activity. Well 92 is the only one of these wells that has received considerable study with (24 analyses for both radionuclides and tritium) (Table 8-11). Tritium was not detected at the 99% significance level. However, Pu-238 and Cs-137 were detected twice at the 99% level, and Sr-90, Am-241, and Co-60 were each detected once at this level (Table 8-11). These positive detections were made between 1972 and 1980 and may be related to well completion activities (Hubbell, 1990). The only positive detections for tritium and radionuclides were made for tritium in Wells 77-2 and 78-2 (Table 8-11). Tritium activities from Well 77-2 waters are significantly above the background from above ground thermonuclear device testing. A localized source of H3 is suggested by activities being twice as high, including decay, as expected background (Hubbell, 1990).

<u>What radionuclides have been detected in groundwater at the RWMC?</u>

The only radionuclides detected from wells in and around the SDA are tritium and Sr-90.[10] The tritium plume is speculated to be the result of upgradient injection wells, however, an SDA source for the tritium can not be ruled out considering the tritium level in perched water at the SDA. A sampling program was

[10] Ibid., Rawson.

Table 8-11. Radionuclide concentrations in perched and soil water

Sample Number	Date	H-3 0.028 X Ci/ft^3	H-3 S.D.[a]	Pu-239,240 0.028 X Ci/ft^3	Pu-239,240 S.D.	Pu-238 0.028 X Ci/ft^3	Pu-238 S.D.	Am-241 0.028 X Ci/ft^3	Am-241 S.D.	Sr-90 0.028 X Ci/ft^3	Sr-90 S.D.	Cs-137 0.028 X Ci/ft^3	Cs-137 S.D.	Co-160 0.028 X Ci/f^3	Co-160 S.D.	Reference
Perched																
92	9/18/72											6.0E-14	1.0E-14	9.0E-14	1.0E-14	Hubbell (1990)
	11/20/72											2.0E-13	1.0E-14			Hubbell (1990)
	5/29/74					2.5E-17	8.0E-18									Hubbell (1990)
	10/29/76							4.1E-19	1.2E-19							Hubbell (1990)
	5/2/77					6.3E-17	6.0E-18									Hubbell (1990)
	4/21/80									9.0E-15	2.0E-15					Hubbell (1990)
77-2	3/17/77	5.4E-11	1.0E-12													Hubbell (1990)
	3/21/77	1.8E-11	1.0E-13													Hubbell (1990)
	3/22/90	8.3E-13	1.0E-13													Hubbell (1990)
78-1	7/16/90	3.0E-13	8.0E-14													Hubbell (1990)
Soil Water																
PA02, L16	6/13/86			2.0E-17	3.0E-17	1.3E-16	6.0E-17									Laney et al.(1988)
W24, L08	5/1/87			6.0E-17	6.0E-17	5.3E-16	1.3E-16									Laney et al.(1988)
W23, L09	6/13/86			2.0E-17	4.0E-17	5.0E-17	7.0E017			1.2E-14	1.2E-15					Laney et al.(1988)

a. standard deviation

initiated in 1975 to determine if reproducible background concentration of plutonium and americium and other radionuclides in groundwater beneath the SDA could be established (Polzer et al., 1976).

Well 47, located at the ICPP, gave positive detections for Am-241, and Pu-240, Pu-239, and Pu-238 mean background concentrations were established for the Snake River Plain Aquifer. SDA concentrations for these radionuclides were indistinguishable from the established mean value.

<u>Can atmospheric contamination exist at the SDA?</u>

Airborne migration of radioactive contaminants at the SDA is most likely to occur when contaminated surface soils are disturbed. This migration is minimized by maintaining adequate soil cover in conjunction with routine monitoring.

<u>Where have organic contaminants have been detected at the SDA?</u>

Organic contaminants have been detected in the surficial sediments (Laney et al., 1988), sedimentary interbeds (Laney et al., 1988), perched water (Laney et al., 1988), and in the aquifer (Mann and Knobel, 1987).

<u>What organic contaminants have been found in surficial sediments?</u>

A soil gas survey was conducted by Golder Associates of Redmond, Washington, to determine the identity, location, and relative concentration of selected chlorinated and aromatic volatile organic compounds in the vadose zone in and around the RWMC. The sampling in the surficial sediments was conducted at 200-ft spacings covering the SDA. Samples were generally collected to 200-ft beyond the SDA fence with 63 supplemental locations also being sampled usually based on high volatile organic compound concentrations (Figure 8-5) (Laney et al., 1988).

The target compounds for the soil gas survey were 1,1,1-trichloroethane, carbon tetrachloride, trichloroethylene, tetrachloroethylene,

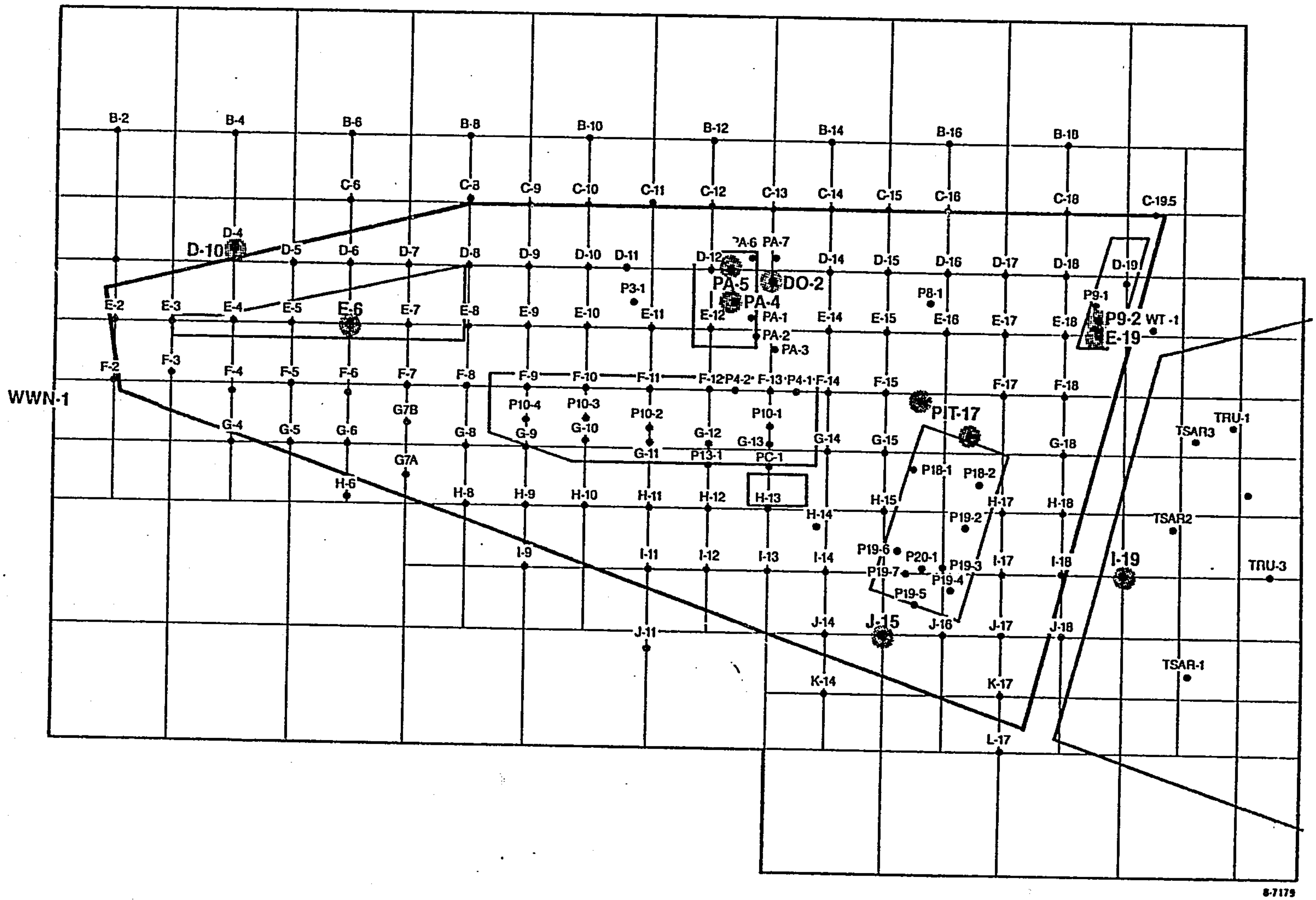

Figure 8-5. Locations of sampling points for the soil gas survey (Laney et al., 1988).

1,1-dichloroethylene, methylene chloride, 1,2-trans-dichloroethylene, trans-1,3-dichloropropene, 1,2-dichloropropane, 1,1,2-trichloroethane, benzene, and toluene. Carbon tetrachloride, 1,1,1-trichlorothane, trichloroethylene, and tetrachloroethylene were detected during the survey. Lack of detection may be because of limitations of the gas chromatograph (Laney et al., 1988).

Concentrations of carbon tetrachloride correlate well with trichloroethylene and tetrachloroethylene concentrations, suggesting mixing of the contaminants at the source(s). This linear relationship was present for carbon tetrachloride and 1,1,1-trichloroethane, but a significant number of samples showed either carbon tetrachloride and no 1,1,1-trichloroethane or no carbon tetrachloride and 1,1,1-trichloroethane. This indicates both mixed and separate sources of these organic wastes (see Laney et al., 1988, Appendix C for volatile organic compound concentrations).

Carbon tetrachloride, trichloroethylene, and tetrachloroethylene have similar distributions with an order of prevalence from highest to lowest of carbon tetrachloride, trichloroethylene, and tetrachloroethylene. Highest concentrations of these contaminants occur near 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 (Figures 8-6 through 8-8). The Pit 2 area also shows elevated concentrations of Carbon tetrachloride, trichloroethylene, and tetrachloroethylene. Source(s) for this accumulation have not been identified.

The distribution of trichloroethane differs from that of the other three volatile organic compounds (Figure 8-9). Concentration highs for trichloroethane are at the southern end of Pit 5, the middle of Pit 3, and near the southeast corner of the SDA. Other areas of elevated TCA concentrations include Pits 2 and 4 and Trenches 24, 29, and 32. Samples from neutron access tubes open just above the basalt at the SDA were generally higher than those taken at the surface. Samples taken at TSA showed moderate concentrations of carbon tetrachloride, 1,1,1-trichloroethane, and trichlorcethylene.

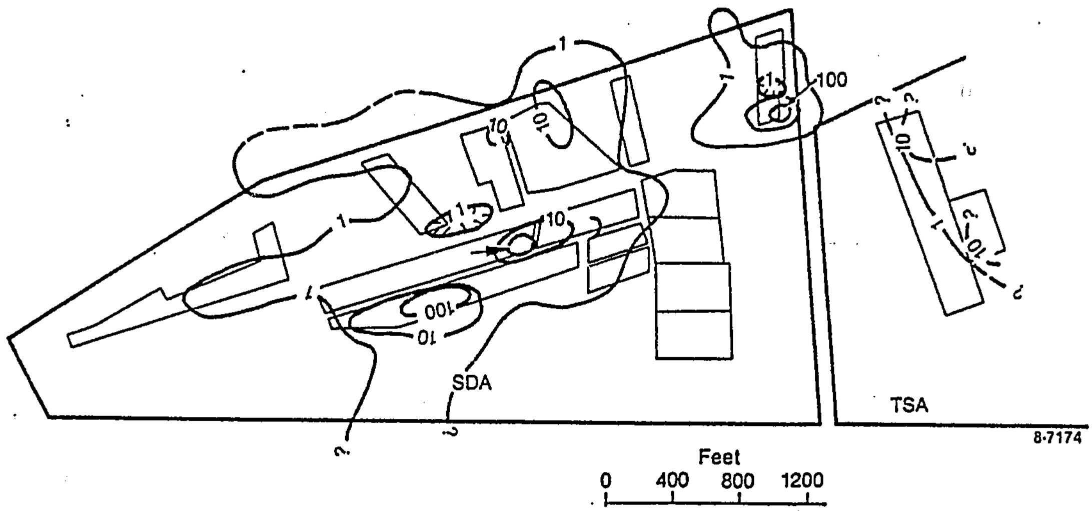

Figure 8-6. Isopleth map of the concentrations of carbon tetrachloride measured during the soil-gas survey at the RWMC [units of pound mass per cubic foot (62.43×10^{-9} lbm/ft^3)].

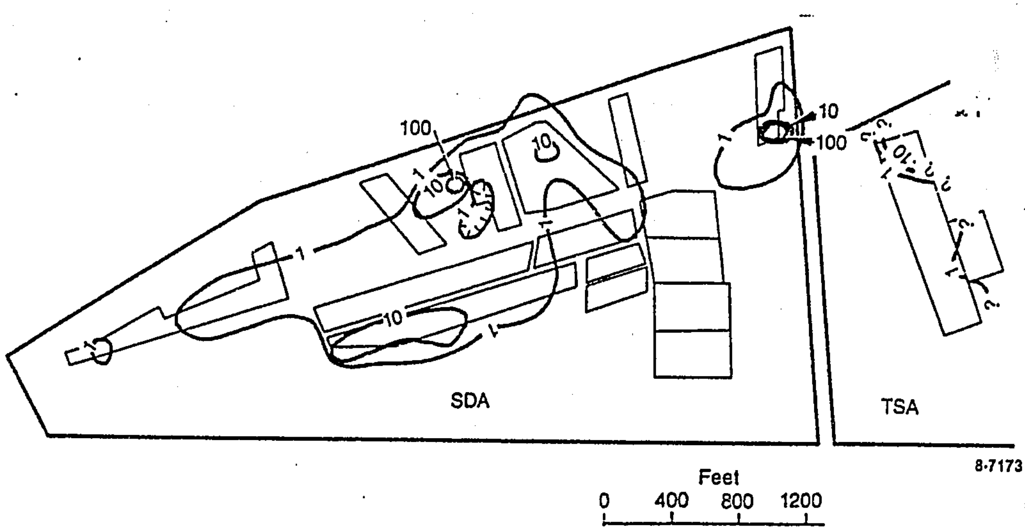

Figure 8-7. Isopleth map of the concentrations of trichloroethylene measured at the RWMC [units of pound mass per cubic foot (62.43×10^{-9} lbm/ft^3)].

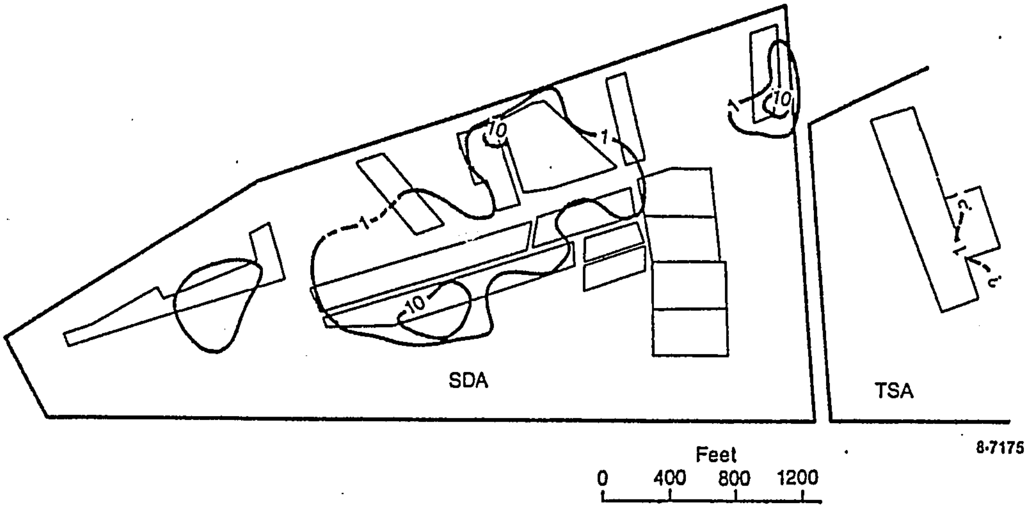

Figure 8-8. Isopleth map of the concentrations of tetrachloroethylene measured at the RWMC [units of pound mass per cubic foot (62.43×10^{-9} lbm/ft^3)].

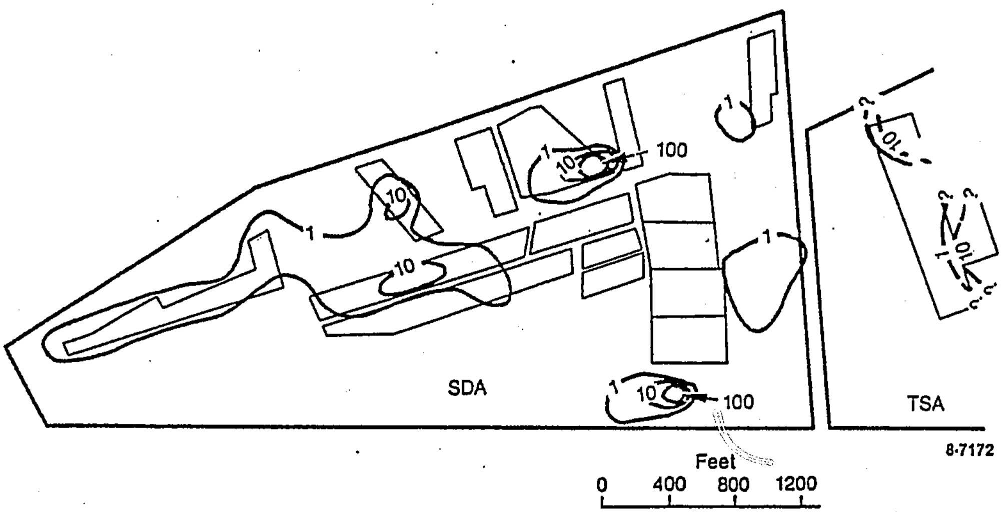

Figure 8-9. Isopleth map of the concentrations of 1,1,1-trichloroethane measured at the RWMC [units of pound mass per cubic foot (62.43×10^{-9} lbm/ft^3)].

The majority of volatile organic compounds that are released to the environment because of container failure will be vented to the atmosphere as gaseous phase emissions. Initially significant amounts of the organic compounds will move toward the aquifer, as concentrations below the site increase, the downward flux slows and atmospheric release dominates (Walton et al., 1989).

What organic compounds have been found in the vadose zone?

Detectable quantities of carbon tetrachloride, chloroform, 1,1,1-trichloroethane, and trichloroethylene were found in several RWMC wells. Wells 92 and 8802D tap perched water bodies beneath the SDA and have had concentrations above EPA drinking water standards. Wells 89, D02, and D10 have also had positive detections of 1,1,1-trichloroethane, carbon tetrachloride, trichloroethylene and tetra chloroethylene,(see Table 8-12) (Laney et al., 1988; Hubbell, 1990).

Three boreholes at the RWMC (77-1, 78-4, and WWW-1) are equipped to take volatile organic compounds samples at multiple depths. Maximum concentrations occur near the 110-ft interbed, 80 to 150-ft. Detectable concentrations have been recorded to 576-ft, but they drop off below 170-ft in depth. These results, along with modeling studies, suggest that the 110-ft interbed is a major pathway for the organic vapor migration (Laney, et al., 1988).

What organic contaminants have been found in the groundwater?

Organics were first detected in the groundwater beneath the SDA (Mann and Knobel, 1987). Estimates of carbon tetrachloride, 1,1,1 trichloroethane, tetrachloroethylene, and chloroform concentrations in the groundwater below the SDA based on sample detections are depicted in Figures 8-10 through 8-13, respectively.[11]

[11] J. M. Hubbell, 1989. Survey of Geochemistry/water Level Data from the RWMC. Note gram, May 10.

Table 8-12. Results of analysis of deep borehole gas samples taken during soil gas survey (62436.21 lbm/ft^3)

Borehole	Sample Depth (ft)	1,1,1-Trichloroethane[a]	Carbon Tetrachloride	Trichloroethylene	Tetrachloroethylene
WWW1-1	15	<0.01	8.8	1.6	0.4
WWW1-2	48	<0.01	8.0	1.2	0.4
WWW1-3	74	<0.01	30.0	3.8	0.9
WWW1-4	112	P	6.6	1.0	0.4
WWW1-5	135	P	28.0	4.0	1.0
WWW1-6	180	P	3.0	2.0	0.1
WWW1-7	240	<0.01	0.9	P	P
77-1-2	171	P	2.3	0.04	0.1
77-1-3	153	5.00	20.0	5.00	2.4
77-1-4	112	5.00	20.0	4.00	1.0
77-1-5	107	0.80	4.0	0.90	0.4
77-1-6	66	7.00	4.0	8.00	2.0
78-4-1	335	<0.01	0.6	0.04	0.04
78-4-2	253	<0.01	2.0	0.03	0.03
78-4-3	227	<0.01	0.1	<0.01	<0.01
78-4-4	118	<0.01	26.0	6.00	2.00
78-4-5	78	<0.01	36.0	9.00	2.00

a. P indicates that the constituent was detected an unquantified level.

8-42

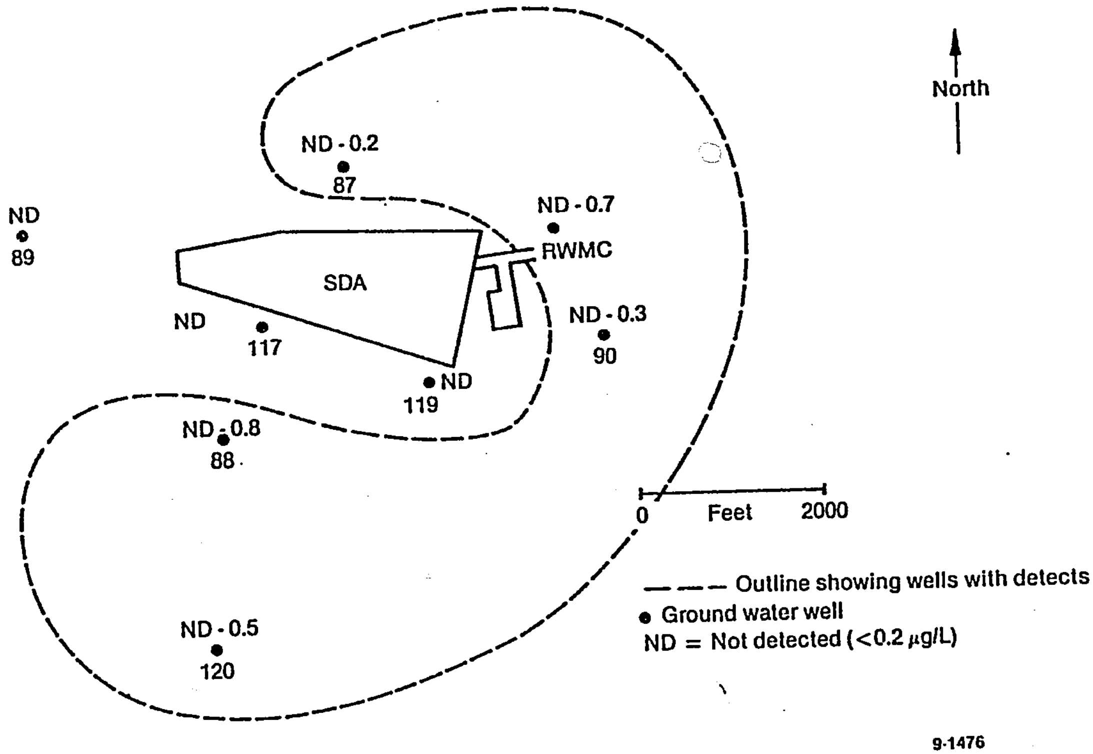

Figure 8-10. Range of concentrations of carbon tetrachloride from June 1987 to December 1988.[12]

[12] Ibid., Hubbell.

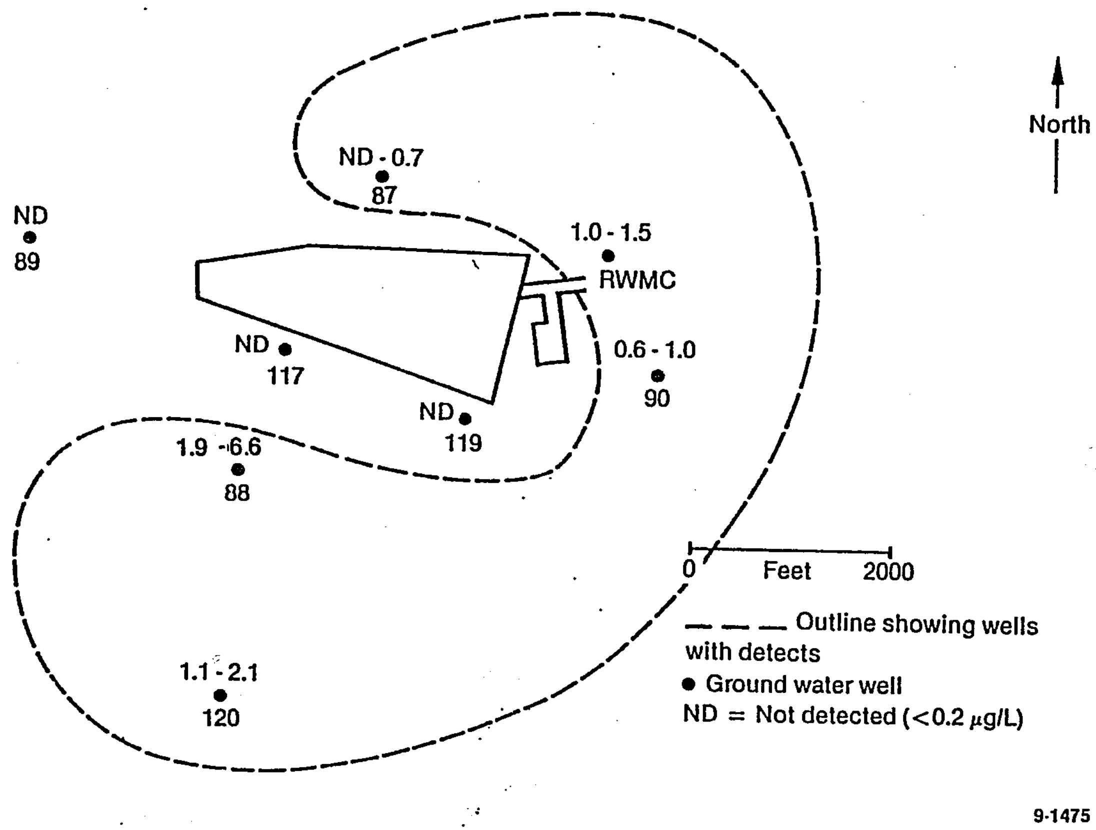

Figure 8-11. Range of concentrations of 1,1,1-trichloroethane from June 1987 to December 1988.[13]

[13] Ibid., Hubbell.

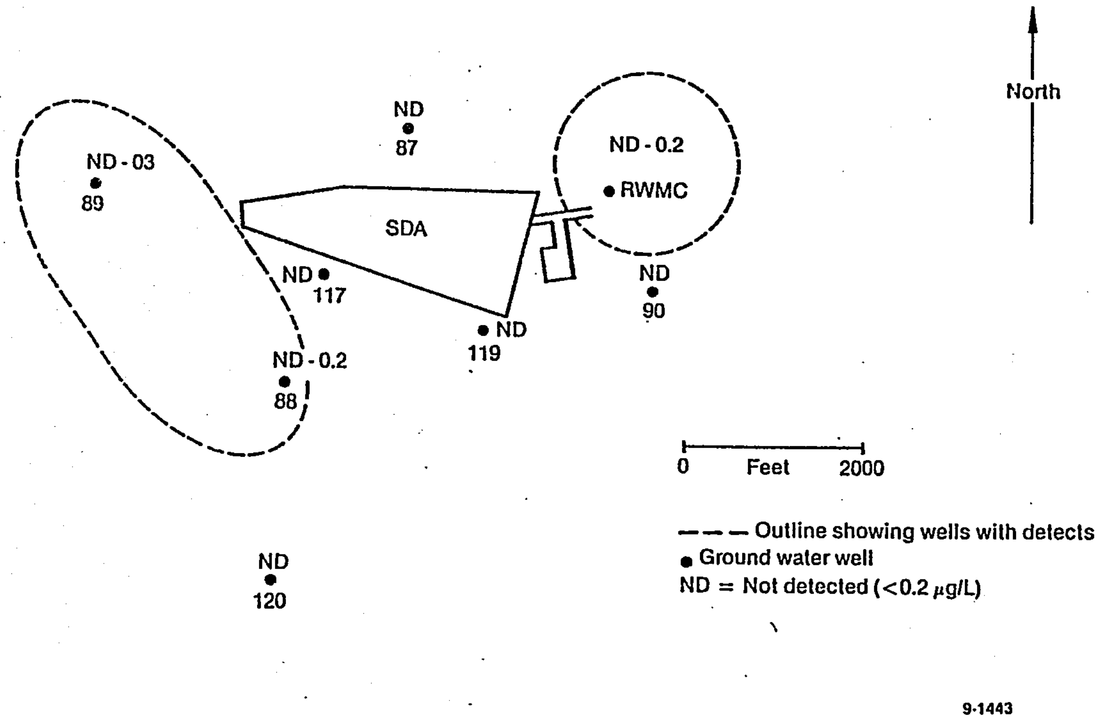

Figure 8-12. Range of concentrations of tetrachloroethylene from June 1987 to December 1988.[14]

[14] Ibid., Hubbell.

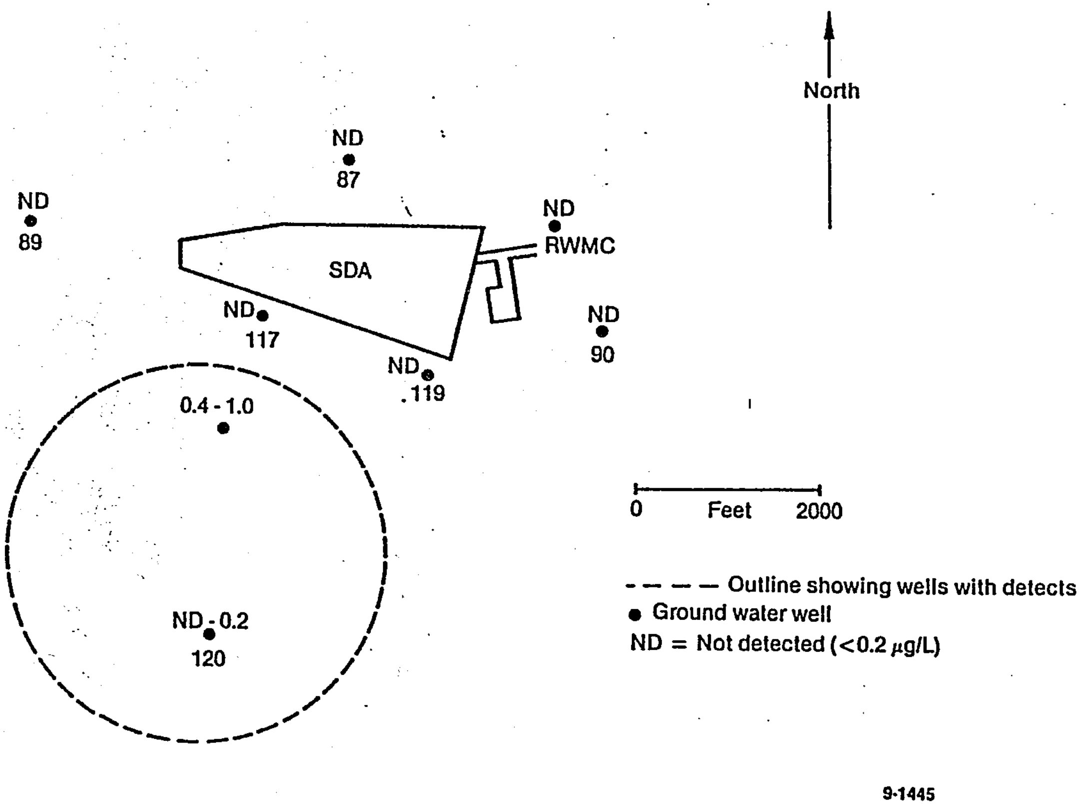

Figure 8-13. Range of concentrations of chloroform from June 1987 to December 1988.[15]

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[15] Ibid., Hubbell.

8-45

Detectable quantities of carbon tetrachloride, chloroform, 1,1,1-trichloroethane, and trichloroethylene were found in several RWMC wells (Table 8-13). Only one sample was above EPA drinking water standards. Wells used in the sampling effort include the RWMC Production Well; Well 92 (perched water); and Wells 86, 87, 88, 89 ,90, 9, 105, and 109 (Laney et al., 1988, Pittman et al., 1988).

<u>What is the distribution of contaminants from upgradient sources?</u>

Migration studies have been conducted on waste plumes from TRA and ICPP to estimate the fate and transport of several radioactive waste components. Tritium is the only contaminant that has been detected in groundwater at the RWMC that is suspected of migrating from a source outside the RWMC. This section will focus on the potential for contamination of the RWMC from ICPP and TRA.

Plumes of chemical and radioactive wastes have been identified within the boundary of the INEL site. Tritium (as tritiated water) and strontium are the only plumes that are present at RWMC. For further information on these plumes see Robertson et al. (1974) and Pittman et al. (1988).

A large, dispersed tritium plume has developed as a result of injecting tritium into the Snake River Plain Aquifer at ICPP and the percolation from disposal ponds at TRA and ICPP (Figure 8-14). The general southwest flow of the groundwater is depicted by the plume. Tritium discharges from the TRA and ICPP facilities have occurred in large quantities and make up the largest component of radioactive waste discharged to the wells and ponds at the INEL.

8.5 CONTAMINANTS FROM UPGRADIENT SOURCES

<u>What are the upgradient contaminant sources of concern to the RWMC?</u>

Regional groundwater flow at the INEL site is in a southwest direction. The TAN, TRA, ICPP, and NRF facilities are located upgradient from the RWMC

Table 8-13. Groundwater monitoring results and vicinity (62436.21 lbm/ft^3)[a]

Well Number	Date Sampled	Carbon Tetrachloride	Chloroform	1,1,1-trichloroethane	Trichloroethylene	Tetrachloroethylene	Dichlorodifluoromethane	Toluene	1,1-Dichloroethane	Remarks
87	06/03/1987	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	
	08/11/1987	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	
	09/23/1987	0.7	0.2	0.2	0.2	0.2	0.2	0.2	0.2	
88	06/03/1987	6.6	3.0	3.0	3.0	3.0	3.0	3.0	3.0	
	07/08/1987	2.7	0.2	0.6	1.1	0.2	0.3	0.2	0.2	40 minutes
		3.2	0.2	0.7	1.2	0.2	0.2	0.2	0.2	pumping
		3.1	0.2	0.7	1.2	0.2	0.2	0.2	0.2	1 h pumping
		2.9	0.2	0.6	1.2	0.2	0.2	0.2	0.2	2 h pumping
		2.8	0.2	0.6	1.2	0.2	0.2	0.2	0.2	3 h pumping
										4 h pumping
	07/15/1987	4.4	1.0	0.9	1.4	0.2	0.2	0.2	0.2	
	08/11/1987	2.1	0.4	0.4	1.2	0.2	0.2	0.2	0.2	
	09/22/1987	2.9	0.7	0.5	1.1	0.2	0.2	0.2	0.2	
89	06/03/1987	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	
	08/11/1987	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	
	09/22/1987	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.2	
90	06/03/1987	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	
	08/11/1987	0.6	0.2	0.2	0.2	0.2	0.2	0.2	0.2	
	09/23/1987	0.8	0.2	0.2	0.3	0.2	0.2	0.2	0.2	
9	07/30/1987	0.2	0.2	0.2	0.2	0.2	0.3	0.2	0.2	
	10/05/1987	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	
86	08/04/1987	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	
	10/06/1987	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	

Table 8-13. (continued)

Well Number	Date Sampled	Carbon Tetrachloride	Chloroform	1,1,1-trichloroethane	Trichloro-ethylene	Tetrachloro-ethylene	Dichloro-difluoro methane	Toluene	1,1-Dichloro-ethane	Remarks
105	07/30/1987	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	
	09/28/1987	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	
		0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	QA Replicate
109	07/31/1987	0.2	0.2	0.2	0.2	0.2	0.7	0.2	0.2	
	10/05/1987	0.2	0.2	0.2	0.2	0.2	1.0	0.2	0.2	
92[b]	10/23/1987	1200.0				0.2	0.2	0.2	0.2	equipment blank;
	10/22/1987	0.2	0.2	0.2	0.2	3.0	3.0	3.0	3.0	styrene, 3E-8
	06/03/1987	3.0	3.0	3.0	3.0	0.2	0.2	0.2	0.2	lbm/ft^3
	08/11/1987	1.0	0.2	0.2	0.5	0.2	0.2	0.2	0.2	
	09/23/1987	1.3	0.2	0.3	0.5	0.2	0.2	0.2	0.2	
	10/14/1987	1.5	0.2	0.5	0.6					

a. Source: Laney et al., (1988).
b. Well 92 taps a perched water body.

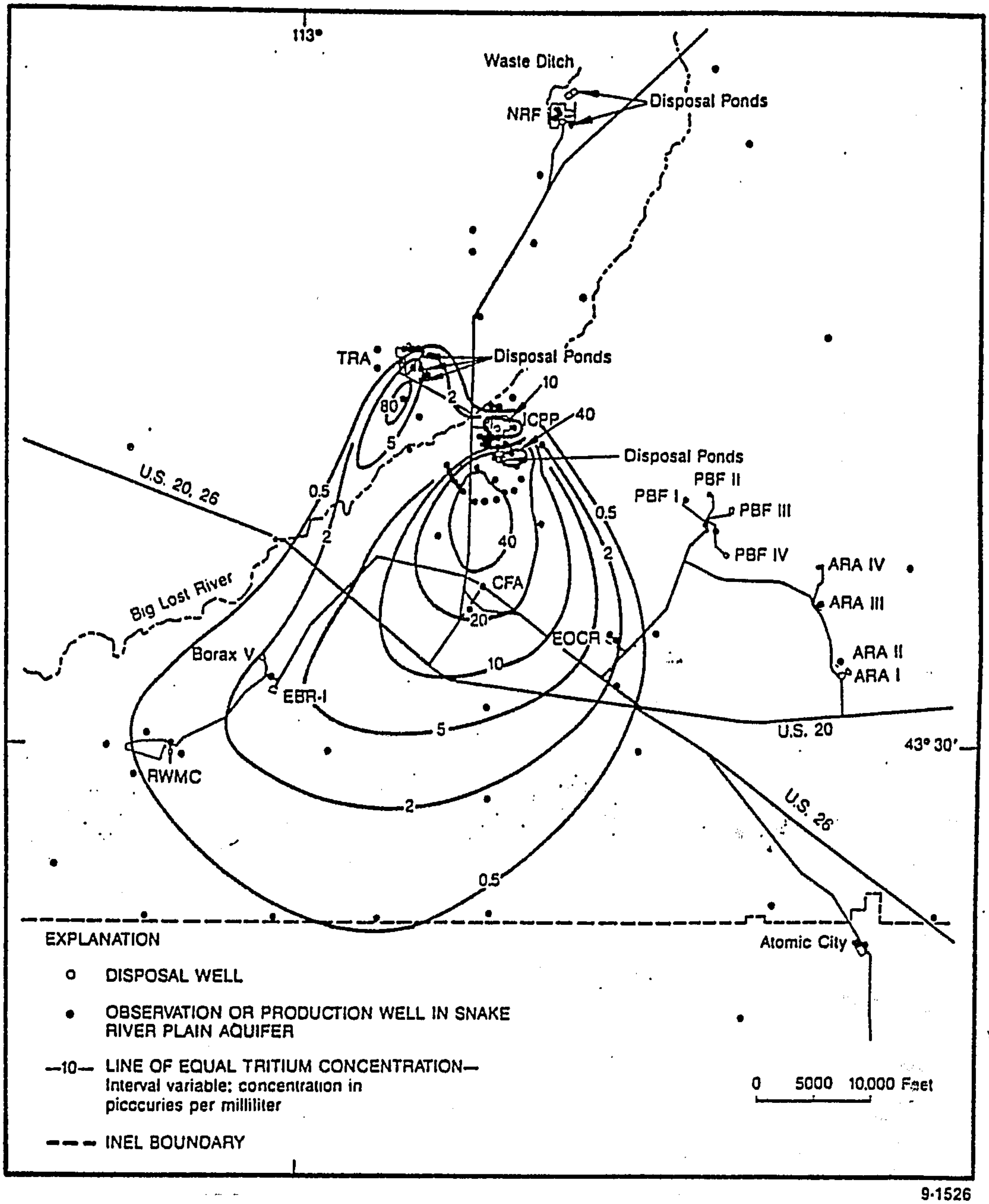

Figure 8-14. Distribution of tritium in the Snake River Plain Aquifer in the south-central part of the INEL, October 1985 (Pittman et al., 1988)

and also account for approximately 86% of the total wastewater discharge at the INEL site. Since 1952, discharges from the TRA and ICPP facilities have occurred in large quantities and make up the largest component of radioactive waste discharged to the wells and ponds at the INEL site.

The mobility of tritium is similar to water because it substitutes into the water molecule for hydrogen. It is not retarded by adsorption reactions and has a half-life of 12.3 years. Tritium was detected at the southern INEL site boundary during 1985 (Pittman et al., 1988). The RWMC first detected tritium in 1975. A migration velocity for tritium of 4 to 5-ft/day has been calculated based on arrival times from the TRA radioactive-waste disposal ponds and the ICPP disposal well.

The location of the highest concentrations in the plume has moved to a point south of ICPP because of attenuation and migration following the cessation of waste injection (Pittman et al., 1988).

Sr-90 has been disposed of both in the ICPP disposal well and the TRA radioactive disposal pond. No Sr-90 has been detected in the aquifer below the TRA disposal pond. This has been linked to the reported higher adsorption potential in the unsaturated zone than in the saturated zone (Robertson, 1977).

Approximately 21 Ci of Sr-90 was discharged at the ICPP disposal well from 1952 to 1985. Measured concentrations of Sr-90 in the aquifer around the ICPP appear to be from discharges at the ICPP injection well (Pittman et al., 1988). Concentrations in the plume have decreased, and the location of the peak concentration has moved south of ICPP because of discontinued use of the well (Figure 8-15).

Predictions indicate that any Sr-90 detected in the groundwater below the RWMC is because of release(s) of strontium from the RWMC. Also, tritium found in the groundwater at the RWMC is at least partially because of upgradient facility operations. Although no documentation has been found that confirms

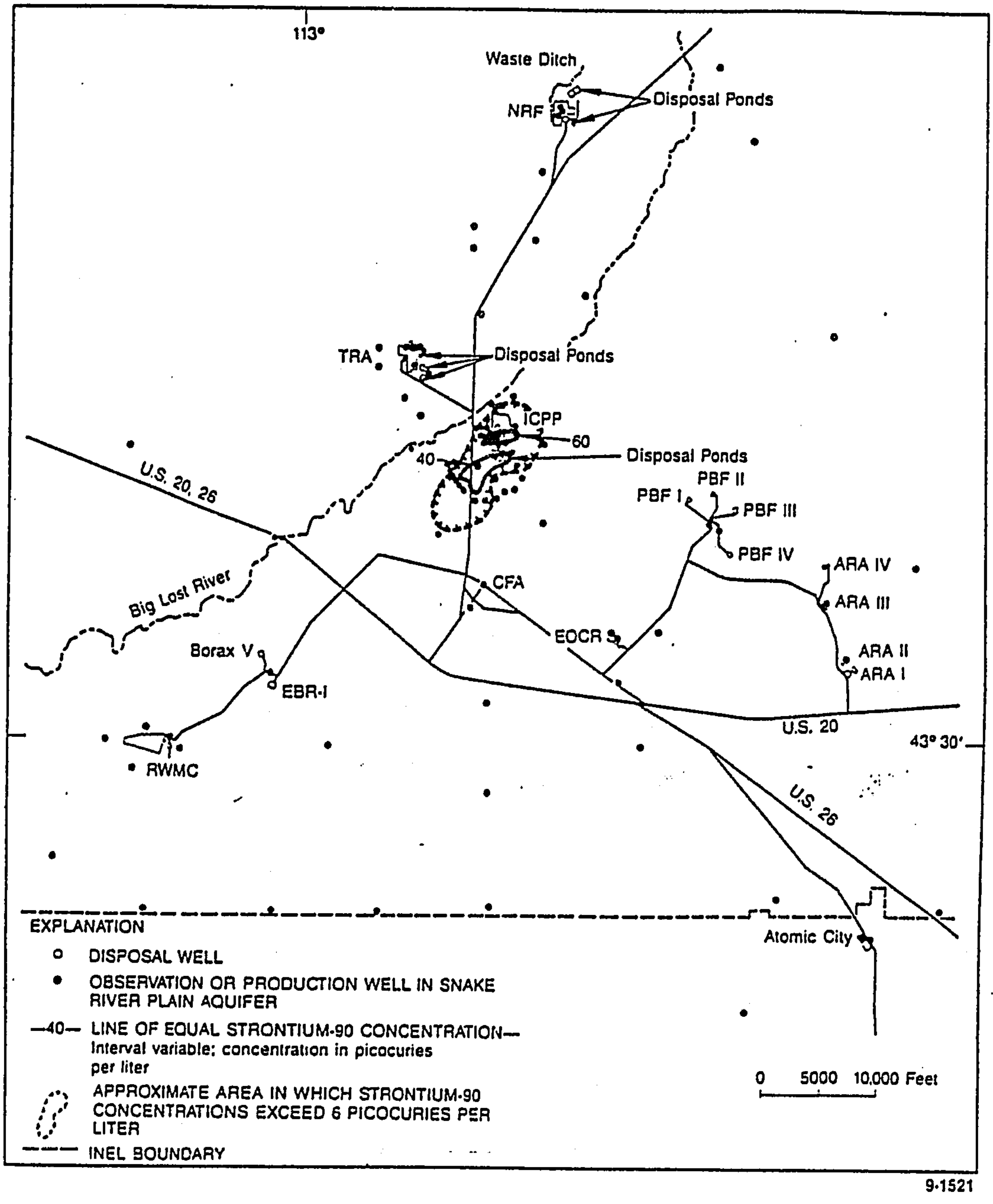

Figure 8-15. Distribution of strontium-90 in the Snake River Plain Aquifer in the south-central part of the INEL site, October 1985 (Pittman et al., 1988).

tritium was disposed of at the RWMC, a lack of records does not eliminate the possibility.

8.6 SUMMARY

The SDA has been the site of disposal/storage of a wide variety of chemical and radioactive wastes. Initially, waste disposed at the RWMC was not segregated by type (e.g., beta-gamma, TRU), but rather by place of origin. Trenches were filled by INEL site-generated materials, and pits were used to dispose of RFP wastes. The radioactive waste going to the trenches from INEL site facilities was of higher activity than that coming from the RFP. Some of the waste sent to pits and trenches was comprised of mixed beta-gamma and TRU contaminated material. In response to Federal regulations, TSA was completed to store TRU wastes, and segregation of TRU from beta-gamma waste was instituted. Currently, LLW waste is being disposed of in several large pits located in the southeast portion of the SDA.

Large volumes, at least 88,400 gal, of organic wastes have been sent to the pits at the SDA. These wastes were comprised primarily of carbon tetrachloride, trichloroethylene, tetrachloroethylene, 1,1,1-trichloroethane, Texas Regal Oil, and other machining oils.

The soil gas survey showed carbon tetrachloride, trichloroethylene, 1,1,1-trichloroethane, and tetrachloroethylene to be present in the soils at the SDA. These organics with the exception of tetrachloroethylene have been found in perched water and groundwater at the SDA. Chloroform has also been detected in perched and groundwaters.

Surficial soils at the SDA have also been shown to have detectable quantities of plutonium, americium, cesium, strontium, cobalt, and europium. Two studies have been conducted to determine radionuclides that have moved into the soils in and beneath several of the pits and trenches. Plutonium, americium, cesium, cobalt, and cerium were detected during the Initial Drum Retrieval demonstration at Pit 12. These radionuclides, along with strontium, were detected during the Early Waste Retrieval demonstration conducted at Pit 2.

Radionuclides have also been detected in the interbed sediments below the RWMC. The 110-ft interbed has had positive detections for plutonium, americium, strontium, cesium, and cobalt. Plutonium has been detected in the 240-ft interbed.

Sr-90 and either Pu-238 and/or Am-241 were detected in soil waters during sampling using suction lysimeters located across the RWMC. Positive detections of plutonium, cesium, strontium, americium, and cobalt have been made on perched waters from Well 92. This well taps a perched water body that lies above the 240-ft interbed. Tritium concentrations well above background have been detected in Well 77-2, suggesting a localized source of tritium is present at the RWMC.

Only tritium and Sr-90 have been detected in wells in and around the SDA. Tritium has long been considered to be present in the aquifer because of upgradient sources (i.e., ICPP and TRA). Because tritium was found in perched water, this assumption needs to be re-evaluated.

The most significant problem in defining the nature and extent of contamination at the RWMC is the records of types, location, and containment of wastes sent to the SDA, particularly for the time period following the opening of the site. The lack of recorded waste disposal is particularly prevalent in wastes generated onsite. These wastes were buried in soil vaults and trenches and have higher activities than the pit wastes. Looking at current documentation, it is unclear in if all pertinent information for the soil vaults and trenches has been collected.

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